

## SESSIONS AT-A-GLANCE

SESSION TITLE	START TIME	ROOM/ LOCATION	PAGE #
MONDAY, FEBRUARY 25 – MORNING			
KEYNOTE SESSION	8:30 AM	Four Seasons Ballroom	11
MONDAY, FEBRUARY 25 – AFTERNOON			
DREYER LECTURE	1:30 PM	113	106
BULK MATERIAL HANDLING: CONVEYOR MAINTENANCE AND SAFETY	2:00 PM	507	106
COAL & ENERGY: BEST OF GROUND CONTROL	2:00 PM	711	108
COAL & ENERGY: COALBED METHANE, SHALE GAS, & CARBON SEQUESTRATION	2:00 PM	706	111
COAL & ENERGY: DUST CONTROL I	2:00 PM	704	113
COAL & ENERGY: ENERGY: GEOTHERMAL INNOVATION	2:00 PM	702	116
COAL & ENERGY: RARE EARTH ELEMENTS IN COAL I	2:00 PM	708	119
ENVIRONMENTAL: BIODIVERSITY, OFF-SETS, AND PEOPLE; SUSTAINED ENGAGEMENT WITH COMMUNITIES	2:00 PM	104	122
ENVIRONMENTAL: MINE WATER: FRIEND OR FOE	2:00 PM	108	124
ENVIRONMENTAL: SITE CHARACTERIZATION IN THE ERA OF BIG DATA	2:00 PM	107	128
GEOSTATISTICS IN THE ERA OF BIG DATA	2:00 PM	603	133
HEALTH & SAFETY: HEALTH AND SAFETY TRAINING AND DEVELOPMENT	2:00 PM	605	135
INDUSTRIAL MINERALS & AGGREGATES: FRACKING MATERIALS	2:00 PM	110	138
INDUSTRIAL MINERALS & AGGREGATES: INNOVATIONS IN INDUSTRIAL MINERALS & AGGREGATES INDUSTRY I	2:00 PM	106	140
INDUSTRIAL MINERALS & AGGREGATES: RESOURCE ESTIMATION, MINE PLANNING & OPERATIONS I	2:00 PM	112	142
FUNDING AND ACCESSING CAPITAL FOR MINING AND EXPLORATION: KEY TRENDS	2:00 PM	703	131
MINING & EXPLORATION: GEOSCIENCES: GEOLOGY OF STRATEGIC MINERAL DEPOSITS	2:00 PM	501	145
MINING & EXPLORATION: GEOSCIENCES: SURFACE MINE GEOTECH I	2:00 PM	502	148
MINING & EXPLORATION: INNOVATIONS & TECHNOLOGIES: EMERGING TECHNOLOGIES AND ENGINEERING ADVANCEMENTS: CHALLENGING THE STATUS QUO I	2:00 PM	504	151
MINING & EXPLORATION: MANAGEMENT: STRIVING FOR EXCELLENCE: CASE STUDIES OF SUCCESSFUL CONTINUOUS IMPROVEMENT INITIATIVES	2:00 PM	505	155
MINING & EXPLORATION: MANAGEMENT: THIS IS MY JOB AND HERE'S WHY I LOVE IT. A LOOK AT EARLY CAREER CHOICES WITH MINERAL INDUSTRY DEGREES	2:00 PM	503	158
MINING & EXPLORATION: OPERATIONS: MINE DATA MANAGEMENT	2:00 PM	506	160
MINING & EXPLORATION AND HEALTH AND SAFETY: THE DIGITAL JOURNEY: CROSS CUTTING INNOVATION AND TECHNOLOGY THAT IMPACT H&S	2:00 PM	610	162
MOVING MINING CURRICULUM TO EMBRACE THE FUTURE	2:00 PM	210	165
MPD PLENARY	2:00 PM	705	168
SME YOUNG LEADERS: MY FIRST FIVE YEARS OF EXPERIENCE IN INDUSTRY/ACADEMIA	2:00 PM	612	169
OUTLOOK FOR COMMODITIES IN THE CURRENT GLOBAL, GEOPOLITICAL AND ECONOMIC ENVIRONMENT	2:30 PM	710	170

# SESSIONS AT-A-GLANCE

SESSION TITLE	START TIME	ROOM/ LOCATION	PAGE #
<b>TUESDAY, FEBRUARY 26 – MORNING</b>			
US SEC'S RULE S-K 1300 FOR MINING PROPERTY DISCLOSURE	8:30 AM	601	171
BULK MATERIAL HANDLING: CONVEYORS AND THE IOT	9:00 AM	507	171
COAL & ENERGY: ACCESSING CAPITAL IN THE EVER CHANGING ENERGY LANDSCAPE	9:00 AM	702	173
COAL & ENERGY: APPLICATION OF CFD IN MINE VENTILATION	9:00 AM	711	175
COAL & ENERGY: COAL MINE SAFETY & HEALTH I	9:00 AM	706	177
COAL & ENERGY: INNOVATIONS IN UNDERGROUND COAL MINING	9:00 AM	704	180
COAL & ENERGY: RARE EARTH ELEMENTS IN COAL II	9:00 AM	708	182
CMA: BLOCKCHAIN AND THE MINING INDUSTRY	9:00 AM	710	186
ENVIRONMENTAL: EFFECTIVE PERMITTING STRATEGIES FOR CAPITAL PROJECTS	9:00 AM	107	186
ENVIRONMENTAL: INNOVATIVE WATER TREATMENT	9:00 AM	104	189
ENVIRONMENTAL: SURFACE PLACEMENT OF PASTE AND CEMENTED PASTE: PROMISING TECHNOLOGY OR PIE-IN-THE-SKY?	9:00 AM	108	192
FUERSTENAU SYMPOSIUM: FLOTATION & TECHNOLOGY	9:00 AM	709	195
HEALTH & SAFETY: CMSP BEST PRACTICE SHARING	9:00 AM	605	199
HEALTH & SAFETY: DISRUPTIVE, VIRTUAL, AND AUGMENTED REALITY: THE 4TH INDUSTRIAL REVOLUTION	9:00 AM	610	202
INDUSTRIAL MINERALS & AGGREGATES: DIGITIZATION, AUTOMATION & CONTROL STRATEGIES, PART I: PROCESSING AND APPLICATIONS	9:00 AM	106	205
INDUSTRIAL MINERALS & AGGREGATES: ENERGY AND CRITICAL MATERIALS	9:00 AM	110	209
INDUSTRIAL MINERALS & AGGREGATES: RESOURCE ESTIMATION, MINE PLANNING & OPERATIONS II	9:00 AM	112	212
INTERNATIONAL I: WOMEN IN MINING	9:00 AM	603	215
MINING & EXPLORATION: GEOSCIENCES: SURFACE MINE GEOTECH II	9:00 AM	502	217
MINING & EXPLORATION: GEOSCIENCES: UNDERGROUND MINE GEOTECHNICAL I	9:00 AM	503	220
MINING & EXPLORATION: INNOVATIONS & TECHNOLOGIES: EMERGING TECHNOLOGIES AND ENGINEERING ADVANCEMENTS: CHALLENGING THE STATUS QUO II	9:00 AM	504	223
MINING & EXPLORATION: MANAGEMENT: LEADERSHIP MATTERS: DEVELOPING A WELL ROUNDED WORKFORCE	9:00 AM	501	226
MINING & EXPLORATION: OPERATIONS: BLASTING I	9:00 AM	505	228
MINING & EXPLORATION: OPERATIONS: MINE SCHEDULING AND OPTIMIZATION I	9:00 AM	506	231
MPD: CHEMICAL PROCESSING: PYROMETALLURGY	9:00 AM	703	234
MPD: PHYSICAL SEPARATION I: PHYSICAL SEPARATION TECHNOLOGIES AND PROJECTS IN MINERAL PROCESSING	9:00 AM	707	237
MPD: PLANT DESIGN I	9:00 AM	705	240
UCA OF SME: SHAFTS	9:00 AM	612	243
VALUATION: CASE STUDIES	9:00 AM	210	246
CMA: THE FUTURE FOR COAL USE IN THE U.S.	9:45 AM	710	248
CMA: AN EPHEMERAL LANDSCAPE: TRAVERSING THE FRACTURED REGULATORY DYNAMICS SURROUNDING ABANDONED MINES AND MINING DISTRICTS	10:30 AM	710	248

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CMA: TECHNOLOGY IN MINING	1:30 PM	710	249
BULK MATERIAL HANDLING: NEW TECHNOLOGY IN BULK MATERIAL HANDLING	2:00 PM	507	250
COAL & ENERGY: AUTOMATION INNOVATION AND CURRENT DEVELOPMENTS	2:00 PM	706	252
COAL & ENERGY: COAL MINE RECLAMATION I	2:00 PM	702	255
COAL & ENERGY: RESEARCH AND DEVELOPMENT I	2:00 PM	708	258
COAL & ENERGY: SURFACE MINING: ADVANCEMENT THROUGH INNOVATION	2:00 PM	704	260
COAL & ENERGY: VENTILATION INNOVATIONS	2:00 PM	711	263
ENVIRONMENTAL: INNOVATING ANALYTICAL MEASUREMENTS AND PROCEDURES CREATING SOLUTIONS IN MINING AND PROCESSING	2:00 PM	104	266
ENVIRONMENTAL: INNOVATIONS IN MINING TO DRIVE SUSTAINABLE BUSINESS VALUE	2:00 PM	107	268
ENVIRONMENTAL: PASSIVE AND IN-SITU WATER TREATMENT	2:00 PM	108	272
FUERSTENAU SYMPOSIUM: COMMINUTION, MODELING & FLOTATION	2:00 PM	709	275
HEALTH & SAFETY: COMPLIANCE IS NOT ENOUGH! SAFETY CULTURE TRANSFORMATION	2:00 PM	610	279
INDUSTRIAL MINERALS & AGGREGATES: APPLICATIONS OF DATA ANALYTICS & ARTIFICIAL INTELLIGENCE IN INDUSTRIAL MINERALS & AGGREGATE INDUSTRY I	2:00 PM	110	282
INDUSTRIAL MINERALS & AGGREGATES: DIGITIZATION, AUTOMATION & CONTROL STRATEGIES, PART II: GEOLOGY AND MINING	2:00 PM	106	285
INTERNATIONAL II	2:00 PM	603	288
MINING & EXPLORATION: GEOSCIENCES: GEOLOGY OF BASE METALS DEPOSITS	2:00 PM	501	291
MINING & EXPLORATION: GEOSCIENCES: UNCERTAINTY & RISK IN RESOURCE MODELLING	2:00 PM	506	294
MINING & EXPLORATION: GEOSCIENCES: UNDERGROUND MINE GEOTECHNICAL II	2:00 PM	503	297
MINING & EXPLORATION: INNOVATIONS & TECHNOLOGIES: DATA DRIVEN INNOVATION: INSPIRATION TO ACTION	2:00 PM	502	300
MINING & EXPLORATION: MANAGEMENT: MINE MANAGEMENT IN A DIGITAL WORLD: HOW EMBRACING INNOVATION HAS CHALLENGED MANAGEMENT SYSTEMS	2:00 PM	504	303
MINING & EXPLORATION: OPERATIONS: BLASTING II	2:00 PM	505	305
MINING HISTORY	2:00 PM	112	308
MPD: CHEMICAL PROCESSING: HYDROMETALLURGY	2:00 PM	703	311
MPD: FLOTATION: CHEMICAL ASPECTS OF FLOTATION I	2:00 PM	707	313
MPD: PLANT DESIGN II	2:00 PM	705	316
SME YOUNG LEADERS: WHAT I WISH I KNEW DURING SCHOOL AND AT THE BEGINNING OF MY CAREER	2:00 PM	605	319
UCA OF SME: TUNNELS	2:00 PM	612	320
VALUATION: LESSONS LEARNED	2:00 PM	210	323
BARRICK OPERATORS SESSION	3:00PM	601	326

# SESSIONS AT-A-GLANCE

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<b>WEDNESDAY, FEBRUARY 27 – MORNING</b>			
FUERSTENAU SYMPOSIUM: TECHNOLOGY & INNOVATIONS	8:30 AM	709	327
COAL & ENERGY: ATMOSPHERIC MONITORING SYSTEMS IN UNDERGROUND COAL MINES	9:00 AM	707	329
COAL & ENERGY: COAL PREPARATION AND ADVANCES IN CLEAN COAL TECHNOLOGIES	9:00 AM	711	332
COAL & ENERGY: DUST CONTROL-II	9:00 AM	704	335
COAL & ENERGY: RESEARCH AND DEVELOPMENT-II	9:00 AM	708	337
CMA: SAFETY AND HEALTH: FROM THE NATION'S CAPITAL TO CMA MEMBERSHIP'S OPERATIONS	9:00AM	712	340
CMA: STATE AND FEDERAL MINING POLICY UPDATE	9:00AM	710	341
ENVIRONMENTAL: ABANDONED MINE LANDS – CLOSURE AND RECLAMATION	9:00 AM	107	342
ENVIRONMENTAL: HOLISTIC MINE WATER MANAGEMENT	9:00 AM	104	345
ETHICS	9:00 AM	210	349
HEALTH & SAFETY: EMERGENCY MANAGEMENT AND RESPONSE PLANNING	9:00 AM	610	350
HEALTH & SAFETY: INDUSTRY DISCUSSION OF PRACTICES TO UNDERSTAND AND IMPROVE MINER HEALTH	9:00 AM	605	353
INDUSTRIAL MINERALS & AGGREGATES: APPLICATIONS OF DATA ANALYTICS & ARTIFICIAL INTELLIGENCE IN INDUSTRIAL MINERALS & AGGREGATE INDUSTRY II	9:00 AM	110	356
INDUSTRIAL MINERALS & AGGREGATES: INNOVATIONS IN INDUSTRIAL MINERALS & AGGREGATES INDUSTRY II	9:00 AM	106	358
INDUSTRIAL MINERALS & AGGREGATES: SUSTAINABLE DEVELOPMENTS INCLUDING ENVIRONMENTAL REMEDIATION & WATER MANAGEMENT RESOURCES	9:00 AM	112	360
INTERNATIONAL III	9:00 AM	603	362
MINING & EXPLORATION: GEOSCIENCES: MICROANALYTICAL TECHNIQUES IN MINERAL EXPLORATION	9:00 AM	501	365
MINING & EXPLORATION: INNOVATIONS & TECHNOLOGIES: ADVANCES IN SPACE MINING: MATURING MARKETS AND TECHNOLOGY READINESS LEVELS	9:00 AM	502	368
MINING & EXPLORATION: INNOVATIONS & TECHNOLOGIES: TECHNOLOGY IMPLEMENTATIONS: THE FIELD EXPERIENCE	9:00 AM	503	371
MINING & EXPLORATION: MANAGEMENT: SLIDE RULES TO BIG DATA: THE EVOLUTION OF TECHNICAL KNOWLEDGE IN MINING	9:00 AM	504	374
MINING & EXPLORATION: OPERATIONS: EFFICIENCY GAINS THROUGH AUTOMATION AND INNOVATION	9:00 AM	505	376
MINING & EXPLORATION: OPERATIONS: MINE SCHEDULING AND OPTIMIZATION II	9:00 AM	506	379
MPD: CHEMICAL PROCESSING: POX	9:00 AM	705	381
MPD: FLOTATION: CHEMICAL ASPECTS OF FLOTATION II	9:00 AM	706	384
RESEARCH: GEOMETALLURGY	9:00 AM	612	386
SMART MINING COMPLEXES AND MINERAL VALUE CHAINS	9:00 AM	108	389
SME YOUNG LEADERS: MY INTERNSHIP EXPERIENCE	9:00 AM	601	393
THE POWER OF ENGAGEMENT IN BUILDING ORGANIZATIONAL STRENGTH	9:00 AM	507	396
MPD: PHYSICAL SEPARATION II: GOLD PROCESS FLOWSHEETS – GOLD RECOVERY WITH ADSORPTION (DESORPTION RECOVERY (ADR) CIRCUITS	11:00 AM	EXHIBIT HALL LANDING	397

## SESSIONS AT-A-GLANCE

SESSION TITLE	START TIME	ROOM/ LOCATION	PAGE #
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COAL & ENERGY: A REVIEW OF REFUGE CHAMBERS IN UNDERGROUND COAL	2:00 PM	702	398
COAL & ENERGY: COAL AND ENERGY INNOVATION: THINKING FORWARD	2:00 PM	711	400
COAL & ENERGY: COAL MINE HEALTH & SAFETY II	2:00 PM	706	403
COAL & ENERGY: RESEARCH AND DEVELOPMENT-III	2:00 PM	708	405
ENVIRONMENTAL: "WALK AWAY" PIT LAKE CLOSURE; SUCCESSES AND FAILURES	2:00 PM	107	407
ENVIRONMENTAL: MINE WASTE PROFITABILITY	2:00 PM	104	410
FUERSTENAU SYMPOSIUM: GENERAL SESSION	2:00 PM	709	413
HEALTH & SAFETY: NATIONAL OCCUPATIONAL RESEARCH AGENDA AND THE FUTURE OF MINERS' HEALTH	2:00 PM	610	417
IMPACTS OF SME PHD GRANTS ON EDUCATION AND RESEARCH IN MINERALS INDUSTRY	2:00 PM	106	421
INDUSTRIAL MINERALS & AGGREGATES: HEALTH AND SAFETY IN INDUSTRIAL MINERAL AND AGGREGATE OPERATIONS (CO-SPONSERED SESSION BY IM&A AND H&S DIVISIONS)	2:00 PM	110	424
INDUSTRIAL MINERALS & AGGREGATES: PHYSICAL SEPARATIONS IN INDUSTRIAL MINERALS PROCESSING	2:00 PM	112	427
INTERNATIONAL IV: SUSTAINABLE ARTISANAL AND SMALL SCALE MINING IN LATIN AMERICA	2:00 PM	603	430
MINING & EXPLORATION: GEOSCIENCES: GEOLOGY OF GOLD DEPOSITS	2:00 PM	501	433
MINING & EXPLORATION: GEOSCIENCES: RESOURCE GEOLOGY & GEOSTATISTICS	2:00 PM	502	436
MINING & EXPLORATION: INNOVATIONS & TECHNOLOGIES: AUTOMATION IN MINING: THE PRESENT AND THE FUTURE	2:00 PM	503	439
MINING & EXPLORATION: INNOVATIONS & TECHNOLOGIES: TECHNOLOGY INNOVATION AND APPLICATIONS: GAINING VALUE FROM FLEET MANAGEMENT SYSTEMS	2:00 PM	504	442
MINING & EXPLORATION: MANAGEMENT: ECONOMIC DEVELOPMENT: THE IMPORTANCE OF REIMAGINING MINING COMMUNITIES	2:00 PM	505	446
MINING & EXPLORATION: OPERATIONS: NEW AND EXPANDING MINE OPERATIONS	2:00 PM	506	447
MPD: CHEMICAL PROCESSING: SECONDARY VALUE RECOVERY	2:00 PM	703	449
MPD: COMMINUTION	2:00 PM	707	452
MPD: FLOTATION: FLOTATION EQUIPMENT AND OPERATIONAL ASPECTS	2:00 PM	705	455
RESEARCH: CURRENT RESEARCH ACTIVITIES AND RESEARCH NEEDS IN MINING AND MINERALS INDUSTRY- PANEL	2:00 PM	612	459



## **Be sure to attend these CMA sessions:**

### **MONDAY, FEBRUARY 25**

**2:00pm-2:30pm**

**CMA Annual Membership Meeting**

Sponsored by Wagner Equipment Co.

**2:30pm-4:25pm**

**The Outlook for Commodities in the Current Global, Geopolitical and Economic Environment**

Sponsored by Wagner Equipment Co.

### **TUESDAY, FEBRUARY 26**

**9:00am-9:45am**

**Blockchain and the Mining Industry**

Sponsored by Metro Denver EDC/Colorado Resource Council

**9:45am-10:30am**

**An Ephemeral Landscape: Traversing the Fractured Regulatory Dynamics Surrounding Abandoned Mines and Mining Districts**

**10:30am-11:30am**

**The Future for Coal Use in the U.S.**

**1:30pm-4:00pm**

**Technology in Mining**

Sponsored by Wagner Equipment Co.

### **WEDNESDAY, FEBRUARY 27**

**9:00am-11:05am**

**Safety and Health: From the Nation's Capital to CMA Membership's Operations**

**9:00am-11:05am**

**State and Federal Mining Policy Update**

Climax Molybdenum,  
a Freeport-McMoRan Company

All CMA sessions are held in room 710/712

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## TECHNICAL PROGRAM

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**MONDAY, FEBRUARY 25**

*AFTERNOON*

**1:30 PM | ROOM 113**

### **Dreyer Lecture: Why Choose Industrial Minerals for a Career Path**

*Recipient and Lecturer: Dennis P. Bryan*

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**MONDAY, FEBRUARY 25**

*AFTERNOON*

**2:00 PM | ROOM 507**

### **Bulk Material Handling: Conveyor Maintenance and Safety**

*Sponsored by: BEUMER Corporation*

*Chair: N. Madison, Cornerstone Conveyor Engineering, Fayette, AL*

**2:00 PM**  
**Introduction**

**2:05 PM**  
**Constructing Toromoch's 5.2 KM Conveyor Through the Andes Mountains**

*C. Torres and E. Michiels; Maccaferri Mining Solutions, Lithia, FL*

Constructing a 5.2 KM conveyor has many challenges, combine that with building it at nearly 5,000m in elevation through the Andes mountains and it can be hazardous. Identifying the structure's best travel path still required a 250m climb, a 300m decent as well as 7 horizontal turns. This path still left the conveyor exposed to falling debris and ice, the construction of a 20m reinforced slope and a tunnel to allow vehicles to cross the structure. Construction at this elevation is challenging and the weather; wind snow and rain, can be create quite a burden on the installation crews. For the safety and construction timeline experienced crews were necessary to construct various aspects of this project. This presentation will share design and construction details on the rockfall protection system, the MSE wall supporting this massive conveyor and the tunnel on this project.

**2:25 PM**

## **Bulk Material Flowability Testing – What Is It and Why Does It Matter?**

*C. Hartford and T. Holmes; Jenike & Johanson, San Luis Obispo, CA*

Bulk solids handling systems are often the weakest links in the process plant, and their performance can dictate the performance of the entire operation. Therefore, they deserve special attention. When designing a bin, hopper, transfer chute, or stockpile for a bulk material, it is critical to understand how the bulk solids will “flow” through the system. Flowability is a function of the material and the equipment handling it. A “free-flowing” material placed in poorly designed equipment may have difficulty flowing reliably. Similarly, a material that seems difficult to handle placed in the correct equipment may flow without a problem. When designing a liquids plant, the density and viscosity of a liquid is looked up or tested and used as a design parameter. With bulk solids, the design process is similar except the friction, cohesive strength, compressibility and sometimes permeability need to be measured for the material. It is important for these tests to be run at representative process conditions. Measuring flow properties and applying them correctly will reduce project risk and potentially save a significant amount of capital.

**2:45 PM**

## **The Importance of Being Conservative with the Packing Ratio in Discrete Element Modeling to Improve the Design Phase and Simulated Behavior of Transfer Chutes**

*J. Amoroso; Overland Conveyor Co., Lakewood, CO*

Using discrete element modeling to simulate transfer chutes is an important step towards designing a well-engineered transfer chute. It is beneficial to visualize the material flow through the transfer chutes before fabrication and without building a full scale model. The difficulty with discrete element modeling is understanding what parameters and values to use for the simulated material in order to match the onsite material as close as possible. Onsite tests can be performed on the material to find specific material details which are used to optimize the discrete element modeling parameters. This paper will explain how the packing ratio affects other parameters due to the change in particle density. Once the other parameters are adjusted to match the onsite material details, the packing ratio may need to be revised as a result of how the simulated material settles. The revolving nature of modifying the packing ratio along with other parameters will be discussed concluding in a conservative packing ratio, not only for simulating material behavior but as a best practice for designing transfer chutes.

**3:05 PM**

## **Maximizing Conveyor System Efficiency with New Drum Motor Technology**

*A. Kanaris; Engineering, Van der Graaf, Shelby Township, MI*

Conveyors powered by external motors and gearboxes, along with v-belts, chains, couplings & pillow block bearings, often operate with relatively low efficiency and require regular maintenance. With rising electrical and labor costs, mining & aggregate industries are forced to evaluate ways to minimize downtime, reduce maintenance costs, increase worker safety and ultimately increase profits. New drum motor technology has addressed efficiency and operator safety concerns. The drum motor, an internally driven conveyor drive, eliminates external components, houses the electric motor & gearbox inside the drum, increases operator safety, saving space, eliminates sched-



uled maintenance, increases longevity and overall efficiency. With v-belts, chains and couplings no longer required, the internal drive design drum motor, has efficiency gains of up to 30% and lower operating costs. Reliability & longevity of conveyor drives pose challenges for belt conveyors to operate in harsh & abrasive environments and failure is ground zero for loss of production. The latest Van der Graaf GrizzlyDrive™ drum motor with IronGrip lagging, is developed specifically to operate in these extreme environments.

**3:25 PM**

## **The Different Types of Conveyor Belts Used in Mining**

*L. Hoggan; Rema Tip Top, Oregon City, OR*

Mining is a broad term that captures a lot of different products and processes for extracting the earth's minerals. There is not just one type of conveyor belt that works well in all mining applications. Learn about the different rubber compounds, types of conveyor belt construction and configurations that impact the life, capacity and functionality of conveyor belts around the mining site. You'll walk away understanding the terminology and differences in specifications, ensuring that you have the knowledge to ask the right questions and make the right purchasing decisions.

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## **MONDAY, FEBRUARY 25**

*AFTERNOON*

**2:00 PM | ROOM 711**

## **Coal & Energy: Best of Ground Control**

*Chairs: M. Murphy, National Institute for Occupational Safety and Health, Pittsburgh, PA  
B. MISHRA, West Virginia University, Morgantown, WV*

**2:00 PM**

### **Introduction**

**2:05 PM**

### **Analysis of Coal Pillar Stability (ACPS): A New Generation of Pillar Design Software**

*Z. Agioutantis<sup>1</sup> and C. Mark<sup>2</sup>; <sup>1</sup>University of Kentucky, Lexington, KY and  
<sup>2</sup>Mine Safety and Health Administration, Pittsburgh, PA*

Thirty years ago, the Analysis of Longwall Pillar Stability (ALPS) inaugurated a new era in coal pillar design. ALPS was the first empirical pillar design technique to consider the abutment loads that arise from full extraction, and the first to be calibrated using an extensive database of mining case histories. ALPS was followed by the Analysis of Retreat Mining Stability (ARMPS) and

the Analysis of Multiple Seam Stability (AMSS). Today, these empirical methods are used in nearly every underground coal mine in the US. However, the piecemeal manner in which these methods have evolved resulted in some weaknesses. In certain situations, it may not be obvious which program is the best to use. Other times the results from the different programs are not entirely consistent with each other. The Analysis of Coal Pillar Stability (ACPS) integrates all three of the older software packages into a single pillar design framework. ACPS also incorporates the latest research findings in the field of pillar design, including an expanded multiple seam case history data base and a new method to evaluate room and pillar panels containing multiple rows of pillars left in place during pillar recovery.

## 2:25 PM

### **The Limitations and Potential Design Risks When Applying Empirically-Derived Coal Pillar Strength Equations to Real-Life Mine Stability Problems**

*R. Frith and G. Reed; Mine Advice Pty Ltd, Beresfield, NSW, Australia*

The paper explores the reasons as to why empirically-derived coal pillar strength equations tend to be problem-specific, and so should perhaps be considered as providing no more than a pillar strength “index”. These include the nonconsideration of overburden horizontal stress within the mine stability problem, an inadequate definition of super-critical overburden behaviour as it applies to coal pillar loading and the non-consideration of overburden displacement and coal pillar strain limits, all of which combine to potentially complicate and so confuse the back-analysis of coal pillar strength from failed cases. A modified coal pillar design representation and model is presented based on coal pillars acting to reinforce a horizontally-stressed overburden, rather than suspend an otherwise unstable self-loaded overburden or section thereof, the latter having been at the core of historical empirical studies into coal pillar strength and stability.

## 2:45 PM

### **What Factors Over and Above Those Included in the Existing Coal Mine Roof Rating (CMRR) Could Also Be Predictive of Roof Instability in Underground Coal Mines?**

*M. Young, E. Holley and G. Walton; Colorado School of Mines, Golden, CO*

The coal mine roof rating (CMRR) was developed by NIOSH to bridge the gap between geological variation in underground coal mines and engineering design. The CMRR has been widely used and validated in Eastern US coal mines, but has seen limited application in the Western US. This study focuses on roof behavior at two Western coal mines. The first mine presents laterally continuous roof stratigraphy, yet the roof stability is not uniform even though the geology is. The second mine shows significant lateral geological variation, along with localized faulting and a laterally extensive sandstone channel network. It is hypothesized that there are other factors that are correlated with roof instability in underground coal mines that could also be included in the CMRR. This hypothesis was tested by collecting 30-50 CMRR measurements at the aforementioned mines. At each measurement location, a binary record of the roof condition (stable or unstable) was made along with parameters such as depth of cover thought to also correlate with roof stability. A statistical analysis of the data was performed to determine the parameters above and beyond the CMRR which can be correlated to roof stability.

**3:05 PM**

## **Management of Initial Convergence Events at Broadmeadow Mine**

*R. Coutts<sup>1</sup>, K. Mills<sup>2</sup>, D. Lynch<sup>1</sup> and M. Martin<sup>1</sup>; <sup>1</sup>BHP, Moranbah, QLD, Australia and <sup>2</sup>SCT Operations Pty Ltd, Wollongong, NSW, Australia*

Broadmeadow Mine is located in Central Queensland, Australia. The mine introduced a Top Coal Caving (TCC) longwall (LW) face in 2010 but since then experienced a series of severe convergence events soon after starting each panel. During LW8, LW9 and LW10, weighting events occurred at 60-70m retreat resulting in equipment damage and the longwall almost becoming iron bound. Considerable effort was required in LW10 to regain sufficient clearance for operations to resume. LW11 was characterised to have a similar risk of a weighting event to LW10. This presentation documents the learnings from a geotechnical monitoring programme undertaken during LW11 and details the operational methods used to mitigate these initial convergence events. It also comments on the significance of the top coal caving technique to the convergence events.

**3:25 PM**

## **Review of Evaluation and Design of Secondary Support Performance in Longwall Ventilation Entries**

*B. Mirabile<sup>1</sup> and E. Westman<sup>2</sup>; <sup>1</sup>Jennmar Corporation, Pittsburgh, PA and <sup>2</sup>Virginia Tech, Blacksburg, VA*

A longwall ventilation system is designed to continuously dilute and move methane-air mixtures and other contaminants from the active face, to bleeder systems, and out of the mine. The #2 entry of a three-entry tailgate gateroad serves to transport contaminated air from the longwall face through the bleeder system. The #2 entry is required to function as an air course between two longwall gobs, and is subject to significant ground movement and loading. Substantial research has been conducted on secondary support performance in longwall tailgates. However, current ground support design and evaluation practices in the #2 entry are based on empirical evidence, and little to no quantitative data on support performance exists for the #2 entry. Extending published evaluation and design methodologies for secondary support in longwall tailgates, a ground response curve unique to the loading conditions and required functionality of the #2 entry can be developed.

**3:45 PM**

## **Challenges of Mining the First Right-Handed Longwall in Pittsburgh Seam**

*J. Lu<sup>1</sup> and G. Hasenpus<sup>2</sup>; <sup>1</sup>CONSOL Energy Inc., Southpointe, PA and <sup>2</sup>Barr Engineering, Salt Lake City, UT*

In this presentation, the mining experience and challenges for the first right-handed longwall panel in the Pittsburgh seam was introduced. The longwall headgate T-junction experienced very high face convergence (up to 2 feet), accompanied by roof sag, floor heave, and rib loading. The headgate convergence was so large that in a few places it threatened longwall retreat, and ultimately required the bottom to be re graded. Different underground instruments, such as roof scope, de-gas drill, tell-tale, laser meter, and Borehole Pressure Cell (BPC), were employed to explore the roof geology, monitor the entry convergence and the stress changes in the pillar. In addition, the impact of other geologic factors, such as large overburden depth, laminated sandstone roof geology, soft floor, and large headgate equipment, etc., were also analyzed. Subsequently, geotechnical solutions were provided to avoid or mitigate the impact of these challenging geologic factors.

## MONDAY, FEBRUARY 25

AFTERNOON

2:00 PM | ROOM 706

### Coal & Energy: Coalbed Methane, Shale Gas, & Carbon Sequestration

**Chairs:** *N. Ripepi, Virginia Polytechnic Institute and State University, Blacksburg, VA*  
*R. Pandey, Southern Illinois University Carbondale, Carbondale, IL*

2:00 PM  
Introduction

2:05 PM  
**New Perspectives on Supercritical Methane Adsorption in Shales and Associated Thermodynamics**

*X. Tang and N. Ripepi; Department of Mining & Minerals Engineering, Virginia Polytechnic Institute & State University, Blacksburg, VA*

Understanding methane adsorption behavior in shales lays the foundation for shale gas exploitation and recovery as the adsorbed methane is a large portion of the subsurface shale gas resource. However, the adsorption mechanism of supercritical methane in shales and associated thermodynamics are still remain mystery because the equation of state of the adsorbed methane is unmeasurable. This work analyzed adsorption equilibria (up to 32MPa and 393.15K) using a rigorous framework that can account for non-ideal gas properties and accurately extrapolate absolute adsorption uptakes from measured adsorption isotherms. The framework also allows a straightforward calculation of the thermodynamic potentials such as enthalpy and entropy relevant to adsorption. Methane adsorption isotherms in shale under different pressures and temperatures are found to be a part of a two dimensional adsorption isotherm surface. The density of the adsorbed methane in shales depends on temperature and pressure which is always lower than the liquid methane density. The isosteric enthalpy/entropy of adsorption and enthalpy/entropy of adsorbed methane are found to be temperature-and surface coverage-dependent.

2:25 PM  
**Modeling Fluid Flow Behavior in Microbially Recharged Coalbed Methane Reservoirs**

*R. Pandey and S. Harpalani; Mining and Mineral Resources Engineering, Southern Illinois University Carbondale, Carbondale, IL*

Imaging of bioconverted Illinois basin coal to methane using nutrient-amended microbial solution revealed significant changes in its physical structure. Coal matrix swelled due to bioconversion, resulting in narrower cleat apertures. However, wider fractures increased in width. Such variations in the size of the matrix and fractures/ cleats was accounted for by bioconversion-induced pore, matrix and bulk strains. The measured strains were then used as input parameters in a flow model developed to characterize Darcian transport and geomechanical response of a biogenic CBM reservoir. The results showed suppression of permeability and increased sensitivity to changes in effective stress.

**2:45 PM**

## **Converting CO<sub>2</sub> from Coal-Fired Power Plants to Oxalic Acid**

*S. Valluri and S. Kawatra; Chemical Engineering, Michigan Technological University, Houghton, MI*

Carbon dioxide capture from coal-fired power plant flue gas and subsequent sequestration is expected to play a vital role in mitigating global climate change. To meet the growing need for CO<sub>2</sub> capture Technology, Michigan Technological University is researching CO<sub>2</sub> capture and Utilization. We have successfully converted CO<sub>2</sub> into oxalic acid using an electrochemical approach. If oxalic acid can be produced in bulk from CO<sub>2</sub>, it can be used to leach rare earth minerals at low cost. Electrochemical reduction of CO<sub>2</sub> to hydrocarbons and other chemicals is a complex multistep reaction with adsorbed intermediates. The exact reaction mechanisms leading to various products are not clear from the literature to date and will likely change over the range of conditions like pH, electrode potential, electrolyte medium, catalyst, etc. In this paper, we will present an idea of how the above-mentioned factors will effect electrochemical reduction of CO<sub>2</sub> to Oxalic acid.

19-068

**3:05 PM**

## **Identification of the Main Variables That Affect the Spontaneous Combustion of Coal and Prevention Strategies for an Open Pit Mine in Colombia**

*A. Daza, P. Bustamante and M. Bustamante; Materials and Minerals, National University of Colombia, Medellín, Colombia*

Spontaneous combustion in coal seams is a problem that occurs in coal mines around the world. Theories have been developed that speak of various factors that generate self-heating in coal. Synergy of these factors contributes to the increase of the temperature in the oxidation reaction, facilitating reaching the activation energy of the system. Currently, the incidence of each variable in the susceptibility to coal spontaneous combustion is unknown, therefore in this work a methodology was developed to determine statistically which of the variables have the greatest contribution in this phenomenon. For the analysis, field and laboratory data were collected from different seams of an open pit coal mine in Colombia, considering extrinsic and intrinsic factors. Based on these variables that constitute an ignition scenario, some strategies of sealing were proposed to prevent spontaneous combustion in coal seams such as diluted bitumen with brine (combustion inhibitor), cement-lime, fine-sand cement and clinker-lime. Finally, through pilot tests it was confirmed that the bitumen diluted with brine in a concentration of 50/50 is the best alternative.

**3:25 PM**

## **Carbon Dioxide Capture from Flue Gas at Michigan Tech Steam Plant**

*S. Root, S. Valluri and S. Kawatra; Chemical Engineering, Michigan Technological University, Houghton, MI*

Carbon dioxide, a byproduct of combustion reactions, is a greenhouse gas linked to climate change. At Michigan Technological University, we have studied the capture of CO<sub>2</sub> using alkali scrubbing solutions in a pilot scale packed bed counter-current scrubbing column. To do this, we have simulated flue gas by combining streams of CO<sub>2</sub> and compressed air. Real flue gas has impurities such as SO<sub>2</sub> and NO<sub>x</sub>, and has lower levels of O<sub>2</sub> than our simulated flue gas. In order to study CO<sub>2</sub> capture from a real flue gas, the

Department of Chemical Engineering worked with the facilities department to install a pilot scale scrubbing column in the Michigan Tech steam plant. Experiments were conducted using a sample stream of the flue gas from the boiler in the steam plant. Data collected from these experiments were compared to the data collected from identical experiments conducted on simulated flue gas in the lab. The capture efficiency of the real flue gas scrubbing column is discussed in this paper.

19-070

## MONDAY, FEBRUARY 25

AFTERNOON

2:00 PM | ROOM 704

### Coal & Energy: Dust Control I

*Chair: S. Schafrik, University of Kentucky,  
Lexington, KY*

2:00 PM

#### Introduction

2:05 PM

#### Float Coal Dust Sampling and Preliminary Analysis

*A. Kumar and S. Schafrik; Mining Engineering, University of Kentucky,  
Lexington, KY*

Maintaining sufficient rock dust coverage is vital to preventing a coal dust explosion following a methane ignition. The objective of this research is to sample float coal dust deposited in underground mine airways. Based on research done by the US Bureau of Mines we sampled settled float dust in longwall and, room and pillar mines. Coal samples were taken from the roof, ribs, and floor at multiple breaks along single air splits. The samples were analyzed using thermogravimetric analysis to quantify float coal dust deposition. Preliminary results show the coal dust weight per unit area has uniform variation without regard to ventilation air split. This paper presents the sampling and analysis techniques used with the results obtained with a theory as to the reason for the uniform variation. Keywords: Coal mine ventilation, Rock dusting, Thermogravimetric analysis.

19-135

2:25 PM

#### Field Comparison of Roof Bolter Dry and Wet Collection Systems for Dust Control

*W. Reed<sup>1</sup>, M. Shahan<sup>1</sup>, G. Ross<sup>2</sup>, D. Blackwell<sup>3</sup> and S. Peters<sup>3</sup>;*

*<sup>1</sup>CDC-NIOSH, Pittsburgh, PA; <sup>2</sup>J.H. Fletcher & Co., Inc., Huntington, WV  
and <sup>3</sup>Deserado Mine, Blue Mountain Energy, Rangely, CO*

Roof bolting machine dust collectors use a dry box to collect the roof bolting material. Recently, an underground mining operation converted a dry box dust collector to a wet box dust collector. The wet box utilizes a water spray

to wet the incoming material. Testing was conducted comparing the different collector types. The average respirable dust concentration during cleaning of the wet box was 0.475 mg/m<sup>3</sup>, and 1.188 mg/m<sup>3</sup> for the dry box. The results from this study indicate that using the wet box as a collector reduced exposure to respirable dust when cleaning the collector boxes.

19-019

## 2:45 PM

### Thermogravimetric Analysis of Laboratory and Field Respirable Coal Mine Dust Samples to Determine Coal and Mineral Mass Fractions

*E. Agioutanti, C. Keles and E. Sarver; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA*

It has long been known that chronic exposures to respirable coal mine dust can cause occupational lung diseases such as Coal Worker's Pneumoconiosis and silicosis. However, all dust is not created equal – meaning that the dust composition can play a significant role in determining health outcomes. Moreover, dust composition is dependent on dust sources (e.g., coal and rock strata, rock dust products). For regulatory compliance purposes, total mass concentration and silica mass fraction are monitored, but the whole composition of coal mine dust is not typically determined. Similar to proximate analysis of bulk coal materials, we have previously shown that thermogravimetric analysis (TGA) can be used to determine the coal and total minerals mass fractions in respirable dust samples. With sufficient dust mass, carbonates and non-carbonate minerals fractions can also be differentiated, which may help to distinguish rock strata (i.e., mostly non-carbonate minerals) versus rock dust product (i.e., carbonates) dust sources. Here we present an improved TGA method that is verified by laboratory-generated dust samples, and TGA results for field samples collected in 13 underground coal mines.

## 3:05 PM

### A Comparison of Respirable Dust Characteristics in 24 US Coal Mines

*A. Norris<sup>1</sup>, E. Sarver<sup>1</sup>, C. Keles<sup>1</sup> and M. Rezaee<sup>2</sup>; <sup>1</sup>Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA and <sup>2</sup>Mining Engineering, Penn State, State College, PA*

Reported cases of occupational lung disease amongst Appalachian coal miners have recently skyrocketed. While a range of contributing factors have been speculated or offered anecdotally, including unique mining practices and conditions that could affect characteristics of respirable dust and dust exposures, there is little hard data available beyond what is gathered for regulatory compliance purposes. To shed some light on dust characteristics, our team has been working to adapt and apply analytical techniques to study particle size and mineralogy distributions, as well as metal and trace element concentrations. Here, we present results from samples collected in various locations of 24 mines between 2013-2018.

### 3:25 PM

## The Design of a Laboratory Apparatus to Simulate the Dust Generated by Longwall Shield Advances

*M. Shahan and W. Reed; CDC NIOSH, Pittsburgh, PA*

A laboratory apparatus (shield dust simulator) was designed and constructed to simulate the dust generated during the advance of longwall hydraulic roof supports, or shields. The objective of the study was to develop a tool that could be used to test the hypothesis that foam applied to a mine roof prior to a shield advance could be used to reduce the respirable dust generated during shield advances. This paper will outline the design parameters for the development of the system, as well as describe baseline testing of coal and limestone dust. Results show the average instantaneous respirable dust concentrations that occurred during simulated shield advance. Confidence intervals were calculated from the instantaneous respirable dust data to determine the repeatability of the data produced by the device.

19-018

### 3:45 PM

## Managing Mine Dust Pollution in Near Real Time Leveraging IoT and Analytics

*N. SHARMA; Mining Engineering, Indian institute of Technology, Dhanbad, Jharkhand, India*

The pollution levels due to continuous mining is deteriorating the air quality around mining complexes. Increased focus on environment compliance has led to many ways of monitoring and regulating the environment at mines and mineral/ore handling points. The poisonous gases, mineral particles getting mixed in the water bodies, air and the food chain are the detrimental impacts of mining. The dust is generated from vehicle movement on haulage roads, excavation, crushing, milling, conveyors belts, blasting, loading, unloading, wind erosions of stockpiles and overburden. Presently the dust is controlled as a scheduled activity with process control systems and spray trucks. As the industry is moving towards the 'Digital mine', the connectivity between equipment systems in real time, enable real time analysis and decision making. Real time IoT and Analytics based solutions, will ensure safety, reliability and compliance to the environmental standards and norms set by the statutory and regulatory bodies. Real time IoT and Analytics solutions provide real time monitoring, extrapolation of dust, moisture and weather insights to provide a decision framework for "Dust Conditioning."



**MONDAY, FEBRUARY 25**

*AFTERNOON*

**2:00 PM | ROOM 702**

## **Coal & Energy: Energy: Geothermal Innovation**

**Chairs:** *M. Mohanty, University of Nevada Reno, Carbondale, IL*  
*M. Nakagawa, Colorado School of Mines, Golden, CO*

**2:00 PM**

### **Introduction**

**2:05 PM**

### **Resource Competition and Stakeholder Network Evolution in Geothermal Development Projects**

*K. Bahr; Graduate School of Environmental Studies, Tohoku University, Sendai, Miyagi-ken, Japan*

Social License to Operate (SLO) is a stakeholder management methodology that has been successfully used in traditional resource extraction sectors. Geothermal development projects have many similar characteristics to Mining and Oil & Gas projects, but they also have some unique features, which bring particular social challenges. Specifically, the many potential usages of geothermal waters can often lead to stakeholder competition and difficulties in building consensus around usage schemes, scale, and distribution of risks and benefits. In this talk, a comparative case study of a geothermal resource in the U.S. and Japan is used to explore some of these competition issues and how the SLO model can be used to understand and mitigate them, as well as the evolution of the stakeholder network that may occur as the development matures.

**2:25 PM**

### **Constructive Use of Geothermal Energy to Ventilation and Mine Power Management**

*G. Danko<sup>1</sup>, A. Jobbik<sup>2</sup> and K. Baracza<sup>2</sup>; <sup>1</sup>Mining and Metallurgical Engineering, Univ. of Nevada, Reno, Reno, NV and <sup>2</sup>Research Institute of Applied Earth Sciences, University of Miskolc, Miskolc, Hungary, Hungary*

Strata heat is a liability in deep and hot mines considering the ambient air temperature at the work place. Heat must be removed from the ventilating air to cool it below a temperature limit for safety and health. Strata heat is also an asset for accessing renewable energy from the earth. Deep, mechanized mines have both: the need for strong power supply and the excess amount of strata heat albeit at low temperature level. The connection between the two contradictory components is addressed showing a technology of combining the supply with the demand. Geothermal energy removal in a Carnot cycle of compressed air is used to drive a turbine for mechanical power supply for underground transportation or booster fan operation. The heat removed

from the strata at the work place and put to shaft work is cycled back to the thermodynamic system at the compressor that is placed at the bottom of the exhaust shaft. The heating power transferred from the compressor to the exit air enhances natural ventilation by the chimney effect. Altogether, the simple and safe system described may be economically viable if and when the turbine air motors can operate at or above an overall efficiency of 70%.

## 2:45 PM

### Feasibility of Ground Source Heat Pumps (GSHP) and Geothermal Energy Systems for Cooling Underground Mines

*K. Scalise<sup>1</sup> and K. Kocsis<sup>2</sup>; <sup>1</sup>Geological Sciences and Engineering/Mining Engineering, University of Nevada, Reno, Sparks, NV and <sup>2</sup>Department of Mining & Metallurgical Engineering, University of Nevada, Reno, Reno, NV*

Many deep and highly mechanized underground metal mines require some method of cooling. The cooling requirements might be fulfilled by ventilation alone, but some additional cooling. Presently, the most common cooling systems in use are bulk air cooling and localized/spot cooling systems, which typically employ a compressor cycle and refrigerant to cool the mines' intake air. These systems are effective, but they use massive amounts of electrical energy. Ground source heat pump (GSHP) technology has the ability to supplement existing cooling systems by utilizing constant ground temperature to aid in both cooling in summer and heating in winter, if necessary. Geothermal systems have the possibility to cool the mines in their entirety if there are significant heat sources present. A major advantage of these systems is that they are based on renewable energy, thus reducing the carbon footprint of the mines. This paper discusses the methods and technologies regarding GSHP and geothermal systems, and the feasibility of implementing these systems. This paper will demonstrate the possibilities of renewable cooling systems that are rarely discussed or considered.

## 3:05 PM

### Correlation Between Seismicity Induced by Geothermal Heat Extraction and Reservoir Temperature

*Z. Khademian and M. Nakagawa; Mining Engineering, Colorado School of Mines, Golden, CO*

Extraction of heat from geothermal reservoirs may activate preexisting faults and cause seismic events whose intensity is reported to be related to the reservoir temperature. This paper employs a thermo-mechanical model within UDEC and provides an insight in how the reservoir temperature may affect the intensity of seismic events. We simulate four faults surrounded by rocks initially heated to 100, 200, 300, and 400 C. Heat extraction is gradually performed by a heat sink with a constant temperature of 30 C along the faults until slip occurs. A computational framework previously developed by the authors is then employed for estimating the radiated seismic energy as a measure of the event intensity for each case. Results indicate that assuming mechanical properties of rocks and faults are temperature-independent, radiated seismic energy stays constant between the models with different temperatures. This conclusion contradicts the reported relationship between induced event intensity and reservoir temperature and suggests that accounting for the temperature dependence of the fault and rock mechanical properties may be the missing piece of understanding thermally induced seismicity.

**3:25 PM**

## **Coupled Hydromechanical Analysis of an EGS in Nevada Using DFN Model**

*H. Rashid, B. Abbasi and M. Mohanty; Mining and Metallurgical Engineering, University of Nevada, Reno, Reno, Bangladesh*

The geomechanical and hydrological behaviors of fracture networks are very important for the performance of an enhanced geothermal system (EGS). In this study, discrete fracture network (DFN) modeling was used for coupled hydromechanical process analysis of an EGS in Nevada. Fracture networks were generated using image log data from the field. Fracture aperture, porosity, permeability, transmissivity, effective area and fracture radius were used for hydrological analysis. This hydrological analysis was used to understand the transport behavior of fracture networks. Critical stress, Young's modulus, Poisson ratio and bulk density were analyzed and upscaled for the geomechanical analysis. The effect of change in geomechanical properties on the transport behavior of fracture networks was also studied. DFN simplification was performed to make computational time convenient. The upscaled fracture networks were analyzed ultimately to understand coupled hydromechanical behavior of the system using Golder associate's software FracMan. Optimum operating parameters for well location, flowrate, thermal breakthrough, operation period and inlet water temperature was set based on this study.

**3:45 PM**

## **Benefits of Passive-Source Seismic Imaging for Enhanced Geothermal Systems**

*J. Louie; Nevada Seismological Laboratory, University of Nevada Reno, Reno, NV*

A project in progress, supported by DOE-EERE, is evaluating the effectiveness of passive seismic recording techniques in the characterization of potential Enhanced Geothermal Systems (EGS) ahead of drilling. The project recorded microtremor along six "Large-N" deployments of 500 geophones across the geothermal well field in Dixie Valley, central Nevada. The processed seismic cross-sections that result compare well to prior passive results using just dozens of seismometers; and to prior "active source" results of typical energy-industry seismic-reflection lines in the region. The passive-source sections suggest bedrock structures to EGS depths and faults into deep basement. There are several ways of assessing the cost savings of passive over active-source seismic surveys: gross or per-kilometer DOE project cost comparisons; and industry quotes; varying from 28-98% savings. The non-cost benefits of passive seismic surveys are many: potential deeper imaging; no need for heavy truck access outside lease boundaries or in environmentally sensitive or inaccessibly steep areas; and easier permitting. A principal benefit of passive-source seismic surveys is greater project feasibility.

## MONDAY, FEBRUARY 25

AFTERNOON

2:00 PM | ROOM 708

### Coal & Energy: Rare Earth Elements in Coal I

**Chairs:** *A. Noble, West Virginia University, Blacksburg, VA*  
*M. Mosser, Mosser Resource Consulting LLC, Morgantown, WV*

2:00 PM  
Introduction

2:05 PM  
Rare Earth Elements and Critical Materials from Coal-Based Resources

*M. Alvin; NETL, Pittsburgh, PA*

The Department of Energy (DOE), Office of Fossil Energy (FE) and the National Energy Technology Laboratory (NETL), Rare Earth Elements (REE) Program is developing technologies that enhance conventional extraction and separation processes to enable the domestic production of economically competitive and environmentally benign, market-ready, rare earth element oxides (REOs) from domestic coal and coal-based feedstocks (coal refuse, power generation ash, clay and/or shale coal seam over-/under-burden materials, acid mine drainage sludge [AMD]). In addition, second-generation and transformational REE extraction and separation concepts are being developed to further enhance the economic viability of U.S. based REO production. This paper provides an overview of the REE program and summary of the technical accomplishments that have been achieved.

2:25 PM  
Design, Development and Testing of a Pilot Plant for Rare Earth Recovery from Coal-Based Sources

*R. Honaker<sup>1</sup>, J. Werner<sup>1</sup>, W. Zhang<sup>1</sup>, R. Yoon<sup>2</sup>, G. Luttrell<sup>2</sup> and A. Noble<sup>2</sup>;*  
*<sup>1</sup>Mining Engineering, University of Kentucky, Lexington, KY and <sup>2</sup>Virginia Tech, Blacksburg, VA*

Two years of extensive studies funded by the U.S. Department of Energy into the recovery of rare earth elements (REEs) from coal-based sources have resulted in the design and development of a ¼-tph pilot-scale processing facility. The pilot plant integrates advanced mineral and hydrometallurgical processes to allow the treatment of multiple types of feed stocks including run-of-mine feed, mixed-phase material, solid waste, acid mine drainage and precipitate material. A crushing and grinding circuit provides the ability to liberate coal and rare earth minerals at any required particle size. High quality coal and rare earth minerals are recovered using a novel separation technology known as the hydrophobic-hydrophilic separation process. Dissolution of the rare earth minerals is achieved using a counter-current leaching circuit that can be altered as needed. A novel solvent extraction is installed that has proven ability to produce REE concentrate mixes having a content greater than 80%. The paper will review the design aspects of the pilot plant and present preliminary results.

**2:45 PM**

## **Bench-scale Testing Update – Recovery of Rare Earth Elements from Lignite Coal**

*D. Laudal<sup>1</sup>, N. Theaker<sup>1</sup>, B. Rew<sup>1</sup>, C. Lucky<sup>2</sup>, S. Benson<sup>3</sup> and R. Addleman<sup>4</sup>;  
<sup>1</sup>Institute for Energy Studies, University of North Dakota, Grand Forks, ND;  
<sup>2</sup>Barr Engineering Company, Minneapolis, MN; <sup>3</sup>Microbeam Technologies Inc.,  
 Grand Forks, ND and <sup>4</sup>Pacific Northwest National Laboratory, Richland, WA*

The University of North Dakota is developing a novel technology to recover and concentrate rare earth elements from lignite coal. This 3-year project, funded by the US Department of Energy and the North Dakota lignite industry, involves three primary objectives: 1) Identify lignite coal and lignite byproducts with high concentrations of rare earth elements and determine modes of occurrence, 2) with promising feedstocks, perform laboratory- and bench-scale testing of environmentally benign methods to extract and concentrate the REE to a minimum of 2wt%, and 3) perform a technical and economic feasibility assessment. The efforts have identified locations in North Dakota with REE concentrations in lignite coals of over 1,000 ppm on a dry whole coal basis, and the unique properties of lignite coal permit a simple and low-cost REE extraction technique. Also in the process, the lignite coal is beneficiated, reducing ash yield and some deleterious inorganic fuel impurities. This paper will provide the results of the bench-scale testing as well as preliminary results of the techno-economic analysis. Next steps and plans for future demonstrations will also be discussed.

**3:05 PM**

## **Physical Beneficiation of Fly Ash for Rare Earth Element Recovery**

*J. Groppo<sup>1</sup> and J. Hower<sup>2</sup>; <sup>1</sup>Mining Engineering, University of Kentucky, Lexington, KY and <sup>2</sup>Center for Applied Energy Research, University of Kentucky, Lexington, KY*

Characterization studies have shown that rare earth elements (REEs) are found at elevated concentrations in strata associated with coal seams. One general data trend is that REE concentration increases with ash content, suggesting that recovery strategies should focus on the higher ash content material such as refuse and middlings. However, another general trend is increasing HREE/LREE ratio with decreasing ash content, suggesting enrichment of heavier elements in the organic phase. While physical and/or chemical extraction of REEs from coal would be problematic, an alternative approach is removal of organic phases via combustion, thus increasing the concentration of REEs in post-combustion ash. A flowsheet has been developed and demonstrated at 250 lbs/hr feed rate to concentrate REEs in coal combustion fly ash, in order to produce an enriched feedstock suitable for extraction via leaching and precipitation processes.

**3:25 PM**

## **Utilization of X-Ray Sorter Technology to Enhance the Economic Viability of Recovering Rare Earth Elements from Coal-Based Feedstocks**

*A. Noble<sup>1</sup>, C. Sechrist<sup>1</sup>, S. Keles<sup>1</sup>, G. Luttrell<sup>1</sup> and R. Honaker<sup>2</sup>; <sup>1</sup>Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA and <sup>2</sup>Mining Engineering, University of Kentucky, Lexington, KY*

The U.S. Department of Energy has identified several rare earth elements (REEs) that are critical to the continued development of new technologies for generating, storing, transmitting and conserving energy. Recent studies funded by this agency have further demonstrated that the waste products discarded by the nation's fleet of coal processing facilities contain significant amounts

of these critical elements that can be extracted, upgraded and refined into salable products. To further enhance the economic viability of this opportunity, an experimental test program was undertaken to evaluate the use of low-cost x-ray sorter technology to preconcentrate coal-based REEs feedstocks prior to comminution, physical separation and hydrometallurgical processing operations. This article (i) reviews the working principles of dual-scan x-ray sorter technology, (ii) presents results from bench-and pilot-scale testing for REE preconcentration, and (iii) examines the potential financial impacts of this low-cost process on REE production from coal-based resources.

**3:45 PM**

### **Concentrating Rare Earth Elements from Coal Fly Ash Leachates Using Ligand-Associated Organosilica Media**

*T. Dittrich<sup>1</sup>, M. Dardona<sup>1</sup>, J. Hovey<sup>2</sup> and M. Allen<sup>2</sup>; <sup>1</sup>Civil and Environmental Engineering, Wayne State University, Detroit, MI and <sup>2</sup>Chemistry, Wayne State University, Detroit, MI*

Rare earth elements (REEs) have many critical uses in advanced technology and the lack of a reliable domestic supply has been identified by the US DOE as a vulnerability to US economic security. Our research focuses on developing an economical process for extracting REEs from coal fly ash by coupling a hydrothermal extraction process with the engineering of a ligand-associated media for concentrating REEs from the extraction liquid. We will first discuss the process of collecting and characterizing coal fly ash feedstock from coal-fired power plants near Detroit, MI by scanning electron microscopy (SEM), x-ray diffraction (XRD), and x-ray fluorescence (XRF). Ash samples are then subjected to hydrothermal conditions from 100-350 °C for 1-24 h and REE concentrations are measured by inductively coupled plasma-mass spectroscopy (ICP-MS) and compared to hydrofluoric acid digestion results. We will present preliminary results for the selection and loading of ligands such as DIPEX and derivatives of DTPA to a commercially available swellable organically modified silica (SOMS) media to sorb/concentrate the REEs dissolved in the leachate after the hydrothermal extraction process.

19-097

**4:05 PM**

### **Removal of Radioactive Elements from Rare Earths Using Various Separation Methods**

*D. Talan<sup>1</sup>, Q. Huang<sup>1</sup> and R. Honaker<sup>2</sup>; <sup>1</sup>Mining Engineering, West Virginia University, Morgantown, WV and <sup>2</sup>Mining Engineering, University of Kentucky, Lexington, KY*

Coal and coal byproducts have been identified as promising feedstock materials for the extraction and recovery of rare earth elements (REEs). Multiple projects have been funded by the US Department of Energy to initiate the efforts due to the urgent needs of REEs in the high-tech and clean energy industries. However, prior studies have shown that radioactive material such as thorium and uranium are normally enriched along with the REEs extraction process, which may potentially impose an environmental hazard and thus, the treatment of radioactive elements needs to be addressed. In order to develop an efficient separation approach, three processing methods including selective precipitation, solvent extraction, and ion exchange were applied during the present work. The impact of a variety of operating parameters including solution pH, retention time, reagent concentration/ type, organic to aqueous ratio on the separation efficiency was evaluated so as to optimize each separation process. The optimum processing route can thus be determined and suggested for the future incorporation into the overall REEs extraction process from coal and coal byproducts.

**MONDAY, FEBRUARY 25**

*AFTERNOON*

**2:00 PM | ROOM 104**

## **Environmental: Biodiversity, Off-sets, and People; Sustained Engagement with Communities**

*Chairs: A. De la Cruz-Novey, EcoAnalysts, Inc  
Washington, DC*

*G. Rueb, EcoAnalysts, Inc*

*A. George, Freeport-McMoRan*

**2:00 PM**

### **Introduction**

**2:05 PM**

### **Mining, Sustainability and International Lenders: Case Studies**

*J. Craynon and S. Parsons; Engineering & Environment, Export-Import Bank of the United States, Washington, DC*

The implementation by international lending institutions of international frameworks for protection of environmental and social values has changed the way mining does business around the world. The increasing role of debt financing has expanded the number and type of operations that are influenced by these conventions. This presentation focuses on case studies of some famous mining operations and how the requirements of the World Bank Group and the Equator Principles, among others, affected their development and operations.

**2:30 PM**

### **Practical and Quantifiable Integration of Social Values into Biodiversity Offsets for Mines**

*G. Rueb; Ecoanalysts Inc, Olympia, WA*

This presentation describes a framework where Ecosystem Services are integrated into the determination of the quantity and quality of a biodiversity offset to create a net benefit to biodiversity and project stakeholders. The framework uses information normally collected during the environmental documentation process to establish a baseline, project effects and required offset. The process demonstrates 1. environmental stewardship, 2. the appropriate amount of offset, 3. it directly incorporates values from the affected public, 4. provides detailed, science-based, 5. is a transparent process that allows direct input from stakeholders and 6. satisfies regulatory and banking requirements and is legally defensible.

**2:55 PM**

## **Biodiversity Offsets and Local Communities – Three Case Studies from Latin America**

*J. Hardner; Hardner & Gullison Associates, LLC, Amherst, NH*

Based on our experience in the design of biodiversity offsets in a number of countries, we have selected three case studies from Latin America that examine the opportunities and challenges in achieving the dual objectives of conservation and community engagement. In the ideal situation, local communities support biodiversity conservation and offset projects serve to assist them in achieving that goal. Furthermore, strong local support is widely regarded an essential factor in the longterm success of any conservation project. However, the ideal situation may not always be encountered. We present case studies from Peru, Panama, and Dominican Republic where offset projects fall within a spectrum of contexts, ranging from local support to mutual exclusivity. We will discuss the need to have realistic expectations about what can be achieved, based on the context, and possible approaches. This presentation will also include discussion of IFC Performance Standards and the debate regarding offsets within legal protected areas.

**3:20 PM**

## **Newmont Mining Corporations Approach to Greater Sage-Grouse Mitigation and Conservation Banking**

*C. Jasmine; S&ER, Newmont, Spring Creek PKWY, NV*

Newmont will share its views on what is working for them and how they are navigating the mitigation hierarchy for Greater Sage-grouse, while working with our partners to ensure a beneficial outcome while continuing to develop our social license to operate. This presentation will include information on Newmont's Sagebrush Ecosystem Conservation Program and how Newmont is using the Nevada Conservation Credit System (CCS) on their mine and ranch properties as one tool of biodiversity offsets. Discussion includes challenges, opportunities, strategies, and options for assessing project debits and developing credits before and during National Environmental Policy Act (NEPA) analysis of a proposed action. Attendees will learn how to address sage-grouse management and mitigation for their own projects and how others within the mining realm are currently using the CCS with regards to Greater Sage-grouse mitigation.

**3:45 PM**

## **Field Case of Social Performance App for Project Development**

*A. Recalde; AuSIMM, Carlton South, VIC, Australia*

Over the last ten years a number of software suites have been created for management and control of social performance of mining projects. This paper will describe the process to implement one in particular. GESSO is a modular suite that supports the following social management aspects: Stakeholder Mapping Social Baseline Social Investment Plan Grievance Mechanism Land Tenure (Lease Purchase) Community Resettlement The field case is taken from a five years experience in an ejido land in Southern Mexico. The presentation will demonstrate its usefulness and limitations as a management tool.



**MONDAY, FEBRUARY 25**

AFTERNOON

**2:00 PM | ROOM 108**

## **Environmental: Mine Water: Friend or Foe**

**Chairs:** *R. Kaunda, Colorado School of Mines,  
Golden, CO*  
*D. Williams, Bureau of Land Management,  
Butte, MT*

**2:00 PM**

### **Introduction**

**2:05 PM**

### **The Tail End: The Future of Mining Effluent**

*K. Hays; Research, Bluefield Research, Barcelona, Spain*

Every ten years over thirty mine tailings storage incidents occur, causing massive damage to populations, environments, and industries. Significant improvements since the 1990s have reduced the total number of events, though the number of very serious events has increased. This presentation aims to address three central issues: What are policymakers doing to improve tailings management? What technology options are being implemented? Which companies are leading the way in terms of investments and transparency? Results from the research tasks included: -Several countries have drafted/initiated the design of increased tailings regulation, but eased off on implementation of these policies with the downturn of commodities prices between 2014-2016. -Mine operators move towards greater water efficiency primarily driven by supply security issues for mine operations, more than environmental/safety concerns. -Governments and companies in a selection of countries are showing greater interest in 'smart mining' that can improve tailings management going forward (e.g. real-time monitoring of tailings dams, 'waterless mine' pilots).

**2:25 PM**

### **Identifying and Controlling the Impacts of Mining Activities on Groundwater Quality in the State of New Mexico**

*S. Kuykendall and P. Roghanchi; Mineral Engineering, New Mexico  
Institute of Mining and Technology, Socorro, NM*

Groundwater pollution poses a serious threat to both human health and to ecosystem stability. Sources of groundwater impacts from mining activities require identification to better develop solutions to protect. This research will identify solutions to this problem, while also raising awareness of the impact of abandoned mines on groundwater contamination. Abandoned mines in New Mexico are often unmonitored, and little data is available as to their effect on groundwater quality. Solutions to impacts that abandoned mines have on groundwater quality will be recommended by determining moni-

toring procedures and cost-effective cleanup plans based upon the level of groundwater contamination. Both the mining industry and regulatory agencies need to employ advanced treatment techniques to protect groundwater from the influence of closed and abandoned mines to minimize environmental impacts. This research will develop strategies to minimize that disturbance both to the groundwater and to the surrounding habitat. It is evident that continued environmental stewardship and a focus on future cleanup plans and ongoing mine site restoration should be a part of every mine's operating process.

**2:45 PM**

### **Determination of the Optimal Beach Distance as the Guideline for Water Management in Upstream TSF**

*Y. Jeong and K. Kim; Mining and Geologicla Engineering, University of Arizona, Tucson, AZ*

Extraction of the targeted resources produces a huge amount of waste material, including tailings. The disposal of these waste is a significant concern since tailings contain water mixed with many contaminants and the TSF's failure cause an environmental disaster. It is well known that most of the TSF failure occurred in the upstream type of TSF and their main cause is unexpected weather conditions, such as heavy rainfall and strong wind. This paper presents the optimal tailing beach distance as the guideline of TSF management plan. First, an aerial scanning using an Unmanned Aerial Vehicle(UAV) was performed to develop a digital model. A coupled stress-seepage FEM analysis was carried out to evaluate the geotechnical stability(Dcritical). And Probable Maximum Precipitation(PMP) data in Arizona were used to determine the distance of rainfall effect(Drainfall). To figure out effect of the strong wind, the increase of water level(Dwind) due to the wind-driven surge was predicted. By considering these three factors together, it is expected that it is possible to manage effectively of the TSF by preventing accidents by unexpected weather conditions.

**3:05 PM**

### **Endless Onsite-Manufactured Pipe for Remote Mining Sites and In-Situ Leaching**

*M. Ehsani; QuakeWrap, Inc., Tucson, AZ*

Mines often rely on water that may have to be transferred from remote sources. At times, the mountainous terrain makes such pipeline construction challenging. In addition, the In-Situ Leaching (ISL) process that is gaining popularity, requires large quantities of pipes for lining of wells. The conventional technique of building short pipe segments, shipping them to the mine and joining them together to make a long pipe are costly and inefficient. To overcome these shortcomings, the author has developed a technique that allows onsite construction of an endless FRP pipe, named InfiniPipe®. The project has been supported through the funding from the National Science Foundation and the US Department of Agriculture. A compact Mobile Manufacturing Unit (MMU) is shipped to the site. Layers of resin-saturated carbon or glass fabric are wrapped around a heated mandrel and within a few minutes the pipe is fully cured. As the MMU travels, it leaves a continuous pipe behind. For ISL applications, the MMU is positioned on top of the well and as the pipe is built, it is pushed into the well. It is estimated that a 1000 ft of pipe can be produced and placed in less than 5 hours!



**3:25 PM**

## **The Dead Parrots Society: The Data-Driven Process That Lead to the Removal of the Parrot Tailings Complex, Butte, Montana**

*N. Tucci; Geosciences, Water & Environmental Technologies, Butte, MT*

The Parrot Tailings mine waste, located in Butte Montana, has been identified as the primary source area for a highly acidic ( $5\text{e}+05$  mg/L), metal-laden ( $[\text{Cu}] = 1\text{e}+0+9$  ug/L;  $[\text{Zn}] = 4\text{e}+05$  ug/L;  $[\text{Cd}] = 4\text{e}+03$  ug/L) contaminant plume that emanates for over a mile downgradient of the site within the Summit Valley alluvial aquifer. Removal of the Parrot Tailings mine waste began in July 2018. This paper summarizes a series of supplemental remedial investigation that led to a data-driven decision process by the State of Montana to remove the Parrot Tailings under restoration-related activities. The scientific rationale that supported removal focused on the results of a series of hydrogeologic, geochemical fingerprinting, and tracer investigations. Parrot Tailings removal is anticipated to continue over multiple phases and will continue through 2019. An overview of the remedial design, and the robust groundwater performance monitoring program that has been designed and implemented to evaluate the efficacy of removal will also be discussed.

**3:45 PM**

## **Modern Data Management for Large Scale Dewatering Tests**

*B. Radtke<sup>1</sup>, S. Douglas<sup>2</sup> and L. Cope<sup>1</sup>; <sup>1</sup>Geoenvironmental, SRK Consulting (US), Inc., Denver, CO and <sup>2</sup>Long Canyon Mine, Newmont Mining Corporation, Elko, NV*

Modern technology allows collection, transmission, and compilation of enormous amounts of data in near-real time. Mine permitting, engineering trade-off studies and design of mine dewatering systems all benefit from large scale pumping tests to evaluate impacts to water resources. Tests to stress the hydrologic system to the extent that can be used to reasonably evaluate future mining and post mining impacts can involve large pumping rates over long durations with dozens to hundreds of monitoring points that ultimately accumulate millions of data values. A pumping test at Newmont's Long Canyon mine in Eastern Nevada is a good example. The test was conducted at 4,000 to 5,600 gpm pumping from three wells over a span of 75 days was monitored at 192 groundwater monitoring wells and piezometers and 35 surface water monitoring stations that recorded data on 1 to 15-minute intervals, producing a very large volume of data. Automated data are telemetered SCADA database and uploaded to a web page that displays tables and time plots in near real time. Expedited data management allow a more rapid use of model predictions to support mine planning trade-off studies and permitting.

**4:05 PM**

## **Elimination of Contaminating Ions from Mine Wastewater Using Wetlands**

*M. Guzman, M. Valencia and J. Pulcha; Engineering, PUCP, Lima, Peru*

Mining activity through the production of wastewater can produce alterations in the work area, which can lead to negative environmental impacts, both for the surrounding communities and for the operation itself, especially in water bodies. To avoid producing socio-environmental conflicts with the communities, it is necessary to comply with the quality standards of the effluents. The problem for the different mining companies is the high cost of the treatment of the aforementioned waters. The wetlands can operate with low or no energy

input, favorable public perception, increased aesthetics, and lower noise than mechanical systems, habitat creation or restoration provides land reclamation upon completion and increasing regulatory acceptance and standardization. In this sense, the implementation of artificial wetlands for the treatment of wastewater would seem to be an environmentally friendly alternative.

**4:25 PM**

### **When the Bill Comes Due: Understanding and Managing Tailings Influenced Groundwater at the Butte Superfund Site. A Historical Perspective.**

*D. Williams; U.S. Department of Interior, Bureau of Land Management, Butte, MT*

In a very real sense, Butte, Montana is where the copper came from that won two world wars. The price for that unrestricted mining and smelting of copper came due in 1983 when Butte was declared a Superfund site. One of the most complex remnants of this mining history is the Parrot Tailings site. The Parrot Smelter operated from 1881 to 1910 moving Upper Silver Bow Creek to the south and depositing approximately 370,000 cubic yards of waste material adjacent to Upper Silver Bow Creek. Additional mixed waste from other processing sites deposited below the Parrot Tailings at the Northside Tailings, Diggings East and Blacktail Creek Berm total approximately 224,000 cubic yards of contaminated material. As part of the Superfund remedy, EPA proposed leaving all these wastes in place. This proposal prompted a detailed criticism by several geoscientists familiar with the site. The EPA's 2006 Record of Decision (ROD) did in fact leave these wastes in place which set the stage for a series of studies which continue to refine how best to protect extensive completed Superfund Remediation downstream of Upper Silver Bow Creek.

**19-068**

**MONDAY, FEBRUARY 25**

*AFTERNOON*

**2:00 PM | ROOM 107**

## **Environmental: Site Characterization in the Era of Big Data**

***Chairs:** D. Levitan, Barr Engineering, Minneapolis, MN  
A. Haus, Foth Infrastructure and Environment,  
Lake Elmo, MN*

**2:00 PM**

### **Introduction**

**2:05 PM**

### **Elongated Mineral Particles in the Gogebic Iron Range; What Does It Mean for Future Mineral Development?**

*P. Eger; Global Minerals Engineering, Hibbing, MN*

In 2015, LaPointe Iron and the USGS developed a cooperative study to investigate the presence and forms of amphibole minerals in the Ironwood Iron formation. About 1.1 billion years ago, the Mellen Complex intrusion produced conditions favorable to the creation of amphibole minerals, some of which might be fibrous, or considered elongated mineral particles (EMP). EMPs, if not properly managed, can produce environmental and health impacts. Samples were collected from 4 drill cores and 10 outcrops and analyzed with X-ray diffraction, optical and scanning electron microscopy, and electron microprobe analysis. Most of the amphiboles in the drill cores were the result of contact metamorphism and decreased with distance from the contact. However, fibrous amphiboles were found in all cores. The more distal isolated occurrences are believed to be related to localized dikes and sills. Although only a limited set of samples were analyzed, the presence of these minerals highlights the need for careful waste characterization and the development of adaptive waste management plans to control emissions to air and water from future mining operations.

**2:25 PM**

### **What Water Quality Parameters Need to be Included in Baseline Study?**

*A. Haus and M. Ciardelli; Foth Infrastructure and Environment, Lake Elmo, MN*

The identity of potential contaminants of concern (COCs) is site specific, driven by ore deposit geology and geochemistry, and by regulatory setting. Determination of which parameters to include in initial baseline studies at potential mine sites should be founded on both the geochemical and regulatory perspectives; there is no one-size-fits-all list of parameters to monitor. Geochemical information collected during exploration can provide insight as to what parameters to monitor. The site location within a given state or region can also lead to required monitoring of certain parameters. Public awareness of particular COCs can also lead to changes in monitoring.

**2:45 PM**

## **Comparison and Use of Aerial and Terrestrial LiDAR for Stream Mitigation**

*J. White; Civil & Environmental Consultants, Inc., Worthington, OH*

LiDAR is an effective, efficient, and economical remote sensing method for stream mitigation. Aerial and terrestrial LiDAR can be used in combination to create high resolution DEMs for stream mitigation sites. Aerial LiDAR is ideal for identifying surface features such as headwater streams, roads, trails, landslides, and anthropogenic disturbances that cannot be identified with 3.0 and 10.0 meter DEMs, or topographic maps. Aerial LiDAR is used to create high resolution field maps to target specific areas of interest within a watershed, and is a valuable time-management tool for planning field assessment of a project site. Terrestrial LiDAR DEMs and spatial data models created with a 3D laser scanner create a point cloud with greater local precision than aerial LiDAR. Laser scanning rapidly captures detailed information needed for mitigation goals while economically decreasing expenses. Terrestrial LiDAR is ideal for stream and floodplain designs. 3D scanning also produces as-built surveys including 3D True Views of imagery draped over point clouds. These LiDAR based capabilities aid in detailed remote stream analysis thereby reducing project costs.

**3:05 PM**

## **Drones Drive Successful Reclamation**

*E. Suardini, J. Diamond and A. Thatcher; Arcadis U.S., Inc., Broomfield, CO*

Drones were used during excavation to quickly and efficiently calculate volume estimates for reclamation. Combining environmental expertise, FAA certified drone-pilots and state-of-the-art equipment, drones were piloted over large areas of land to safely and accurately assess reclamation progress and volumes of material moved. Small unmanned aircraft systems (sUAS), commonly known as drones, mitigated the safety concerns associated with sending employees into the field and use high-quality cameras to pick up details and information that the human eye cannot detect. Capturing sharper, more insightful images and gathering more data points faster, drones advanced progress on reclamation. Drones served as the first step in more efficient, cost-effective and thorough data collection. Combining improved data collection with an innovative approach toward managing and visualizing that data, the digital output from drones was used to educate all stakeholders with the one definitive version of the truth. This paper will discuss lessons learned for the application of drone technology at the cleanup of elevated metals in soil from legacy zinc smelter site.

**3:25 PM**

## **Quantifying and Insuring Against Mine Risks from the Changing Climate**

*S. Kembell-Cook<sup>1</sup>, R. Fitzpatrick<sup>2</sup>, A. Kornberg<sup>2</sup>, T. Taylor<sup>1</sup> and D. Heinze<sup>1</sup>;  
<sup>1</sup>Environment and Health, Ramboll, Novato, CA and <sup>2</sup>Trade Support, JLT Capital Markets, New York, NY*

Climate change presents risks to mine infrastructure, operations and long-term obligations to protect environmental conditions. Changes in rainfall and snowpack that result in flooding and/or drought, and changes in extreme temperatures can affect mining operations and cause economic losses. For example, heavy rainfall can flood mining sites and close access roads. Extreme temperatures can affect staff, machinery, and their ability to produce.

Data-driven assessments using climate model future projections quantify: site-specific risks to mine structures, access, containment facilities, operations and staff safety; potential for acid mine drainage and erosion and changes in vegetation and water balance/chemistry. These risks are a serious threat to the mining industry, but risk transfer solutions can alleviate climate-related vulnerabilities. Mining companies can protect themselves through bespoke solutions which provide operators and buyers with protection against weather-related delays. Climate disruptions to operations can be mitigated through hedges which can smooth revenues. Risk transfer structures are available to all types of mines world-wide to mitigate climate risks.

19-084

3:45 PM

## **Current PMP Estimation Practices and Meteorological Parameter Development for Mining Facilities in Data Limited Regions**

*B. Kappel; Applied Weather Associates, Monument, CO*

Applied Weather Associates (AWA) has completed 100's of Probable Maximum Precipitation (PMP) and other meteorological studies since the mid 1990s. The majority of the work was completed for the dam safety and nuclear communities in regions where data are plentiful and often included a long period of record. Recently, AWA has completed PMP, precipitation frequency climatologies, and other meteorological analyses for several mining facilities in many varied regions across the world. Several of these mine sites have been located in areas of extreme topography with very limited data coverage in both time and space. This has presented unique challenges in the development of storm data, storm adjustments, spatial and temporal patterns of rainfall accumulations, and PMP development. This presentation will discuss the general PMP development background, lessons learned from the many years of PMP work that have been applied to the mining community, how this process is completed for the mine locations where data are limited and terrain is often very complex, discuss major challenges encountered, and provide solutions utilized to overcome the challenges.

19-114

## MONDAY, FEBRUARY 25

### AFTERNOON

#### 2:00 PM | ROOM 703

### Funding and Accessing Capital for Mining and Exploration: Key Trends

**Chair:** *T. Alch, Executive Director of NY SME & Managing Partner of TAA Advisory, LLC, Edgewater, NJ*

#### 2:00 PM

##### Introduction

#### 2:10 PM

##### Review of Current Operating Trends and Impact on Valuations

*G. Malensek; RPA, Lakewood, CO*

Operating trends in the mining space in recent years have been impacted mainly by the effects of a strong US dollar. The main reason given for the strengthened dollar, which has remained anonymously high compared to a twenty year historical trend, is safe harbor sentiments amongst investors. The higher dollar impact on the mining space is reflected in both lower commodity prices which are generally reported in US dollars as well as higher dollar denominated cost inputs like diesel fuel. When those impacts are combined with other industry trends such as lower average head grades and aging technology, it is no surprise that the current period shows lower valuations for operations and projects. But on a positive note, while current near term valuations are down, the demand side of the equation continues upward with globalization and urbanization trends around the world meaning that the current period may represent an investing opportunity.

#### 2:35 PM

##### Pre-Pay Agreements – The Newest Alternative in the Mine Financing World

*B. Skull; Duff & Phelps, LLC, San Francisco, CA*

As royalty financing has matured and streaming has become popular, new entrants looking to provide capital in the mining sector continue to create new methods of financing. While public equity markets continue to be tight and traditional debt financing is available only once projects have already achieved major milestones, miners are looking for any alternative to finance their projects. Over the past 10 years, private equity companies and specialized mine finance investors have helped bridge the gap between traditional debt and equity financing. These companies have provided billions in royalty and streaming financing and continue to innovate in developing financing methods attractive to investors and miners alike. Over the past couple of years, pre-pay agreements with related options have started to appear in the mine financing world. The pre-payments can take on various structures as can the associated options, but the goal remains similar to the goals associated with royalties and streaming: provide a financing arrangement that is not overly onerous to the mine developer while limiting downside and allowing for some upside exposure to the investor.



**3:00 PM**

## **Use of Sustainability Metrics in Mining Finance**

*O. Chernoloz, Toronto, ON, Canada and N. Smith; Colorado School of Mines, Golden, CO*

In the last 20 years, as awareness of anthropogenic impacts on the planet has increased, so has an interest in responsible and sustainable mining. A number of metrics, including the Responsible Mining Index, the Sustainability ESG ratings and others have been developed to gauge the sustainability of mining projects and companies. Responsible, sustainable, and/or impact investing is growing rapidly every year, and more companies are screened based on environmental, social and corporate-governance concerns (ESG), and it can be argued that more sustainable companies are rewarded with better financing, and higher stock valuations among other benefits. The research team at Colorado School of Mines surveyed a group of investment fund managers and analysts investing in and covering the mining sector, exploring the question of if and how sustainability indicators are incorporated into their investment decision-making process, and to what degree.

**3:25 PM**

## **Engineering Studies, Their Use and Ranges of Accuracy**

*J. Uhrie; RPMGlobal, Greenwood Village, CO*

Critical to the funding of new mining projects is review of engineering studies. Studies come in a wide variety of names such as a preliminary economic assessment (PEA), scoping study, prefeasibility study, feasibility study, check-estimates, etc., or by various synonyms such as “Estimate Class,” “Stage-Gate,” and “Front-End Loading” (FEL). Each of these terms has an industry accepted standard definition and purpose developed over many years by groups such as the AACE or the CIM relating to varying levels of engineering and an associated OPEX/CAPEX range of accuracy.

**3:50 PM**

## **Financing the Acquisition of Mining Assets: The Differing Options for Operating, Development and Exploration Stage Assets**

*C. Urda Kassis, Shearman & Sterling LLP, New York, NY*

Theoretically, there are more sources and structures than ever available to finance the acquisition of mining assets. Syndicated commercial bank loans, Term B financing, high yield bonds, streams and royalties, structured private equity products to name some of the key sources/structures. How does a company determine which is available for its proposed acquisition and, of those available for its acquisition, which is most appropriate given the characteristics of the asset and the company’s key objectives for the financing? This presentation will examine the various financing options for mining acquisitions and the key considerations from a company’s perspective in choosing one over the other.

**4:15 PM**

## **Good Practice Due Diligence & Technical Modeling**

*N. Michael; Orion Resource Partners (USA) LP, Englewood, CO*

Regardless of the investor (private equity, strategic, lender, et al), the project of interest will virtually always be subject to an appraisal to; evaluate its commercial potential, and to identify and quantify its inherent risks. The types and magnitude of these risks vary depending on the definition level of the

project. For example, exploration target, conceptual, PFS/FS, basic/detailed engineering, and operating projects will be considered using vastly different risk criteria. Investment firms, often with assistance from Independent Engineers or Technical Consultants (IEs or ITCs), review Feasibility Studies and other engineering documents in the counterparty's data room to make these assessments. This presentation will provide some good practice guidelines for; (1) counterparties in preparing their Technical Economic Models for their clients' Financial Model, and (2) IEs and ITCs when completing their due diligence that could be used regardless of the project's level of definition.

## MONDAY, FEBRUARY 25

AFTERNOON

2:00 PM | ROOM 603

### Geostatistics in the Era of Big Data

*Chairs: A. Jewbali, Newmont Mining Corporation,  
Greenwood Village, CO  
L. Allen, Newmont Mining Corporation,  
Greenwood Village, CO*

2:00 PM

#### Introduction

2:05 PM

### Grade and Volume Uncertainty Quantification of Gold Deposit Using Multiple-Point and Two-Point Geostatistical Simulation

*B. Sovinski<sup>1</sup>, A. Paithankar<sup>1</sup>, S. Chatterjee<sup>1</sup> and L. Allen<sup>2</sup>; <sup>1</sup>Department of Geological and Mining Engineering and Sciences, Michigan Technological University, Houghton, MI and <sup>2</sup>Newmont, Denver, CO*

In this study, both grade and volume uncertainty of a gold deposit of Nevada were quantified using combined multiple-point and two-point geostatistical algorithm. The multiple-point simulation methods were applied for volume uncertainty quantification; whereas, the two-point method was used for grade uncertainty quantification. Two different multiple-point simulation methods i.e. modified CDFSIM (cumulative distribution function based simulation) and SNESIM (Single normal equation based simulation) were applied to generate multiple equi-probable orebody models to analyze uncertainty of ore volume and tonnage of the gold deposit. The uncertainty of gold grade was quantified by sequential Gaussian simulation within each equiprobable orebody models. The results are validated by reproducing the marginal distribution and two and three-point statistics. The results show that the deviation of the volume of the simulated orebody models varies from 9.5% to 21.3% compared to the training image in case of SNESIM and -2.52% to 7.82% compared to the training image in case of CDFSIM. These quantified uncertainties can be easily incorporated into the mine plan to generate robust mine plan.

**2:25 PM**

## **Validation of Geostatistical Simulations for Stochastic Mine Planning in an Operating Mine**

*J. Paradis and L. Allen; Newmont Mining Corp, Greenwood Village, CO*

Newmont has long used conditional simulations to evaluate drillhole spacing requirements for operations and projects, as well as for assessing geological uncertainty during project economic evaluation. For these studies, typical simulation validation workflows were developed and used. In preparation for the use of stochastic mine planning for a mining operation, the consideration of production data adds some complexity to the simulation validation process. This study identifies issues and presents solutions using data from Newmont operations.

**2:45 PM**

## **Effects of High-order Simulations on the Long-term Optimization of Mining Complexes**

*J. de Carvalho and R. Dimitrakopoulos; Mining Engineering - COSMO Lab, McGill University, Montreal, QC, Canada*

A mining complex composed of a gold mine, a leach-pad, a stockpile, a waste dump and a mill is simultaneously optimized. The study compares the effects of characterizing the orebody model by simulation frameworks based on the Gaussian assumption (SGS) and high-order simulation (HOSIM). The HOSIM case produces a schedule following the areas of better connected high-grades, causing richer material is processed earlier. To maintain a similar throughput at the mill, a 5% larger pit is extracted in the SGS case. As result, the economic value of the more informed schedule increases by 5 to 16%.

**3:05 PM**

## **High-Order Stochastic Simulation via Statistical Learning**

*L. Yao<sup>1</sup>, R. Dimitrakopoulos<sup>2</sup> and M. Gamache<sup>1</sup>; <sup>1</sup>École Polytechnique de Montréal, Montreal, QC, Canada and <sup>2</sup>Mining and Materials Engineering, McGill University, Montreal, QC, Canada*

The present work proposes a new high-order simulation framework using statistical learning. The training data consist of training images together with sample data (such as borehole data). The learning target is the underlying random field model of geological attributes. The learning process attempts to find a model whose expected high-order spatial statistics coincide with those observed from the training data. We approach the learning problem within the framework of reproducing kernel Hilbert space (RKHS). Specifically, the required RKHS is constructed via a spatial Legendre moment (SLM) reproducing kernel in such a way that the highorder spatial statistics are systematically incorporated. By defining the so-called kernel mean mapping as feature mapping, the target distributions of the random field are mapped into the SLM-RKHS to start the learning process, where solutions of the random field model amount to solving a quadratic programming problem. Case studies show that the new framework is less sensitive to the potential conflicts between the training image and the sample data, and addresses the numerical instability issue of the existing high-order simulation methods.

**3:25 PM**

## **Geostatistical Modeling of Geometallurgical Parameters**

*J. Deutsch; Resource Modeling Solutions, Edmonton, AB, Canada*

The geostatistical modeling of geometallurgical parameters poses unique challenges. Geometallurgical properties are typically sparsely sampled, may average nonlinearly, have complex relationships with geological measurements, and may be measured on substantially larger scales than assays and geological attributes. Best current practice in geostatistical modeling incorporates a comprehensive plan for domain selection, attribute modeling with a combination of geostatistics and machine learning, and model validation using both cross and k-fold validation. Domains are selected considering both geologic domains and multivariate interactions. Within these domains, either multivariate imputation or machine learning for response surface modeling should be applied depending on data density. Cross validation and k-fold validation applied to validate and assess the choice of modeling approach. The author presents a novel technique for the application of machine learning with multivariate data imputation to model geometallurgical variables in the context of the comprehensive approach to geostatistical modeling for geometallurgical parameters.

## **MONDAY, FEBRUARY 25**

*AFTERNOON*

**2:00 PM | ROOM 605**

## **Health & Safety: Health and Safety Training and Development**

*Chairs: L. Guasta, Safety Solutions International, Inc.,  
Parker, CO*

*M. Lutz, Custos Fratrís, L3C, Tucson, AZ*

**2:00 PM**

### **Introduction**

**2:05 PM**

## **Challenges of Multi-Generational Safety Training**

*M. Reiher and K. Vault; Colorado School of Mines, Golden, CO*

For the first time in history, today's workforce is comprised of five generations. Each generation brings to the table their own strengths, weaknesses and viewpoints that are seemingly very different from the next. Therefore, creating safety training programs that target and engage multigenerational learners is essential, but it can often be difficult as the way in which employees prefer to learn and communicate has changed. In this presentation you will learn about the different generations and what influenced them while learning strategies to engage multiple generations to create a safer work environment.



**2:25 PM**

## **A Comparison of Heat Stress Indices**

*M. Tuck<sup>1</sup> and M. Pillay<sup>2</sup>; <sup>1</sup>School of Science, Engineering and IT, Federation University Australia, Ballarat, VIC, Australia and <sup>2</sup>School of Health Sciences, University of Newcastle, Newcastle, NSW, Australia*

Historically, a number of heat stress indices have been developed and applied in underground mines. These can be classed under three broad headings; single measurement, empirically based and rational indices. Do any of these indices perform better than the others? Which one allows simple determinations and decisions to be made in the mine? This paper aims to provide answers to these questions by comparing and contrasting three indices; effective temperature, simple air cooling power and Thermal work limit for a range of typical mining wet and dry bulb combinations? The paper concludes with the identification of areas for future research.

**19-063**

**2:45 PM**

## **Giving Effective and Impactful Training**

*R. Lindsay; Training, Craft Development, Palmer Engineering & Forensics, Highland, UT*

In the mining industry we have a great opportunity to impact the lives and safety culture of miners every year. Yet few organizations and trainers see this as the opportunity it is to impact the lives of their miners and cultures of their companies. Most companies and miners see this as a necessary evil to be endured. As such most annual training is boring and dull having little impact on the development of miners and companies. How can we as companies and trainers use this time to develop a culture and bring excitement to our companies, mines and the industry in general? We need trainers and companies to interact with those they are instructing and see this as an opportunity to engage their workers and company and improve their cultures and lives. Interaction implies a two sided exchange. This is not happening during training enough but it can.

**3:05 PM**

## **On Demand Training for the Surface Mining Industry**

*T. Woerdeman; Transit Mix Concrete Co., Colorado Springs, CO*

As the mining industry recruits younger generations and MSHA requests feedback on technology that can provide safer working environments, the mining industry must strive to continue to bring best safety practices and training to industry personnel. The Mine Safety Institute's interactive, on-demand safety training platform provides surface mining personnel, subject to Part 46 training requirements, with the initial 4 hours of training required by 30 C.F.R. §46.5(b) and 30 C.F.R. §46.5(c). This presentation will educate SME attendees on the benefits of using on-demand training developed by real miners, real regulators, and using real video footage. Mine safety individuals who benefit from this tool share the advantages and flexibility of utilizing it for many types of MSHA required training.

**3:25 PM**

### **Self-paced Working in the Mining Industry: A Challenge or an Opportunity?**

*P. Roghanchi; Mineral Engineering, New Mexico Institute of Mining and Technology, Socorro, NM*

Mine workers complete tasks on a shift-by-shift schedule, therefore, there has historically been pressure by mine operators on workers to complete enough tasks to get to a certain point in the cycle of mining. However, with modern mining companies adopting comprehensive safety programs, safety goals now overpower production targets. The increasing level of mechanization also resulted in redesigned jobs that promote safety and self-care to the personnel. Still, the focus of these safety programs is mainly towards reducing injuries and preventing fatality without considering the individual differences. There are several personal factors including the state of health, state of mind, and level of awareness that affect an individual's response to a potential hazard. The self-paced workers are well-informed, educated individuals who can regulate their work-rate and is not subject to supervisor pressure. This paper highlights the challenges and opportunities of promoting self-paced working in mine environments. It is demonstrated that how self-paced working can reduce the risks associated with health and safety hazards such as fatigue, heat stress, lack of concentration, carelessness, etc.

**3:45 PM**

### **Measuring the Effects of Active Learning on Health and Safety Training**

*L. Wilson<sup>1</sup>, L. Brown<sup>1</sup> and R. DiBona<sup>2</sup>; <sup>1</sup>Lowell Institute for Mineral Resources, University of Arizona, Tucson, AZ and <sup>2</sup>ASARCO, Kearny, AZ*

For more than a decade, training practitioners have called for changes in the way new and experienced miners are trained. There is an increasing emphasis on active learning approaches, which better reflect the experiential processes by which adults learn most effectively, and a recognized need for better assessment of outcomes, both within the classroom and on the worksite. In this talk, we survey the components of a comprehensive active learning design plan, which include learning objectives, course outlines, media, and assessments developed in cooperation with industry and subject matter experts. As part of our data-driven approach, we are now evaluating the effects of our active learning modules on new miner and annual refresher training, focusing on the knowledge, skills, and abilities for hazards recognition and hierarchy of controls. Working with industry partners, over 500 mine workers have participated in our study; treatment groups received training via active learning while control groups used traditional didactic approaches. We discuss initial results on training transfer, with insight on learner motivation, self-efficacy, and commitment to goals.

**4:05 PM**

### **Believe in Safety**

*B. Schroeder; Believe in Safety, Marion, IA*

Thank you for your interest in Believe In Safety for your event. Believe In Safety is quickly becoming a top ranked motivational safety presentation that is changing the landscape of safety presentations nationwide. Brandon Schroeder takes his audience on a journey from his quintessential life the day of the accident through his agonizing recovery, unavoidable depression, and

ultimately accepting his situation and persevering. Brandon's raw emotion and relatable nature commands resonance of his message, Believe In Safety. One of the most valued aspects of Brandon's story is the full disclosure of his pre-accident mindset; he discusses the realities of the safety culture on the job and how this led him to that fateful day. He vividly describes how this accident changed not only his life, but the lives of those that love him. Through his 20 years of electrical and safety experience, Brandon has worked on and toured hundreds of job sites through every aspect of industry, construction, and municipality and utility.

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## MONDAY, FEBRUARY 25

AFTERNOON

**2:00 PM | ROOM 110**

### Industrial Minerals & Aggregates: Fracking Materials

*Chairs: B. Elliot, University of Texas at Austin  
L. Moore, ArrMaz, Mulberry, FL*

**2:00 PM**

#### Introduction

**2:05 PM**

#### Are You in Compliance with OSHA's Silica Rule?

*T. Thorn<sup>2</sup> and J. Suldickas<sup>1</sup>; <sup>1</sup>Global Process Consulting Group, ArrMaz, Lakeland, FL and <sup>2</sup>Oil & Gas, ArrMaz, Mulberry, FL*

In accordance with OSHA's respirable crystalline silica rule, companies operating across the hydraulic fracturing supply chain are required to implement engineering controls to reduce worker exposure to silica dust. Have you properly evaluated and implemented engineering controls? This presentation will discuss: 1. Compliance requirements for organizations across the hydraulic fracturing supply chain 2. The potential cost of non-compliance 3. Important criteria that must be considered to effectively evaluate the different engineering control options available today aside from meeting the permissible exposure limit (PEL) 4. Review of a Case Study

**2:25 PM**

#### Permian Basin Frac Sand: A Case Study for Unprecedented Industry Growth

*B. Elliott; Bureau of Economic Geology, University of Texas at Austin, Austin, TX*

The frac sand industry continues to grow and develop in the Trans-Pecos region of west Texas, facilitating the frac sand needs of the Permian Basin. The "Kermit" or "intra-basin" sands represent a virtually untapped resource in west Texas, which had been avoided in the past, due to the typical age and frac

sand properties that industry traditionally sought. The frac sand development is expected to grow as Permian Basin oil and gas activity ramps up. In addition to frac sand needs to facilitate frac jobs across the Midland and Delaware Basins, the economics of the distribution of frac sand resources (from both interstate and intrastate resources), mode of transportation, water availability and environmental issues, transportation logistics and availability, storage considerations, and resource competition are all factors that will affect the projection of frac sand resource and continued economic development.

**2:45 PM**

## **Physical Properties and Characteristics of Permian Basin Frac Sand: When Is Frac Sand “Good Enough”?**

*B. Elliott; Bureau of Economic Geology, University of Texas at Austin, Austin, TX*

The “intra-basin” sands of west Texas could very soon become the largest frac sand producing region in the world, from a non-producing region in just three years. Proppant per frac job has been increasing over the past few years, the industry has shifted toward finer frac sand products than was being used a few years ago, the length of lateral wells requiring fracing has increased and the total number of wells are increasing with the Permian Basin expected to be a significant consumer of frac sand over the next five years. The abundance of finer mesh products and the reduced delivered cost makes the Permian Basin sands a very attractive and cost effective alternative to premium northern white sands. Effective engineering may still require premium coarser fractions if multi-stage variable proppant size frac jobs shows significant improvement in production compared to single stage jobs. This study explores the paradigm shift away from traditional Cambrian-Ordovician, resilient, high crush-strength, premium sands to local, more cost effective, Pleistocene age natural sand proppant that has been industry approved as “Good Enough”.

**3:05 PM**

## **Frac Sand in Places not Called West Texas: Westward’s Frac Sand Exploration Odyssey**

*M. Lee; Westward, Boerne, TX*

The West Texas ‘Frac Sand Frenzy of 2017’ was so immense, it will likely never be duplicated. Once unassuming sand dunes were a playground for many and a nuisance for many more. But that was to change in early 2017 and change in a big way. As operators in the Permian Basin discovered that the sand under their feet was good enough to use in lieu of the Northern White sands shipped from Wisconsin and Minnesota, the In-Basin Frac Sand Frenzy started. Then it grew. Westward Environmental (WESTWARD) has spent over three years designing and overseeing numerous frac sand exploration programs. After starting our first drilling program in January 2015 in Emery County, Utah, WESTWARD has continued to explore for frac sand in Texas, Oklahoma, Arkansas and Louisiana with other sampling in New Mexico. Currently, WESTWARD is also performing preliminary cursory overviews for frac sand potential in the Uintah, Bakken and Marcellus plays. This presentation will summarize frac sand exploration events conducted by WESTWARD in other basin areas not called West Texas.



**3:25 PM**

## **Permian Basin Sand Dune Exploration: “What’s All the Frac About?”**

*M. Lee; Westward, Boerne, TX*

In 2017 & early 2018, Westward Geological Services (WESTWARD) crews spent fourteen months in West Texas assessing the regional dune sands for suitability as use as proppant, or frac sand. WESTWARD designed and supervised numerous exploration programs that were comprised of over 900 borings across 173,000+ acres in Winkler, Ward, Gaines, Andrews, Dawson, Lynn, Midland & Howard Counties. As of last count, that equivocates to over 70,000 ft. core drilled of which over 61,000 ft. of sample was bagged in five-foot intervals and transported to laboratories in Illinois and Texas for frac sand testing. Total depths drilled ranged from 10 ft. to 171 ft. which were drilled in 80 ft. tall dunes as well as on level ground. Although the overall thickness of the deposit varied widely across the region, physical characteristics of the sand did not. WESTWARD was also responsible for the ecological evaluation and environmental permitting of several frac sand plants in the region. This presentation will focus on the methodology used and results obtained from this exploration effort.

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## **MONDAY, FEBRUARY 25**

*AFTERNOON*

**2:00 PM | ROOM 106**

## **Industrial Minerals & Aggregates: Innovations in Industrial Minerals & Aggregates Industry I**

*Chairs: B. Li, Michigan Technological University,  
Houghton, MI*

*G. Tomaino, Minerals Technologies Inc, Easton, PA*

**2:00 PM**

### **Introduction**

**2:05 PM**

### **Novel Natural Mechanical Insecticide**

*B. Wang<sup>1</sup> and D. Stewart<sup>2</sup>; <sup>1</sup>Platform Technology, Imerys, San Jose, CA  
and <sup>2</sup>Product & Application Development, Imerys Filtration Minerals, Inc.,  
Atlanta, GA*

A mechanical insecticide, defined as industrial mineral particles that produce a mortal response on contact, can be applied as a non-chemical, non-toxic indoor and outdoor residual spray to provide long term residual control of multiple mosquitoes species. Contact with a mosquito results in the static transfer of a few particles which absorb the protective lipid layer necessary for the mosquito survival. In lab and small scale field trial experiments, results demonstrate that the mechanical insecticide is fast acting and persistent and a viable new tool for vector control.

**2:25 PM**

## **Effects of Mine Waste-Based Materials on Acid Resistance of Shotcrete for Sewer Tunnel Rehabilitation**

*L. Wu<sup>1</sup>, C. Hu<sup>2</sup> and W. Liu<sup>1</sup>; <sup>1</sup>School of Mining and Petroleum Engineering, University of Alberta, Edmonton, AB, Canada and <sup>2</sup>Drainage Engineering, EPCOR, Edmonton, AB, Canada*

The reuse of mine waste is of great importance to the sustainability of mining. This study aims to investigate the effects of three locally sourced mine waste— fly ash, metakaolin, and silica fume—on improving the acid resistance of shotcrete mixtures for sewer rehabilitation. In this study, cement was replaced by these three mine waste-based materials at up to 30%. Then the cured shotcrete samples were immersed in sulfuric acid for three months. The results from weight change, strength change, and visual observation indicated that the addition of metakaolin and silica fume improved the acid resistance.

**2:45 PM**

## **Laser Level Measurement a Reliable Solution for Mining Industry**

*J. Labrecque; Sales and marketing, ABB, Quebec, QC, Canada*

The mining industry relies on level measurement for a number of applications. In recent years, non-contact level measurements has gained more and more interest due to its simplicity and reliability. In this particular environment, where sensors are prone to damage, not being in contact with the material to perform the measurement is especially useful. Amongst non-contact level measuring instruments, laser level sensors have found many applications in this industry. One of the benefits of laser level measurement products is their great reliability since they are positioned away from the falling material preventing any damage. Also, their remote installation makes them easier to install and access. Efficient level measurement for blocked chute detection or crusher level control, for instance. Crusher level control with the ABB LM80 laser level transmitter is a typical application. Level measurement allows process optimization and prevents overfilling which could cause problems. The laser beam detects the rocks level accurately, even in the presence of dust. This technology is immune from the effect of noise, vibrations, ambient air conditions, and the material angle.

**3:05 PM**

## **Rheological Improvements in Alumina Industry Clarification Circuits**

*L. Andermann<sup>2</sup>, A. Mullins<sup>3</sup>, C. Smyth<sup>3</sup> and C. Roscoe<sup>1</sup>; <sup>1</sup>Applications, Solenis, Wilmington, DE; <sup>2</sup>Applications, Solenis, Wilmington, DE and <sup>3</sup>Research, Rio Tinto Aluminium, Gladstone, QLD, Australia*

Dewatering and transporting slurries are two common challenges alumina refineries face today. Alumina Refineries are seeing lower available alumina and increased gangue minerals which makes handling of red mud more difficult. While polymers are necessary to achieve faster rates of liquid-solid separation, they can impart negative rheological characteristics, so polymers alone in most cases are not sufficient in the washing of red mud that contains higher gangue minerals and lower available alumina content. Solenis' rheology modifiers have been successful in bench-top testing, pilot and plant trials at improving rheological characteristics, liquid-solid separation and washing efficiency (savings of caustic and alumina by efficient washing of red mud) within the counter current decanter circuits of alumina refineries. This paper will cover the efficacy of the rheology modifiers that have been successfully demonstrated from bench-top experiments to full plant trials as a viable solution for rheology modification improvement in the alumina industry.

**3:25 PM**

## **Pozzolans-Part II: Characterization and Determination on the Degree of Reactivity and Crystallinity of the Pozzolan Reaction on a Microscale Using Laboratory Instrumentation**

*G. Tomaino; Minerals Technologies Inc, Easton, PA*

This talk adds to previous work presented in 2018 on the characterization and determination on the degree of reactivity and crystallinity for the pozzolan reaction [ $AS + CH + H \rightarrow C-S-H$  and  $C-A-H$ ] on a microscale using laboratory instrumentation. Additional experiments for natural and artificial pozzolans at elevated temperatures above 150C in addition to new source minerals or materials will be reviewed following preparations and characterizations utilizing XRD, TGA-DSC and TGA-DSC with specialized pressure-DSC crucibles that are capable of achieving low pressure (100 bar) and intermediate temperature ( $\leq 500C$ ) processing conditions.

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## **MONDAY, FEBRUARY 25**

*AFTERNOON*

**2:00 PM | ROOM 112**

## **Industrial Minerals & Aggregates: Resource Estimation, Mine Planning & Operations I**

*Chairs: A. Brickey, South Dakota School of Mines and Technology, Rapid City, SD*

*S. Chatterjee, Michigan Technological University, Houghton, MI*

**2:00 PM**

### **Introduction**

**2:05 PM**

### **Incorporating Life Cycle Cost Thinking into Aggregate Mine Operation Planning**

*N. Manser; Geological and Mining Engineering and Sciences, Michigan Technological University, Houghton, MI*

The extraction and processing of land won aggregates is one of the most widespread forms of mining occurring globally. Despite its prominence, aggregates are considered a low-value high-bulk material that often do not generate high profit margins for the producer. Furthermore, the mining and processing operations needed to produce a finished product have significant negative impacts on the environment. This paradox places pressure on decision-makers at aggregate producers to appropriately allocate capital resources without inflating the cost to produce, while at the same time, behaving within a mode social responsibility. This paper investigates the use of a life cycle cost assessment framework to help aggregate producers understand where in their operations the largest environmental impacts are hap-

pening in conjunction with the highest operating costs so that better capital resource allocations can be made. The goal is to promote profitable and more sustainable mining in a prevalent part of the industry.

**2:25 PM**

## **We Want to Look at Another Way**

*M. Harman, J. Wientjes and K. Miles; Application Engineering, Komatsu America Corp., Peoria, IL*

It is not uncommon for certain mining methods to become preferred amongst regional operations within companies, and even the industry as a whole. Operators can become hesitant to explore beyond proven practices. This paper will review a customer with a brownfield site that wanted to evaluate alternatives to seek greater efficiency and performance. In the reserve area, the customary mining practice involved using typical load and haul fleets for shallow deposits. Alternatively, a suggestion arose that a dozer methodology utilizing a movable material handling system may offer a more continuous operation. However, the variability in the strata characteristics were of concern, emphasizing a need to incorporate such dozer application variables as push distance and angle into the analysis was essential. The result of this study was the development of an integrative tool illustrating the performance variability of a bulldozer application. Traditional haulage means was also studied to allow comparison between methods. This presentation describes the process used to perform this exercise and illustrates how application variables can be represented in a simplified and understandable manner.

**2:45 PM**

## **Sandwich Belt High Angle Conveyors from Mine/Quarry to Plant and Beyond**

*J. Dos Santos; Dos Santos International LLC, Marietta, GA*

Over the past 35 years Sandwich Belt high angle conveyors have found use in continuous elevating duties from mines/quarries, at the processing plants and beyond. This writing will first describe the Sandwich Belt installations that elevate primary crushed rock from the mine/quarry, open pit and underground, to the surface along a most direct path. Special features along with customized design for the application ensure gentle handling of the coarse bulk along the sandwiched path ensuring long life of the belts and components. At the processing plants the high angle advantage allows significant reduction in the footprint reducing cost and environmental impact. This is especially significant in northern Canada where winter temperatures routinely drop below minus 50 deg celsius. The high angle advantage reduces the footprint of the heated facilities, reducing the construction costs and the recurring heating costs. Beyond the plant, Sandwich Belt high angle conveyors are utilized at bulk export terminals and docks. In Southern Australia the most publicized Sandwich belt high angle conveyor is a ship loader, loading mineral sands into Panamax class ships for more than ten years.



**3:05 PM**

## **Stabilization for Mining Pads, Access Roads and Semi-permanent Roads**

*S. Clark; EnviroTech Services, Inc, Greeley, CO*

Mining Access Roads and Pads built to last When building stable access roads and pads for a light truck fleet, heavy machinery, or material storage, options available are limited. Constructing with native soil greatly limits the effectiveness and longevity of these necessary facilities. Collaborating with mines, DOTs, oil and gas industries, and construction companies, EnviroTech has developed a process utilizing stabilization products. This build out process can be constructed and deconstructed in only a few days. This presentation will focus on examples of how this process has aided many sites and can be incorporated into your next large build or facility improvement plan.

**3:25 PM**

## **A New Methodology to Design Maximum Value Pushbacks in Open Pit Mines**

*J. Yarmuch<sup>1</sup>, M. Braziř, H. Rubinstein<sup>3</sup> and D. Thomas<sup>1</sup>; <sup>1</sup>Mechanical Engineering, University of Melbourne, Melbourne, VIC, Australia; <sup>2</sup>Electrical Engineering, University of Melbourne, Melbourne, VIC, Australia and <sup>3</sup>Department of Mathematics and Statistics, University of Melbourne, Melbourne, VIC, Australia*

Traditional mine planning process starts by defining the ultimate pit limit (UPL), which is the contour of the excavation that maximises the mining profit. Then, the UPL is subdivided into manageable mining units called pushbacks (also known as mining cuts or mining phases) which are mined to feed the processing plants. In the industry, pushbacks are considered as workable volumes that contain an amount of ore equivalent to 1-3 years of plant production. Besides considering wall slope constraints, workable pushbacks need to, first, satisfy a minimum width to allow safe operation of the mining equipment, and, second, being connected i.e. not having separated parts. Traditional models of pushback design avoid the complexity of the workability constraints. As a consequence, most of the output from these models requires significant intervention by mining engineers. This work presents a new methodology to generate maximum net present value pushbacks. Finally, a set of numerical experiments shows that our formulation performs better than traditional approaches, reducing the engineer's intervention needed to generate workable designs.

**3:45 PM**

## **Grasberg Block Cave Underground Railway Construction Risk Management Evaluation Using Monte Carlo Method**

*A. Parhusip; GBC Construction, PT Freeport-McMoRan Indonesia, Nottingham, Nottinghamshire, UK*

Risk Management is a means of dealing with uncertainty – identifying sources of uncertainty and the risks associated with them, and then managing those risks such that negative outcomes are minimized (or avoided altogether), and any positive outcomes are capitalized upon. The need to manage uncertainty is inherent in most projects which require formal project management. Construction is a full loaded business with many activities with many uncertainties in process. The Monte Carlo method is a stochastic simulation method consisting of the identification of criterion and relevant variables, the allocation of probability for relevant variables, the determina-

tion of correlation coefficient among relevant variables, simulation execution and result analysis. The Monte Carlo simulation for risk management is carried out using the MATLAB software with aiming it can be used for various use in many construction process case. PT Freeport-McMoRan Indonesia is constructing a massive underground railway infrastructure. The massive construction process has many risks and this paper will try to elaborate the risk that may be happen during the process and the management of the construction process.

## MONDAY, FEBRUARY 25

AFTERNOON

2:00 PM | ROOM 501

### Mining & Exploration: Geosciences: Geology of Strategic Mineral Deposits

*Chair: E. Eckberg, Bureau of Land Management*

2:00 PM

Introduction

2:05 PM

### U.S. Geological Survey Mineral Deposit Database Critical Minerals Initiative

*J. Mauk, C. San Juan, N. Karl, K. Long, T. Reyes and G. Schmeda; U.S. Geological Survey, Denver, CO*

The U.S. Geological Survey (USGS) is working to develop a comprehensive 21st century geospatial database that will be the most authoritative source of important mines, mineral deposits, and mineral districts in the U.S. and its territories. The purpose of the database is to (1) provide high-quality, landscape scale data to support land management actions and policies, (2) provide electronic databases for the U.S., including the minerals industry, and (3) make electronic data and metadata available free on the USGS website at <https://www.usgs.gov/energy-and-minerals/mineral-resources-program/science/usgs-mineral-deposit-database>. Since May 2017, the database effort has focused on critical minerals in the U.S. There are significant differences between critical minerals produced as products, and those produced as byproducts. There is good geologic knowledge of the types of mineral deposits that host product critical minerals. For byproduct critical minerals, our knowledge is comparatively sparse, in part because the quantity of these byproducts that occur in mineral deposits in the U.S. are not generally reported. Collaborative research could help to fill these knowledge gaps.

**2:25 PM**

## **Critical Minerals in New Mexico**

*V. McLemore; NMBGMR/NM Tech, Socorro, NM*

Critical minerals are mineral resources that are essential to our economy and whose supply may be disrupted; many critical minerals are 100% imported into the U.S. Both uranium and potash are important commodities in NM and are considered critical minerals. Rare earth elements deposits are also found in NM. REE-Th-U veins are found in the Gallinas, Capitan, and Cornudas Mountains and Laughlin Peak-Chico Hills; all are associated with Tertiary alkaline igneous rocks. Disseminated Y-Zr deposits in Proterozoic syenite and nepheline syenite are known at Pajarito Mountain on the Mescalero Apache Indian Reservation near Ruidoso. Other critical minerals are associated with various mineral deposits in New Mexico. For example, vanadium and molybdenum, by-products of uranium mining, as well as selenium and REE, are associated with sandstone uranium deposits in the Grants uranium district. Rhenium is found in porphyry copper and porphyry molybdenum deposits in New Mexico. Coal deposits are abundant in the state and could be source of several critical minerals (REE, Se, V, Ge), but more work is needed to fully understand the distribution of critical minerals in New Mexico coal deposits.

19-132

**2:45 PM**

## **Geology of Utah's Produced Strategic Minerals**

*A. Rupke; Utah Geological Survey, Salt Lake City, UT*

Utah produces three strategic (or critical) minerals from the Department of the Interior's 2018 list: beryllium, magnesium, and potash. Utah is the sole domestic producer of both beryllium and magnesium metal, and one of only two states that produce potash. Beryllium is produced from the Spor Mountain district in west-central Utah from deposits associated with Miocene high-silica topaz rhyolites. The primary beryllium ore mineral is bertrandite (a beryllium silicate), which occurs as replacement deposits within volcanic tuffs. Magnesium is produced from the brine of Great Salt Lake (GSL), a terminal lake with high levels of dissolved solids. Potash production in Utah comes from a variety of geologic settings including surface brines (GSL), relatively shallow subsurface brines (Bonneville Salt Flats), and deep subsurface bedded evaporites (Paradox Basin). Two types of potash are produced in Utah: potassium chloride and potassium sulfate. GSL, which has high potassium and sulfate content, is currently the only domestic source of potassium sulfate, the more valuable potash commodity. Potassium chloride is produced from subsurface brines and Pennsylvanian evaporite mineral beds.

**3:05 PM**

## **The Geology and Holistic Development of BlackRock Metals' Polymetallic Vanadium – Titanomagnetite Deposit, Chibougamau, Quebec**

*D. Caldwell; Geology and Technical Services, BlackRock Metals, Montreal, QC, Canada*

BlackRock's vanadium-titanomagnetite deposit is hosted in a classic layered mafic intrusive forming part of the Archean core of the Canadian Shield. The deposit was discovered during a Gulf Dominion regional airmag survey in 1948, and subsequently explored and drilled as a pure iron play. It ultimately failed metallurgically due to the high titanium content being incompatible with the prevailing blast furnace technology at that time. In 1966 Gilles Allard, work-

ing for a Quebec Crown company, recognized appreciable quantities vanadium bound in the magnetite, staked the deposit and it became a pure vanadium play. After spending approximately \$20MM it ultimately failed on economics and financibility. BlackRock acquired the claims as a polymetallic play in 2008 and, taking a more integrated business strategy, has developed a Best-in-Class project with lowest quartile unit production costs and environmental footprints for each of its products. Project financing has been secured, and construction of the \$850MM mine and transformation plant has begun. Production of ~530Ktpa of high purity iron, ~5Ktpa of vanadium and ~130Ktpa of titanium feedstocks is expected to begin ramping in Q4-2020.

### 3:25 PM

#### Lithium Brine Deposits: Challenges of Finding, Evaluating, and Reporting Mineral Resources

*P. Cortegoso; SRK Consulting, Denver, CO*

Economic concentrations of Lithium-bearing brines occur in salt lakes (salars) in select arid regions around the world. These brines account for over half of global lithium production in 2017. Brines are unique amongst mineral deposits because the valuable elements are contained in a mobile environment, and both brine composition and grade have a temporal component, before and during extraction. As each salar can exhibit highly variable characteristics there are no “rules of thumb” when it comes to evaluating and classifying resources. The chemical and hydrogeological complexity of closed evaporite basins makes the exploration, evaluation, and reporting of Mineral Resources for lithium brines challenging. Brine deposits differ from hard rock deposits in that the resource classification is largely influenced by the hydrostratigraphic parameters and transmissivity of the units that comprise the Salar. Compared to traditional hard rock deposits, reporting of Mineral Resources for lithium-rich brines requires a separate set of skills, challenges, and multidisciplinary approach to ensure correct project assessment and reporting.

### 3:45 PM

#### Strategic Minerals in Nebraska

*S. Honan; NioCorp Developments Ltd., Centennial, CO*

Nebraska may not be the first place that comes to mind in a discussion of strategic minerals. Yet that state is home to the Elk Creek Superalloys project, which aims to produce Niobium, Scandium and Titanium. All three of these elements are on the U.S. Critical Minerals list, and Niobium and Scandium are not produced in the U.S. today. With a large resource, excellent local infrastructure and support at all levels in the state, the Elk Creek Project is poised to provide a secure supply of these important materials for many years.

### 4:05 PM

#### A New Rapid Brine Release Extraction Method in Support of Lithium Brine Resource Estimation

*T. Yao<sup>1</sup>, M. Milczarek<sup>1</sup>, F. Reide<sup>2</sup>, D. Weber<sup>3</sup>, E. Peacock<sup>3</sup> and M. Brooker<sup>4</sup>;*

*<sup>1</sup>GeoSystems Analysis, Tucson, AZ; <sup>2</sup>FloSolutions, Santiago, Chile;*

*<sup>3</sup>Montgomery and Associates, Phoenix, AZ and <sup>4</sup>Hydrominex Geoscience, Sydney, NSW, Australia*

Lithium brine mining via groundwater extraction accounts for the majority of the world's lithium production. Lithium concentrations can be highly variable across a lithium deposit and host aquifers typically consist of highly



heterogenous layered sediments. Whereas aquifer pumping tests can provide data on large-scale aquifer properties, results typically cannot resolve explicit estimates of lithium grade and specific yield. Consequently, brine mineral resource estimation requires supporting data from both field and laboratory testing programs to estimate the lithium concentrations associated with various lithologies. Laboratory methods to determine brine release range from moisture retention characteristic and centrifugal tests to simple suction methods to establish drainage. We have developed a new rapid brine release test based on a modified standard method to determine specific yield characteristics of core samples collected during exploration drilling. To date this method has been used to determine specific yield characteristics on hundreds of samples from several different brine deposits in North and South America. Case studies will be presented.

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## MONDAY, FEBRUARY 25

AFTERNOON

**2:00 PM | ROOM 502**

### **Mining & Exploration: Geosciences: Surface Mine Geotech I**

*Sponsored by: Piteau Associates*

**Chairs:** *R. Kaunda, Colorado School of Mines,  
Golden, CO*

*E. Wellman, SRK Consulting (US), Denver, CO*

**2:00 PM**

#### **Introduction**

**2:05 PM**

#### **Using Slope Design Fundamentals and Technology for Slope Steepening on a Final Wall at the Goldstrike Open Pit**

*J. Mattern; Barrick Nevada, Elko, NV*

Steepening of bench face angles via pre-split blasting is not an uncommon method for steepening of inter-ramp slope angles. As an alternative at Goldstrike, the commonly used Modified Ritchie Criteria for catch bench width has been adjusted resulting in quantified, rock specific formulas for bench width and rock fall berm placement. The result is an inter-ramp slope angle increase of 2 degrees on a 300m high slope, without the necessary purchases and procedural changes that would be required for pre-split drilling. This presentation describes current mine operating and data collection practices, field rock fall testing and results, and the bench design compliance methods for this work. The results have shown significant net benefits through reduction in mined waste tons and an increase in gold reserves.

**19-026**

**2:25 PM**

## **Slope Steepening Investigations for the Valley Pit at the Teck Highland Valley Copper Mine Using Pre-Split Blasting**

*M. Veillette<sup>1</sup>, N. Rose<sup>2</sup> and M. King<sup>2</sup>; <sup>1</sup>Mine Engineering, Teck, Logan Lake, BC, Canada and <sup>2</sup>Piteau Associates, North Vancouver, BC, Canada*

The Teck Highland Valley Copper (THVC) mine is located approximately 55 km southwest of Kamloops, BC, Canada. The Phase 8 pushback in the Valley pit was mined from 2011 to 2016, and an ultimate mining phase is currently being mined that extends the mine life to 2029. Successful slope steepening of the interramp slope angles (IRAs) by up to 6° was achieved in the later stage of the Phase 8 mining with the implementation of detailed design assessments and pre-split blasting in 2015 and 2016. This paper summarizes the investigation and design approach that included structural and kinematic analysis, discrete fracture networks, rockfall modelling, evaluation of rock mass strength, anisotropic limit equilibrium analysis, 2D and 3D distinct element modelling, and iterative final wall blasting trials to improve bench face conditions and increase bench catchment width. The development of steeper IRAs with pre-split blasting resulted in significant economic gains in high grade ore, but also improved safety by significantly reducing rockfall hazards. The results of the slope steepening investigations has resulted in pre-split blasting being utilized on all final slopes in the ultimate pit.

**19-104**

**2:45 PM**

## **Monitoring of Slope Stability and Tailings Dams: Increasing Mining Safety and Efficiency with Satellite Based Deformation Monitoring**

*J. Granda, J. Duro, D. Albiol and J. Duro; Management, DARES Technology, Castelldefels, Spain*

Slope failures and tailings dam failures constitute a risk for mining safety and operations: Not detecting precursors at time might lead to operational stops with economic losses, to accidents with fatalities and to environmental damages. Radar satellites map precursors everywhere over whole mines and contribute to prevention of accidents. Mine managers use satellite data to take decisions about excavations and tailings dams. Thanks to the global view of radar satellites whole mines can be monitored over time with millimetric precision, in particular slope stability over pit areas, settlement of waste dumps, deformations in tailings dams and subsidence in infrastructures areas. This new satellite technology is applied for measuring slope failures, settlements at tailings dam walls and in their surroundings. We map and identify discontinuities over the retaining walls before a crack appears to avoid collapses or leakages. The objective of this paper is to present new radar satellite remote sensing technology (also known as InSAR): a smart and efficient technology for reducing geotechnical risks in mines, contributing to slope stability and tailings dam monitoring.

**3:05 PM**

## **Innovative Rockfall Solutions Based on Calibration and Field Testing**

*C. Williams<sup>2</sup>, J. Morkeh<sup>1</sup>, K. Dorfschmidt<sup>3</sup>, C. Poon<sup>3</sup>, P. Matlashewski<sup>3</sup> and J. Carvalho<sup>3</sup>; <sup>1</sup>Geotechnical Engineering, Rio Tinto Kennecott Copper, Riverton, UT; <sup>2</sup>Geotechnical Center of Excellence, University of Arizona, Tucson, AZ and <sup>3</sup>Golder, Mississauga, ON, Canada*

Rockfall hazards are ubiquitous in mining environments making their control critical for safe mining operations. The complex processes involved in rockfall events necessitate a probabilistic modeling approach with well calibrated material properties. The controls designed to mitigate rockfall hazards need to be reliable, efficient, and safe to deploy to meet the constraints present at an active mine. This paper presents an innovative solution to rockfall at Rio Tinto's Bingham Canyon Mine. The solution incorporates the site-specific calibration and creation of a predictive rockfall model with the design, field testing, implementation, and monitoring of the rockfall controls.

**3:25 PM**

## **High Density Vibrating Wire Piezometer Installations at Kennecott**

*C. Humphrey; Rio Tinto, South Jordan, UT*

The installation of multiple Geokon vibrating wire piezometers, up to twelve, within a single borehole presents challenges in the physical installation and data management. In a sedimentary rock environment, each unit has the potential to have a different water level. With the multiple piezometers, Kennecott is able to gain an increased understanding of the pore pressures within specific units that are a key input into geotechnical models. Vertical gradients become more apparent, with a high density installation of piezometers due to the increased resolution. Kennecott has also developed a piezometer enclosure that significantly increases the overall safety of installations.

**3:45 PM**

## **Development of Scarp Blasting Design for Successful Slide Mass Remediation in the Genesis District – Newmont Mining Company**

*E. Rose, J. Cappleman and E. McGregor; Newmont, Elko, NV*

The Genesis District, containing weak geologic formations bounded by structural discontinuities and significant faulting networks, provides a complex mining environment. After a series of failures in 2016, the Genesis Pit was left with undesirable vertical slope faces, causing challenging mining conditions. Dewatering activities began in 2017 to safely access the vertical face; creating the necessary access to design a targeted angle blast to effectively remove the vertical face. Blasting the vertical face caused the material to lie at angle of repose, allowing slide mass remediation activities to commence.

**19-119**

**4:05 PM**

## **Novel Techniques to Evaluate the Instability Potential of Open-Pit Mine Slopes**

*M. Zare Naghadeh<sup>2</sup> and A. Siam<sup>1</sup>; <sup>1</sup>Department of Mining Engineering, Hamedan University of Technology, Hamedan, Iran (the Islamic Republic of) and <sup>2</sup>Department of Mining & Metallurgical Engineering, University of Nevada, Reno, Reno, NV*

The complexity in failure mechanisms of the large-scale open-pit mine slopes causes the conventional methods to be unable to thoroughly analyze and predict these events. Comprehensive research has been conducted using a number of novel techniques to tackle this problem. In the first step, the Rock Engineering Systems (RES) has been considered, and a large open-pit mine slopes database from throughout the world has been established, resulting in a new Mine Slope Instability Index (MSII). The second step entails the utilization of the full probabilistic RES and the grey matrix coding methods to achieve more realistic results. Multifactorial Fuzzy Approach and Gene Expression Programming have also been applied to the cases within the database that have presented even more accurate results compared to those achieved using deterministic and probabilistic systems. This paper summarizes the above-mentioned new methods to introduce and formalize their usage in real applications. An excellent agreement between predictions and observations has been found in all means of introduced slope behavior predictions with a small number of cases providing errors in the assessments.

## **MONDAY, FEBRUARY 25**

*AFTERNOON*

**2:00 PM | ROOM 504**

## **Mining & Exploration: Innovations & Technologies: Emerging Technologies and Engineering Advancements: Challenging the Status Quo I**

*Sponsored by: OceanaGold*

***Chairs:*** *S. Lee, South Dakota School of Mines  
L. Diaz, Caterpillar Inc, Peoria, IL*

**2:00 PM**

**Introduction**

**2:05 PM**

## **Blasting Process Optimization Using Empirical Fragmentation Modeling, Aerial Imaging and Photogrammetry**

*J. Sattarvand and J. Valencia; Mining and Metallurgical Engineering, University of Nevada Reno, Reno, NV*

The paper explains different methodologies that are applied to the blasting operations in the studied open pit cases in order to automate, monitor and optimize the process. Firstly, an empirical rock fragmentation model is investigated in a gold open pit mine based on three main variables including Uniaxial Compression Strength, Rate of Penetration and Explosive Powder Factor. Secondly, aerial imaging, photogrammetry, and computer vision technologies are studied in several blasting stages such as drilling accuracy testing, blasted volume expansion, displaced material altitudes, fragmentation, flyrock analysis, damage analysis and video recording. In particular, the paper presents the approaches to identify drillholes on aerial imaging and photogrammetry models using machine learning techniques.

**2:25 PM**

## **Implementing Optimal Grade Control Polygons at Newmont's Mines**

*M. Deutsch<sup>1</sup>, N. Kusuma<sup>2</sup>, L. Allen<sup>2</sup> and M. Godoy<sup>2</sup>; <sup>1</sup>Maptek, Lakewood, CO and <sup>2</sup>Newmont, Greenwood Village, CO*

The entire grade control process is of utmost importance at operating open pit mines. Misclassifying ore as waste, or waste as ore, due to suboptimal polygon design can have a drastic effect and can lead to leaving revenue on the table. Recent innovations in optimized polygon design have created opportunities for increasing profits, improving reconciliation, reducing mistakes, and facilitating sensitivity studies in open pit grade control. In this talk we will share the challenges and benefits of implementing this technology across some of Newmont's operating mines.

**2:45 PM**

## **New Approaches and Technology for Tailings Pipeline Design and Operation**

*J. Stowe and R. Cooke; Paterson & Cooke, Golden, CO*

The conventional slurry pipeline design approach is to select a pipeline diameter which ensures the pipeline operates in turbulent flow without a deposit for all expected operating conditions. Recent improvements in the understanding of slurry pipeline flows allows for the design of pipelines operating with a deposit on the pipe invert, allowing the system to operate at moderate velocities for high flow rates, optimizing system energy requirements and maximizing pipeline wear life. Tailings pipelines are increasingly operated at higher solids concentrations where there is a greater likelihood the pipeline will operate in laminar flow due to the higher tailings rheology. Historically slurry pipelines have been operated in turbulent flow but we now know that laminar flow pipeline operation is possible as there are several operational laminar flow tailings pipelines. While our understanding of laminar flow slurry pipelines is not complete, recent research provides guidance on how to approach the design of these pipelines.

**19-090**

**3:05 PM**

### Evaluation of Novel Dewatering Methods Using a Groundwater Flow Model

*S. Meyerhoff<sup>1</sup>, B. Hanna<sup>1</sup>, H. Liu<sup>1</sup> and M. Shultz<sup>2</sup>; <sup>1</sup>Itasca Denver, Inc., Lakewood, CO and <sup>2</sup>REI Drilling, Salt Lake City, UT*

Recent advances in technology have resulted in the development and refinement of new techniques in drilling. These advanced drilling techniques, such as directional drilling with magnetic ranging, are now available to support novel dewatering and depressurization designs at mining operations. In this study, we evaluate the use of these novel techniques with a numerical groundwater flow model. Groundwater flow model simulations under different geologic settings are evaluated and compared with standard drilling and dewatering/depressurization techniques. These simulations are used to evaluate the potential effectiveness of novel drilling techniques for dewatering and depressurization at mining operations.

**3:25 PM**

### Representing Complex Joint Sets in Mine-Scale Numerical Models

*J. Furtney<sup>1</sup>, L. Lorig<sup>1</sup>, T. Katsaga<sup>2</sup> and R. Silva<sup>3</sup>; <sup>1</sup>Itasca Consulting Group, Minneapolis, MN; <sup>2</sup>Itasca Consulting Canada, Inc., Sudbury, ON, Canada and <sup>3</sup>Itasca Chile SpA, Santiago, Santiago, Chile*

Numerical modeling is increasingly used in geomechanical design and analysis of mines. Mine-scale models must include the effects of complex joint-sets to give useful insights. Two categories of methods have been developed to represent discontinuities: discrete and continuous. Discrete methods explicitly represent each joint. Two discrete methods are described: the polyhedra-based distinct element method and the sphere-base discrete element (lattice) method. Continuum methods see more use and are often more practical. Sliding interfaces between meshes or structure conforming mesh generation techniques can be used to explicitly represent joints. Constitutive behaviors, like ubiquitous joint models, can implicitly represent joints. Discrete methods offer a natural and intuitive representation of jointed rock but are often more complex and more computationally intensive. Continuum methods are simpler and faster but may lack detailed joint representation. Continuum models can lack important mechanisms like step-path failure and can be discretization dependent. This paper presents case studies of each method and discusses the conditions under which each technique is favorable.

**3:45 PM**

### Dry Beneficiation of Low-Grade Iron Ore Fines Using a Tribo-Electric Belt Separator

*L. Rojas Mendoza, F. Hrach, K. Flynn and A. Gupta; ST Equipment & Technology, Needham, MA*

ST Equipment & Technology LLC (STET) has developed a novel processing system based on tribo-electrostatic belt separation that provides the mineral processing industry a means to beneficiate fine materials with an energy-efficient and entirely dry technology. In contrast to other electrostatic separation processes that are typically limited to particles  $>75\mu\text{m}$  in size, the STET triboelectric belt separator is suited for separation of very fine ( $<1\mu\text{m}$ ) to moderately coarse ( $500\mu\text{m}$ ) particles, with very high throughput. The STET tribo-electrostatic technology has been used to process and commercially separate a wide range of industrial minerals and other dry granular powders.

Here, bench-scale results are presented on the beneficiation of low-grade Fe ore fines using STET belt separation process. Benchscale testing demonstrated the capability of the STET technology to simultaneously recover Fe and reject SiO<sub>2</sub> from itabirite ore with a D50 of 60 $\mu$ m and ultrafine Fe ore tailings with a D50 of 20 $\mu$ m. The STET technology is presented as an alternative to beneficiate Fe ore fines that could not be successfully treated via traditional flowsheet circuits due to their granulometry and mineralogy.

19-077

4:05 PM

## Challenges and Success Factors When Deploying Tablet and IoT Based Fleet Management Systems and Digital Forms

*S. Dessureault<sup>1</sup> and D. Callahan<sup>2</sup>; <sup>1</sup>MST Global, Tucson, AZ and <sup>2</sup>The Doe Run Company, St. Louis, MO*

Tablet and Internet of Things (IoT) based fleet management and digital form systems are now available and are beginning to be deployed at operations that could not afford traditional FMS. A series of case studies that identify the challenges and success factors in deployments of such technology is presented as a roadmap to help companies learn how to avoid the pitfalls and leverage the advantages these new technologies bring to operations of all sizes. For example, a key challenge is both an advantage and tempting weakness: the flexibility of such systems and the ease of updating apps, where scope creep during deployments to add new features or more complex configurations and then redeploy within days rather than months or years as is done in more traditional technologies. Another key challenge is again both a benefit and challenge: the sudden availability of data, and the need to deliver the data to users within complex security topologies which often result in the inability to access the information, or the analysis paralysis that ensues when presented with more data than has ever been available before. Specific examples of real deployments will be provided.

## MONDAY, FEBRUARY 25

AFTERNOON

2:00 PM | ROOM 505

### Mining & Exploration: Management: Striving for Excellence: Case Studies of Successful Continuous Improvement Initiatives

*Chairs: B. Scholz, Newmont Mining Corp, Aurora, CO  
T. Bush, Greenwood Village, CO*

2:00 PM  
Introduction

2:05 PM  
Quantification and Operational Management of Ore Loss  
and Dilution at Cripple Creek and Victor Gold Mine; Cripple  
Creek, Colorado

*S. Siebenaler and B. Dayley; Mine Technical Services, Newmont Mining  
Company, Cascade, CO*

The Cripple Creek and Victor gold mine is a world class deposit that has produced ~25 million gold ounces over a 120 year history, culminating in the on-going surface mining which commenced in the 1980's. Operationally, all ore is crushed which provides the mine a measured received tonnage and grade. This gives the site the opportunity to closely monitor dilution and dig compliance in a mine that mines through a complex network of stopes and drifts. The presentation discusses studies conducted using data from drone flights, laser scans, GPS imbedded shovel tooth technology, weightometer sampling, ore control models, and cross stream cutting crusher belt data to discuss studies and best practices used at the mine to prevent ore loss and dilution in the course of mining operations.

2:25 PM  
Minimizing Dilution and Ore Loss by Accounting for Blast  
Movement at Golden Queen Mining Company's Soledad  
Mountain Project

*S. Holden<sup>1</sup> and A. Kendir<sup>2</sup>; <sup>1</sup>Fort Lewis College, Durango, CO and <sup>2</sup>SME  
Young Leaders Committee, Denver, CO*

Controlling ore contacts prior to excavation is essential to ensuring that material types reach the correct downstream locations in order to achieve optimal ore recovery. This practice is especially pertinent to narrow vein deposits, where very small discrepancies between assumed and actual locations of ore contacts can translate to significant ore loss and dilution. However, blast movement is a problem for every mine, including those targeting massive, disseminated deposits. An analysis of blast movement was conducted at Golden Queen Mining Company's Soledad Mountain Project, a narrow vein-hosted gold/silver deposit, to evaluate its effects on ore loss



and dilution. One example of a monitored blast showed that the entire ore block moved by 4.5 –10.5 ft. Although this movement was modest, such a displacement without tracking would have resulted in an estimated 3% (~4,000 tons) ore loss as a result of ore migrating into a waste block. The overall increase in recovered value from this blast was estimated at US \$69,195. Blast movement calculations from the first year of implementation at the Soledad Mountain Project indicate an average recovered estimated value of US \$55,000 per blast.

**2:45 PM**

## **A Bench Height Study at Merian: Theory and Practice**

*A. Jewball and B. Haverland; Newmont Mining Corporation, Greenwood Village, CO*

A bench height study was completed for the Merian mine in Suriname. Due to floor conditions, the mine was struggling to maintain production and dilution on 5m benches. It was hoped that these conditions might be somewhat ameliorated by mining on a 10m high bench. This study consisted of two parts, a simulation based study to determine the amount of dilution and ore loss in mineable polygons (at the ore control level) if mining were to switch to a 10m bench and a second component which looked at the economical and operational aspects of switching to a 10m bench. This paper details the results of the study and concludes with a back reconciliation i.e. how do the results, after the switch to 10m benches, compare against the predictions from the study?

**3:05 PM**

## **Gold Mining MOS – Management Operating Systems Driving Continuous Improvement**

*M. Routledge; H&S Division Board, Park City, UT*

The journey to operational excellence is based on a foundation of solid risk management and the need to develop and drive a management operating system (MOS). The visibility of data from basic operating processes in any mine is critical to measuring and understanding the current state then driving continuous improvement in performance from exploration and geology to mining, processing and delivering metals to the market. This case study will briefly outline the journey Anagold, part of Alacer Gold Corp, has taken to introduce operational excellence to its Turkish gold operations and the significant impact it had on delivering additional value.

**3:25 PM**

## **Operational Excellence Transformation in a Cross-Cultural Mining Environment**

*L. Mottola; Engineering, McGill University, Verdun, QC, Canada*

Sherritt Intl; operating since 1994 in partnership with Cuba in the Metals ENT Joint Venture comprising Pedro Soto Alba mining & mineral processing facilities in Cuba Cobalt Refining Co. Inc. (Corefco) plant in Fort Saskatchewan, CA & Intl Cobalt Co. Inc. (ICCI) sales & marketing outfit based in Nassau, BS. Since Feb/16 the Joint Venture has embarked on a transformational program toward OE based on Lean Mining; the application of Lean Thinking to the mining and metals sector. LM is an operating strategy improving & sustaining performance of the business via the development of people's capability to continuously identify waste & implement improvements. In an initial mapping exercise of

the production system, a cross-cultural team of Cuban-Canadians analysed flow of material from mine to market & systemically identified waste, analysed root-causes, & developed improvement projects that were executed over a 90-day period. This initial wave of 11 projects realized both tangible and intangible benefits to the Metals ENT and its people. This presentation will address the challenges & achievements of this transformation journey that will raise the joint venture to new levels of performance.

### 3:45 PM

#### Electric Drive Trucks – Accelerated NPI Product Development

*A. Reid and Y. Wang; Caterpillar, Washington, IL*

We at Caterpillar Surface Mining, we embrace a lean product development system which encompasses key attributes such as engineered value chain, virtual product development (VPD), and concurrent engineering to maximize benefits. We are constantly looking for ways to minimize R&E and develop quality products that meet VOC and VOB and are faster to market to take advantage of emerging opportunities. New Product Introduction (NPI) cycles for LMT typically spanned about 3-4 years. By working closely with a customer/dealer as product development partners, meant this project had to deliver a brand-new truck from concept to completing the first truck build in less than 8 months.

### 4:05 PM

#### Grasberg Final Wall Slope Optimization

*A. Kinney, T. Christanto, P. Siburian and A. Keith;  
Freeport-McMoRan, Phoenix, AZ*

This paper presents final wall Slope Optimization practices at Grasberg Mine which lead to a 15% increase to both bench face angle (BFA) and inter-ramp slope angle (ISA), and subsequent increase in a metal recovery totaling 18% additional copper, and 28% additional gold at. Located in remote jungle province of West Papua Indonesia, at an elevation of 4,200 meters, sits the Grasberg open pit mine. Grasberg mine implemented high quality Slope Optimization program for final pushback, with the goal to safely increase recoverable metals through steeper slopes, while utilizing existing infrastructure and equipment. Most emphasized programs are blast QA/QC improvement, as built slope measurement (slope audit program), and short term planning modification. Grasberg was divided into two primary areas for slope steepening, with ISA of 51° and 52°, respectively, all areas in pit with 70° BFA. Through continuous developments, collaboration and achievement, Grasberg final pit was modified for BFA increase to 80° for all areas, and an ISA increase from 51° to 56°, and 52° to 60°, in respective areas.

**MONDAY, FEBRUARY 25**

*AFTERNOON*

**2:00 PM | ROOM 503**

## **Mining & Exploration: Management: This is My Job and Here's Why I love It. A Look at Early Career Choices with Mineral Industry Degrees**

***Chairs:** J. Humphrey, Caterpillar, Decatur, IL  
K. Boyce, Caterpillar, Tucson, AZ  
L. Diaz, Caterpillar Inc, Peoria, IL*

**2:00 PM**

**Introduction**

**2:05 PM**

### **Choices to Contract Mining: What Made Me a Contractor**

*Z. Forest-Dupont; Cementation USA Inc., Marquette, MI*

Mining engineers find themselves in vastly differing roles across many industries. This variety of options is often overwhelming for students and new graduates. My path has lead me to the underground mining contracting business; a path that is often overlooked by students. Working for a contractor offers tremendous opportunities for exposure and growth in the mining industry. More often than not, engineers are not exposed to the massive effort that constitutes building these mines. Within my 3 years with Cementation I have had the opportunity to work on the deepest shafts, estimate international projects, and implement stoping. This work is one reason among many why I love my job and hope to grow within my organization. I want to urge students and graduates interested in mining to research and discover these contracting firms to see what they have to offer. Many of the decisions I made in high school, throughout college, and into my early career have paved the way to where I am now, and where I hope to go. This session is a discussion on the choices made that have brought me here.

**2:25 PM**

### **How I Learned to Succeed in Mining**

*C. Smith; Global Mining, Caterpillar, Perth, WA, Australia*

Cory Smith is a first-generation college student from a small town in Missouri. With no family members experienced in higher education or mining, he had to forge his own way ahead. Land surveying, a great recession, waiting tables and even failing a few classes have all shaped his career. A career that has taken him as far as the Pilbara region of Western Australia, where he has implemented and operated the largest fleets of autonomous haul trucks in the world. He offers guidance and lessons learned to help young engineers on their own paths to success in the industry.

**2:45 PM**

## **Academic Choices: Transitioning from Industry to Research and Teaching**

*J. Wempen; Mining Engineering, University of Utah, Salt Lake City, UT*

Jessica is an assistant professor of mining engineering at the University of Utah. She has experience as a mine planning engineer and worked for Peabody Energy and Maptek before pursuing a PhD. Jessica is a licensed Professional Engineer and is certified as a Remote Pilot by the Federal Aviation Administration (FAA). Her research is focused on applied geophysics and on applied remote sensing using satellite and unmanned aerial vehicle (UAV) imaging.

**3:05 PM**

## **From West Philly to the Wild West: My Journey in Mining and Why I Think the Question “Where Do You See Yourself in 5 Years? 10 Years?” Is Dumb**

*R. Rogers; Maptek, Golden, CO*

Today, I work for a software company. I have a strong interest in creating better user experiences through design of our products which in turn helps people enjoy their job more. Helping others is a part of my role that I really value. If someone told me while I was an undergraduate student approaching my last semester of college, that nearly 10 years later I would be working with defining software requirements and testing software, I would have laughed. Yet here I am. How I got here? Well, it started with an offer for a job in underground coal in West Virginia, then a rescinded job offer, followed by learning about SPME fibers and more chemistry in pursuit of a masters degree focused in mine ventilation, to a grandiose role at a corporate office, followed by a layoff, some substitute teaching and then a job at where I am now. A job I was excited for, but I had no idea where it would take me or the unknown interests this job would uncover. What I have learned all along the way is to be open minded, take what you can get and make the most of it, do not be afraid to try something uncomfortable, and always, always, be nice to people. It is a good way to live.

**MONDAY, FEBRUARY 25**

*AFTERNOON*

**2:00 PM | ROOM 506**

## **Mining & Exploration: Operations: Mine Data Management**

*Chair: A. Howse, Rossland, BC, Canada*

**2:00 PM**

### **Introduction**

**2:05 PM**

### **Integrating Data Sources for Better Decision Making**

*R. Tamir; Seekers Strategy, Boynton Beach, FL*

The vast array of data-generating tools at our disposal today monitor many aspects of mine to gate performance and creates islands of information. Harnessing these tools under one roof, "Capstone concept", creates a mine to gate picture, Situational Awareness, leading to Decision Making Process / System (DSS). This concept, deeply rooted in the military way of "winning in complex environments", lends itself seamlessly to mining and creates an environment where all stakeholders are prompt to contribute to good decision-making that impacts the bottom-line cost. This paper presents the methodology, examples and benefits to the mining community of implementing this concept.

**2:25 PM**

### **On the Verge of Industry 4.0: the Data Dilemma in Mining**

*M. Kahraman; Gumushane University, Gumushane, Turkey*

Price fluctuations in commodity prices and decreasing grades forced the mining market to become more competitive. There is an increasing trend in the adaption of new technology in machine monitoring, people tracking, and process control. Every new technology or system creates its own mountains of databases. Only a limited amount of the recorded data is used in reporting and fraction is used in decision making. The reports are the results and decisions made are very basic decisions in the production chain. Big Data, machine learning, Industry 4.0, Internet of Things, data mining, artificial intelligence, robotics, data science are new trendy terms being introduced into the mining industry, without a comprehensive plan for utilization of these tools. Today effective use of data in mining industry compares relatively very behind compared to other industries. This paper presents a comprehensive approach for mining firms to create a tech utilization policy and data driven management plan.

**2:45 PM**

### **Some Concepts and Tools for Reporting Grade Control Results in Underground Mines**

*D. Cameron; Cameron Resource Consulting, LLC, Harrison, ID*

Grade control decisions and production tracking in many selective underground mines rely on calculations based on combinations of face, rib and back sampling. In the author's experience, these calculations generally em-

ploy some incorrect assumptions and calculation methods, and under-utilize the information that can be collected from a sample site. Individual sample weighting in a string is often done on the basis of sampled length alone, whereas in the general case, density and area represented by the sample should be the weighting factors. Thus, data beyond sample numbers, lengths and descriptions are necessary to produce accurate, representative results. Production unit grades are often reported from the result of a single sample line, or over longer periods, as the simple average of a string of sequential sample site results. In both cases, reporting can be optimized. The STOPE-CALC app is a simple desktop tool that takes these important factors into consideration, provides accurate reporting of tons and grade, and flexibility. The application uses cloud storage with security and user profiles; it can be used with a tablet as a portable data collector underground.

### 3:05 PM

#### Data Storage for Drone Mapping

*J. Berg; Surveyor, Spring Creek, NV*

Drone technology has come along way in the past few years enabling operations to get fast and accurate data from UAVs. But one of the challenges to this is managing the enormous amounts of data created that previously was not generated with traditional GPS surveys. At Barrick Nevada's Goldstrike operation, in NE Nevada, 2 terabits of drone data have been produced over the last 2 years and the workload for drones is only increasing. A potential solution to our data management problem was to partner with a company called Airware. Airware is a Drone Analytics company that stores and processes drone data for clients. Users can also view data in 3D, get 5' contours, calculate stockpiles, do simple measurements, and create polygons or poly lines that will stay on the map for others to see. All of this is included with the base package in Airware. Road analytic packages can also be requested that give berm heights on roads, road widths, cross fall of roads, and slope percentage of ramps. Barrick has experienced time saving for data processing freeing up time to do more flights and reduced on site data storage by utilizing Airware's storage solution.

### 3:25 PM

#### Embrace Exploration Data to Maximize Exploration Programs

*J. Anderson; Technical Services, Maptek, Denver, CO*

Exploration projects are a costly yet necessary mining task. Exploration Drilling is a critical stage to gather information of the potential economic material. Managing and knowing how to utilize current and archive data is the key to a deposit's success that reaps rewards downstream to other mining activities. The stress of trying to gather as much information as well as daunting exploration project schedules can cause incomplete or simplistic data that often can result in re-drilling of the locality. In addition to traditional data types collected, ancillary data from common collection techniques such as geophysical logs can give an extra insight into your deposit.

**3:45 PM**

## **Presentation of a Modern, Scalable and Extendable Mine Control Station for Small and Medium Enterprises**

*T. Krichler; Institute for Mining and Civil Engineering, TU Bergakademie Freiberg, Freiberg, Germany*

At last year's SME Conference in Minneapolis TU Bergakademie Freiberg presented a new approach how to setup a modern mine control station while using OPC Unified Architecture and single-board computer. The main goal is to reduce installation and maintenance costs to implement the Internet of Things also at small and medium enterprises. The follow up will show a first prototype of the system especially in-depth the visualization cockpit, the different display options and the general setup of field devices. The main differences to the common products on the market are the use of open communication architecture and low cost field devices without any binding to restricted protocols or software to reduce license costs. Maintenance and installation costs will be reduced by using standardized software and hardware.

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## **MONDAY, FEBRUARY 25**

*AFTERNOON*

**2:00 PM | ROOM 610**

## **Mining & Exploration and Health and Safety: The Digital Journey: Cross Cutting Innovation and Technology that Impact H&S**

***Chairs:** W. Rogers, University of Utah,  
Salt Lake City, UT  
M. Momayez, The University of Arizona,  
Tucson, AZ*

**2:00 PM**

### **Introduction**

**2:05 PM**

## **Achieving Safety and Comfort with an Environment-Aware Ventilation System for Underground Mines**

*M. Risso and M. Momayez; Mining and Geological Engineering, The University of Arizona, Tucson, AZ*

Ventilation-on-Demand represents a reliable alternative for underground mines where achieving improved health, safety and energy efficiency are top priorities. With the advent of new technologies such as Wireless Sensor Networks (WSN) underground mining operations can readily augment

existing monitoring capabilities with smarter and more efficient solutions. In particular, we consider here taking advantage of already available low cost sensors which can be integrated into an Internet-of-Things (IoT) framework, to extract information for the implementation of intelligent ventilation strategies. Our goal is to achieve an optimal personal comfort level (PCL) within safety constraints and a cost-efficient ventilation solution in underground mines. We use a fuzzy logic approach to create a ventilation-on-demand strategy, considering environmental variables and number of mineworkers as decision parameters, which can be easily integrated into existing data infrastructure frameworks, such as PI system.

## 2:25 PM

### Determination and Comparison of Thermal Stress Indices in Mining: TWL, PHS and WBGT

*P. Lazaro and M. Momayez; Mining and Geological Engineer, University of Arizona, Tucson, AZ*

Heat stress in hot mining environments can cause different effects, from skin irritation to heat stroke, which is often fatal. Heat stress and heat strain are commonly used terms where the former represents external factors and the latter is related to the body's core temperature. More than 200 indices have been proposed to identify and predict heat related hazardous conditions, however, the trend in the last decade has focused on the determination of the heat strain which is based on environmental conditions, physiological measurements, type of clothing and work intensity. Using the appropriate index in a mining work-site environment is crucial. The objective of this research is to compare three well established indices in the same working environment: The Thermal Work Limit (TWL), the Predicted Heat Strain (PHS) and the Wet Bulb Globe Temperature (WBGT). The study was carried out in southwest United States at two mining operations where workers are exposed to hot indoor and outdoor environments leading to potential health risks. We analyzed the indices at the mines and performed a comparative study to determine the most suitable index to use in a hot mining environment.

## 2:45 PM

### Digitizing Health, Safety and Environment (HSE) Data, Processes, and Metrics at Remote or Disconnected Locations

*C. Barnett and B. Calcote; Jacobs Engineering, St. Louis, MO*

In the past, HSE data from remote sites may have been a few paper forms and several days removed from landing in the HSE system of record, a lag that could lead to increased safety risk or potential regulatory violations. However, today's leading HSE applications have evolved to bring simplified mobile interfaces and offline capabilities that not only shrink or eliminate that lag but also serve to enforce HSE business processes and best practices. In this session we will discuss how to leverage new capabilities of HSE software applications and help automatically monitor the location of equipment or staff, biometrics, and facilitate incident or spill reporting in areas where automation was once not possible to achieve. We will cover how offline tools can bridge gaps in connectivity, how modern Internet of Things (IoT) sensors can still be useful in remote areas, and how mobile-enabled applications can create a safer work site.



**3:05 PM**

## **Machine Learning Models for Suspension System Performance Prediction in Large Dump Trucks**

*D. Ali and S. Frimpong; Mining & Nuclear Engineering, Missouri University of Science and Technology, Rolla, MO*

Large dynamic impact force is generated as the large capacity shovel loads 100 tons of material into the dump truck, which in-turn generates high-frequency shockwaves that travels through the truck body, chassis and exposes the operator to whole body vibrations (WBV). Vibration attenuation system in the dump truck commonly consists of hydro-pneumatic suspension struts which lose its capability to effectively attenuate the vibration levels, as the truck ages, requiring its performance to be monitored in real time. Machine learning algorithm support vector machine (SVM) has been implemented along with the regularized dual non-linear regression to model the performance of these hydro-pneumatic suspension struts. These models can be implemented in the dump truck controller to monitor the performance of the suspension system in real-time, and with that proper maintenance and/or replacement can be scheduled by the maintenance personnel. Workplace safety, operator's health and the overall system efficiency can be greatly improved with an implementation of such an intelligent system.

**19-037**

**3:25 PM**

## **The Economic Burden of Fatal Occupational Injuries to Miners in the United States – Fatalities Cost in Mining**

*J. Heberger; CDC NIOSH, Pittsburgh, PA*

To better understand the burden imposed by fatal mining accidents, it is necessary to develop measures of the economic component of loss to complement existing surveillance research efforts. The Fatalities Cost in Mining web application, developed by the NIOSH Mining Program, uses an adapted version of a wellknown cost of illness methodology to estimate the societal cost of an individual fatality based on key characteristics of the fatally injured miner. The user can select fatality characteristics (demographics, incident, employer, etc.) and reporting year (2000-2016 currently available) to generate a report and view the average societal cost per fatality as well as the total cost for all fatalities matching the criteria. For example, in 2016 there were 26 fatal accidents averaging \$1.35 million per fatality with a total societal cost of \$35.1 million. Researchers, occupational health professionals, workplace safety organizations, and labor unions have proven to be willing and avid users of these estimates. This manuscript reviews the Fatalities Cost in Mining web app including its development and how it can be used to estimate the economic burden of fatal mining injuries.

**19-101**

**3:45 PM**

## **The Nexus of Supervised Learning and Analytics: Speeding Up Informed Critical Decisions**

*W. Rogers; Mining Engineering, University of Utah, Salt Lake City, UT*

The speed of appropriate decisions can be a key determination between safe and unsafe operations, profitable and non-profitable operations, and ultimately sustainable or unsustainable organizations. Distributed leadership models have changed the pace and location of decisions. Technological ad-

vances, such as internet of things, information systems, supervised learning, and analytics, have been critical to facilitating these management changes. In practice, supervised learning systems and analytics are often treated independently. This segregation often disrupts the data to understanding process, therefore, hampering the speed of informed decisions. Learning algorithms identify key correlations and causations but, do not inherently change a decision making culture. Analytics provide these change agents tools but, lack the predictive elements needed to amplify the intelligence of decision makers. The nexus of learning systems with analytics is vital to maximizing the value of data assets. Several case studies are given showcasing the need for this nexus along with several best practices to consider.

## MONDAY, FEBRUARY 25

AFTERNOON

2:00 PM | ROOM 210

### Moving Mining Curriculum to Embrace the Future

*Chairs: A. Brickey, South Dakota School of Mines and Technology, Rapid City, SD  
V. Kecojevic, West Virginia University, Morgantown, WV*

2:00 PM  
Introduction

2:05 PM  
Moving Mining Curriculum to Embrace the Future

*A. Brickey; Mining Engineering and Management, South Dakota School of Mines and Technology, Rapid City, SD*

The mining industry is continuously changing and evolving through the development and adaptation of new technology. Industry's expectations of new graduates' skills are also changing. Universities have always been expected to produce graduates capable of solving complex problems, but the future will require that these graduates also excel at creativity, people management, and emotional intelligence. The challenge to universities is how are these skills taught and incorporated into required curriculum. In this session, national and international speakers and panelists will discuss and answer questions related to the needs, efforts, and challenges of incorporating new technology into undergraduate and graduate curriculum. Ideas for incorporating technical knowledge, as well as encouraging skill development, will be presented. This session will be hosted by the Educational Committee of the Society of Mining Professors (SOMP).

**2:25 PM**

## **Mining Engineering Curriculum of the Future**

*R. Mitra; Mining Engineering, University of the Witwatersrand, Wits, Johannesburg, South Africa*

“Industry 4.0” refers to the next development stage in the organisation of the entire value chain process in the manufacturing industry (Deloitte 2014). From a mining industry point of view, complex tasks are increasingly being handled by smart analytics software packages, while smartphones and other hand-held devices have transformed the way that workers interact — not only with each other but with machines (Carter 2017). The challenges facing the mining industry are increasing with environmental concerns becoming broadly understood, emergent technology changing the nature of work and society and resource nationalism fuelling the expectations of a better life. This is changing the roles and attributes of the mining engineer of the future (Smith 2017). This paper will look into the role of the Society of Mining Professors (SOMP) in developing a framework for training Mining Engineering graduates of the future. It will also include an example of a redefined curriculum at the School of Mining Engineering at the University of the Witwatersrand.

**19-149**

**2:45 PM**

## **Keeping Mining Engineering Curriculum Relevant**

*S. Rosenthal; Mining Engineering, Montana Tech, Butte, MT*

As Mining Engineering educators, we are challenged with keeping our curriculum relevant for the needs of the employers that hire our graduates while meeting the needs of our students, our institution, our professional societies and our accreditation board. Any additions in content requires a deletion of content in another place due to fixed course duration. The tension of balancing all of these needs, while simultaneously keeping content taught engaging for the students, is a never ending struggle. This paper explores the incorporation of new technology into mining engineering curriculums, what to consider for addition, how to weigh additions vs. deletions, and how to invigorate faculty to remain up to date.

**3:05 PM**

## **Coupling Innovative Technology in the Academic Environment with Theory-Based Curriculum**

*M. Moore; Maptek, Lakewood, CO*

The next generation of technical mining engineers and geologists will be more comfortable with technology than with the theory the technology supports. This presentation will discuss practical case studies of the implementation process of theory taught at the secondary education level, coupled with technology to allow students to understand the theory and best practices identified in industry, at a higher level. Solutions in bridging the gap between academic theory and practical application will be addressed. As well as exploring how to aid in the balancing act of educating future professionals on innovative technologies and fundamental theories that these technologies support. Leveraging Bloom's taxonomy of learning, generational differences, and learning styles will also be examined. In addition, best practices in the approach of training professors and teachers assistants for curriculum implementation will be discussed; the best way to engage the next generation is to embrace and leverage their strengths in their own educational journey into becoming creative and resourceful engineers, geologists, and surveyors to lead the future of mining.

3:25 PM

## The MINETRAIN Project; Developing an Advanced Level Training Program for Mining Industry Professionals in an Actual Deep Mine Site

*G. Barakos<sup>1</sup>, M. Bueno<sup>2</sup>, S. Luukkanen<sup>2</sup>, H. Mischo<sup>1</sup>, Z. ZHANG<sup>2</sup>, M. Sinche Gonzalez<sup>2</sup>, P. Holopainen<sup>3</sup> and A. Remes<sup>4</sup>; <sup>1</sup>Institute of Mining, TU Bergakademie Freiberg, Freiberg, Germany; <sup>2</sup>Oulu Mining School, University of Oulu, Oulu, Finland; <sup>3</sup>NORMET, Iisalmi, Finland and <sup>4</sup>Outotec, Espoo, Finland*

In a competitive mining industry, onsite experience is a big advantage. Mining education at the universities is still focusing on theoretical studies without a possibility of practical training in mining sites. Hence, experimental mines suitable for practical education are needed for giving a platform for systematic research and education in industrial scale and for training in real mining conditions. Yet, such mine sites are rare worldwide. Thus, a new research project namely MINETRAIN is introduced in this paper evaluating the transition of the Pyhäsalmi mine in Finland from an active base metal mine to a research, educational and training underground facility. The uniqueness of MINETRAIN compared to other test mine programs is that the existing state of art infrastructure in Pyhäsalmi enables research and training tools among all disciplines related to the overall mine value chain. Though all the above sound interesting in the context of research and education purposes, in practice Pyhäsalmi will have to become an experimental mine that can be sustainable in the future. Accordingly, a prefeasibility study has been conducted, the results of which are also presented in this paper.

19-061

**MONDAY, FEBRUARY 25**

*AFTERNOON*

**2:00 PM | ROOM 705**

## **MPD Plenary**

*Sponsored by: thyssenkrupp*

***Chairs:*** *M. Jeffrey, Newmont Mining Corp.,  
Englewood, CO  
A. Cole, Barrick Goldstrike Mines Inc, Elko, NV*

***Opening Remarks:*** *Jim Metsa, 2019 MPD Program Chair*

### **Robert H. Richards Lecture**

*Introduction by Richards Award Committee Chair, Andrew Cole*

***Award Recipient and Lecturer:*** *Jaime E. Sepúlveda*

***“Comminution Circuit Optimization: Theory Put into Practice”***

### **Milton E. Wadsworth Lecture**

*Introduction by Wadsworth Award Committee Chair, Matthew Jeffrey*

***Award Recipient and Lecturer:*** *Kathryn C. Sole*

***“The Battery Revolution: Emerging Trends in***

***African Hydrometallurgy”***

### **Rong Yu Wan Ph.D. Dissertation Award Presentation**

*Introduction by MPD Scholarship Committee Member, Nick Gow*

***Recognition Presentation:*** *Seyed Hassan Amini*

### **Fuerstenau Mineral Processing Symposium:**

#### **Keynote Address and IMPC-SME Plaque Presentation**

*Introduction by Barbara Arnold*

***Plaque Recipient and Lecturer:*** *Douglas Fuerstenau*

***“Seven Decades as a Mineral Engineer: From the Black Hills to Butte, Boston, Berkeley and Beyond”***

### **International Mineral Processing Council (IMPC) Recognitions**

*Introduction and award presentation by Cyril O'Connor*

***IMPC Distinguished Service:*** *Douglas Fuerstenau*

*Introduction and award presentation by Cyril O'Connor*

***IMPC Lifetime Achievement Award:*** *Jan Miller*

***Closing Remarks:*** *Jim Metsa*

## MONDAY, FEBRUARY 25

AFTERNOON

2:00 PM | ROOM 612

### SME Young Leaders: My First Five Years of Experience in Industry/Academia

2:00 PM

Introductions

2:05 PM

#### My First Five Years of Experience in Industry/ Academia

*H. Lammers; Mining Engineering, Colorado School of Mines, Denver, CO*

Mining is a challenging, diverse, and rewarding industry to work in, with a number of career paths and seemingly endless opportunities for growth and involvement. My career path as a geological and mining engineer for the past 11 years has included consulting on development, operation and closure designs for several mining facilities around the world, and has recently included a return to academia in pursuit of a Ph.D. As part of this technical session, I plan to share some of my thoughts and experiences related to navigating the mining industry, and the balance between consulting, academics, research, and life.

2:25 PM

#### My First Five Years of Experience in Industry/ Academia

*A. Naeimipour; Pennsylvania State University, University Park, PA*

The first five years of professional life is all about finding what exactly you are interested in and what skill sets you need to gradually reach this goal. This requires that you be a smart, courageous and confident hard-worker. After you find your professional life passion, it is time to plan how to be an expert in your field over the time. It is very important to find and get help from good mentors to guide you along the way. In addition, you need to evaluate your progress and where you are heading to at least annually and have reasonable expectations from yourself to avoid unreasonable disappointments.

2:45 PM

#### My First Five Years

*B. Teschner; Mining Engineering, Colorado School of Mines, Golden, CO*

Benjamin Teschner has spent his career in industry and academia working on the relationship between mining companies and stakeholders. Ben earned his Bachelor's Degree in Geological Engineering (2008) and Masters of International Political Economy of Resources (2011). Ben worked for Gold Fields Exploration on mining and exploration projects in West Africa, and did a small amount of consulting on proliferation of conflict minerals in the D.R. Congo. He returned to academia in 2014 where he is currently working on his PhD in Mining Engineering with a focus on integrating stakeholder variables into mine valuation and planning.

**3:05 PM**

## **Mining Safety Research: Journey from Undergraduate Student to Full-Time Researcher**

*V. Gangrade; National Institute for Occupational Safety and Health (NIOSH), Pittsburgh, PA*

The presentation discusses the important highlights of the journey from undergraduate student to a full-time researcher. The differences and similarities of working in different research communities. Vasu Gangrade is a Mining Engineer working in the area of mine ventilation and ground control at the National Institute for Occupational Safety & Health (NIOSH) in Pittsburgh, PA. Vasu holds a M.S. in Mining Engineering from University of Utah and a B.S. degree from Indian School of Mines. Before joining NIOSH, he worked as a Ventilation Engineer at the Lively Grove Mine in Southern Illinois. He is an active member of the SME Young Leaders Committee since 2016 and an enthusiastic participant in SME local and annual conferences. He has published 8 papers in the area of mine ventilation and ground control in the last 5 years and has presented at several international conferences, including, World Mining Congress, North American Mine Ventilation Symposium, and SME Annual Conference. His ongoing research work impacts multiple mining commodities, including coal, stone, and shale gas.

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## **MONDAY, FEBRUARY 25**

*AFTERNOON*

**2:30 PM – 4:25 PM | ROOM 710**

## **CMA: The Outlook for Commodities in the Current Global, Geopolitical and Economic Environment**

*Sponsored by Wagner Equipment Co.*

Hear from leading international experts from the precious metal, base metal and coal industry discuss their views on the future supply/demand, strengths and weaknesses of the mineral industry and global factors that enhance or threaten the future for the mineral industry.

### **Moderator:**

**Barney Guarnera**

*Broadlands Mineral Advisory Services Ltd., Las Vegas, NV*

### **Panelists:**

**Lachlan Broadfoot**

*Behre Dolbear, Greenwood Village, CO*

**Steve Doyle**

*Doyle Trading Consultants, Grand Junction, CO*

**Rohit Savant**

*CPM Group, Brooklyn, NY*

**David Sferra**

*Freeport-McMoRan Inc., Phoenix, AZ*

## TUESDAY, FEBRUARY 26

MORNING

8:30 AM | ROOM 601

### The US SEC's Rule S-K 1300 for Mining Property Disclosure

#### Overview

In December 2018, the SEC published Rule S-K 1300 which replaces Industry Guide 7, that had been used since 1981. The SME and the National Mining Association had been advocating modernization of disclosure standards for over 30 years. The new rule brings the SEC's disclosure standard in alignment with 13 reporting guides, standards and codes that are now used in 13 countries and regions that are members of the Committee for Mineral Reserves International Reporting Standards (CRIRSCO).

#### Panels:

*The session will be organized in five panels that will cover the following topics:*

**Chronology of the 30 Year Advocacy:** Led by David Abbott

**Summary Features of Rule S-K 1300:** Led by Brian Groff

**Disclosure Format:** Led by Stella Searston

**Legal Issues:** Led by Lee Terry

**Path Forward:** Led by Ian Douglas

**Q&A**

## TUESDAY, FEBRUARY 26

MORNING

9:00 AM | ROOM 507

### Bulk Material Handling: Conveyors and the IoT

*Sponsored by: BEUMER Corporation*

**Chair:** S. Shadow, Baldor/ABB Inc, Parker, CO

9:00 AM

Introduction

9:05 AM

### 24/7 Condition Monitoring of Gearboxes in the Mining Industry

*A. Soder; Sumitomo Drive Technologies, Chesapeake, VA*

In an age where everyone wants to be digitally connected to every aspect of life, the power transmission component of many applications has been historically left behind. Recently, the reduction in cost of condition monitoring



components has allowed users to fully embrace Industry 4.0 in many different industries and applications. Vibration monitoring, Oil Condition, Temperature monitoring, are just some of the data points in which users can monitor to prevent costly downtime and keep profits up. Integrating a Condition Monitoring System (CMS) into an existing maintenance program can greatly improve overall productivity of an operation. By monitoring the most critical assets of a plant and being able to plan the downtime for a piece of equipment based on real data, CMS system integration can greatly improve overall productivity.

**9:25 AM**

## **Actual Challenges and Benefits of Monitored Rollers**

*J. Perlacia and J. Eguluz; Mining Division, Ulma Conveyor Components, Otxandio, Bizkaia, Spain*

The Bulk Handling Technology is already started its transformation to the Industry 4.0. Having some of the harshest working conditions, the possibility of remote analysis and maintenance of the components seems a perfect target to focus on. The paradigmatic example is the lack of monitored rollers whereas all the other components of the conveyor belt installations (belt, motors, drums etc.) were monitored some time ago. The digitalization of rollers has unique difficulties in addition to the usual IoT (Internet of Things) implementation challenges like the demanding electromagnetic environment (metallic structures and particles suspended in the atmosphere) that interfere in the communications or the continuous contact with aggressive agents like iron ore or potash. All the tests done in real installations from the Australian extreme heat to the freezing cold Norway, have given a valuable knowledge in the identification of problems, their solution and the advantages of a roller monitoring system. We're proud to introduce the current situation of Monitored Rollers Technology, how it has been possible to become real and which are the advantages that this technology is already offering.

**19-027**

**9:45 AM**

## **The Creation and Practical Use of a Digital Twin of a Conveyor System**

*P. Ormsbee; Overland Conveyor Company, Inc., Lakewood, CO*

The accurate prediction of the power and belt tension demands for a conveyor is the primary basis for any conveyor design as the power and belt tension are the primary input into conveyor component selection. However, once a conveyor is built and installed, much of the theory behind the prediction of the power and belt tensions may be ignored. The real world operating data from the conveyor can be used to replace much of the design theory and a more accurate digital twin of the conveyor system can be used to understand the exact loading and utilization of conveyor components. This digital twin can then be used as a conveyor monitoring tool to evaluate many things like whether operating conditions are within design expectations, identification concerning anomalies within the operating data, and evaluation of under-utilization/potential further design optimization. This paper will discuss what a digital twin of a conveyor is, and its practical uses to improve conveyor application reliability and operating efficiency.

10:05 AM

## A Cost-Effective Communication Mechanism for Underground Mine Internet of Things

*B. Li, S. Saydam, M. Hassan and K. Zhao; University of New South Wales, Sydney, NSW, Australia*

For underground mines, existing wired communication methods cannot connect to all these small devices directly because of the complexity and unreliability. Hence it must be a combination of wired and wireless communication. Wired cables can reach to all the main tunnels; the last mile to the sensors is left to the wireless like capillaries. IEEE 802.15.4 and Bluetooth Low Energy (BLE) are two widely used wireless standards for ultra-low power Internet of Things technologies. It has been reported that in mobile indoor scenarios, BLE is on average more energy-efficient than 802.15.4. A concept of a BLE broadcasting-scanning mechanism has been developed and tested by UNSW researchers to meet the requirement to obtain a small amount of data at a low rate. The sensors are transmitters to broadcast message using BLE; the BLE scanners are receivers which scan the message in the environment to obtain the data. The simplicity, long range and flexibility are the main advantages of this system. The disadvantage is that it is not suitable for a large amount of data transmission. The direct application is a positioning system for the underground mines – collecting the location of the workers.

## TUESDAY, FEBRUARY 26

MORNING

9:00 AM | ROOM 702

## Coal & Energy: Accessing Capital in the Ever Changing Energy Landscape

**Chairs:** *T. Alch, Vice Chair NY Section of SME and Cochair of SME's Mining Finance Conference, Edgewater, NJ, L. Stotts, Coal Source*

9:00 AM

Introduction

9:10 AM

## A Banker's Perspective of the Coal Mining, Capital Markets and Utility Marketplace in North America

*R. McCormick, Capstone Headwaters MB LLC, Dallas, TX*

Ray will discuss the coal and related sectors reflecting on his 40 years of experience in the mining, banking and advisory industries.

**9:35 AM**

## **Current Trends and Issues Impacting Coal Mine Operators and Electricity Generators**

*M. Oommen; Golder Associates, Ballwin, MO*

Mathew Oommen will share his views of the current trends and issues impacting coal companies, utilities and power generators reflecting on his work with coal companies, utilities and power generators, investors and financial institutions on power projects worldwide and knowledge of coal supply strategies for electric utilities, steelmakers, and other consumers.

**10:00 AM**

## **Mapping Opportunities in Uncharted Territory – Policy Impacts on Current and Future Demand**

*L. Lupori; CRU International Ltd., Cranberry Township, PA*

Lynn will present a view of global policy changes and the subsequent anticipated reactions that will likely impact different sectors and different regions of the world in vastly different ways. We are in unprecedented times as governments try to address continually evolving demands to address the issues at hand. Emerging technologies and changing regulations will alter the course of energy markets for many years to come.

**10:25 AM**

## **The Impact of Regulations and Government Policy on Coal Miners, Utilities and Investors**

*J. Craynon; Export-Import Bank of the United States, Washington, DC*

Increasingly, debt plays a larger role in the financing of mining projects internationally. The institutional lenders, including both development banks and export credit agencies, such as the Export-Import Bank of the United States (EXIM), provide significant and important capital in many of these deals. This presentation reviews the changes in the economic situation in mining and the ever-changing acceptance of the risks inherent in financing mining related projects by EXIM. Additionally, the opportunities for mining companies and the mining supply chain to avail themselves of the programs of institutions such as EXIM will be discussed.

**10:50 AM**

## **Three Reasons Why the War on Coal Hasn't Stopped in the U.S.**

*S. Piper, S&P Global Market Intelligence, Boulder, CO*

**11:15 AM**

## **Coal and Related Industry Trends Impacting Transactions, Financings and Restructurings Today**

*R. Reeves; Northcott Capital, Denver, CO*

Rick Reeves' talk will focus on whether the industry is finally emerging from the financing nadir of the last 2-3 years and what are the characteristics of projects and coal operators that appear to be able to raise capital. Commodity markets have continued to improve, and both the legal and regulatory environments are more favorable. This all begs the question of whether or not more equity and debt investors will re-enter the mining finance markets, and will traditional sources of senior debt financing for mining projects eventually return. As always no one can forecast the future, but Rick will attempt to provide paradigms under which expectations can be made. These paradigms will be supported to the extent possible with case study analysis.

## TUESDAY, FEBRUARY 26

MORNING

9:00 AM | ROOM 711

### Coal & Energy: Application of CFD in Mine Ventilation

*Chairs: K. Raj, NIOSH, Spokane, WA*

*S. Arya, University of Kentucky, Lexington, KY*

9:00 AM

Introduction

9:05 AM

#### Discrete Modeling of a Longwall Coal Mine Gob for CFD Simulation

*A. Juganda<sup>1</sup>, J. Brune<sup>1</sup>, G. Bogin<sup>2</sup> and C. Strebinger<sup>2</sup>; <sup>1</sup>Mining Engineering, Colorado School of Mines, Golden, CO and <sup>2</sup>Mechanical Engineering, Colorado School of Mines, Golden, CO*

To analyze explosion hazards in longwall coal mine gobs through CFD modeling, researchers at Colorado School of Mines are developing a 3D, full scale longwall ventilation model capable of modeling methane gas explosions. One area of concern is the active gob directly behind the longwall face, where high concentrations of methane likely accumulate and active roof caving still occurs. Many researchers have represented the entire gob as a porous medium with a specific permeability and porosity, governed by Darcy's law. While this assumption may be applicable for the consolidated center of the gob with significantly lower permeability and porosity compared to the surrounding edge area, Darcy-type flow may not apply directly behind the longwall shields and along the edges of the gob along the gate roads. To model these flows more accurately, researchers have adopted a hybrid approach to model the gob, representing the outer part of the gob as discrete objects that simulate rock rubble, while keeping the gob center as porous medium. This approach will be used for simulating methane-air explosion flame propagation in the gob in the later stage of the research.

19-110

9:25 AM

#### Computational Fluid Dynamics Modeling of Dust Transportation and Deposition under Newtonian Forces in a Mine Airway

*A. Kumar, A. Kumar and S. Schafrik; Department of Mining Engineering, University of Kentucky, Lexington, KY*

Dust is ubiquitous in underground mining activities, carrying with it risk to personnel and machines. Sources of dust are widely studied, but the transportation has been mainly based on experimental data and simplified models. A fundamental understanding of dust transportation in the mine airways is instrumental in the implementation of local dust control strategies. Com-

putational fluid dynamics models were developed using Lagrangian particle tracking approach in a pseudo two-dimensional flow volume. This paper presents the transportation and deposition profile of different sized dust particles moving under the effects of Newtonian forces along a 7' high airway.

19-131

**9:45 AM**

## **Activating Mine Ventilation to Future Engineers a Practical Didactic Approach to Teach Mining Engineering Students in An Activating Manner**

*F. Schemmer and L. Rattmann; Geo-Resources and Process Engineering, Georg Agricola University Bochum, Essen, NRW, Germany*

THGA's mission is to impart outstanding engineering skills by putting theoretical concepts into practical application. Constantly striving to optimize teaching methods, the Department of Underground Mining teamed up with the nearby German Mining Museum. Rather than running theoretical numbers through a mine ventilation software, the department had students collect real mine ventilation data in the visitor's mine and feed those into the software. This hands-on experience proved a great success and has now been integrated into the university's curriculum. The paper shows measured data from successfully run measurements and the implementation methods.

**10:05 AM**

## **The Impact of Rock Pile Location, Length and Depth on the Propagation of Methane Flames in Simulated and Experimental Flame Reactors**

*M. Fig<sup>1</sup>, C. Strebing<sup>1</sup>, G. Bogin<sup>1</sup> and J. Brune<sup>2</sup>; <sup>1</sup>Mechanical Engineering, Colorado School of Mines, Littleton, CO and <sup>2</sup>Mining, Colorado School of Mines, GOLDEN, CO*

A knowledge of flame propagation characteristics through and around obstacles is needed to accurately model methane-air longwall coal mine explosions originating or propagating in the gob. Experimental investigations of methane flames in horizontal reactors with simulated gob (rock piles) were carried out alongside coupled CFD and combustion simulations. Stoichiometric methane-air mixtures were ignited in semi-open reactor vessels of 5cm, 9.5cm and 71cm diameter, all with a fixed length to diameter ratio of 8.6. Experimental results indicate that the magnitude of flame acceleration depends on pile location and geometry, and scaling trends are presented. The model captures several of these features.

19-117

**10:25 AM**

## **Geometric and Dynamic Scaling for a 1/40th Scaled Physical Model of a Longwall Coal Mine**

*J. McMack<sup>1</sup>, G. Bogin<sup>1</sup>, C. DeRosa<sup>1</sup>, M. Gilliland<sup>2</sup> and J. Brune<sup>3</sup>; <sup>1</sup>Mechanical Engineering, Colorado School of Mines, Golden, CO; <sup>2</sup>Electrical Engineering, Colorado School of Mines, Golden, CO and <sup>3</sup>Mining Engineering, Colorado School of Mines, Golden, CO*

Researchers at the Colorado School of Mines are currently designing and building a 1:40 scaled physical model of a fully operational longwall coal mine. The purpose of the model is to minimize the occurrence of methane

related risks by testing various ventilation strategies and determining optimal methane sensor placement throughout the mine. Fluid scaling factors were analyzed using Computational Fluid Dynamics software ANSYS® Fluent at both full and 1:40 scales. Researchers were able to identify key scaling factors and subsequently developed suitable flow parameters that would maintain full scale accuracy of flow patterns in the 1:40 model.

19-118

## TUESDAY, FEBRUARY 26

MORNING

9:00 AM | ROOM 706

### Coal & Energy: Coal Mine Safety & Health I

*Chairs: S. Bealko, GMS Mine Repair, Oakland, MD  
R. Boothby, GMS Mine Repair and Maintenance*

9:00 AM

Introduction

9:05 AM

### Risk Assessment of Fire Incidents in U.S. Underground Coal Mines from 2000 to 2012

*A. Haghighat<sup>1</sup> and K. Luxbacher<sup>2</sup>; <sup>1</sup>Fire Life Safety, Tunnel Ventilation Group, Aecom, Oakland, CA and <sup>2</sup>Mining Engineering, Virginia Tech, Blacksburg, VA*

A risk analysis on mine fires for all U.S. underground coal mines from 2000–2012 was completed to identify locations that have a high risk for fire incidents. The data for this analysis was extracted from the Mine Safety and Health Administration's (MSHA) mine fire accident reports database. After identifying fire incidents from this database, a risk matrix was developed for underground locations that showed a significant propensity for fire incidents. This matrix associates the hazards and risks with the severity and frequency of their consequences at each location. These significant mine areas will be the concentration of future studies in fire behavior, suppression techniques, and simulation methodologies.

**9:25 AM**

## **An Analysis of Mining Injuries Involving Machinery and Powered Haulage from 2008 Through 2017 and Recommendations for Future Mining Machine Safety Research**

*J. Carr, M. Reyes and R. Matetic; CDC NIOSH, Pittsburgh, PA*

From 2008 through 2017, more than 53,000 lost-time injuries were reported to the Mine Safety and Health Administration (MSHA), with 1273 resulting in permanent disability or death. 19% of lost-time injuries and 41% of disabilities and fatalities were classified as powered haulage or machinery. Over this period, accident rates generally decreased. While this trend is encouraging, it is important to understand how these accidents occur. In this paper, surveillance data is analyzed, including analyses of accident type, victim activity, equipment involved, and other factors. Similarities and differences between mining sectors is discussed, and potential future research areas are presented.

**9:45 AM**

## **Committing to Excellence in Mining Safety through CORESafety and Reality Based Leadership**

*K. Walster; Lively Grove Mine, Prairie State Generating Company, Marissa, IL*

Through CORESafety and Reality Based Leadership we educated everyone from secretary to CEO that our mine's strength is not a function of the talent of individual members. It is due to collaboration, tenacity, and mutual respect. So how do you get to that point? How do you pay respect to the "old school" mindset while moving forward to embrace technology and everything millennials have to offer? We chose to ditch the drama and redirect energy into more helpful actions which produced real results. By giving employees the right tools and training they naturally combined talents and strengths to work together to seize opportunities. My presentation will focus on continuous improvement for all mine departments, creative safety initiatives, and building teams that value each other.

**10:05 AM**

## **Shielding Material Comparison for Electromagnetic Interference Mitigation for Air Pump of Personal Dust Monitor**

*J. Li, J. Carr, C. Zhou, C. DeGennaro, B. Whisner and P. McElhinney; The National Institute for Occupational Safety and Health, Pittsburgh, PA*

The use of personal dust monitors (PDM) and proximity detection systems (PDS) is critical to protect mineworkers in underground mines. However, using PDMs near PDSs can affect the functionality of a PDS due to electromagnetic interference. NIOSH researchers investigated component-level shielding to mitigate EMI between the two systems. The findings show that copper and aluminum foil shielding could reduce the emission of the PDM air pump motor, which was identified as the strongest RF emission source, by 50% to 85% at frequency ranges typical of commercially available PDS. This paper presents the measurement results for shielding materials tested.

**19-145**

**10:25 AM**

## **Analysis and Characterization of Treated Rock Dust to Prevent Coal Dust Explosions**

*I. Perera, M. Harris and M. Sapko; CDC NIOSH, Pittsburgh, PA*

In order to effectively inert a coal dust explosion, rock dust must be able to disperse as individual particles to quench the heat generated from a propagating explosion. Rock dust readily absorbs moisture and becomes a cake. Therefore, rock dust manufacturers created treated rock dusts that resist caking. Researchers conducted a series of lab tests on four base rock dusts and their treated counterparts to assess the effectiveness after being exposed to moisture and then dried. The dusts were then evaluated for dispersibility after drying. All results were compared to a reference rock dust.

**19-051**

**10:45 AM**

## **A Comparison of Treated vs. Non-treated Rock Dust in Large-scale Dust Explosion Tests**

*M. Harris, M. Sapko and G. Goodman; CDC NIOSH, Pittsburgh, PA*

Past research showed that bituminous coal dust remains dry and dispersible in the presence of moisture. Rock dust must disperse with the coal dust to effectively inert a propagating coal dust explosion. Non-treated rock dust readily absorbs moisture, limiting its dispersibility, while anti-caking treated rock dusts can remain dry. The National Institute for Occupational Safety and Health contracted the Central Mining Institute in Poland to conduct large-scale testing in their Experimental Mine Barbara to determine if a treated rock dust can be as effective as non-treated rock dust in attenuating or quenching coal dust explosions under the same experimental conditions.

**19-029**



**TUESDAY, FEBRUARY 26**

*MORNING*

**9:00 AM | ROOM 704**

## **Coal & Energy: Innovations in Underground Coal Mining**

*Chairs: E. Nica, Murray Energy, Saint Clairsville, OH  
G. Bylapudi, Southern Illinois University  
Carbondale, Carbondale, IL*

**9:00 AM**

### **Introduction**

**9:05 AM**

### **Analysis and Characterization of Treated Rock Dust to Prevent Coal Dust Explosions**

*I. Perera; Fires & Explosions, CDC/NIOSH, Pittsburgh, PA*

Laboratory-scale and large-scale experiments conducted with limestone dusts and dolomitic marble dusts have indicated that when rock dust is wetted and subsequently dried, it becomes a solid, non-dispersible cake. Rock dust manufacturers created treated rock dusts that will resist caking after moisture exposure and disperse properly to quench a propagating explosion. NIOSH researchers conducted a series of laboratory-scale experiments on four base rock dusts and their treated counterparts to assess the effectiveness of various anti-caking additives after being exposed to moisture and then dried. The dusts were exposed to moisture using humidity cabinets having a relative humidity (99% RH) and by also exposing the rock dust bed to water through bottom wicking. The dry dusts were then evaluated for dispersibility using the NIOSH-designed dust dispersion chamber. All results were compared to a reference rock dust used to conduct large-scale experiments in the Lake Lynn Laboratory (LLL). Laboratory-scale experiments and large scale-experimental results indicate that rock dusts treated with anti-caking agents were readily dispersible even after exposure to moisture for six months.

**9:25 AM**

### **How Mine Digitization Through Connected Machines And Systems Enables Improved Decision Making Leading to Better Safety, Increased Productivity and Higher Reliability**

*N. van Wyk; Smart Solutions, Komatsu Mining Corp, Warrendale, PA*

The latter part of the 20th century witnessed the acceleration to an information based economy. The internet, big/small data and improvements in processing power, meant that more could be measured, monitored and analyzed. However, the mining industry has generally struggled to integrate these technologies into the mining environment. Komatsu Mining Corporation has pioneered many of the systems and processes to capture machine data and transform it into information and useful decision-making knowledge with their Joy product range. This knowledge is used to drive safety, productivity and reliability at many operations. It provides a deeper link between the boardroom and the coal face enabling improved decision making and management. The avail-

ability of information has traditionally been used in a reactive manner, but with new technology, its real power is as a pro-active and predictive intervention in the mining operation. This paper discusses the transition from a reactive machine or unit-based monitoring methodology for the proactive monitoring and intervention into the wider system's performance linking together various data sources, such as machine, operator, logistics & maintenance.

**9:45 AM**

### **A Partnership of Products: the FCT (Flexible Conveyor Train) and the HGX210**

*T. Cressman; Komatsu, Franklin, PA*

Safety and productivity are at the forefront of development for Komatsu Mining Corp. (KMC). To increase safety and productivity, KMC recently partnered with a customer to combine an HGX210 drill rig and a flexible conveyor train (FCT). By integrating these two products, a mine can convey material at over 1600 TPH while simultaneously bolting closer to the face. By bolting closer to the face, the mine achieves better strata control increasing operator safety. The combination of these two products, a result of the partnership between KMC and the customer, provides a solution that increases productivity, utilization, and safety.

**10:05 AM**

### **Studies of Roof Deformation Associated with Longwall Mining in Steeply Dipping Coal Seam Mining Using Surface Damage Prediction and Physical Simulation Experiments**

*P. Xie<sup>1</sup>, Y. Luo<sup>2</sup>, W. Yongping<sup>1</sup>, X. Gao<sup>1</sup>, S. Luo<sup>1</sup> and Y. Zeng<sup>1</sup>; <sup>1</sup>College of Energy Resources, Xi'an University of Science and Technology, Xi'an, China and <sup>2</sup>Dept. of Mining Engineering, West Virginia University, Morgantown, WV*

A steeply dipping seam (SDS) is one with a dipping angle in the range of 35°–55°. Such coal seams are geologically complex and widely distributed in China. In western China, more than 50% of coal mines are mining such SDS. However, the strata movement process associated with longwall mining in SDS often leads to uneven load on face supports, asymmetric failure of pillars that can affect the mining safety. Therefore, it is important to study the deformation and failure mechanism of mine roof induced by SDS mining so that the stability of support-surrounding rock system of working face can be maintained. Physical simulation method has been used to study overburden deformation, interaction between adjacent longwall panels and instability of coal pillar in mining process. At the same time, a roof deformation prediction program for SDS longwall mining is developed based the principle of surface subsidence prediction method for flat coal seam. The roof deformation at different layers above longwall panels is predicted and the prediction results agree with physical simulation well. The program provides an efficient and accurate prediction tool for analyzing roof deformation in mining SDS.

**10:25 AM**

### **An Experimental Study of the Effect of Mesh on Magnetic Proximity Detection Systems (PDSs)**

*C. Zhou, J. Carr, B. Whisner and M. Reyes; CDC NIOSH, Pittsburgh, PA*

Proximity Detection Systems (PDSs) are required on continuous mining machines (CMMs) in underground coal mines to protect miners. It is known that the presence of wire mesh can influence the performance of magnetic PDSs. In this paper, NIOSH researchers characterize this influence by measuring the magnetic field change observed with and without metal mesh present.

The results show that the fields are enhanced by the presence of mesh and therefore cause the detection zones to be increased correspondingly affecting the functionality of PDSs. The information in this paper will provide considerations for implementation of systems in underground coal mines.

19-082

10:45 AM

## Techniques for Assessing and Mitigating Longwall Subsidence Effects on Bridges

*Y. Luo, J. Yang and H. Jiang; Mining Engineering, West Virginia University, Morgantown, WV*

The longwall mining operations in underground coal mines causes surface subsidence which can cause various problems to surface structures ranging from integrity, stability to functionality. Bridges, as a kind of special surface structure, are particularly susceptible to ground movements and deformations, which frequently causes damage and occasionally collapse. However, based on accurate subsidence prediction and correct influence assessments, effective mitigation measures can be proposed and implemented during the underground mining operations to insure the continuity of service of bridges, safety of the travelling public and smooth mining operations. In this paper, based on the predicted final and dynamic surface movements and deformations, the techniques to assess their influences on the integrity, stability and functionality of bridge components (e.g., decks, beams, piers, etc.) are presented. A number of mitigation measures to protect the bridge structures are recommended along with an actual application case.

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## TUESDAY, FEBRUARY 26

MORNING

9:00 AM | ROOM 708

## Coal & Energy: Rare Earth Elements in Coal II

*Chairs: M. Fan, Eriez Manufacturing Co., Erie, PA  
Y. Zhao, Xuzhou, China*

9:00 AM

Introduction

9:05 AM

## Occurrence and Distribution of Rare Earth Elements in Acid Mine Drainage Precipitates: Results of a Regional Survey

*P. Ziemkiewicz<sup>2</sup>, C. Vass<sup>2</sup> and A. Noble<sup>1</sup>; <sup>1</sup>Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA and <sup>2</sup>Water Research Institute, West Virginia University, Morgantown, WV*

Acid mine drainage (AMD) is a longstanding environmental problem and has

been studied extensively since the 1960s. AMD's potential to supply critical materials, specifically REEs has been studied only recently. AMD treatment is focused on meeting the pollution discharge limits imposed by the Clean Water Act. Treatment systems remove metal contaminants as flocculated precipitates which are then separated from discharge-quality water by either mechanical or gravitational settling methods. Known as AMD treatment sludge, these metal flocs are enriched in REEs. We will summarize the findings of our regional AMD sludge sampling effort including REE distributions and concentrations.

**9:25 AM**

### **Recovery of Rare Earth Elements from Acid Mine Drainage and Associated Sludge Materials**

*M. Rezaee, S. Pisupati, M. Klima, B. Vaziri Hassas and X. Yang; Energy and Mineral Engineering, The Pennsylvania State University, University Park, PA*

A recent analysis of Pennsylvania acid mine drainage (AMD) streams that originate from abandoned mines and coal refuse streams revealed that these streams not only contain favorable quantities of rare earth elements (REEs) but also contain high HREE/LREE ratios. These AMD streams, however, pose environmental concerns and hence are treated before being discharged to the environment. During the treatment process, the AMD streams are neutralized to circumneutral pH. The precipitates (sludges) produced during the treatment process are stored in ponds. This paper presents the characteristics of several AMD streams and associated sludge materials as potential sources of REEs and other critical elements and discusses the preliminary REE recovery results.

**9:45 AM**

### **Speciation of Rare Earth Elements in Springfield, Herrin, and Baker Coal Formations Southern Parts of the Illinois Basin**

*A. Valian<sup>1</sup>, J. Groppo<sup>1</sup>, C. Eble<sup>2</sup>, J. Hower<sup>3</sup> and R. Honaker<sup>1</sup>; <sup>1</sup>Mining Engineering, University of Kentucky, Lexington, KY; <sup>2</sup>Kentucky Geological Survey, University of Kentucky, Lexington, KY and <sup>3</sup>Center for Applied Energy Research, University of Kentucky, Lexington, KY*

To assess lateral and vertical trends in distribution of rare earth elements (REEs), 24 columns were collected from Springfield, Herrin, and Baker coal beds and associated rocks in the southern parts of the Eastern Interior (Illinois) Basin. To examine the variations of REEs with ash yield and density, several float sink and flotation separations were performed. Samples from subdivision of the columns and from the separation procedures were analyzed for REEs using an ICP-MS analyzer. Results indicate the highest total REE concentrations to occur in the Baker coal and a part of the Springfield coal in Indiana. Results also indicate that most of the REEs are associated with the high-ash fractions of the coal, and that coal-associated rocks generally have the highest REE concentrations. Although REE contents increases with the ash yield, the heavy-to-light REE ratio decreases. In addition, while the fractionation of individual REEs in high-ash samples always follows the crustal pattern, most of the cleaner coal samples behave differently. This suggests various mechanisms of chelation and deposition events during the evolution of the coal.



**10:05 AM**

## **Geologic Review of Elevated REE Content in the Raton Basin, Colorado and New Mexico**

*T. Gray<sup>1</sup>, H. Andersen<sup>2</sup>, D. Richers<sup>2</sup>, R. Bryan<sup>2</sup>, M. Mosser<sup>3</sup> and F. Wood<sup>1</sup>;  
<sup>1</sup>Tetra Tech, Pittsburgh, PA; <sup>2</sup>Nexus, Denver, CO and <sup>3</sup>Mosser Resources Consulting LLC, Morgantown, WV*

Analysis of coal and coal related lithologies in the Raton Basin of Colorado and New Mexico as part of a NETL/DOE sponsored study found many sites that had rare earth elements (REE) present in coal and coal related lithologies. These sites were generally found in close proximity to igneous dikes, sills, and intrusions. In addition to our study, several published investigations of igneous material in the region found appreciable amounts of REE present. Many of the coal beds have undergone natural coking from the igneous activity and this activity may be the primary control for enrichment in roof rock, coal partings, and floor material in the region. While high REE content is not universal, clusters of samples in the basin do show appreciable (>300 ppm) total REE content. We will report our finding to date and suggest what further investigations of these areas could further define the REE resource of this region.

**10:25 AM**

## **Possible Basement and Geologic Controls on Elevated REE in Select Central Pennsylvania Coal Deposits**

*T. Gray<sup>1</sup>, R. Bryan<sup>2</sup>, D. Richers<sup>2</sup>, M. Mosser<sup>3</sup>, F. Wood<sup>1</sup> and H. Andersen<sup>2</sup>;  
<sup>1</sup>Tetra Tech, Pittsburgh, PA; <sup>2</sup>Nexus, Denver, CO and <sup>3</sup>Mosser Resources Consulting LLC, Morgantown, WV*

Previous studies of rare earth elements (REE) in coal and coal related materials suggested at least three possible mechanisms for introducing REE into the sedimentary coal deposits of central Pennsylvania. The mechanisms were thought to be detrital REE-bearing intrusion of sand igneous materials into and adjacent to sedimentary units, and hydrothermal activity. Recent studies sponsored by NETL/DOE in central Pennsylvania indicated elevated REE content. While one cannot discount detrital resistant sands in the system, or completely discount igneous dikes and intrusions, evidence does not appear to support either of these mechanisms. These samples were obtained in a portion of the Allegheny Plateau adjacent to the Pennsylvania Salient which shows an increase in fault-fracture density and possibly lines up with ancient mid-ocean transform faults. Because these samples show higher REE content, one must question whether deep seated fluids associated with the tectonic development of the region are, in part, responsible for their presence. A discussion of these mechanisms and a review of the geology and geophysical makeup of the basement will be presented.

**10:45 AM**

## **Characterization Study of Rare Earth Elements from Various Colombian Coal and Coal Byproducts**

*Q. Huang<sup>1</sup>, D. Talan<sup>1</sup>, O. Restrepo Baena<sup>3</sup>, V. Kecojevic<sup>1</sup> and A. Noble<sup>2</sup>;*

*<sup>1</sup>Mining Department, West Virginia University, Morgantown, WV; <sup>2</sup>Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA and <sup>3</sup>Departamento de Materiales y Minerales, Universidad Nacional de Colombia, Medellín, Colombia*

A total of 24 samples were collected from various Colombian coal basins for the rare earth elements (REEs) characterization study. Density fractionation and semi-release analysis were performed on the selected coal samples to study how REEs were partitioning among organic and inorganic constituents. All the specimens generated from the characterization tests were subjected to both ash and REE assay analyses. Test results show that inorganic constituents are the driven factor for the enrichment of REEs in Colombian coal and coal byproducts, which is reflected by a strong and positive linear relationship existing between REE and sample ash contents for various coals. The examination of heavy to light rare earth ratio as a function of ash content further indicate that heavy and critical REEs are preferentially associated with the mineral matters dispersed within the organic matrices. In the end, an average REE abundance of 75 ppm, on a dry whole mass basis, was determined for the Colombian coal on the basis of the REE characterization data of the 24 test samples.

**11:05 AM**

## **Low-Temperature Plasma Treatment for Enhanced Recovery of Rare Earth Elements from Coal**

*T. Gupta, W. Zhang and R. Honaker; Mining Engineering, University of Kentucky, Lexington, KY*

The mode of occurrence of trace elements in coal-based resources dictates its leaching characteristics. Most previous researches show a pH-dependent solubility of Rare Earth Elements (REEs). The principal objective of the work is to investigate the effect of Low-Temperature Plasma (LTP) treatment for recovery of critical REEs, from coal and coal byproducts. The REEs in LTP treated coal is expected to be recovered under mild leaching conditions (temperature and pH). A 2-factorial parametric experimental test program was deployed to identify the significant operational factors (temperature, RF power, oxygen flow rate, treatment time) and sample characteristics (sample weight, particle size) with response (REE recovery). A three-factor Box-Behnken design was subsequently formulated to optimize the operating parameters. The LTP technique will be integrated with hydrometallurgical processes to obtain a product containing  $\geq 2\%$  of total REEs.

**TUESDAY, FEBRUARY 26**

*MORNING*

**9:00 AM – 9:45 AM | ROOM 710**

## **CMA: Blockchain and the Mining Industry**

*Sponsored by Metro Denver EDC/Colorado*

*Resource Council*

Blockchain technology could have a major impact on mining operations, from increased transparency in supply chain transactions to logistics and trade finance. Originally devised for the digital currency, Bitcoin, blockchain is a revolutionary new technology that allows digital information to be distributed but not copied, creating a continuously growing list of highly secure records. This “Blockchain 101” panel discussion will guide you on the basics of this emerging technology.

### **Panel:**

***Eric Kintner***

*Snell & Wilmer, Denver, CO*

***Wayne Williams***

*Former Colorado Secretary of State, Denver, CO*

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**TUESDAY, FEBRUARY 26**

*MORNING*

**9:00 AM | ROOM 107**

## **Environmental: Effective Permitting Strategies for Capital Projects**

***Chairs: A. Patel, Barr***

*A. Tinklenberg, Intera*

**9:00 AM**

**Introduction**

**9:05 AM**

## **The Continuing Evolution of Federal Modeling Requirements for Air Quality Permits**

*B. Macdonald and J. Reed; SLR International Corporation, Fort Collins, CO*

The recent Regional, State, and Local (RSL) modeling conference hosted by EPA in June 2018 introduced new and proposed changes to modeling techniques. These proposed changes are intended to continue model refinements, provide a more robust database for NO<sub>2</sub>, ozone and PM<sub>2.5</sub> analyses; and other updates to model inputs and preprocessors. The unique characteristics of mining operations, including characterizing the PM<sub>2.5</sub> emissions

present challenges to designing and permitting new sources and modifications. Preliminary model runs can be used to determine acceptable site layout, and where source testing for PM<sub>2.5</sub> emissions or more refined background PM<sub>2.5</sub> concentrations may be warranted. There are opportunities to propose and use model refinements that are available now, or soon to be, under the Guideline. This presentation will concisely summarize the changes to the NAAQS and modeling requirements that have occurred over the past eight years. The overall discussion will be placed in context to the potential effect on project design, permitting schedules, and modeling requirements for permitting, with a special emphasis on surface operations at mine sites.

## 9:25 AM

### Permitting Success – What does it take?

*L. Gietzen, C. Kearney and B. Moore; PolyMet Mining, Hoyt Lakes, MN*

I am proposing that we (three key members of the PolyMet team) present and discuss what it takes to permit a new mine in the United States in the 21st Century. Permitting boils down to three broad themes or key items needed for success: technical, political and emotional. We will discuss the need for the project to be technically sound and how you achieve buy in and convey technical information on the project. We will also discuss some of the challenges associated with the technical aspects of permitting a new mine in the US. We will discuss the importance of the political aspects of permitting a new mine. We will cover how you gain and keep political support throughout a lengthy permitting process. We will discuss how you successfully deal with the heightened emotions that surround permitting a new mine. We will cover the importance of local community, labor and local officials in dealing with the heightened emotions surrounding permitting a new mine development. We will spend some time walking through specific examples where PolyMet successfully navigated through the technical, political and emotional facets of permitting a new mine.

## 9:45 AM

### Litigation: Strategies to Strengthen the Case for Your Permit

*A. Martin and S. Donohue; Mining, Foth Infrastructure & Environment, LLC, De Pere, WI*

Permitting has become a minefield (pun intended) of litigation opportunities for opposition groups to at worst, bring a project down, and at best, add unwieldy costs to a new project. What can technical personnel and managers do to put forth strong applications and supporting work to withstand the efforts of opposition to impact a project? It must be more than just good modeling and application preparation. What does litigation entail for the owner, its legal team, and the technical expert witnesses? This presentation will summarize general and specific experiences in the Great Lakes region addressing opposition group capabilities, the agencies, commonly litigated issues, and strategies to succeed through the gauntlet of litigation.

## 10:05 AM

### Mitigation Banking as a Section 404 Permitting Tool for the Mining Industry

*J. Zsiros; Ecosystem Investment Partners, Baltimore, MD*

Our presentation's objectives include an in-depth review of the mitigation banking concept and a demonstration of how banking provides a benefit to the mining industry in meeting Section 404 Clean Water Act (CWA) permit



requirements. Specifically, our presentation will provide a regulatory overview and background of the mitigation construct, provide the advantages of mitigation bank credit purchase as compared to other available options, evaluate the mitigation banking tools available to the mining industry, and provide an overview of credit reservations, contracts, and purchase agreement processes.

**10:25 AM**

## **Designs That Drive the Success of Stream and Wetland Mitigation**

*N. Ober; Ecology, Civil & Environmental Consultants, Inc., Bridgeport, WV*

Federal and state regulations require compensatory mitigation for unavoidable impacts to streams and wetlands. Navigating the regulations can be a challenge and executing a mitigation plan can be even more complicated. Despite these impediments, cost effective and constructible stream restoration designs can be accomplished through rapidly evolving technologies. Data acquisition with LiDAR can produce economical but highly detailed information on existing conditions. The AutoCAD Civil 3D design platform creates three-dimensional natural channel designs that dynamically and inherently link the pattern, profile, and dimension of a stream, allowing a designer to make iterative changes with instantaneous and accurate three-dimensional updates. GPS guided construction equipment optimizes the execution of the design by taking the AutoCAD drawings into the cabin of the excavator. Other technologies such as Small Unmanned Aerial Mapping Systems (sUAS) have provided opportunities to improve designs and document as-built conditions. A well-planned design using these technologies can expedite the permitting process, provide cost-effective restoration, and improve ecosystem functions.

**10:45 AM**

## **Effective Regulatory Compliance and Air Quality Permitting Strategies for Mining Appalachian Coal**

*L. Blinn and A. Lashgari; Civil & Environmental Consultants, Wexford, PA*

The mining industry continually moves toward becoming more environmentally sustainable by developing and integrating practices that reduce the environmental impact of mining operations. The potential impact of mining on air quality can be significant if proper actions are not taken. In addition to federal air quality requirements, each state administers air quality permitting in a unique way by imposing state-level regulations and requirements. This presentation will focus on federal and state permitting requirements in northern Appalachia (Pennsylvania, Ohio and West Virginia). Federal air quality regulations and a comparison of state-level regulations will be detailed in this presentation. The most recent air quality requirements that may affect the mining industry in this region will also be discussed. In addition, a brief comparison will be made to other state regulations. This presentation will help air quality professionals better understand permitting and compliance requirements in northern Appalachia for new or modified sources.

**11:05 AM**

## **Permitting a Mine in B.C.'s Golden Triangle**

*R. Schmitt; Technical Director, Vacnouver, BC, Canada*

Recently, CAD \$250 million has been spent in the pursuit of gold, copper, silver, nickel, zinc and cobalt in British Columbia's "Golden Triangle". This region includes the past-producing Eskay Creek and Johnny Mountain mines,

alongside the operating Red-Chris copper-gold and Brucejack gold mines. Galore Creek and KSM are also approved for development and permitting. No new mine has been approved in 5 years, while we've seen an accelerated evolution of social, environmental and regulatory requirements. Do shareholders, communities, and Aboriginal peoples believe that recent levels of exploration, development and discoveries will result in new permitted mines? Changes to Aboriginal consultation, expanded environmental assessments and regulations, and new young professional administrators, make the prospect of getting a mine approved daunting, costly and time-consuming. How can developers meet shareholder expectations for timely and responsible permitting? How can companies efficiently address governments' risk averse and time-consuming reviews? We will examine the strategies and success factors companies need to take to achieve the successful approval and permitting of new mines.

## TUESDAY, FEBRUARY 26

MORNING

9:00 AM | ROOM 104

### Environmental: Innovative Water Treatment

**Chairs:** *D. Kratochvil, BQE Water, Vancouver, BC, Canada*

*S. Benowitz, Water Engineering Technologies, Inc., Bozeman, MT*

9:00 AM  
Introduction

9:05 AM

### Sibanye-Stillwater Benbow Exploration Portal: Utilizing Grouting, Treatment, Re-Use, and Deep Well Injection for Innovative Management of Underground Mine Water

*R. Weimer<sup>1</sup>, J. Harris<sup>1</sup>, D. Johnson<sup>1</sup> and S. Benowitz<sup>2</sup>; <sup>1</sup>Sibanye-Stillwater, Columbus, MT and <sup>2</sup>Water Engineering Technologies, Bozeman, MT*

Sibanye-Stillwater Mining's Blitz Project development area is adjacent to the existing Stillwater Mine and could potentially add 25 years to the operating life of the mine. The Benbow exploration portal is being developed at the far end of the two primary Blitz tunnels and is designed to intersect the two tunnels from the surface. Initially, this portal will provide needed exploration and development information, while in the long-term it will provide mine ventilation and emergency egress. Groundwater seepage into the Benbow portal is managed utilizing a combination of grouting, treatment for solids and nitrogen removal, and re-use for mining and support activities. Excess treated water is discharged to deep well injection into a similar water holding



formation. The water management system complies with Sibanye-Stillwater's policy of optimal management of the water resource and water infrastructure, ensuring water conservation, safety, security and regulatory compliance by the effective use of knowledge and innovative technology. This paper provides a case study of how the water management system evolved throughout the various phases of planning, development, and operations.

**9:25 AM**

## **Ettringite Precipitation for Sulfate and TDS Reduction: A 10gpm Pilot Plant Study**

*R. Bryce, T. Doughty and K. Stoll; Environmental Technology/Life Cycle, Freeport-McMoRan Inc., Oro Valley, AZ*

Mine waters impacted with sulfate are receiving increased regulatory scrutiny due to the effect of sulfate on the TDS. Freeport-McMoRan Inc. (FMI) has performed extensive pilot testing at 10 gallons per minute of The Water Company's (TWC) ettringite precipitation process. FMI and TWC have collaboratively developed a high-efficiency process, targeting sulfate and TDS reduction. The use of metallic aluminum as the primary aluminum source for ettringite precipitation eliminates the addition of other ions resulting in significant demineralization. The process has achieved greater than 98% water recovery while controlling effluent sulfate levels below 250ppm.

**19-092**

**9:45 AM**

## **Application of SAGR Bioreactors for Ammonia and Cyanate Treatment in Mining Effluents**

*M. Bratty; Golder Associates, North Vancouver, BC, Canada*

Ammonia treatment is a growing concern in the mining industry. Ammonia is commonly found in mining effluents as a byproduct of cyanide degradation, and as a residual of blasting compounds. This paper explores the application of the Submerged Attached Growth Reactor (SAGR) in mining effluents, in particular in cold climates, exploring the fundamental principles and related experience from other sectors. The SAGR now started up at the subject site of this paper is the first implementation of the technology in a mining context, and the paper will explore technology selection, comparative net present costs, piloting experience, and preliminary operating experience.

**10:05 AM**

## **Sulfate Mine Water Management at Mule Canyon Mine, Lander County, Nevada**

*J. Koreny; HDR Engineering, inc., Seattle, WA*

Management of high-sulfate concentration mine water is a concern at many hard rock mines with pit lakes. A case study presentation will be used to discuss options for the treatment of elevated sulfate concentrations in pit lakes at the Mule Canyon Mine. Sulfate concentrations in the South Pit Lake have increased over the last 15 years from approximately 2,000 mg/L to a high of 6,000 mg/L with recent concentrations of 4,000 to 5,000 mg/L. The increase in sulfate concentrations is due to exposed sulfidic rock, evapotranspiration, and management methods to control lake levels. The water quality of the pit lake is somewhat unusual in that the elevated sulfate concentration is accompanied by relatively low concentrations of heavy metal ions. A feasibility study was completed to evaluate methods to reduce sulfate concentra-

tions, including in-situ and conventional ex-situ treatment alternatives, and this presentation will share the results, as well as discuss the applicability of alternative methods at a variety of mine water management settings.

### 10:25 AM

#### **New Twists to an Old Process: Doing More with HDS**

*J. Stefanoff and G. Hickman; JACOBS, Spokane, WA*

The high density sludge (HDS) treatment process has matured since its development in the 1960's into one of the most commonly applied technologies for treatment of acidic and metal-laden mine water. However, changing regulatory conditions and the growing demand for water reuse poses new challenges. This presentation describes various "twists" to HDS which can be used to enhance metal and metalloid removal, reduce TDS, soften water to facilitate membrane treatment, and to further reduce sludge production.

### 10:45 AM

#### **Bench to Build: Development of a Non-biological Selenium Treatment Technology**

*P. Littlejohn; BQE Water, Vancouver, BC, Canada*

In 2012, BQE Water began the development of Selen-IX™ treatment technology to remove selenium from mine impacted water. The process combines ion exchange and electrochemistry to comply with selenium regulations in a cost and risk conscious manner. Over the past six years, this has entailed four pilot campaigns, thousands of engineering design hours, multiple regulator and third party technical reviews, and an industrial scale demonstration. This paper details the development and commercialization path of Selen-IX™ from bench scale to the first full-scale plant currently under construction at a mine site in British Columbia, Canada and that is slated to begin operation in 2019.

### 11:05 AM

#### **Arsenic Removal from Mine-Influenced Water Using Membrane Filtration**

*L. Linton, N. Rogers, D. Dye and C. Judy; WesTech Engineering, Salt Lake City, UT*

Arsenic contamination in groundwater is a common regulatory concern associated with industrial processes, like mining and power generation. As a naturally occurring element, arsenic is a constituent in coal ash and as an impurity in metal ores. Addressing contamination requires effective treatment technologies to consistently meet low level discharge standards, typically 10 ppb or less. In mine water remediation applications, hollow-fiber ultrafiltration (UF) is used in conjunction with proper pretreatment chemistry to address speciation and solubility. Additional treatment by nanofiltration (NF) can further aid in reduction of soluble species. Multiple sites using full-scale membrane filtration systems for arsenic reduction are analyzed in this work, with treatment volumes ranging from 190 to 1100 gpm. The aim of this paper is to discuss treatment options for arsenic, contaminant speciation and pretreatment chemistry, aspects of equipment design including mobile and temporary systems, and operational data. In all discussed projects, arsenic was reduced to meet discharge requirements, typically representing greater than 95% reduction.

**11:25 AM**

## **A Eco-Friendly Mine Water Treatment Plant**

*S. Muddasani and K. Benson; Veolia water, Pittsburgh, PA*

A mine water treatment plant is currently under construction in a remote area in the mountains of Idaho will treat water from underground mine and runoff from tailing facility. The objective of this treatment plant is to meet strict regulatory limitations (NPDES Permit Limits) imposed by Idaho Department of Environmental Protection for surface water discharge. The system is designed to treat a maximum flow of approximately 0.2 million gallons per day (150 gpm) of mine water. The mine water is treated using advanced treatment technology for metals and nitrogen removal to produce clean water for reuse or discharge. The treatment plant is committed to protect water quality in the region and also maintain sustainable water management. Our paper will describe influent and effluent water quality and various treatment process steps.

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## **TUESDAY, FEBRUARY 26**

*MORNING*

**9:00 AM | ROOM 108**

## **Environmental: Surface Placement of Paste and Cemented Paste: Promising Technology or Pie-in-the-Sky?**

*Chairs: L. Kirk, Enviromin Inc, Bozeman, MT  
K. Seipel, Enviromin*

**9:00 AM**

## **Application of the Paste Fill Backfill Method in Different Mining Sectors (Coal, Ore, Salt) in China and Germany**

*D. Wang<sup>1</sup>, S. Poetzsch<sup>1</sup> and H. Mischo<sup>2</sup>; <sup>1</sup>Chair for Underground Mining Methods, TU Bergakademie Freiberg, Scientific Assistant, Freiberg, Saxony, Germany and <sup>2</sup>Chair for Underground Mining Methods, TU Bergakademie Freiberg, Professor, Freiberg, Saxony, Germany*

The paste backfill method is one of the world most used techniques for backfilling nowadays. Among the many advantages of paste backfilling is early rock support ability. Another advantage is that there is no need to pump out excess water from the stopes. This paper discusses the application of the paste backfill method in different mining methods for mining different commodities. Thus, an overview is made of the influence factors on the application of the paste backfill method. Such influence factors are the grain size of the aggregate as well as the binding agent used. For a better understanding of these influence factors, different case studies in China and Germany are presented. Details are given for a long wall coal mining operation and an open stope mining operation in China, as well as a room & pillar salt mine in Germany. The boundary conditions that influence the application of this backfill method in diverse mining projects are shown; different materials and sequence or processes used in cases are further discussed. This paper aims to cover frontier research and determine the difficulties that the industry might be facing while applying paste backfilling.

**19-127**

## 9:20 AM Introduction

### 9:40 AM Improvement of Hazardous Tailings Storage Sites Using Surface Paste Disposal Method

*S. Tuylu, A. Bascetin, D. Adiguzel and Y. Baktarhan; Mining Engineering,  
Istanbul University, Istanbul, Avcilar, Turkey*

The main purpose of this study is recovery old stored Pb-Zn tailings with high water content using SPD. In this study, firstly, a laboratory scale unique test cabin was used to simulate the field disposal conditions and testing of the layer configurations. Thickness of each layer is 4 cm and total 10 layers have been cast to dry faster and create a comparison with other studies in this area. The first layer is expected to be cast for about 40 days until 3rd layer in order for the first layer to be in a better consolidation. In this process, the volumetric water content (VWC) was decreased by ~30%. However, the VWC was increased in the next casting 3 layers and then it was stabilized by ~60%. Similar to the 1st layer, the VWC in the 5th layer was fixed at ~ 50% after the first casting. Also the matric suction values after the 5th layer were measured to be -10 kPa that were saturated. The tailings previously stored at solid content ~50% has been increased to ~85% by this study. Thus, the risks of conventional tailings dam are decreased by using the geotechnical and geochemical advantages of the SPD method.

### 10:00 AM Reinforced Soil Structures with High Fines Content Backfill Material

*M. Isola and E. Michiels; Maccaferri, Williamsport, MD*

Reinforced soil structures in mining (i.e. perimeter walls, earth berms, pond slopes, tailing impoundment slopes) are conventionally constructed using expensive granular backfill material. Local available soils such as in-situ soil, dry stack tailings or other recycled materials are always an appealing option, however they often are poor draining soils, with high fine contents. A geogrid has been developed that combines reinforcement and drainage and has been successfully used for the construction of steep RSS with low-permeability soils. The drainage embedded in the reinforcement allows for the dissipation of excess pore water pressure build up in the fill during construction, increasing the internal shearing resistance of the fill and therefore increasing the interface shear strength between the geogrid and the fill. This allows to drastically increase the consolidation rate, leading to a much faster construction process. This presentation will explore the updated design method, the construction process and several case studies.

### 10:20 AM Cemented Paste Tailings: A Logical Application of Proven Technologies

*L. Kirk and K. Seipel; Enviromin, Bozeman, MT*

The addition of cement to paste tailings is an increasingly-common management strategy. Cemented-paste tailings backfill technology has been in use for more than half a century. While the placement of paste tailings in surface facilities is a more recent development, it has been in use for more than 15 years and is well-researched. More recently, the placement of cemented-paste tailings in surface facilities has also been proposed. Critics from the mining

industry claim that adding binder to paste tailings in a surface facility creates unnecessary expense, while mining opponents claim it is unproven technology. A brief history of cemented-paste tailings backfill and surface placement of paste tailings will be followed by results from a series of geochemical tests simulating various management strategies. In leach tests of underground backfill and subaerial, surface placement, cemented paste tailings released lower solute concentrations than non-amended tailings. The results demonstrate the superior performance of cemented paste for sulfide-rich tailings, which was attributed to reduced surface area following binder addition.

**10:40 AM**

## **Experimental Study on Early-Strength of Cemented Paste Backfill**

*A. Bascetin<sup>1</sup>, S. Tuylu<sup>1</sup>, h. eker<sup>2</sup>, d. adiguzel<sup>1</sup> and y. baktarhan<sup>1</sup>; <sup>1</sup>Mining Engineering, Istanbul University, Istanbul, Avcilar, Turkey and <sup>2</sup>Gumushane University, Gumushane, Turkey*

The purpose of this study is improving the strength of the cemented paste backfill. Also the effect of blast furnace slag (BFS) was investigated on short term mechanical properties (of CPB). In this study, CPB samples were prepared by 9% portland cement and also 25%, 50% and 75% of the cement were replaced with BFS. The paste materials prepared according to the value of 180 mm slump were cast into cylinder molds. The uniaxial compressive strength (UCS) and Ultrasonic P-Wave Velocities tests were performed. The maximum values of UCS 0.80, 1.70 and 3.03 MPa respectively at 3, 7 and 14 curing period were obtained from 25 wt% BFS added samples. 25%wt. BFS showed a strength of 1.79 times in the 7 days cure period and 2 times in the 14 day cure period according to the reference cemented samples. On the contrary, substitution of 50 and 75 wt.% BFS were reduced strength of CPB samples. Ultrasonic pulse velocity of cemented paste backfill showed similar trend with UCS. But, substitution of 25, 50 and 75 wt.% BFS were below the values of reference samples. The maximum values of UCS are 25% additive BFS. This situation directly affects the cost of CPB due to reduces the cement ratio.

**19-122**

## TUESDAY, FEBRUARY 26

MORNING

9:00 AM | ROOM 709

### Fuerstenau Symposium: Flotation & Technology

*Chairs: J. Gebhardt, FLSmidth Inc, Midvale, UT*

9:00 AM

#### Introduction

9:05 AM

#### On the Management of Gangue Minerals in the Flotation of Platinum Group Minerals

*C. O'Connor; Chemical Engineering, University of Cape Town, Cape Town, W Cape, South Africa*

The Bushveld Complex of South Africa contains almost 90% of the world's reserves of platinum group minerals (PGMs). In the flotation of PGMs, there are significant challenges arising from the need to treat ever-decreasing grades of the relevant ore deposits. The challenges are exacerbated by the need to treat greater quantities of fine particles produced through ultra-fine grinding devices. The major challenge in the flotation of these ore bodies is the control and management of the gangue minerals and to reduce the recovery of, particularly, orthopyroxene, plagioclase feldspar, pyroxene and chromitite. This paper presents results obtained by the authors aimed at investigating the influence of various factors on the control of the gangue minerals, the possible inadvertent activation of gangue minerals and on methods used to reduce the entrainment of chromitite. These factors include type of depressants, interactive effects between collectors, frothers and depressants, the impact of gangue depression on froth stability, the effect of different ions present in the process water and the effect of the changing shape of chromitite particles on their entrainment.

19-016

9:25 AM

#### Effect of $\zeta$ -Potentials on Bubble-Particle Interactions

*K. Huang and R. Yoon; Virginia Tech, Blacksburg, VA*

Derjaguin and Dukhin (1961) were the first to develop a flotation model from first principles by considering the surface forces present in wetting (or flotation) films. The model predicts that the energy barriers in bubble-particle attachment arise from the  $\zeta$ -potentials of fine particles, which corroborates well with an earlier work of Fuerstenau (1957) showing that flotation recovery reaches a maximum at the pH of zero  $\zeta$ -potentials. In the present work, a series of surface force measurements have been conducted by accurately monitoring the changes in bubble curvature during bubble-surface interactions. The curvature changes are then used to calculate the Laplace force, which is the sum of the hydrodynamic and surface forces. The results obtained as functions of pH and collector concentrations show that control of the  $\zeta$ -potentials of both particles and bubbles is critical for improving flotation kinetics and recovery.





**9:45 AM**

## **The Significance of CO<sub>2</sub> Nanobubbles in the Collectorless Flotation of Pyrite**

*J. Miller<sup>1</sup>, B. Vaziri Hassas<sup>2</sup>, J. Jin<sup>1</sup>, L. Dang<sup>3</sup> and X. Wang<sup>1</sup>; <sup>1</sup>Metallurgical Engineering, University of Utah, Salt Lake City, UT; <sup>2</sup>Energy and Mineral Engineering, Pennsylvania State University, University Park, PA and <sup>3</sup>Pacific Northwest National Laboratory, Richland, WA*

The flotation recovery of low grade auriferous pyrite from the Carlin trend high carbonate ores has been less than satisfactory due, in part, to pH control difficulty. Recently significant progress has been made to improve pyrite recovery from these ores using CO<sub>2</sub>/N<sub>2</sub> gas phase mixtures. In this way, better pH control is achieved and it is expected that the hydrophobic character of the pyrite surface is improved by minimizing oxidation and hydroxylation. In addition to elimination of these well recognized effects (oxidation and hydroxylation), current collectorless flotation research has shown that bubble attachment and pyrite flotation is improved with CO<sub>2</sub> due to the formation of nanobubbles and the spreading of these CO<sub>2</sub> molecules at the pyrite surface, as demonstrated from AFM measurements and MD simulations. The decrease in N<sub>2</sub> bubble attachment time at CO<sub>2</sub> treated pyrite surfaces accounts, in part, for the improved flotation response. The CO<sub>2</sub> nanobubbles and/or the CO<sub>2</sub> molecular multilayers at pyrite surfaces facilitate film rupture and displacement during subsequent attachment of millimeter N<sub>2</sub> bubbles at the CO<sub>2</sub> decorated pyrite surfaces for more efficient flotation recovery.

**10:05 AM**

## **Particle Effects on Bubble Surface Tension Linked to Bulk Froth Stability Measurements**

*K. Hadler and J. Cilliers; Imperial College London, United Kingdom*

It is widely accepted that particles stabilise flotation froths, however the mechanism by which this occurs is less clear. While particles are known to hinder film and foam drainage, their effect on the stability of bubbles at the single-bubble scale is difficult to quantify. Dynamic surface tension measurement using the maximum bubble pressure technique presents an attractive technique to investigate the effect of surfactant and particles at the air-water interface. The range of bubble lifetimes that can be studied (typically 0.1 to 60 s) is analogous to variations in air rate in flotation cells, and the corresponding changes in surface tension give an indication to the diffusion and adsorption of particles at the interface. In this paper, we use dynamic surface tension measurements to investigate the effect of particles on bubble surfaces at the microscale, and link this to bulk froth stability measurements carried out using a froth column based on the Bikerman design.

**10:25 AM**

## **Flotation in Seawater**

*J. Laskowski; Mining Engineering, University of British Columbia, Vancouver, BC, Canada*

A classification of flotation processes carried out in concentrated electrolyte solutions, e.g., seawater, is proposed using the most obvious features of these processes: low or high content of Mg<sup>2+</sup> and Ca<sup>2+</sup> ions, pulp ionic strength, and pH. The first distinguishable groups are the processes carried out in NaCl/KCl solutions, about 0.5 M in the case of salt flotation of inherently hydrophobic minerals, and at concentrations about 10 times higher in

the flotation of potash ores. The presence of  $Mg^{2+}$  and  $Ca^{2+}$  ions in seawater adversely affects flotation in the pH ranges over which these ions hydrolyse. Flotation of Cu-Mo ores in seawater requires removal of the hydrolysis products of these ions or the use of a pyrite depressant that can be effective over the pH ranges that are much below the pH of hydrolysis.  $Mg^{2+}$  and  $Ca^{2+}$  ions also affect flotation of phosphate ores with fatty acids, this depression however is not caused by precipitating magnesium hydroxides on the mineral surface but by precipitation of collector insoluble salts.

**10:45 Am**

### **Metallurgy Analytics: Four Steps for Increasing Rougher Metal Recovery**

*O. Bascur; OSIssoft, LLC., Houston, TX*

Ores are becoming extremely variable with mineralogy, hardness disturbing the grinding, and flotation circuits. The current grinding and flotation sensors provide large amounts of data for process optimization. Adding the right context and operational events enables to augment to operational knowledge for proactive actions for improving the performance of the grinding and flotation circuits. A novel strategy to cleanse operational data based on business targets provides a new way to transform data into insights. This paper presents an integrated approach for grinding and flotation optimization. An optimal Gaudin particle size distribution shape (PSD) estimator provides information from traditional sensors to find the cut size to reduce metal losses in grinding-rougher flotation circuits. In addition, fundamental work on the flotation hydrodynamics provides flotation recovery improvements by manipulation of an air hold up profile (AHP) of a flotation bank. Industrial examples of predictive data analytics for PSD shape and air hold up profiles to improve grinding/flotation recovery are discussed.

**11:05 AM**

### **Desorption and Decomposition of Flotation Collectors in Tailings-Seawater Systems**

*O. Ibragimova<sup>1</sup> and R. Kleiv<sup>2</sup>; <sup>1</sup>Department of Geoscience and Petroleum, Post Doc Researcher, Trondheim, Norway and <sup>2</sup>Department of Geoscience and Petroleum, Professor, Trondheim, Norway*

Submarine tailings placements (STPs) is a viable alternative to land-based waste disposal. However, disposal of tailings with accumulated chemicals continues to contribute to degradation of the marine ecosystem. In order to justify the application of STPs it is imperative to evaluate the tailings as non-toxic materials at the point of disposal. The properties of the tailings are governed by the preceding operations, but they are not necessarily understood for the reactions that take place when process water meets seawater. Tailings-seawater systems are generally complex due to the various dissolved ions, accumulated chemicals, their decomposition products, mineral particles etc. In this study the kinetics of sorption reactions in tailings-seawater systems, as series of adsorption/desorption have been performed for cationic and anionic collectors in relative mineral systems. As part of this work, rapid and simple analysis procedures have been developed based on a UV-spectroscopy. Combined with techniques for direct characterisation of surface adsorbed species, this methodology offers new insight into the faith of flotation chemicals when the tailings are exposed to seawater.



**11:25 AM**

## **Novel Biosurfactants in Sulfide Flotation**

*H. Kota<sup>1</sup>, P. Dhar<sup>1</sup>, M. Thornhill<sup>1</sup>, S. Roelants<sup>2</sup> and W. Soetar<sup>2</sup>; <sup>1</sup>Department of Geosciences and Petroleum, Professor, Trondheim, Norway and <sup>2</sup>Bio Base Europe Pilot Plant, Head of Centre of Expertise, Ghent, Belgium*

Acidic sophorolipids and acidic glucolipids are bio-surfactants composed of a carbohydrate-based hydrophilic head covalently linked to a fatty acid. Acidic glucolipids are the most general form of glycolipids with one glucose unit connected to oleic acid. Additionally, acidic sophorolipids are a class of glycolipids, composed of a sophorose unit attached to an oleic acid moiety through an ether bond on the C17 carbon atom of the fatty acid chain. The feasibility of sulfides (chalcopyrite, chalcocite, bornite, pyrite, pyrrhotite) and silicates flotation by the above bio-surfactants/collectors have been investigated by Hallimond flotation, zeta-potential and FTIR studies on pure mineral systems and the results illustrate selective silicate and sulfide flotation in a wide pH region with both collector systems. Furthermore, the frothing phenomena of these environmentally benign surfactants have been characterized and their efficacy of sulfide flotation compared with that of traditional collectors. The results underline the high potential these bio-surfactants possess for use as collectors in the flotation of valuable copper sulphide minerals.

**11:45 AM**

## **Progress on Hydrophobic Force Over the Last Fifty Years: from Nanobubbles to Interfacial Gas Enrichment of Dissolved Gases**

*A. Nguyen; The University of Queensland, Brisbane, QLD, Australia*

Hydrophobic force is critical to flotation separation of hydrophobic particles using air bubbles. In this paper, the experimental and theoretical research outcomes over the last fifty years are reviewed and reconciled. The hydrophobic force in the absence of nanobubbles was measured by AFM colloid probe technique on the first approach of the hydrophobic solid surfaces in aqueous solutions of different saturation levels dissolved gases. If dissolved gases are removed from the solutions, no hydrophobic force can be detected experimentally. The hydrophobic force observed in the absence of interfacial nanobubbles is attributed to the interfacial gas enrichment (IGE) in the form of a dense gas layer (DGL) at hydrophobic surfaces. This force can increase with increasing gas saturation and decrease with decreasing gas solubility. Both IGE and DGL have been confirmed and analyzed by molecular dynamics simulations. The extended van der Waals dispersion forces can be used to predict the hydrophobic force between two solid surfaces, between a bubble and a solid hydrophobic particle, and between two bubbles.

## TUESDAY, FEBRUARY 26

### MORNING

9:00 AM | ROOM 605

## Health & Safety: CMSP Best Practice Sharing

**Chairs:** *A. Lashgari, Civil & Environmental Consultants,  
Wexford, PA*  
*M. Wegleitner, Hecla Mining Company,  
Coeur d'Alene, ID*

9:00 AM  
Introduction

9:05 AM  
Creating a Safety Culture That Leads to Zero Fatalities

*S. Kramer; Freeport-McMoRan, Phoenix, AZ*

While H&S is often measured by incident rates and reactionary measures, at the end of the day, safety is about the people. It's about creating relationships and building trust amongst the workforce. Front line supervisors and health and safety professionals are the core of safe production and have the best opportunity to influence those doing the work. Developing our front-line supervisors and H&S professionals and arming them with the tools to work with the employees in the field creates a culture of trust, respect and collaboration. In this session we will review an approach to elevate the role of the front line supervisor and H&S professionals, develop tools to keep them in the field and focused on the critical work to drive positive culture change.

9:25 AM  
Critical Risk Management - Methods to Drive Fatal Accident  
Prevention and Consequence Reduction

*M. Routledge; H&S Division Board, Park City, UT*

There are many tools and techniques to use for recognizing and controlling critical risks relating to mining and processing operations. This is a case study describing the successes and difficulties in using several methods including simple tools like historical incident mapping and basic hot spot analysis to more complex methods like Bow-Tie analysis and process safety management techniques like HAZID, HAZOP, LOPA and Occupied Buildings analysis. The case study should give a view of how you can assess where you are on the risk management journey and then which tools might give you the best performance impact over a 1 year and up to a 5 year period.

9:45 AM  
Legal & Ethical Considerations for Mine Safety Professionals

*A. Abrams; Law Office of Adele L. Abrams PC, Beltsville, MD*

Individuals responsible for mine safety and health have significant legal exposure based upon their knowledge, recommendations and written communications. They also are often responsible for ensuring that training is

properly provided to miners, and that workplace examinations are conducted, documented and hazards remediated. For those with professional certifications, such as CMSP, CIH and CSP, revocation of credentials is possible if the professional does not exercise appropriate judgment or becomes subject to personal civil or criminal prosecutions. This session will explore the most significant exposures that safety and health professionals encounter and will provide recommendations for best practices in auditing, documentation, training and supervision of safety activities at mines.

**10:05 AM**

## **Measuring Traffic Safety Performance Indicators (PIs) in Mining**

*M. Bayuelo; Product Management, Hexagon Mining, Baar, Switzerland*

Mining safety has always been measured differently compared to production, where the end result is what matters (# of accidents), when there is not a continuous measurement of the performance. This raises several questions: How do we define the measurables of traffic safety performance? What criteria should be embodied in a PI system? How can we measure good performance and who determines it? Answering these questions compels us to use the best available knowledge when shaping PIs for better safety decisions that prevent traffic-related accidents. By using reliable integrated solutions, we can address one or multiple traffic risks, such as collisions, fatigue and distraction, and pedestrians concealed by blind spots. The information collected by these integrated technologies can be transformed into performance indicators, creating firm guidelines that prevent critical incidents. All mines are unique, but a combination of experience, knowledge and the right technology can help determine performance indicators flexible enough to evolve and adapt across regions and mine types.

**10:25 AM**

## **Bolting Solution Dramatically Reduces the Risk of Hand Injuries**

*R. Reagan and E. Stone; HYTORC, Mahwah, NJ*

This paper introduces an improved bolting solution that dramatically reduces the risk of hand injuries in mining applications. This solution introduces new fastener components namely the Reaction Washer and Backup Washer which are combined with standard nuts and bolts to provide safety advantages not available with other solutions. The Reaction Washer eliminates the need for an external reaction arm typically used with conventional power bolting tools thereby significantly reducing the risk of hand injury. The solution also includes the use of the Backup Washer to prevent rotation of the back nut thus eliminating the need for a backup wrench and further reducing the risk of hand injury. To achieve the greatest advantage both the Reaction and Backup Washers are used together with power torque tools configured to interface with the washer designs although both washers may be used individually as part of a fastener assembly to achieve incremental improvements. This solution is simple yet highly economical often offering major overall cost saving while producing additional advantages in efficiency, reliability and most of all safety.

**19-091**

10:45 AM

## Application of Predictive and Behavior Analytics for the US Mining Accidents Data Analysis

*Z. Hyder and K. Siau; Business and Information Technology, Missouri University of Science and Technology, Rolla, MO*

Big data analytics and visualization tools are now available that can help in capturing, curating, managing, and processing data with a tolerable processing time requirement. These tools can assist in finding new correlations, visualizing new trends, and revealing new information hidden within big data that was not accessible using primitive data analysis techniques. In this paper, the authors have used powerful data mining and machine learning algorithms, predictive and behavior analytics tools, and big data manipulation software to analyze accidents data of the US mining industry over the last several decades. The paper analyzes the causes and factors leading to accidents and discusses preventive measures that can be designed with more focus on removing the causes and factors leading to these accidents. Based on the findings of these analyses, intelligent systems can be designed with a focus on removal of potential hazardous situations, decrease or removal of human presence from dangerous and hazardous work such as transporting, loading, and blasting explosives, installing roof supports, and monitoring toxic gases and dusts. This will help in reducing accidents and fatalities.

11:05 AM

## Safety Engagement With Purpose Using Technology to Create A Personal Safety Experience

*J. Wickizer; Safety and Health, Acknowlogy, Kaysville, UT*

Let us look at the safety experience from the eyes of an individual worker. Perhaps a field Electrician, line Supervisor, Operator or the CEO of an organization. Let us evaluate that experience. Each individual works for a company that has safety policies that have been developed by their company, based on type of work the company performs, the customers and facilities the company services, the industry the company works in and even the regulatory agency that regulates the overall compliance expectations. Individuals operate under the guise that each safety experiences is the exact same within the organization. From a compliance perspective this is foundationally true and the basic expectations are set. Realistically though this leads to frustration, complacency, poor information collection and safety effort that is without purpose. What if the experience and expectation for everyone could be specific to the individual need? Is this even possible, and what would that look like? Let us discuss some possible examples of the future experiences we are going to create for individuals that lead to meaningful and purposeful safety improvement efforts.

**TUESDAY, FEBRUARY 26**

*MORNING*

**9:00 AM | ROOM 610**

## **Health & Safety: Disruptive, Virtual, and Augmented Reality: The 4th Industrial Revolution**

*Chairs: J. Sattarvand, University of Nevada Reno,  
Reno, NV*

*J. Brune, Colorado School of Mines, Golden, CO*

**9:00 AM**

**Introduction**

**9:05 AM**

### **Challenges in High-Resolution Imaging by UAVs in Open Pit Mines**

*J. Sattarvand<sup>1</sup>, J. Valencia<sup>1</sup>, R. Battulwar<sup>1</sup>, G. Winkelmaier<sup>2</sup> and B. parvin<sup>2</sup>;*

*<sup>1</sup>Mining and Metallurgical Engineering, University of Nevada Reno, Reno, NV and <sup>2</sup>Electrical Engineering, University of Nevada, Reno, Reno, NV*

The paper explains the difficulties in taking high-resolution pictures from open pit mines. Conventionally, the UAV images of the open pits are taken either manually or from a constant altitude, however, the new applications for the drone pictures requires a series of high-resolution pictures (below 1cm/pixel) that can not be obtained from high altitudes. For this purpose, the drone needs to get close enough to the ground and keep a constant distance above the ground by adjusting its flying altitude. This brings new challenges to the operation because most of the ground control stations use public terrain models such as SRTM for drone control. These models don't get updated very often and usually have above 100 feet resolution. Additionally, even if you could provide DEM for the open pit, it will be a file at the scale of GB which makes it difficult to run everything on a single tablet. There is software like UgCS that enables you to upload DEMs to their server and use a laptop computer to run the drone. This paper describes the approaches that we used in our NIOSH granted project to monitor tension cracks on the ground through image analysis.

**9:25 AM**

### **Developing a Virtual Reality Environment for Mining Research**

*J. Bellanca, T. Orr, W. Helfrich, B. Macdonald, J. Navoyski and B. Demich;  
CDC NIOSH, Pittsburgh, PA*

Recent advances in computing, rendering, and display technologies have generated increased accessibility for virtual reality (VR). VR allows the creation of dynamic, high-fidelity environments to simulate dangerous situations, test conditions, and visualize concepts. Consequently, numerous products have been developed, but many of these are limited in scope. Therefore, National Institute for Occupational Safety and Health researchers developed a VR framework, called VR Mine, to rapidly create an underground mine for human data collection, simulation, visualization, and training. This paper de-

scribes the features of VR Mine using self-escape and proximity detection as case studies. Features include mine generation, simulated networks, proximity detection systems, and the integration and visualization of real-time ventilation models.

19-008

9:45 AM

### If the Technology Fits: An Evaluation of Mobile Proximity Detection Systems in Underground Coal Mines

*L. Swanson and J. Bellanca; Pittsburgh, PA, CDC NIOSH, Pittsburgh, PA*

Even though proximity detection systems for mobile machines (mobile PDS) have the potential to decrease injuries and fatalities, some mine operators and managers have experienced challenges integrating the systems. Applying task-technology fit, this study investigates the fit between mobile PDS and mining relative to health and safety. This study evaluates fit from the perspective of leaders at two coal mines. Quantitative results show that mine leaders evaluated mobile PDS favorably for training and ease of use, system feedback, user authorization and experience, and less favorably for safety, compatibility, task completion, and reliability. Qualitative results reveal specific task, mine, and system characteristics that may have influenced leaders' evaluations. The study includes considerations and recommendations for safe technology integration.

19-053

10:05 AM

### Investigation on the Creation of Stereoscopic Images Using Infrared Cameras

*S. Gaab; Department of Mining and Metallurgical Engineering, Mackay School of Earth Sciences and Engineering, Reno, NV*

Since infrared cameras are robust to harsh environments, they draw interest in various application fields of the mining industry. This thesis investigates how to recover 3D-information of a scene from infrared images, based on photogrammetry. Different camera lenses, objects and processing software were used to obtain point-clouds. A best practice was derived, including following findings: Normallenses are more suitable than wide-angle-lenses and objects preferably show several unique and small-sized points. Contrary to common expectations, some software generates less-accurate point-clouds with an increasing number of populated images. Prospectively, this thesis could serve as foundation for standardizing 3D-data acquisition through infrared.

10:25 AM

### Usage Paradigms for Synthetic Learning Environments: Strategies and Lessons Learned

*L. Brown<sup>1</sup>, B. Granillo<sup>2</sup> and M. Poulton<sup>1</sup>; <sup>1</sup>Lowell Institute for Mineral Resources, University of Arizona, Tucson, AZ and <sup>2</sup>Mel & Enid Zuckerman College of Public Health, University of Arizona, Tucson, AZ*

Synthetic Learning Environments (SLEs) support acquisition of expert knowledge by combining best practices in adult learning, realistic simulation, and serious games. Reflecting on five years of experience, we have found SLEs to be useful not only in training but also for a wide range of organizational planning and risk assessment use cases. Applying insights gleaned from testing



with hundreds of mine workers and field deployments at sites across the US, we propose a series of nine usage paradigms, which include 1) Assessing “true self” and risk-taking behaviors; 2) Reinforcing and evaluating competencies; 3) Preparing for drills and apprenticeship; 4) Supplementing training for specific deficiencies; 5) Providing modules for scenario-based training; 6) Developing worker job action sheets; 7) Performing job hazard analysis; 8) Enhancing standard operating procedures; and 9) Testing resiliency in emergency response plans. In this talk, we will provide investigator perspective and examples based on our experience with both “Harry’s Hard Choices,” an SLE for mine emergency response and evacuation, and “Harry’s Hazardous Day,” an environment for hazards recognition and mitigation.

**10:45 AM**

## **Visualization of AI Results for Big Data of Underground Mines in Virtual Reality**

*E. Isleyen and S. Duzgun; Mining Engineering, Colorado School of Mines, Golden, CO*

Underground mines are complex environments in terms of data collection, analysis and visualization of analytics results for making decisions. Artificial intelligence (AI) methods used for big data from a large number of different sensors provide opportunities of understanding hidden patterns. Three-dimensional self-organizing maps (3-D SOM) are one of the effective AI methods for revealing patterns in the data sets. This study presents a framework to visualize 3-D SOM results in virtual reality (VR) for underground mines. A set of sensor data from an underground mine, is analyzed using SOM and the resultant topological map for data points are visualized in the virtual underground mine. The results indicate that visualization of AI outputs in virtual reality serves as effective tool for building situational awareness.

**11:05 AM**

## **RSSI-Based Indoor Localization System for Smart Mining Operations: A Case Study**

*M. Cavur<sup>1</sup>, M. Camalan<sup>3</sup> and S. Duzgun<sup>2</sup>; <sup>1</sup>Management Information System, Acemician, Istanbul, Turkey; <sup>2</sup>School of Mines, Academician, Denver, CO and <sup>3</sup>Mining Department, Academician, Ankara, Turkey*

Health and Safety of miners is the most important issue that should be provided by companies. Many solutions are being provided to ensure the safety of mining workers in recent years. Tracking of miners in a real-time manner is one of the methods to take critical precautions before and after the mine accidents. The realtime tracking can be achieved in open areas with the help of global positioning system (GPS). However, the smartness of the system and indoor tracking that provides this service should be achieved by the new technological developments. In this study, a unique RSSI-dependent algorithm is developed with the RFID technology. The technique applied in this study is the fingerprint. The signal map of each mine should be collected and configured is the only disadvantage of fingerprints technique. The methodology is applied in this study is unique and a kind of integrated solution. The solution is applied in a metallic mine and now being used in 25 underground metallic mines in Turkey. The accuracy of the system is 5m. In future, not only the localization of miners but also performance and productivity of mines should be configured by these type of communication system.

11:25 AM

## Mining Asset Development for Virtual Reality

*T. Orr, J. Bellanca, J. Navoyski, B. Macdonald, W. Helfrich and B. Demich;  
CDC NIOSH, Pittsburgh, PA*

The pervasiveness of high-fidelity video games raises expectations of quality, detail, and lighting in virtual reality (VR) applications. However, high-quality models of mining equipment and environments are often not readily available, and developers may not be familiar with the latest techniques like physically-based rendering (PBR). Because a consistent aesthetic is critical for maintaining immersion and controlling visual stimuli in research as well as training, researchers created an asset development workflow. This paper details the workflow including PBR and precision modeling techniques as well as a rigorous review process. It also describes lessons learned in the creation of photorealistic VR assets.

19-052

## TUESDAY, FEBRUARY 26

MORNING

9:00 AM | ROOM 106

## Industrial Minerals & Aggregates: Digitization, Automation & Control Strategies, Part I: Processing and Applications

*Chairs: R. Dube, Outotec, Centennial, CO  
R. Raitani, Solvay, Stamford, CT*

9:00 AM

### Introduction

9:05 AM

## Measuring Liquid Flow Applications in the Mining and Mineral Industry and Getting the Most Out of Your Magnetic Flow Meters.

*K. Burnett; General Industry Sales, ABB, Burlington, ON, Canada*

Successful selection, installation and operation of the magnetic flowmeter depends on many factors. This paper will review different magnetic flow meter coil excitation technologies available and how their selection will impact on the application performance. What data is required to size the flow meter and what are the best practices for meter sizing. What materials of construction are available for liners, electrodes and grounding/protection plates to ensure a long meter life expectancy? Where to install your flow meter and what factors should be considered. What are the upstream and downstream piping requirements and potential impacts to the accuracy of your meter.

**9:25 AM**

## **Sodium Bicarbonate Plant Saves Significant Time and Money With Wireless Deployment**

*K. White<sup>1</sup> and R. Pfister<sup>2</sup>; <sup>1</sup>Rosemount Measurement, Emerson Automation Solutions, Clifton, CO and <sup>2</sup>Electrical and Instrumentation Maintenance, Natural Soda, LLC, Rifle, CO*

Natural Soda is a solution mining/processing company located 50 miles northwest of Rifle, Colorado. The facility was built in 1990 to produce 60,000 tons per annum (tpa) of feed grade product. A 1996 expansion increased capacity to 125,000 tpa, and added food grade production. In 2013 Natural Soda commissioned a state of the art expansion, doubling capacity. The number of solution mining well pads doubled too. Prior to expansion, a Delta V M-series serial card was used for wireless I/O control; serial data & data sets were all used up. With increased I/O demands, we needed a fix, quickly! Hard wired devices too difficult, too costly & taking a great deal of time to install. Additional PLC's & wireless radios would have been used. More parts, more pieces, more fail points. The expansion added S-series controllers, allowing a WIOC (Wireless I/O Card). Rosemount wireless devices had already been installed in the field, making a WIOC a perfect solution. The WIOC was easy & fast to install/commission; less than 36 hours to move 30 devices from an existing gateway to the WIOC, with little interruption to the process. Serial data set usage was reduced by 1/2, allowing future expansion.

**9:45 AM**

## **Ground Penetrating Radar for Karst Detection in Underground Stone Mines**

*J. Baggett<sup>1</sup>, A. Baghbadorani<sup>2</sup>, J. Monsalve<sup>1</sup>, R. Bishop<sup>1</sup>, N. Ripepi<sup>4</sup> and J. Hole<sup>3</sup>; <sup>1</sup>Mining & Minerals Engineering, Graduate Student, Blacksburg, VA; <sup>2</sup>Geosciences, Graduate Student, Blacksburg, VA; <sup>3</sup>Geosciences, Professor of Geosciences, Blacksburg, VA and <sup>4</sup>Mining & Minerals Engineering, Professor of Mining Engineering, Blacksburg, VA*

This work confronts the operational and safety issues associated with karst voids in large opening underground mines. Issues include water inrush, structural instability, and engineering uncertainty in these environments. Coupled with the fracturing prevalent in folded sedimentary rocks, karsts are complex and challenging ground control risks. Traditional methods of predicting karst locations, such as probe drilling, are impeded by the inconsistent spatial distribution and variable sizes of the features. Ground penetrating radar (GPR) is a geophysical technique that transmits radio waves into a medium and subsequently detects reflection waves via a receiver. The travel time and energy of received signals are then processed and interpreted. The difference in material properties between limestone and open karsts causes strong reflections. GPR is frequently used as a geophysical surveying technique in several industries, however there is a lack of published research on underground mining GPR applications. The purpose of this work is to prove the viability of GPR in underground stone mines for karst detection, and to discuss the importance of karst detection ahead of mining.

**19-081**

10:05 AM

## Improved Grinding Performance Through Variable Speed

*D. Andreo and M. Perrucci; Process Industries, Mining, ABB Inc., Littleton, CO*

Most of the grinding operations built prior to the '90s have one aspect in common: SAG and Ball mills driven by fixed speed motors. Operators seek grinding performance optimization only through changes in ball charge and amount of water in the circuit. With today's increasing adoption of digital technologies and the constant cost reduction of sophisticated electronics, multiple world-in-class mines have been profiting from the use of variable speed drives (VSD) in their mills. With the continuously increasing pressure for productivity gains and the need to extend the life-time of the installed base to cope with the mine, a grinding mill drive upgrade can boost profitability while de-risking operations. A VSD mill upgrade enables higher revenues and lower operating costs through multiple improvements, which are the subject of this presentation. This presentation describes the benefits of variable speed on grinding mills, the different scenarios commonly found in the grinding operations worldwide and some practical solutions for their upgrade to variable speed. Concluding, a real example is used to quantify the financial benefits and calculate the expected return of the investment.

10:25 AM

## Intelligent Monitoring System for Improved Worker Safety During Plant Operation and Maintenance

*D. Parks<sup>1</sup>, M. McNinch<sup>1</sup>, R. Jacksha<sup>1</sup>, H. Nickerson<sup>2</sup> and A. Miller<sup>1</sup>; <sup>1</sup>Spokane, WA, CDC NIOSH, Spokane, WA and <sup>2</sup>Central Pre-Mix Concrete Co, Spokane Valley, WA*

Each year hundreds of mine workers are involved in machinery related accidents. Many of these accidents involved inadequate or improper use of lock-out/tag-out (LOTO) procedures. New methods are needed to monitor access to hazardous areas around operating machinery, improve documentation and monitoring of maintenance that requires shutdown of the machinery, and prevent unexpected startup or movement during machine maintenance activities. The National Institute for Occupational Safety and Health (NIOSH) is currently researching the application of the Internet of Things (IoT) technologies to provide intelligent machine monitoring as part of a comprehensive LOTO program. This paper introduces NIOSH's implementation of an IoT based intelligent machine monitoring system to improve safety during operation and maintenance of concrete batch plant.

19-033

10:45 AM

## High Speed X-Ray Computed Tomography (HSXCT) for Plant-Site Analysis of Pebble Phosphate

*S. Puvvada, C. Lin and J. Miller; Metallurgical Engineering, University of Utah, Salt Lake City, UT*

Pebble phosphate is the +1 mm product obtained from phosphate operations in central Florida. Of particular concern is the dolomite content, which poses severe challenges during the production of phosphoric acid, and fertilizers for the agricultural industry. With an increase in demand for fertilizer production, accompanied by reduced availability of high quality phosphate resources, improved particle characterization should be useful for effective processing of existing pebble phosphate reserves. In this regard, application

of high speed X-ray computed tomography (HSXCT) for pebble phosphate characterization was studied for high and low MgO samples obtained from the Mosaic operations in central Florida. Optimum sample preparation, operating conditions, and procedures for HSXCT analysis were established. A maximum scanning rate of 1kg/min, with acceptable image quality and satisfactory results corresponding to chemical analyses, have been demonstrated for the pebble phosphate samples. Statistical significance of the HSXCT results were assessed based on scans of replicate samples.

**11:05 AM**

## **Advanced Analytics for Improved Plant Performance**

*J. Moilanen; Outotec, Espoo, Finland*

Metallurgical performance of minerals processing plants is challenged by increasingly complex ore bodies, the cost for energy and other raw materials is growing and the overall equipment effectiveness (OEE) performance is below expectations. New digital technologies and Industrial Internet enable new functionality on top of local automation and help smart and connected equipment to perform with high OEE, optimize smart processes to adjust for changes and integrate smart site along the value chain for step change in productivity. This paper presents two practical cases where data and advanced analytics were employed for solving complex problems. Identified business targets were implemented into solutions using advanced analytics and process models for improved productivity. The demonstrated solutions include ore quality prediction based on on-line process data, as well as improving the performance of a pressure filter with equipment diagnostic data and machine learning algorithms. Furthermore the presentation discusses the challenges met when applying advanced analytics on operating minerals processing plant big data.

## TUESDAY, FEBRUARY 26

### MORNING

9:00 AM | ROOM 110

## Industrial Minerals & Aggregates: Energy and Critical Materials

**Chairs:** *L. Pan, Michigan Technological University,  
Houghton, MI*

*Y. Smith, University of Utah, Salt Lake City, UT*

9:00 AM

### Introduction

9:05 AM

### Characterization Study of an Abundant Secondary Resource for Yttrium and Heavy Rare Earths

*J. Zhang<sup>1</sup>, G. Allaedini<sup>1</sup>, Z. Jin<sup>1</sup>, D. DePaoli<sup>2</sup> and C. Anderson<sup>3</sup>; <sup>1</sup>Florida Industrial and Phosphate Research Institute, Bartow, FL; <sup>2</sup>Oak Ridge National Laboratory, Oak Ridge, TN and <sup>3</sup>Colorado School of Mines, Golden, CO*

Under Critical Materials Institute (CMI), the Florida Industrial and Phosphate Research Institute in collaboration with Oak Ridge National Lab and Colorado School of Mines are conducting research to recover REEs, P, Mg and U from phosphate clay. Phosphate mining in Florida generates over a ton of phosphate clay (or slime) per ton of phosphate rock produced. Since the start of large-scale washing and desliming for phosphate beneficiation, more than 2 billion tons of slime have accumulated. This tremendous amount of phosphate clay represents a resource of about 600 Mt of phosphate rock, 600 kt of REEs and 80 million kg of U. In addition, REEs in Florida phosphate clay contain a higher proportion of Y and HREEs than many of the primary rare earths minerals. This paper presents the most comprehensive chemical, physical and mineralogical characterization of phosphate clay. Advanced tools such as QEMSCAN, Mineral Liberation Analyzer, Laser Diffraction Particle Analyzer and ICP-MS were utilized for this study. The information generated is vital for formulating mineral separation schemes to concentrate REE and P-containing materials for downstream extraction of these critical elements.

9:25 AM

### Lithium: Resources, Recovery, and Recycling

*H. Pinegar and Y. Smith; Metallurgical Engineering, University of Utah,  
Salt Lake City, UT*

Lithium has become a critical material for renewable energy and modern energy storage systems. Due to rapidly increasing demands of lithium supply and limited global reserves, the future resource availability for lithium remains unanswered. In this talk, geological availability of worldwide lithium resources, production processes of lithium from primary (minerals, brine, sea water) and secondary sources (industrial wastes) will be discussed from technical and environmental perspectives. The experimental results of laboratory-scale recovery process, which were innovated in our research group, to recover lithium from primary resources (The Great Salt Lake) and secondary resources (end-of-life lithium-ion batteries) will also be discussed.



**9:45 AM**

## **Rare Earth Metal Extraction from Geothermal Brine Using Nanofluids**

*P. Thallapally, P. McGrail, J. Liu, M. Sinnwell, S. Elsaïdi and P. Martin; Scientist, Richland, WA*

Rare earth elements (REE) are critical materials in a wide variety of applications such as generating and storing renewable energy. Extracting rare earth metals from geothermal brines is a very challenging problem due to the low concentrations of these elements and engineering challenges with traditional chemical separations methods involving packed sorbent beds or membranes that would impede large volumetric flow rates of geothermal fluids transitioning through the plant. We are demonstrating a simple and highly cost-effective nanofluid-based method for extracting rare earth metals from geothermal brines. Core-shell composite nanoparticles are produced that contain a magnetic iron oxide core surrounded by a shell made of metal-organic framework (MOF) sorbent functionalized with chelating ligands selective for the rare earth elements. This magnetic core shell process was investigated in a magnetic separation loop system and parameters such as magnetic power, flow rate, particle dispersion and recycling life time were studied.

**10:05 AM**

## **Star Regulus and the Triumphal Chariot of Antimony**

*C. Anderson; Colorado School of Mines, Golden, CO*

Antimony is a silvery, white, brittle, crystalline solid classified as a metalloid that exhibits poor conductivity of electricity and heat. Alchemists were fascinated by a property of antimony to form a crystalline star (i.e. the Star Regulus) under certain conditions. For alchemists, of course, that symbolized the quintessence of matter. In the Western world, it was first isolated by Vannoccio Biringuccio and he first described this in 1540. In 1604 Basilius Valentinus (1565-1624) wrote a monograph on Antimony entitled Triumph-Wagen des Antimonij (Triumphal Chariot of Antimony).. This is regarded as the first monograph devoted to the chemistry of a single metal. Currently, the primary production of antimony is now isolated to a few countries and continues to be dominated by China. As such antimony is currently deemed a critical and strategic material for modern society. This presentation will outline the occurrence, production and critical aspects of this fascinating element.

**10:25 AM**

## **Hydrophobic Surface State of Talc as Influenced by Aluminum Substitution in the Tetrahedral Layer**

*J. Jin<sup>1</sup>, V. Atluri<sup>1</sup>, L. Dang<sup>2</sup> and J. Miller<sup>1</sup>; <sup>1</sup>Metallurgical Engineering, University of Utah, Salt Lake City, UT and <sup>2</sup>Pacific Northwest National Laboratory, Richland, WA*

The talc face surface is naturally hydrophobic with a water sessile drop contact angle of nearly 80 degrees. Due to the presence of impurities in the talc structure the surface properties change. One such effect is the presence of aluminum which can replace silicon in the silica tetrahedral layer of the talc structure. This results in a charge imbalance on the face surface because Si+4 is replaced by Al+3. Sessile drop and bubble attachment contact angle experiments were done, and the results compared to results from molecular dynamics simulations (MDS). Based on the extent of Al substitution, the sessile drop contact angle was found to decrease with increased Al content,

decreasing from about 80 degrees to 0 degrees for phlogopite (25% substitution). In addition, bubble attachment time and corresponding contact angle were also influenced in similar fashion. MDS interfacial water structure analysis indicated relatively stronger interaction between the talc surface and interfacial water molecules, as the Al content increased. The results provide additional understanding of talc surface chemistry, and are a basis for the design of improved reagents for talc depression.

**10:45 AM**

## **Industrial Minerals on the U.S. Critical Minerals List**

*S. Fortier; National Minerals Information Center, U.S. Geological Survey, Reston, VA*

The final critical minerals list published in the Federal Register by the U.S. Department of Interior in response to Executive Order 13817 A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals, includes several industrial minerals. These include antimony, barite, fluorspar, graphite, lithium, potash, rare earth elements, and zirconium, among others. Several factors and sources of data were used to evaluate minerals for inclusion on the list. Two quantitative metrics were used, the Herfindahl-Hirschman index, which measures country concentration of production, and net import reliance, a measure of the extent to which the U.S. is reliant on imports for domestic consumption. Both of these metrics rely on data from the U.S. Geological Survey National Minerals Information Center. The data, risk of supply disruption, and the market sectors and applications for which these minerals are deemed critical are examined and explained. Executive Order 13817 mandates the development of a whole-of-government strategy to mitigate potential strategic vulnerabilities resulting from mineral import dependence, to include a renewed focus on the potential for domestic mining.

TECHNICAL PROGRAM: TUESDAY



**TUESDAY, FEBRUARY 26**

*MORNING*

**9:00 AM | ROOM 112**

## **Industrial Minerals & Aggregates: Resource Estimation, Mine Planning & Operations II**

*Chairs: A. Samal, GeoGlobal LLC, Riverton, UT  
R. Winn, R.E. Janes Gravel Co, Slaton, TX*

**9:00 AM**

### **Introduction**

**9:05 AM**

### **LiDAR Applications in Mining**

*M. Bainbridge, Geomatics, Civil & Environmental Consultants, Inc.,  
Bridgeport, WV*

With recent advances in remote-sensing technology, LiDAR technology can be utilized in various ways to complement the mining industry. Terrestrial LiDAR can be used in underground mining operations to analyze pillar cross-sections and assess their structural stability. By acquiring this type of high-definition survey data across the exposed surfaces inside a mine, the varying cross-sectional areas of each pillar can be easily analyzed by engineers back in the office. This same technology provides detailed point clouds from which as-built 3D models and measured drawings can be created for facilities to aid in maintenance and upgrades. The application of LiDAR technology in mining facilities can lead to significant cost-savings for operators and owners by providing high-accuracy models of existing structures and reducing potential change orders during retrofit and upgrade tasks.

**9:25 AM**

### **Geologic Modeling and Reserve Estimation Techniques for Sand & Gravel Deposits**

*B. Groff<sup>1</sup>, T. Faulkner<sup>2</sup> and M. Faulhaber<sup>3</sup>; <sup>1</sup>Groff Engineering & Consulting LLC, Mt. Sterling, KY; <sup>2</sup>Carlson Software, Maysville, KY and <sup>3</sup>Hilltop Basic Resources, Inc., Cincinnati, OH*

Sand & Gravel deposits are an essential mineral resource to the aggregates and industrial minerals industries. These deposits, while having relatively low economic value, are critical toward the production of coarse and fine aggregate products that go into the manufacturing of ready-mix concrete, hot-mix asphalt, and a host of other basic building materials. Reserve estimates, which are based on borings and sieve analyses, are often reduced to an area and thickness determination. Equipment and processing plants are specified according to the expected recovery of the deposit. But how accurate is the geologic model from which the reserve estimate is based? This paper explores an Ohio Valley sand & gravel deposit and compares different techniques of geologic modeling to historical production results.

**9:45 AM**

## **Transitioning Operations Underground – Why and How Much**

*J. Morgan and P. Christensen; Member SME, Littleton, CO*

The demand for aggregates and cement raw materials close to major cities continues to grow. In many cases, quarries once in open rural land are now surrounded by urban development and opportunities to expand are either not physically possible or the permitting/approvals process is extremely difficult. Where deposit geology is suitable, going underground has become an option more quarry operations have decided to consider. This presentation will explore the issues to address and the costs associated with transitioning from surface to underground quarry operations based on several case studies.

**10:05 AM**

## **Saving Time, Money and Lives – Find Out How Surveying Technology Is Transforming Mining Operations**

*M. Tinkham; Survey, Professional Land Surveyor, Omaha, NE*

Growing survey technology has revolutionized mapping capabilities for the mining industry. Drones, photogrammetry and scanning along with traditional survey methods, provide a safe alternative for measuring stock piles, pillar size assessments and deliver 3D maps of underground mines. The benefits? Less operational interference, accurate underground mapping, and lifesaving safety protocol. Lamp Rynearson has incorporated new survey technology in mines throughout the Midwest for over 20 years. Get a clear picture of how these new survey technologies are used in mining operations.

**10:25 AM**

## **Stochastic Open Pit Production Scheduling Using Parametric Maximum Flow and Branch-and-Cut Algorithm**

*D. Joshi<sup>3</sup>, S. Equeenuddin<sup>2</sup> and S. Chatterjee<sup>1</sup>; <sup>1</sup>Geological and Mining Engineering and Sciences, Michigan Technological University, Houghton, MI; <sup>2</sup>Earth and Atmospheric Sciences, National Institute of Technology, Rourkela, Odisha, India and <sup>3</sup>Mining Engineering, National Institute of Technology, Rourkela, Odisha, India*

The open pit mine production scheduling defines the sequence of extraction of mining blocks over the life of mine to maintain the smooth flow of material from mine to mill to maximize profit. The deterministic production schedule fails to incorporate uncertainty, which leads to serious deviations from the target ore and metal productions. The stochastic schedule can overcome this limitation. In this study, a new solution strategy for stochastic production scheduling was proposed. The proposed approach is a two-step process. First, the problem was solved using a parametric minimum-cut algorithm, and then a branch-and-cut algorithm was applied to respect the resources constraints. The validation of the proposed method was performed by solving six small-scale production scheduling problems. The results demonstrated that the proposed method could significantly improve the computational time with reasonable optimality gap. The proposed method was tested with industrial scale copper data set, and compare with its deterministic model. The results show that the stochastic model can improve the net present value by 6% with reasonable computational time.



**10:45 AM**

## **An Economic Model of Dilution-Related Operations in Ridder-Sokolny Mine, Kazakhstan**

*A. Adoko and K. Yakubov; Nazarbayev University, Astana, Kazakhstan*

One vital point for all mining companies is to minimize production costs so that substantial profits can be made. However, the dilution level of the ore extraction could be a threat towards minimization of the production cost. To this end, the main aim of this paper is to establish an economic model in connection with mine dilution. By taking into account the main parameters influencing the dilution, the model is established on the basis of data gathered from Ridder-Sokolny mine located in the east region of Kazakhstan with the use of appropriate mining software programs. The results showed that the most negatively affecting factors were poor blasting and charging along with geological conditions of the region. Moreover, miscommunication among personnel, which is a common case for many mines in the CIS region, could be a contributing factor. It can be concluded that proper economic analysis can eradicate huge financial losses related to unplanned dilution.

**11:05 AM**

## **Formation Temperature Estimation from Well Logs Using Artificial Neural Networks**

*A. Asadi and M. Hajipour; Department of Petroleum Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran, Shiraz, Fars Province, Iran (the Islamic Republic of)*

Static formation temperature should be determined accurately, especially because it is an essential parameter in petroleum systems modeling. In this study, the commonly used empirical methods for log-derived temperature corrections have been reviewed, and a new correlation has been developed by applying an artificial neural networks model to calibrate log-recorded temperature using true formation temperature as the networks target, and measured depth, time since stop circulation, and bottom-hole temperature as input parameters of the networks. In order to establish the relationship, field data of Persian Gulf basin have been used, and it has been concluded that artificial neural networks are a powerful predictor of true formation temperature. The performance of ANN modeling scheme has been implemented using the data sets which have been divided into three groups of training, validation, and testing data. The proposed method provides an accurate calibration of log-recorded temperature according to comparative studies with existing approaches in real formation temperature determination due to the low mean squared error and good correlation coefficient of testing data.

## TUESDAY, FEBRUARY 26

MORNING

9:00 AM | ROOM 603

### International I: Women in Mining

*Sponsored by: FLSmidth*

**Chairs:** *R. Furey, Stantec, Broomfield, CO*  
*R. Rojas University of Arizona, Tucson, AZ*

9:00 AM  
Introduction

9:05 AM  
**Improving Mining's Approach to  
Long-term Gender Parity Goals**  
*V. Gosteva; Black & Veatch, Denver, CO*

Significant attention has been given recently to gender disparity in the mining industry. Encouragingly, many major mining companies have announced gender balance targets as their long-term goals. However, those goals do not necessarily address the issue of occupational dis-balance for women. The fact that women in mining can most often be found in so-called "support" functions (e.g. Human Resources, Finance, Communications, etc.) is hardly a secret for anyone who works in the industry. This paper attempts to investigate this notion, explore the underlying reasons and suggest ways mining could improve its approach to long-term gender parity goals.

9:25 AM  
**Assessing the Effectiveness of Diversity  
Initiatives in the Mining Industry**

*R. Rojas and F. Molaei; Mining and Geological Engineering, University of Arizona, Tucson, AZ*

Nowadays, to achieve sustainable diversity and inclusion, it is necessary to think about it as a revenue generator rather than a cost center. Statistics in the mining industry in the U.S. show that mining companies lack gender and racial/ethnic diversity in the workplace. Establish diversity in the workplace inspires growth and introduces new skills and perceptions. Mining companies require a program to support the diversity initiatives in the workplace. This program requests to focus not only on attracting and retaining a diverse group of employees but also on being inclusive. This research wants to conduct an employee climate survey within our industry with the aim to assess the perception and sentiment of the diverse groups of employees in regard to the effectiveness of diversity initiatives within the respective companies. This research is part of a broader research on the Positive Business Outcomes of Diversity in the Mining Industry.



**9:45 AM**

## **Newmont's Journey Towards Gender Diversity and Inclusion**

*E. Dorward-King<sup>1</sup>, B. Opoku-Asare<sup>2</sup> and A. Coppel<sup>1</sup>; <sup>1</sup>Sustainability and External Relations, Newmont Mining Corporation, Greenwood Village, CO and <sup>2</sup>Human Resources, Newmont Mining Corporation, Greenwood Village, CO*

Inclusion is one of Newmont's core values; through our Global Inclusion and Diversity Strategy, Newmont aims to create an inclusive working environment where everyone can thrive. With 42% Board of Director gender diversity, 20% at executive level and 15% overall workforce, the company has committed to gender parity in senior leadership by 2030 through the Paradigm for Parity coalition. This session will focus specifically on Newmont's efforts; Dr. Elaine DorwardKing, Executive Vice-President of Sustainability and External Relations, will share lessons, highlight the impact of our employee-led Business Resource Groups, and share about her global career in mining.

**10:05 AM**

## **Leveraging Social Science to Attract Diverse Talent to the Mining Industry**

*S. Singh and A. Reid; Caterpillar, Washington, IL*

The mining industry struggles with attracting gender diversity in the workplace. This results in high competition with limited talent availability. As the war for talent increases, that makes every requisition that much more critical to find the best talent, every time. The industry has been vocal about priorities of gender equality, setting staggering and transparent targets for gender diversity. A diverse workforce is a higher performing, highly engaged workforce which translates to better financial performance. Better representation within leadership at all levels creates more inclusive experiences for male and female leaders and employees. Focus on process and social science research being applied to current people processes which would be quick to implement with little support, low/no cost and drive measurable results are the focus of this project. Rather than relying on "listicles" and generic best practices that provide no measurable outputs, we would rely on scientific research. The application of social science research into standard processes resulted in higher diverse applicant rates, hire rates, and overall representation.

**10:25 AM**

## **Mujeres Roca Program Developed by Organización Mundial de Apoyo a la Educación – OMA and the Chamber of Commerce Canada Peru**

*S. Watson; <sup>04225476</sup>, Lima, Lima, Peru*

"Mujeres Roca" is a program developed in association with the Chamber of Commerce Canada Peru inspired in "Women Who Rock", a Canadian initiative to promote a greater participation of women in the mining industry. The program includes a coaching workshop called "Kalpa Warmi", which means "Woman Strength", to reinforce basic skills and values and 8 mentoring sessions with top executives of the mining industry who share their experiences and knowledge with a group of 10 selected young professional women from around Peru. The program provides opportunities for these young women to build their network, share resources, acquire referrals, and develop their skill and knowledge to help their careers move forward. This presentation will provide background and details on the outcomes of the "Mujeres Roca" program.

**19-034**

10:45 AM

## Becoming the Deputy CEO of one of Australia's Largest Mining Companies – Sharing my Story

*J. Shuttleworth; Fortescue Metals Group, East Perth, WA, Australia*

Julie Shuttleworth shares her career journey from graduate metallurgist, to managing some of the world's largest mining operations, to becoming Deputy CEO of Fortescue Metals Group (FMG). Julie has worked and travelled around the world while moving her career to the highest levels. She shares her adventures, challenges, lessons learnt, and leadership tips while recounting her career progression in the mining industry. This presentation will inspire everyone – including students, women and young professionals – to create their future in the mining industry.

## TUESDAY, FEBRUARY 26

MORNING

9:00 AM | ROOM 502

## Mining & Exploration: Geosciences: Surface Mine Geotech II

*Sponsored by: WSP*

**Chairs:** *R. Kaunda, Colorado School of Mines, Golden, CO*

*E. Wellman, SRK Consulting (US), Denver, CO*

9:00 AM

### Introduction

9:05 AM

### Terrestrial LiDAR-Based, Digital Geotechnical Cell Mapping

*J. Cobb<sup>1</sup> and N. Goncalves<sup>2</sup>; <sup>1</sup>Mine Geology, Freeport-McMoRan – Bagdad, Bagdad, AZ and <sup>2</sup>Mine Measurement, Maptek, Golden, CO*

Traditional highwall cell mapping, like other field-based survey techniques common in mine operations, is due for a LiDAR-based procedure upgrade. By systematically utilizing Maptek I-Site Studio's CAD-based visualization and digitization tools, the user can digitally replicate a conventional cell mapping campaign and generate high quality data. An example workflow developed at the Freeport-McMoRan Bagdad mine will be presented and supplemented by a case study comparing data from the same study area collected traditionally vs. digitally. This digital workflow allows for greater access to the highwall, improves mapping efficiency, promotes measurement consistency and completeness, and is a safer alternative to field-based cell mapping.

**9:25 AM**

## **A Study on the Application of Load and Resistance Factor Design in Mining Projects**

*B. Peik<sup>1</sup>, A. Badraddin<sup>2</sup> and B. Abbasi<sup>1</sup>; <sup>1</sup>University of Nevada, Reno, Reno, NV and <sup>2</sup>Mining and Metallurgical Engineering, Amirkabir University of Technology (Tehran Polytechnic), Tehran, Tehran, Iran (the Islamic Republic of)*

The most important solicitude in mining and civil projects is safety. In a traditional design approach, the designer addresses the risk of collapse, or any adverse performance of the structure by implementing a single parameter, the overall factor of safety (FOS). However, it fails to provide a consistent framework for incorporating the individual sources of risks into design. The two components that this factor accounts for, loads and resistance, have different sources of uncertainty and variability. Hence, first in structural engineering FOS was replaced with load and resistance factor design (LRFD) approach which maintains the idea of identifying all potential failure modes or limit states. In this paper, an investigation was carried out on the LRFD implementation in mining projects. The LRFD required measurements, material parameters and calculations were also studied on typical mining case studies and its advantages and disadvantages were evaluated over FOS method. Results showed that the LRFD model can fit to the mining projects by modifications based on the type of project. It was successful in preventing the underestimated or overestimated design caused by factor of safety.

**9:45 AM**

## **Feasibility of Detecting Near Surface Voids with Infrared Technology**

*W. Boyd; Engineering, Newmont Mining, Florissant, CO*

This study takes place in an open pit mine in Colorado which has a high volume of historic underground mining. While the practical use of detecting voids with thermal cameras has not been proven, the practice of observing steam and melted snow in times of cold weather has proven useful in detecting voids just below the surface. These void types also tend to be the most dangerous. Given the thin cover of ground they can be the most unpredictable and have caused the greatest amount of damage and injury in the past. In attempting to build a case for infrared technology, this study walks through the best uses and value of thermal imaging for making assessments of temperature differences on the ground and also discusses the challenges and deficiencies that have come to light during this period of data collection and scrutiny. Infrared technology is a rapidly improving technology and the use of thermal cameras is prevalent in some mine maintenance departments currently. This study has examined the effectiveness of many different cameras and capability limitations and made use of changing seasons and geology to study the effects of image collection.

**10:05 AM**

## **Research and Course Content of the Geotechnical Center of Excellence at the University of Arizona**

*B. Ross and C. Williams; Geotechnical Center of Excellence, University of Arizona, Tucson, AZ*

The Geotechnical Center of Excellence (GCE) at the University of Arizona has been created to develop academic content and research to address some of industries most difficult geotechnical issues. The GCE was across a wide variety of disciplines and departments across the University and is guided by significant industry input. This presentation will discuss some of the most

recent research being performed at the GCE in areas such as rock fall monitoring and mitigation as well progress on developing class content in areas such as slope monitoring methods.

**10:25 AM**

### **Slope Stability and Uncertainty**

*J. Duran; SME, Woodland Park, CO*

For decades we were told on how to assess the behavior of a facility (slope, stope, a tunnel, etc.) and come back with what would be the factor of safety of the facility not failing. This is known as deterministic analysis where a best estimate is used for each parameter is used and the answer is a unique factor of safety. There will be a discussion about factors affecting slope stability and uncertainty created by the variability of the parameters, the assumption of the models, complex models and how calibration affects them. How a factor of safety could be interpreted and how can sensitivity analyses may help. There will be some discussion about probabilistic designs.

**19-123**

**10:45 AM**

### **A Pre-Feasibility Study on Double Bench Mining Trials in Mine X**

*K. Feledi; Mining & Geological Engineering, Botswana International University of Science & Technology, Palapye, Botswana*

Mine X is an open pit mine which uses on average single benches of 16m to move waste and ore. The mine is due to take on an expansion project which will start in 2019 and is aimed at removing waste to expose ore underneath. The expansion project requires extensive stripping of waste hence the need to trial double benching. The aim of the research is to conduct a pre-feasibility study on double benching method; considering the slope stability and financial analysis. Slope stability analysis was performed using the RocScience DIPS 7.0 software and Swedge 6.0 in finding the probability of different failures to occur as well as the corresponding safety factors. An analysis on the financials was also carried out to find the capital and operating costs. The results showed that the pit walls are stable as there are low probabilities of slope failures and the safety factors are greater than 1. Double benching was found to be less costly and there are resources fully capable of executing the trials.

**11:05 AM**

### **Information Overload – How Much Data Is Too Much Data?**

*B. Olewinski; Barrick Nevada Goldstrike Operations, Spring Creek, NV*

In this time of increasing technology, we find ourselves with more and more data at our fingertips. As an industry we have made strides in automated data collection. Instead of having to go out to the field and spend hours collecting the data it is automatically collected at a set time interval. Depending on the time interval that you set versus the frequency of the manual collections this can lead to a large increase in data. So, what do we do with all this additional data? Unless we spend our time and resources analyzing this data, it is wasted. This means that our geotechnical groups need to become more efficient at their day to day duties and make the time to analyze the increased amounts of data. Data storage also can become an issue, which means that increasing cooperation and communication with the IT groups needs to occur. In this presentation we will go through the sources of data, storage of data, need for analysis, staffing issues, training, and some key takeaways.



**TUESDAY, FEBRUARY 26**

*MORNING*

**9:00 AM | ROOM 503**

## **Mining & Exploration: Geosciences: Underground Mine Geotechnical I**

*Sponsored by: WSP*

**Chairs:** *S. Warren, NIOSH, Spokane, WA  
M. Raffaldi, NIOSH, Spokane, WA*

**9:00 AM**

### **Introduction**

**9:05 AM**

### **Photogrammetric Validation of RMR and Q-system Rock Mass Quality Assessment Comparison**

*R. Langston; langston and Associates, Red Lodge, MT*

Rock mass quality assessment data using RMR and NGI Q-System data collected at Barrick Golden Sunlight Mines, Inc. in Whitehall, Montana has been ongoing since mid-2015. Collection of the rock mass parameters is conducted in parallel in the same underground excavation. Results from each method have been calculated and plotted to develop conversion equations and conduct correlation analysis. The conversion equations are compared with conversion equations derived from the original literature and subsequent studies of the two systems in other geological settings. Third party assessment of each system using three-dimensional photogrammetry has subsequently been introduced to provide review, calibration, and validation of each method and comparison. Comparison and validation of photogrammetry models to the on-site assessments will also enable future exploration and validation the feasibility of remote geotechnical mapping in hazardous non-man entry openings.

**9:25 AM**

### **Interpreting Backfill QA/QC Test Data – Do We Need an International Standard?**

*D. Stone<sup>1</sup>, R. Pakalnis<sup>2</sup> and J. Seymour<sup>3</sup>; <sup>1</sup>MineFill Services Inc, Bothell, WA; <sup>2</sup>Pakalnis & Associates, North Vancouver, BC, Canada and <sup>3</sup>NIOSH, Spokane, WA*

Most mines using backfill routinely carry out quality control (QC) testing of backfill mixes with unconfined compression (UCS) test cylinders. This is true for paste operations, hydraulic fill operations and cemented rockfill operations worldwide. However, a large number of mines simply do not prepare and test the backfill samples in a consistent manner and fail to properly analyze or interpret the test results. Conventional concrete test criteria are not applicable given the differences in the mix constituents and the fact that a large number of the backfill QC test cylinders typically fail to achieve the target strength. An international standard is needed to improve the analysis and interpretation of QC test results and to provide a better means of determining if the backfill is achieving its intended target strength. This paper will

attempt to lay the groundwork for an international standard, and will address several key questions raised by operators such as how laboratory test data compares to in-stope performance, and how many QC tests should fail before a red flag should be raised.

19-043

9:45 AM

### Impacts from Mining of the Largest Pit in the United States on the Underground Infrastructure that Facilitates Pit Wall Stability

*W. Robertson; Underground Project Development, Rio Tinto, Draper, UT*

Under Rio Tinto's massive Kennecott open pit mine, exists over 30,000 linear feet of drift that provides dewatering assistance to the surface operation to insure wall stability in the open pit and facilitate mine expansion. A mitigation plan has been implemented to manage the redistribution of stress, blasting impacts, and heterogeneous rock mass associated with pit mining in order to provide safe access to the dewatering galleries and ensure their functionality, inspections, maintenance, and minor rehabilitation of the dewatering drifts.

10:05 AM

### Geotechnical and Groundwater Modeling: An Integrated Approach for Block Cave Mining

*C. Pantano; WSP, Greenwood Village, CO*

Block cave mining significantly alters in-situ rock hydraulic properties, resulting in increases to hydraulic conductivity and specific yield values by orders of magnitude. Although simplistic assumptions regarding hydraulic property changes can be approximated, geotechnical modeling offers valuable data that allows for more detailed estimates of rock-mass changes, particularly with respect to timing and scale. Collaboration with geotechnical engineers and translation of this data into hydraulic property changes is valuable to improve groundwater model predictions. A case study presents the utilization of geotechnical model output and translation methods for integrated groundwater modeling, providing higher confidence predictions.

10:25 AM

### Support Elements and Monitoring Design for the San Javier Sublevel Caving Project

*A. Sinuhaji and M. Gustavo Herrera Rico; Mining Engineering, First Majestic Silver Corp, Vancouver, BC, Canada*

First Majestic Silver's La Encantada is a producing mine, with a capacity of 3,000 tpd. The La Encantada team is currently constructing two small-scale caving mines, including the San Javier Breccia caving mine. The new mine is constructed within the mineralized breccia body that composed of clasts of varying sizes and with a very poor rock quality. Due to the poor rock quality condition, the primary and secondary supports are required to support both the development and production stages. Due to the proximity of the new mining levels to the existing old workings, correct selection of the support system, proper production controls, instrumentation and monitoring are very critical to maintain the stability of pillars and the fortification elements. An increased ground deformations due to the load transfer during the production stage is expected. This report reviews the primary and secondary support elements

used in the different stages of mining, the monitoring of ground deformation, the steps to analyze and visualize the collected data in order to enable the geotechnical team to manage the caving stress and maintain pillar stability.

19-065

10:45 AM

## Design and Testing of High Capacity Surface Support

*T. Roberts; Hard Rock International, Jennmar, Smeaton Grange, NSW, Australia*

Steel wire weld mesh is a common industry standard surface support used in underground mining traditionally installed with mining drills during the bolting cycle. As underground mining depth and stress increase, mining methods and their sequences at these depths place challenges on conventional surface support options. These challenges have provided a need for high capacity surface support options that improve development efficiency, reduce the need for secondary ground support installation and are easily installed with current mining equipment. A mesh testing machine was built, measuring load and displacement accurately using a data acquisition system, which pushes against the restrained mesh module. A testing program comparing conventional surface support were tested for baseline results. New module designs incorporating existing mesh types and new design concepts were manufactured and tested using the same test method. Based on these results, two high capacity mesh modules achieving greater than 20 ton are produced. This paper will detail the test program, load and displacement results and underground mesh module performance.

11:05 AM

## Revised Ground Support and Excavation Strategies at the Turquoise Ridge Mine, Nevada

*L. Sandbak; Tech Services, TRJV; Barrick, Winnemucca, NV*

The Carlin-type gold ore at the Turquoise Ridge underground mine (TRJV) is highly sheared, and is in the weakest rock mass. Design criterion incorporates a optimal drift size to prevent unraveling, minimize supplementary support, and to insure high strength quality controlled crf. Traditional ground support consists of inflatable bolts, wire mesh, covered by shotcrete. Additional support includes shotcrete arches for rehabilitation. Mechanical excavation with roadheaders has facilitated early strength shotcrete as a primary support followed by bolts and mesh. Movement monitoring with cross drift and MPBX extensometers are utilized to monitor drift movement to quantify and validate computer modeling.

11:25 AM

## Developing Mechanized Bolting with the CMAC-DHS in Narrow Vein Mining at Stillwater Mine, Montana

*L. O'Connor<sup>1</sup>, M. Ferster<sup>1</sup> and M. O'Reilly<sup>2</sup>; <sup>1</sup>Engineering, Sibanye-Stillwater, Nye, MT and <sup>2</sup>Production & Planning Manager, Sibanye-Stillwater, Nye, MT*

The Stillwater Mine has been using jackleg drills to mine the J-M Reef, a narrow vein PGM deposit, since the excavation of the first exploratory adit. The goal and major objective of designing a partially mechanized drill is to increase safety in the underground work environment. The Stillwater Mine has been working with CMAC-Thyssen Mining Group to design a drill handling system that is mounted to a platform to decrease strain on the miner while

increasing safety. Jacklegs have presented many advantages while mining in narrow mine openings where reducing dilution is imperative, but the movement to develop a product that aims to increase safety and productivity while bolting unsupported ground is necessary for the future of mining at Stillwater. Ground conditions and mining widths vary in new production areas at Stillwater. With the help of the CMA-C-DHS drill, the possibility of developing a safer and more efficient method of supporting narrow production mine openings, while reducing the 25% injury rate associated with jacklegs, is favorable to the overall safety and production rate of the operation. The challenges, methods, and miner feedback will be covered in this presentation.

## TUESDAY, FEBRUARY 26

MORNING

9:00 AM | ROOM 504

### Mining & Exploration: Innovations & Technologies: Emerging Technologies and Engineering Advancements: Challenging the Status Quo II

*Sponsored by: OceanaGold*

**Chairs:** *L. Diaz, Caterpillar Inc, Peoria, IL*  
*S. Lee, South Dakota School of Mines*

9:00 AM  
Introduction

9:05 AM  
Application of Drones in Underground Mines

*R. Bishop, N. Ripepi, J. Monsalve and J. Baggett; Mining Engineering, Virginia Tech, Statesville, NC*

Unmanned Aerial Vehicles (UAV's) or drones have gained recognition in the mining industry primarily for their capability to assist with aerial mapping of surface mines. Opportunities also exist for using drones in underground mining, particularly for 3D mapping of stopes and abandoned workings too dangerous for miners to enter. However, there are numerous challenges for successful operation of drones underground in a GPS-denied environment such as difficult lighting conditions, ventilation currents, dust, potential collision hazards, and often a lack of line of site data / control communications between the UAV and operator. These challenges are being overcome with advancements in Simultaneous Localization and Mapping (SLAM) technology that allows for autonomous flying of drones with real-time mapping and navigation capabilities. This presentation highlights the recent advancements in UAV technology and their underground mining applications being developed.

**9:25 AM**

## **Drill Core Analysis by Neutron Activation**

*M. Hirsch; AiNT GmbH, Aachen, Germany*

AiNT develops measurement systems based on Neutron Activation Analysis (NAA). The drill core analyzer CorA ("Core Analyzer") is for integral elemental analysis of drill cores extracted during exploration of mineral deposits. Conventional geochemical laboratory analyses provide high sensitivity, yet examine small masses. To provide these individual samples for the analyses, portions of the drill core must be extracted. This can be unfavorable, since these samples might not be representative. Moreover, the samples cannot be recovered, and are not available for further examination. CorA will obtain drill cores' elemental compositions integrally and non-destructively. Several non-destructive methods for drill core analysis already exist. However, surface analyses do not provide information about the core's inner composition. Structural information of drill cores can be gained by the use of radiography, which is to be added to CorA. The development, realization and utilization of CorA may enhance today's methods of drill core exploration by providing an innovative system, which is mobile and equipped with real time telemetry in order to involve experts regardless of geographic position.

**9:45 AM**

## **Evaluating the Feasibility of Using New Epiroc Vein Miner at Hecla Lucky Friday Mine, Through Full Scale Rock Cutting Tests on Ore Samples**

*M. Thyagarajan<sup>1</sup>, M. Board<sup>2</sup> and J. Rostam<sup>3</sup>; <sup>1</sup>Ph.D Student in Mining Engineering/ Earth Mechanics Institute, Colorado School of Mines, Golden, CO; <sup>2</sup>Vice President – Technical Services, Hecla Mining Company, Coeur d'Alene, ID and <sup>3</sup>Associate Professor in Mining Engineering/ Director of Earth Mechanics Institute, Colorado School of Mines, Golden, CO*

To study the feasibility of rock cutting, using the new Epiroc vein Miner, at the Hecla Lucky Friday Mine, full scale linear cutting tests were performed at the Earth Mechanics Institute (EMI) of Colorado School of Mines (CSM). This was a part of the implementation of new vein mining design concept for fully automated underhand cut and fill operation at the site. These tests were performed on a Linear Cutting Machine (LCM), using similar disc cutters employed on the mobile miner, on rock samples obtained from the mine, namely the ore. LCM measure the cutting forces on a cutter, to develop the trend of force penetration curve. This information can be used in simulation models to estimate production rate of the various rock excavation units. This paper will explain the project and its objectives, as well as, the result of full scale cutting tests and related analysis for estimation of production rate of the new vein mining machine under development by Epiroc.

**10:05 AM**

## **Single Pass Drill, Install and Inject Self-Drilling Resin Bolt Application in Poor Ground**

*G. Watt<sup>3</sup>, T. Roberts<sup>2</sup> and D. Faulkner<sup>1</sup>; <sup>1</sup>Engineering, Keystone Mining Services, LLC, Pittsburgh, PA; <sup>2</sup>Hard Rock Geotechnical Manager, Jennmar, Smeaton Grange, NSW, Australia and <sup>3</sup>Geotechnical Manager, Oyu Tolgoi LLC, Ulaanbaatar, Mongolia*

To overcome the quality control issues with resin bolt installation in poor ground, a single pass drill, install, inject and tension self-drilling resin bolt application was designed and implemented. This system allows the operator to inject a

two part polyester resin through a self-drilled hollow bolt to mix and fully encapsulate the rock reinforcement. The self-drilling bolt allows for post injection of the hole after the bolt has been installed into the rock and gives the operator manual or automated control on the amount of resin used in the hole to ensure complete encapsulation and continuously mechanically coupled anchorage to the rock. This allows the reinforcement to work as designed and provide the Geotechnical Engineer extra quality control confidence in these conditions. The implementation of this single pass resin bolting system resulted in significant decreases to the resin bolting cycle time and rock bolt quality control failures. In this paper the design, implementation and embedment into the development cycle will be discussed and the in situ quality control checks used to validate the increase in rock bolt installation quality will be shared.

**10:25 AM**

### **The Characterization of Waterjet Shotcrete Removal During Liner Repair and Maintenance**

*E. Charrier, H. Miller, J. Steele, B. Asbury and J. Bourgeois; Colorado School of Mines, Golden, CO*

The repair of shotcrete liners that have been structurally compromised or damaged is a common activity associated with the maintenance and rehabilitation of underground workings. Age, in-situ stresses, geology, chemical/physical decomposition, accidental impacts, and water are but a few of the many factors that necessitate the repair of these structural systems. In many cases, repair activities utilizing conventional tools inflict unintended damage to the underlying rock substrate and surrounding liner. The primary objective of this research is to compare and analyze the structural damage caused by conventional impact hammers versus a novel waterjet excavation system relative to instrumented concrete panels.

**10:45 AM**

### **Geospatial Monitoring for the Development of Energy Resources in Unstable Terrain**

*E. Morrison and E. Gilliland; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA*

Interferometric Synthetic Aperture Radar (InSAR) has been used successfully to monitor surface deformation in urban environments and flat, barren terrain where permanent structures and stable landscapes produce a relatively dense distribution of permanent scatterers. A carbon sequestration and enhanced coalbed methane test in southwest Virginia presented a unique opportunity to test the capability of InSAR in unstable terrain, characterized by varying topography, dense vegetation, and few permanent structures. GPS readings from the site can cross-validate results from InSAR and assess its potential for monitoring surface deformation caused by activities related to the development of energy resources in similar, unstable terrains.

**19-136**

**11:05 AM**

## **The Technology That Will Take Us to the Next Frontier: Lessons Learned and the Application of New Technologies from Industries at the Forefront**

*N. Bell; Jacobs, South Brisbane, QLD, Australia*

Over the past 20 years, most other industries have seen significant productivity improvements, while construction has remained largely flat. Other industries have had economic, competitive and client drivers to transform through technology, now mining's economic driver is their cost structure is inherently increasing. Industries at the forefront of harnessing the power of technology – aerospace, automotive, aviation and defense – are decades ahead of mining. There is a significant opportunity to take the lessons learned and application of new technologies from industry leaders to increase facility up time, improve productivity, increase plant utilization, improve total recorded incident rate, increase tracking and notification systems and reduce operating costs.

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## **TUESDAY, FEBRUARY 26**

*MORNING*

**9:00 AM | ROOM 501**

## **Mining & Exploration: Management: Leadership Matters: Developing a Well Rounded Workforce**

**Chair:** *I. Guerrero, Freeport-McMoRan, Morenci, AZ*

**9:00 AM**

**Introduction**

**9:05 AM**

## **Investing in Industry Knowledge**

*A. Reid and S. Loomis; Caterpillar, Washington, IL*

For the past three years, Caterpillar's Surface Mining & Technology (SM&T) division has been on a journey to develop greater mining expertise while in partnership with mining industry leading universities within the United States. During a 2015 strategy review, the opportunity to develop employees to understand the entire mining customer value chain & who acted as mining specialists to help create and drive customer success became a goal for success. This opportunity first came to fruition among its management level employees in 2016 & 2017 through the development & execution of several "by invite" mining programs with leading global mining universities. In addition, SM&T partnered with faculty members from Colorado School of Mines to provide guest lectures to SM&T management employees across many functional areas. To date, these guest lectures have provided approximately 38% of SM&T management employees with greater knowledge of the mining industry and the business challenges customers face throughout the full value chain.

**9:25 AM**

## **Increasing Workforce Diversity: A Short Course for Industry Professionals**

*C. Kincaid; Olin College of Engineering, Needham, MA*

Creating and sustaining a diverse and inclusive workforce has many benefits; however, instituting enduring organizational changes to increase D&I is challenging, and often results in well-meant but ineffective policies. To assist mining industry leaders in effectively managing change towards D&I in their organizations, a short course was developed by a team including faculty and staff at the Lowell Institute of Mineral Resources, industry professionals, and undergraduate students. Speakers focused on tools to assist in establishing, managing, and evaluating appropriate diversity and inclusion policies. Participants engaged in discussions and shared personal experiences pertaining to diversity and inclusion in the mining industry.

**9:45 AM**

## **Mining R&D and US Universities**

*C. Fairhurst; Civil, Environmental and Geological Eng., University of Minnesota, Minneapolis, MN*

The May 2018 USGS report outlining a strategy to 'break America's dependence on foreign minerals' is a welcome development. While domestic resources are limited, being in the international forefront of mineral technology can be a powerful element of the strategy. Interdisciplinary 'Earth Resources Engineering' research centers at leading US universities are recommended. These also help address SME's concern over lack of engineers for the US mining 66 industry. Government financial support will be required, but oversight by industry is also essential. Leading mineral producers (e.g. Australia, Canada, China) all provide federal support of mineral resources research. US has not since 1995.

**10:05 AM**

## **New Approaches of Mining Education and Industry Leadership**

*R. Rojas; Mining and Geological Engineering, University of Arizona, Tucson, AZ*

Nowadays, the mining industry is facing a generational and talent gap. In this regard, the Mining and Geological Engineering Department (MGE) at the University of Arizona (UA) is providing a unique approach of innovative mining education through the Mining 360 Executive Program. The program is currently directed to a worldwide selected cohort of leaders within Caterpillar, already expert in other areas of the business. Our vision is to provide a holistic approach to the mining business, in leadership, academics and hands-on experience. That it is why is taught as a cohort to foster collaboration, team building and leadership skills throughout the entire year. The one-year program covers all aspects of mining and includes four one-week in-person rotations. More important, the cohort is exposed to work on a Capstone Project (CP) in order to graduate. The CP is a real-life challenge at a specific mine site where they act as consultants to provide an engineering solution. As educators we believe leadership goes hand to hand with technical skills to develop a well-rounded workforce. This talk will illustrate the advantages of this new educational approach and its achievements so far.



**TUESDAY, FEBRUARY 26**

*MORNING*

**9:00 AM | ROOM 505**

## **Mining & Exploration: Operations: Blasting I**

*Chairs: T. Worsey, Newmont, Lexington, KY*

*J. Silva, University of Kentucky, Lexington, KY*

**9:00 AM**

### **Introduction**

**9:05 AM**

### **Improved Drilling Accuracy Results in Reduced Ore Dilution at Evolution Mining**

*P. Jones<sup>2</sup> and D. Ogan<sup>1</sup>; <sup>1</sup>Accounts Management, Minnovare, Tucson, AZ and <sup>2</sup>Technical Services, Evolution Mining, Sydney, NSW, Australia*

A series of trials were conducted at Evolution Mining over a six-month period to compare drilling accuracy using various methodologies, and the impact on ore dilution. Testing was conducted in an underground narrow vein gold mine. The rig's onboard alignment system was compared to a Minnovare's Production Optimiser system mounted to the rig's boom. Drilling results: 50-65% of toe deviation resulted from collar miss-alignment OEM system setup > 85% borehole collar alignment outside tolerance OEM system > 90% borehole toes outside tolerance Production Optimiser: Setup error at the collar 30-60% Doubled number of borehole toes drilled within tolerance-100% increase Improved hole design and simplified setup Reduced survey time Improved fragmentation: Less over-underbreak Lower production costs Reduced ore dilution 30% Improved ore recovery 10% A cost-benefit analysis extrapolated from the trials showed that a reduction of 5% in dilution would eliminate 25,000 tonnes of material that would have to be trucked and processed. It is estimated that on average this would reduce operating costs by circa AUD2.5 million per annum.

**19-001**

**9:25 AM**

### **Reducing Blasting Costs at Barrick Nevada's Goldstrike Mine**

*J. Thuringer; Engineering, Mining, Carlin, NV*

Minimizing blast costs while preserving rock fragmentation is a reoccurring challenge in mining. Adequate fragmentation for the lowest cost is the ultimate goal for a Drill and Blast Engineer. Barrick Nevada's Goldstrike mine is testing the impact of how reducing borehole size from 9 7/8" to 8 3/4", can minimize cost and improve fragmentation. Decreasing the hole size will reduce the amount of stemming per hole, which in result will decrease the total amount of powder needed for blasting. Similar kilocalories per ton will be sustained, as the powder column will be more evenly distributed vertically throughout the borehole and throughout the pattern. This theoretically will

result in more even fragmentation throughout the bench. The proposed decrease in borehole size would result in a 4% annual blast cost savings. The higher column loading should maintain or potentially improve rock fragmentation. This paper will be a summary of the trial conducted at the Goldstrike mine during late 2018.

## 9:45 AM

### Application of Geographical Information System (GIS) in Blasting

*Y. Pan, A. Jha and P. Tukkaraja; Mining Engineering and Management, South Dakota School of Mines and Technology, Rapid City, SD*

Several studies have been conducted to investigate the blast-induced ground vibrations; though there are several approaches proposed by previous researchers, traditional regression analysis is still being used in predicting blast-induced ground vibrations. This paper highlights the application of GIS in blasting particularly in the analysis of blast-induced ground vibrations. From this study, it was observed that GIS was a viable tool for blast-induced ground vibration analysis. By using the combination of GIS and traditional regression analysis, different areas were identified at a surface mine site based on the distance to the nearest structure, vibration limits, and the charge per delay. Using this approach, subsequent production blasts at this mine site can be designed effectively.

## 10:05 AM

### Ergonomic Selection of Stemming Plugs for Quarry Blasting Operation

*A. Ur Rehman<sup>1</sup>, M. Emad<sup>2</sup> and M. Khan<sup>2</sup>; <sup>1</sup>Department of Mining and Nuclear Engineering, Missouri University of Science and Technology, Rolla, MO and <sup>2</sup>Department of Mining Engineering, University of Engineering and Technology Lahore, Lahore, Punjab, Pakistan*

Stemming plugs are used as an accessory in drilling and blasting industry. They supplement conventional stemming material (i.e. drill cutting) with retention of gases in the drill hole that result in better fragmentation of rock and improved explosive utilization. Better fragmentation and explosive utilization along with economical benefits enhance efficacy of the project. Incorporation of stemming plugs in drilling and blasting industry is in practice for about last three decades. Their effectiveness is one major factor in their increasing demands. Different studies have been conducted on the economic viability of these plugs. The focus of this paper is the selection of stemming plugs for a bench blasting operation and the examination of blasting operation efficiency based on ergonomics and human factors. Three types of stemming plugs were tested on full-scale blasting at one of the biggest limestone quarries in Pakistan. Their performance was evaluated using split desktop software. Based on the human factors plastic molded stemming plug (stemming plug-1) was found to be the best among all selected plugs.

19-089

**10:25 AM**

## **A Study of the Effects of Different Stemming Size on Blasting Performance At Kansanshi Mine**

*S. Sharma; Mining Engineering, First Quantum Minerals Ltd., Solwezi, Zambia*

The Kansanshi mine in Solwezi, Zambia owned and operated by First Quantum Minerals Ltd. targets drilling capacity of 3 million annual meters, translating to 30,000 tonnes of stemming used annually, 60% of this is 165mm and rest is 115mm diameter drilling. Through QA/QC of blasts it has been identified that majority of shots have excessive stemming ejection. The primary source of this problem was identified as inadequate confinement of explosive energy with the potential root cause for this being potentially but not limited to: stemming size, quality and compliance. Stemming particle size is selected as 10% to 20% of hole diameter as a thumb rule. This paper details about the effect of stemming size on blast outcomes such as fragmentation and stemming ejection taking into account the quality and compliance of stemming material. Blasting trials were done using two sizes of stemming material: 16.5 mm and 19.5 mm. It was observed, the use of 16.5 mm stemming material resulted in improved digging rates as high as 32% and reduced stemming ejection as revealed by Blast Video analysis.

**10:45 AM**

## **Comparison of PFC2D Modeled Damage and the Practical Damage Limits from DRIFT Blast Design Software**

*S. Iverson; NIOSH, Spokane, WA*

DRIFT is a software tool developed by the National Institute for Occupational Safety and Health Spokane Mining Research Division for underground blast design that determines practical damage limit circles around each blasthole based on the type and quantity of explosive. Designs built using DRIFT were compared with modeling results from PFC2D by examining blast damage around each blast hole in a blast round. The flat-joint contact model provides realistic rock crushing and cracking damage. Explosions and pressure waves result by applying instantaneous wall pressure in the blastholes as determined for each explosive. The damage around each blasthole is immediate crushing and expanded radial tensile cracking. The damage extent depends on the amount of pressure applied. The DRIFT software practical damage limit circles when overlain onto the PFC2D damage are appropriately beyond the crush zone and within the radial cracking limit. The result was the DRIFT Buffer Row designs show significant damage reduction at the perimeter using both string loaded emulsion or detonation cord in the perimeter holes when compared to not using perimeter control.

**19-060**

**11:05 AM**

## **Optimal Bench Height for Grade Control Using a 3D Optimizer**

*W. Hunt; Principal, OreControl Blasting Consultants, Denver, CO*

Surface metal mines often struggle with conflicting information surrounding bench height. Past wisdom suggested shorter benches in narrow-vein mines led to less dilution, but shorter benches lead to other issues in blasting, fragmentation, differential movement, and production rates. How should the optimal bench height be determined? Presented are two case studies from different mines that use a specialized three-dimensional optimizing tool to make a determination.

## TUESDAY, FEBRUARY 26

MORNING

9:00 AM | ROOM 506

### Mining & Exploration: Operations: Mine Scheduling and Optimization I

*Chairs: R. Diaz, Centennial, CO*

*A. Ashok Parmar, Freeport-McMoRan Inc.,  
Tucson, AZ*

9:00 AM

Introduction

9:05 AM

#### Defining Blending Classes to Solve Open Pit Scheduling Problems – A Practical Application in a Peruvian Mine

*J. Gonzales<sup>1</sup> and P. Alvarado Herrada<sup>2</sup>; <sup>1</sup>Technical Director, Minero Inc, Aurora, CO and <sup>2</sup>CEO, Minero Inc, Aurora, CO*

For this paper, blending is conceived as a linear process that takes a proportion from one stockpile or location and mixes it with another proportion from another stockpile or location, with the aim of obtaining a set of attributes in the final combination that satisfies a given quality standard. Current literature considers the number of blending classes in the Open Pit Scheduling Problem as fixed; however, this paper shows how to define specific blending classes for a given deposit so that the schedule can be solved with Sequential Linear Programming. Finally, a practical application in a Peruvian copper mine is shown, involving four ore attributes: alteration code, arsenic, oxide content and copper grade.

19-010

9:25 AM

#### Comparative Analysis of Open Pit Gold Mine Project NPV's Under Price Uncertainty Using Real Options and Dynamic Mine Plans

*M. Visnjic and K. Dagdelen; Mining Engineering, Colorado School of Mines, Golden, CO*

Open Pit Mine Production scheduling under commodity price uncertainty suffers from an exponentially increasing problem size as simulations and real options flexibility are used to generate and evaluate production schedules. Robustness evaluation techniques attempt to evaluate a production schedule that is generated on a single set of economic parameters against several varying prices and sources of uncertainty. This approach is invalid as the corresponding optimal LOM mine plan will change for each set of evaluation parameters. Using commodity market futures and treasury bonds as production schedule economic input parameters provides fully price and time-value-of-money risked scheduling parameters that maintain a deterministic problem size. This paper will provide a comparative analysis of project NPV's

coming from traditional price uncertainty evaluation based on a single fixed LOM mine plan using varying prices versus evaluation based on varying LOM plans that are both generated and evaluated using varying prices.

19-064

9:45 AM

## Strategic Planning to Tactical Planning – Quantifying a Loss in Value

*R. Diaz, J. Kraft and M. Labonte; Minemax, Inc, Centennial, CO*

The mining industry is rabidly pursuing smart technology to connect systems, increase understanding of processes and add value in overlooked places. Strategic Long Range Planning as an exercise empowers the engineer to evaluate decisions affecting millions and millions of dollars in value. However, once we progress to a more tactical planning horizon, value loss compounds when tactical plans move further out of alignment with strategic plans. How does this affect the value of the project? Is this an acceptable loss of value; an unfortunate circumstance of becoming more tactical in our mine plans? Or are there steps we can take to preserve value as the strategic becomes the tactical? Quantifying this loss in value is the first step for addressing these questions and preserving value for the life of the project.

10:05 AM

## Lane's Algorithm Revisited: A New Look at Lane's Cutoff Grade Optimization Algorithm

*M. Goycoolea; School of Business, Universidad Adolfo Ibañez, Santiago, Chile*

In 1964 Kenneth Lane proposed an algorithm for optimizing, over discrete time, the cut-off grade in a single-metal, single-processor open pit mine production schedule. Though Lane's algorithm has been successfully used in multiple commercial software systems and taught to every mining engineer as a student, it is widely considered heuristic, and little is known regarding the quality of solutions it produces. We formally study Lane's problem from a mathematical programming perspective. We show that Lane's algorithm can be viewed as an approximate dynamic programming scheme, and that Lane's limiting economic cut-off grades can be recovered by deriving optimality conditions of a continuous-time extension of his problem, or a suitable approximation. Finally, by reformulating, we show that Lane's problem can be solved using convex mixed integer programming. Though hypothetical counter-examples can be constructed, computations show that Lane's algorithm produced the optimal solution in every real data-set tested, lending solid support for its use in practice, and suggesting the algorithm should be further studied for adaption into modern mine planning software systems.

10:25 AM

## Life of Mine Schedule: Pre-Feasibility Study for the La Coipa Mine Area

*S. Dutta<sup>1</sup> and A. Prawasono<sup>2</sup>; <sup>1</sup>Technical Services, Hexagon, Tucson, AZ and <sup>2</sup>Mine Planning, Technical Services, Senior Manager, Kinross, Toronto, ON, Canada*

The paper describes the development of the life-of-mine schedule (LOM) for a typical high-sulfidation epithermal gold and silver deposits, and at deeper erosion levels, porphyry-related deposits at the La Coipa mine district in Chile. The various pre-processing steps involved in generating the LOM data such as dilution adjusted tonnages and grades, cycle times, scheduling

objectives and constraints, with results and conclusions are discussed. In addition to a complex mining scenario resulting from multiple mining areas with a number of pits/phases for scheduling, where each competed to provide the best ore available to a capacity-constrained process facility; one of the other striking features in the study was the application of the multi period scheduling approach combined with non-fallibility. This enabled the execution of multiple scenarios quickly and pointed to the problematic periods. The ability to look several periods ahead not only improved the project value but also resulted in the successful realization of several constraining factors in this complex scheduling process. It otherwise could have been difficult for a schedule generated on a period-by-period basis.

**10:45 AM**

### **Generating Pushbacks That Maximizes the NPV of Open Pit Mines Using Direct Block Mine Production Scheduling Algorithm**

*C. Aras, K. Dagdelen and T. Johnson; Mining Engineering, Colorado School of Mines, Golden, CO*

Traditional mine production scheduling relies on generating pushbacks with price parametrization and aggregating the blocks inside these pushbacks into benches to generate long term annual production schedules. However, the incremental fashion of obtaining pushbacks fails to incorporate the operational requirements such as multi capacity, multi destinations, blending requirements, truck hours and stockpiles. Since many production schedule plans highly depend on the design of pushbacks, poor designs will prevent the schedules from achieving a maximum NPV or even obtaining a feasible solution. In this paper, block by block yearly schedules will be generated by solving the mine production scheduling problem under the operational requirements and the resulting yearly schedules will be grouped into phases for the pit design with haul roads. This approach will guarantee that the phases used to take into account operating requirements will honor the production and blending requirements. Then, comparison will be made between the traditionally generated phases versus the phases obtained by using the block by block mine production scheduling algorithm.

**11:05 AM**

### **A New Cone Generation Technique to Honor Complex Pit Slope Angles in Production Scheduling of Open Pit Mines**

*C. Aras, K. Dagdelen and T. Johnson; Mining Engineering, Colorado School of Mines, Golden, CO*

Block by block open pit mine production scheduling solution algorithms require the dependencies between the blocks based on the required pit slope angles to be preprocessed. This is accomplished by generating arcs between the blocks and storing them in map containers when programmed with a C++ coding language. Then the arcs between the blocks are transformed into sequencing constraints. Hence, there is a strong correlation between the number of arcs generated versus the processing time of the sequencing constraints and the memory allocated to store these arcs. In order to achieve fast computing times, the number of arcs generated per block should be optimized. Therefore, a new cone pattern generation scheme is developed with the aim of reducing the number of arcs generated for sequencing of the blocks in the production scheduling algorithm. This paper will discuss how this new technique represents the required pit slopes with the minimum number of arcs. This is accomplished while also minimizing the deviation from the required pit slope angles for block models with any size block dimensions.

**11:25 AM**

## **A New Method to Select the Optimum Undercut Elevation in Block Caving Mines**

*R. Noriega, S. Paravarzar, Y. Pourrahimian and W. Liu; School of Mining and Petroleum Engineering, University of Alberta, Edmonton, AB, Canada*

Block caving has become one of the most attractive underground mining methods due to its high production capacity and low operating costs. One of the key initial decisions when designing a block caving project is the placement of the undercut level, from which the ore will be drawn during the mine life. Current industry practices and state of research lack a truly optimal tool for this decision, which could be very costly or even impossible to change during production. This paper presents a linear programming method to select the optimal undercut elevation that maximizes the NPV of a caving project, subject to common production and geotechnical constraints. The model is based on a simplified scheduling approach that accounts for the vertical draw rate and the horizontal mining advancement front, and is tested on a real deposit.

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## **TUESDAY, FEBRUARY 26**

*MORNING*

**9:00 AM | ROOM 703**

## **MPD: Chemical Processing: Pyrometallurgy**

*Sponsored by: Moly-Cop*

**Chair:** *J. Grogan, Gopher Resource, Eagan, MN*

**9:00 AM**

### **Introduction**

**9:05 AM**

### **OUTOTEC Low NOx Burners for Indurating Furnaces**

*A. Munko, M. Nevens and B. Salagundi; Outotec, Atlantic Beach, FL*

OUTOTEC has developed a Low NOx burner concept for Pelletizing Plants to meet NOx emission limits, which are getting stricter globally. The burner concept has been tested at small-scale tests in laboratory, and a very low NOx emission has been reached. The burners operate with Natural Gas or Diesel. CFD simulations of the small-scale tests have been done for validation of the CFD model and for optimization of the burner design. After up-scaling the burner to full plant size further CFD calculations have shown that low NOx emission is possible with full size burners, too. At the end of 2017, OUTOTEC started first full scale tests at a pelletizing plant. The trials confirmed the effectiveness and feasibility of the Low NOx concept.

9:25 AM

## On the Fundamentals of Arsenic Removal from Lead Bullion via Vacuum Distillation

*E. Tshijik Karumb; Metallurgical and Matgerials Engineering, Colorado School fo Mines, Lakewood, CO*

Impurities present in lead bullion are commonly removed using a lengthy, energy consuming, and complex oxidation process. Consequently, great effort has been invested in the investigation of impurities removal using vacuum distillation; in this case, the focus is given to the removal of arsenic. Arsenic metal sublimates at atmospheric pressure; consequently, data on liquid arsenic has been available only recently; as such, a thorough survey has been conducted to harvest physical properties of arsenic solid and liquid. In order to predict the equilibrium partial pressure above the melt, the activity coefficient  $\gamma$  (T, P) is needed. Three different thermodynamic models which are the Molecular Interaction volume Model (MIVM), the Wilson equation model, and the Non-Random Two Liquid (NRTL) model have been to that purpose. Using these data, vapor liquid equilibrium (VLE) for the binary Pb-As system has been predicted. The equilibrium distribution to distillate and remaining alloy has been calculated for arsenic and lead. These predictions have shown that there exists a considerable thermodynamic driving force for the separation of arsenic from lead bullion.

9:45 AM

## Sodium Stannate Preparation from Cassiterite Concentrates and $\text{Na}_2\text{CO}_3$ Roasted in $\text{CO-CO}_2$ Atmosphere: Effect of $\text{SiO}_2$

*C. Anderson; Colorado School of Mines, Golden, CO*

Sodium stannate ( $\text{Na}_2\text{CO}_3$ ) has been successfully prepared by a novel process of roasting cassiterite concentrates and sodium carbonate under  $\text{CO-CO}_2$  atmosphere, namely soda roasting-leaching process. However, more than 22 wt.% tin of the cassiterite was not converted into  $\text{Na}_2\text{SnO}_3$  and entered the leaching residues. Quartz ( $\text{SiO}_2$ ) is the predominant gangue in the cassiterite, and phase transformation of  $\text{SnO}_2\text{-SiO}_2\text{-NaCO}_3$  system roasted under  $\text{CO-CO}_2$  atmosphere was still uncertain. In this study, the effect of  $\text{SiO}_2$  in cassiterite concentrates on preparation of  $\text{Na}_2\text{SnO}_3$  was clarified. The results indicated that  $\text{Na}_8\text{SnSi}_6\text{O}_{18}$  was inevitably formed when cassiterite and  $\text{Na}_2\text{CO}_3$  were roasted above  $775^\circ\text{C}$  under  $\text{CO-CO}_2$  atmosphere via the reaction of  $\text{SnO}_2 + 6\text{SiO}_2 + 4\text{Na}_2\text{CO}_3 = \text{Na}_8\text{SnSi}_6\text{O}_{18} + 4\text{CO}_2$ , and formation of  $\text{Na}_8\text{SnSi}_6\text{O}_{18}$  would be accelerated with increasing roasting temperature and Si/Sn mole faction. In addition, it was found that  $\text{Na}_8\text{SnSi}_6\text{O}_{18}$  was insoluble in the leachate at pH value range of 1-14, which, therefore, was enriched in the leaching residues. The silicon content of the cassiterite concentrates should be controlled as lower as possible to obtain a higher conversion ratio of  $\text{Na}_2\text{SnO}_3$ .

10:05 AM

## Effects of Calcination Pretreatment on Rare Earth Element Recovery from Bituminous Coal Sources

*W. Zhang and R. Honaker; Mining Engineering, University of Kentucky, Lexington, KY*

Calcination is commonly used in rare earth processing to improve leachability characteristics. An experimental program was conducted to determine the effect on the recovery of rare earth elements (REEs) from Bituminous coal



sources. Representative feed samples were collected from three coal preparation plants. Calcination treatment at different temperatures was conducted on samples obtained from four density fractions of each sample. Calcination significantly enhanced REE recovery for all the three sources and maximum recovery was achieved between 600 and 750 degree Celsius. Leaching kinetics of the calcined material of the density fractionized samples were different, which was correlated with the different REE mineralogy.

**10:25 AM**

## **Electrochemical Extraction and Optimization of Rare Earth Metal in Molten Fluoride Salt Using Statistical Modeling**

*P. Sarfo, A. Das, C. Young and H. Huang; Met & Materials Eng, Montana Tech, Butte, MT*

Most rare earth elements (REEs) are critical materials of perilous prominence. Because of their criticality, their convalescence into metal from rare earth oxide (REO) and their recycle from end-of-life materials are essential for the proficient use and safeguard of natural resources. With pyrometallurgical approaches, REOs are dissolved in a molten halide bath and electrowon. Although this process has its issues, it can be done economically compared to current practices. This paper presents a statistical rejoin model by means of fluoride molten salt electrolysis to recover neodymium from its oxide in a fluoride bath.

**10:45 AM**

## **Thermodynamic Modeling and Experimental Determination of Melting Point of Molten Salts**

*T. Wang, D. Mantha and R. Reddy; Met. Matls. Eng., The University of Alabama, Tuscaloosa, AL*

Concentrating Solar Power (CSP) Technologies are seen as the Solar Program's most attractive option for meeting utility-scale needs. Two key opportunities for cost reduction are the development of improved heat transfer fluids and improved methods for thermal storage. This presentation will deal with our research on development of high temperature molten salt thermal energy storage media with high thermal energy storage density for sensible heat storage systems. Thermodynamic modeling was carried out to calculate the eutectic compositions and temperature for various molten salt mixtures. Experiments were conducted using DSC and TGA methods for the salt compositions obtained from thermodynamic modeling to determine the melting point, heat capacity and other properties. Thermal energy storage densities were calculated based on the melting point, density and heat capacity and are compared with the industrial salts.

## TUESDAY, FEBRUARY 26

MORNING

9:00 AM | ROOM 707

### MPD: Physical Separation I: Physical Separation Technologies and Projects in Mineral Processing

**Chairs:** *T. Rauch, Kappes Cassiday & Associates,  
Reno, NV*  
*M. Rezaee, The Pennsylvania State University,  
University Park, PA*

9:00 AM  
Introduction

9:05 AM  
**Effects of Grinding on Particle Shape: Silica and Magnetite**  
*F. Dehghani<sup>1</sup>, B. Rezaie<sup>2</sup>, A. Sachan<sup>1</sup> and T. Ghosh<sup>1</sup>; <sup>1</sup>Mining and Geological Engineering, University of Alaska Fairbanks, Fairbanks, AK and <sup>2</sup>Department of Mining and Metallurgical Engineering, Amir-Kabir University of Technology, Tehran, Iran (the Islamic Republic of)*

Comminution is an integral part of the mineral extraction process. However, the influence of the comminution method on silica and magnetite particle shapes has not been substantially investigated. Shape parameters for fractions of -250+212, -150+125, and -106+75 $\mu$ m sizes were examined utilizing a SEM and a Clemex vision PE image analysis system. The silica particles displayed higher elongation and flatness parameter values for rod mill products, but roundness and relative width parameter values of rod mill products are less than that of the ball mill products. Magnetite particle elongation and flatness parameter values of ball mill products in fraction sizes of -250+212 and -106+75 $\mu$ m are larger than rod mill products, but for the -150+125 $\mu$ m size range the result is converse. Furthermore, particle elongation and flatness increased with decreasing particle sizes of silica. In case of magnetite, ball mill products displayed an increase of flatness and particle elongations with decreasing particle sizes but flatness increased and roundness and relative width decreased. For rod mills, magnetite fractions of -150+125 $\mu$ m were found to have the largest values of elongation and flatness.

19-083

9:25 AM  
**Beneficiation of North Carolina Lithium**  
*H. Akbari<sup>1</sup>, R. Mensah-Biney<sup>1</sup>, J. Simms<sup>1</sup>, G. Dove<sup>1</sup>, P. Brindle<sup>2</sup> and D. Buckley<sup>2</sup>; <sup>1</sup>NC State University, Asheville, NC and <sup>2</sup>Piedmont Lithium Limited, Bessemer City, NC*

North Carolina was once the heart of the lithium mineral production in the USA with two major lithium producers from Carolina Tin-Spodumene Belt. The production of lithium mineral from both operations was halted in the 90s because of the lower costs associated with processing of lithium brine



deposits. Hard rock lithium deposits have recently gained more interest as a results of the new developments in lithium market specially the lithium-ion battery. This has caused new interest and activities to again mine spodumene from Carolina resources. From 50s to 90s, the Minerals Research Laboratory (MRL) of North Carolina State University assisted both major lithium producers with spodumene processing problems and developing the best flowsheets to recover spodumene and by-products including mica, feldspar and quartz. With the new interest in North Carolina lithium deposits, the MRL is again engaged in developing flowsheet for concentrating spodumene from raw ore samples to a high grade product for the subsequent chemical processing. Lithium extraction from North Carolina hard rock will be presented.

**9:45 AM**

## **ADR Carbon Management – Updates in Carbon Fines Capture and Recovery**

*D. Perkins<sup>2</sup> and T. Rauch<sup>1</sup>; <sup>1</sup>Kappes Cassiday & Associates, Reno, NV and <sup>2</sup>Metallurgical Engineering, Derrick, Buffalo, NY*

Carbon fines management is a continuing operational problem in gold recovery plants due to both process design and operational control. Gold loaded carbon fines lost in ADR plants cause operations to suffer from lost recovery and additional process waste to handle. For operations who are capturing and storing their carbon fines, there is limited market available to sell their fines and often at little economic benefit. For operations who dump fines to tails there is significant loss of recovery and production value. Recent laboratory work shows that carbon fines contain much higher gold loading than traditionally thought, with some samples assaying over 100oz of gold per ton of carbon leading the authors to believe that up to 1% of gold production globally is lost to carbon management shortcomings. This paper focuses on advances in mineral processing technology and updated best practices in plant design to recover lost gold and mitigate carbon fines losses.

**10:05 AM**

## **Gravity Separation of Rare Earth Minerals Allantite and Chevkinite: A Case Study Using Design of Experiment Method**

*I. Kursun; Department of Mining Engineering, Istanbul University, Istanbul, Turkey*

Canakli is a unique type of REE mineralization in Isparta, Turkey, where the ore minerals, mainly allantite and chevkinite, found as fine grained and almost completely liberated grains in unconsolidated and weathered pyroclastic tuffs, similar to placer deposits. In this study, gravity separation allantite and chevkinite from Isparta Canakli region REE ore was investigated using a factorial experimental design. As a result of the experimental studies carried out with shaking table, regression analyses were performed for the effective parameters. The analysis showed that correlation between table inclination parameter and  $\Sigma$ REE grade/recovery for 1000 $\times$ 212  $\mu$ m particle size group were calculated as  $R^2=0.7432$  and  $R^2=0.5955$ , respectively. In the 212 $\times$ 38  $\mu$ m particle size group, correlation between stroke speed and  $\Sigma$ REE grade was found to be relatively higher with  $R^2=0.8512$ . Again for the same particle size group, it was shown that the relationship between the results of the model created for the  $\Sigma$ REE recovery and the experimental results is significantly higher, and the correlation coefficient was calculated as  $R^2=0.9904$ .

**10:25 AM**

### **Investigation of Optimum Design Parameters of Surface Paste Disposal for Pb-Zn Mining**

*A. Bascetin, S. Tuylu, D. Adiguzel and Y. Baktarhan; Mining Engineering, Istanbul University, Istanbul, Avcilar, Turkey*

In this study, laboratory type cabins are designed to the surface paste disposal storage conditions in a laboratory. The tailing samples used in this study was obtained from the mineral processing plant of a Pb-Zn mine located in Turkey. Water content and specific gravity, grain size distribution, Atterberg limits and permeability value of the mine process tailing were determined by experiments and analyzes to characterize the tailing material to be used in making the paste. Then paste material was prepared and were stored in a total of 11 layers (thickness of each layer 10 cm) in the laboratory type cabin. Matric suction, volumetric water content, temperature, and oxygen consumption of the paste materials were measured by sensors placed in the 1th, 5th and 10th layers and the relationship between the volumetric water content of paste materials in different layers was investigated. According to results, when the volumetric water content (VWC) value in the 1st layer casting is 100% after 3 days this value decreased to ~ 45% also the oxygen value decreased from 20.77 to 11.96.

**10:45 AM**

### **Coal Cleaning Via a Semi-Industrial Gas-Solid Fluidized Bed Separation System**

*Z. Fu<sup>1</sup>, C. Zhou<sup>1</sup>, Y. Zhao<sup>1</sup>, J. Zhu<sup>2</sup>, C. Duan<sup>1</sup> and L. Dong<sup>1</sup>; <sup>1</sup>School of Chemical Engineering and Technology, China University of Mining and Technology, Xuzhou, China and <sup>2</sup>Chemical and Biochemical Engineering, Western University, London, ON, Canada*

Gas-solid fluidized bed separation is an efficient dry method for upgrading the coal quality. A semi-industrial separation system has been established by China University of Mining and Technology with the process capacity of 5~10 t/h. The system has less dense medium loss and lower electricity consumption. The system was used for separation of -50 + 25 mm, -25 + 13 mm and -13 + 6 mm coal. The best separation efficiency was 0.03 g/cm<sup>3</sup> for 50 + 25 mm coal, 0.07 g/cm<sup>3</sup>, 25 + 13 mm coal and 0.10 g/cm<sup>3</sup> for -13 + 6 mm coal, showing good separation performance.

**11:05 AM**

### **Investigation of Settling Time of Metallic Process Tailings**

*D. Adiguzel, A. Bascetin, S. Tuylu and y. baktarhan; Mining Engineering, Istanbul University, Istanbul, Avcilar, Turkey*

In this study, settling behaviors of Pb-Zn and Cu mines tailings were investigated and parameters affecting settling were determined. The density values of the Cu tailings vary considerably according to particle size. The settling experiments were carried out on Pb-Zn tailings at different particle size groups. Materials with a size range of 0-38µm were found to settle more slowly due to the small particle size and density, while materials at sizes -150+106µm and -200+150µm were observed to settle more rapidly during the experiment. At the same particle density it was observed that Cu tailings which has an average density of 3,495 settled faster than Pb-Zn tailings. In this study, the average settling time of Cu tailings was calculated as 1.291cm/min. The average velocity of Pb-Zn tailings was calculated as 0.619cm/ min according to between the 1st minute and 15th minute. It is necessary to examine

separately the grain size distribution of the material in terms of its behavior in the water. In other words, it is understood that the grain size distribution in the storage of tailings is important not only in terms of mechanical strength but also in terms of geochemical risks.

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## TUESDAY, FEBRUARY 26

MORNING

**9:00 AM | ROOM 705**

### **MPD: Plant Design I**

*Sponsored by: thyssenkrupp*

**Chair:** *A. House, Samuel Engineering,  
Greenwood Village, CO*

**9:00 AM**

#### **Introduction**

**9:05 AM**

#### **Optimization of Vibratory Feeder System Design for Material Build-up Resistance**

*A. Schrader and R. Foy; Graymont, Townsend, MT*

Graymont Indian Creek mine's current stockpile vibratory feeder design struggles with feeding crushed kiln feed when the limestone contains high moisture in combination with high clay content. The design of a vibratory feeder system includes material introduction, transport from feeder discharge, the feeder configuration, and material characteristics. Primary feeder system design inputs include feed rate, throat to gate height ratio, hopper geometry, material size distribution, moisture content, and temperature. The design process aims to maximize build-up resistance and equipment reliability. Current feeder system installation results in significant build-up which reduces and stops feeder pan operation within one hour. Optimizing the system design maintains our current feeder operation with dry material while increasing our mechanical reliability and operating capacity with high moisture and clay content. Successful feeder system will maintain 24 hours of operating capacity for two 500 ton per day lime kilns.

**9:25 AM**

#### **Real-World Improvement Through Virtual Instrumentation at OceanaGold Haile**

*B. Schug<sup>1</sup> and C. Anderson<sup>2</sup>; <sup>1</sup>ANDRITZ, Decatur, GA and <sup>2</sup>OceanaGold, Kershaw, SC*

The Haile Gold Mine in South Carolina is increasing the automation level of their processing plant in order to improve operational stability. One step towards this goal is the application of a Digital Twin concept to provide Virtual

Instruments. Haile has engaged ANDRITZ to implement Virtual Instruments at their grinding area hydrocyclones and at their tailing thickener underflow pump. These virtual instruments provide density values in a traditionally difficult location for reliable slurry density measurement. The Digital Twin is a first principles IDEAS simulation model, connected in real time to the control system. Results have been promising, with the virtual instrument values matching the physical instrument under normal operating conditions, and showing better prediction under upset conditions. Haile plans to use the virtual instruments as optional process control parameters.

19-086

9:45 AM

### Redesigning the Capstone Pinto Valley Tailing Seal Water System

*C. Churchman<sup>2</sup> and M. Spicher<sup>1</sup>; <sup>1</sup>Weir Minerals, Payson, AZ  
and <sup>2</sup>Capstone Pinto Valley, Miami, AZ*

When casing bolts started failing on the 2nd stage tail pumps, the team at Pinto Valley partnered with Weir Minerals' Integrated Solutions Group to investigate and resolve the issue. A process walk through, equipment review, and observations of typical operations were completed. During the startup and shutdown sequences overpressure conditions of the 2nd stage pumps were noticed. A detailed review of both the sequencing and the raw data from the historian revealed the root cause and contributing factors of the failures. Modifications to the process piping, the startup and shut down sequences, and the control system logic were proposed. The gland water supply system was redesigned to provide separate systems for each stage of tailing pumping under a new control scheme. The turnkey project scope included: engineering design, pump procurement, piping fabrication and installation, electrical installation for the new gland water pumps and VFD drives, additional instrumentation, control system modifications, and minor civil work.

10:05 AM

### A Low-Cost and High-Recovery Leach Method for Extracting Metals from Sulfide Mineral Concentrates

*B. McConnell; Metalox Technologies, Dania Beach, FL*

Metalox Technologies has developed a low-cost leach method to extract all metals from sulfide mineral concentrates, using sulfuric and nitric acid. A plant can be designed to be zero-liquid-discharge and zero-emissions. Solid waste requiring disposal would be minimal. The digestion time is short at relatively low temperature and pressure. The material of construction is 304 stainless steel, metals recovery is 99%, and the problem of sulfur passivation has been solved without resorting to fine grinding, high temperatures, or the use of dispersants. Metalox has developed "recipes" that work with Zinc, Copper, and Lead, which are the principal sulfide mineral concentrates produced worldwide. Operational and economic issues that have prevented nitric acid leaches from commercial viability are resolved. Innovative approaches to producing heat would be incorporated into the first production plant. The presentation will discuss the need for alternatives to traditional smelting and how the Metalox Process offers a viable method to produce metals from sulfide mineral concentrates for low cost and zero emissions. Results of bench-scale and pilot studies on a zinc concentrate will be shared.

19-111

**10:25 AM**

## **Minera San Cristobal – A Different Way of Mining**

*D. King<sup>2</sup> and T. Owen<sup>1</sup>; <sup>1</sup>Minsol, Brighton, CO and <sup>2</sup>Minera San Cristobal, Potosí, Bolivia, Plurinational State of*

Mining and processing always face challenges, but when you are a mining company in an isolated country surrounded by some of the largest mining companies in the world, you have to take a different approach to the business. The “Normal” way of operating a mine needs to be re-thought to adapt and survive in this challenging environment. Minera San Cristobal (MSC) operates an open pit mine and sulfide concentrator facility in Bolivia. The San Cristobal mining operation was first developed between 2004 and 2007 and has been in full production since 2008. The existing process plant was designed at 40,000 tons per day (tpd). After start-up and optimization in the early years, MSC undertook a debottlenecking program and is currently producing over 50,000 tpd, with reduced total water and power consumption. The plant processes high grade zinc and lead-silver sulfide ores producing both zinc and lead/silver concentrates that are transported by rail to a port in Chile for shipment to the Far East. This paper examines how MSC has taken a different approach to mining and processing that has put the company in a position of being one of the lowest cost production facilities in the world.

**10:45 AM**

## **Optimizing the Operation of Paste Thickening at Yara Siilinjärvi Plant**

*A. Baruah; Dewatering, Outotec Canada Limited, Burlington, ON, Canada*

The Yara Siilinjärvi plant in central Finland, was producing 1MT of apatite concentrate, with approx. 10 MT of tailings. Beginning of 2017, Yara has brought a new era, by replacing the conventional tailings storage facility with a new tailings treatment plant. The new high-density tailings disposal system with two paste thickeners increased UF % solid from 45-48% to 66-68%, making it possible to deposit as a paste, increasing the TSF life by 15 years. The project began with lab testing followed by successful pilot trials, the final process design was implemented. An advanced control system with process instrumentation/automation was significant for the project to meet the objective of remotely operating the plant & to achieve desired operational point. This paper discusses the results from the Yara site since the new tailings treatment plant commenced, mainly for consistent operation with an UF %solid of 66-68%, with avg beach slope angles of 3.5 deg. The advanced control system facilitates minimum use of flocculant, reducing operating cost significantly. Robust thickener operation also has led to trouble-free high-density pumping with high availability of 97% during first year of operation.

## TUESDAY, FEBRUARY 26

MORNING

9:00 AM | ROOM 612

### UCA of SME: Shafts

*Sponsored by: Nevada Copper*

**Chairs:** J. McMahon, Frontier-Kemper, Evansville, IN  
J. Terrell, Frontier-Kemper

9:00 AM

#### Introduction

9:05 AM

#### Vertical Conveyors in Deep Shaft Mining

*J. Montoya; Business Development, Frontier Kemper Construction, Evansville, IN*

In a shrinking, global mining economy, operators face challenges with the utilization of available resources and keeping efficiencies in production while minimizing OPEX and CAPEX. OEM's are helping customers achieve this balance through innovative equipment. Skip hoisting systems have traditionally been a preferred method for conveying materials. These systems, though available in many configurations, face the daunting challenge of trying to achieve high production rates with light equipment that is constrained by shaft diameter and hoist load capacity. When these restrictions are combined with intermittent cycles and high demand for power, the result is a system that places high demand on all available resources. To overcome these challenges, FKC-Lake Shore has designed, fabricated, and installed the first vertical conveyor system capable of achieving 400 meters of lift with a production of 200 TPH, working at 400 FPM with a 450 HP drive system. This is a fully-integrated solution, the vertical conveyor system works seamlessly with all the equipment (underground and surface), inter-connected allowing the entire system to work in automatic mode.

9:25 AM

#### Sirius Minerals North Yorkshire Polyhalite Project

*S. Carter; Project Development, Sirius Minerals Plc, Scarborough, North Yorkshire, UK*

Sirius Minerals Plc is currently developing the large North Yorkshire Polyhalite Project in the UK. The Project consists of the Woodsmith Mine, a 23 mile tunnel, a processing facility and a bulk port. Phase 1 of the project delivers 10Mtpa of product to market. The two mine shafts are each approximately 5300ft deep and slightly over 22ft in diameter. Headframes are set into 145ft deep / 110ft diameter foreshafts which have been constructed using Hydrofraise reverse circulation diaphragm wall cutters. The 22ft diameter shafts below the foreshafts are being constructed using Shaft Boring Roadheaders (SBR). Two shallower shafts to 1200ft are also being constructed, each approximately 30ft in diameter. A Vertical Sinking Machine (VSM) is being used for the first 400ft of the sink at Woodsmith, after which traditional sinking is used. The project has moved through a number of significant milestones – including acquiring the mineral rights, getting the necessary permissions to build the mine in a national park, selling a peak aggregate volume of 8.2Mtpa of product on a take or pay basis, and raising the first US\$1.2B tranche of the financing. Construction commenced on Woodsmith in May 2017.



**9:45 AM**

## **Boxhole Back Reaming – A Simultaneous Shaft Excavation and Lining Technology**

*M. Stöhr and S. Dube; Herrenknecht, Etobicoke, ON, Canada*

Over the past 8 years, a remote-controlled machine. Quick relocation of the BBM and minimum space requirements provide a high degree of flexibility. For the economical and safe excavation of ore passes, Herrenknecht developed the innovative Boxhole Back Reaming and Lining System technology, based on its Boxhole Boring Technology. With these, reaming and lining can be processed in one single step. The new technology provides the structure required to prevent collapsing of the hole in unstable rock after the reaming process and eliminates any rework that would traditionally be required. Furthermore, it removes or reduces the amount of activities required to occur on the extraction level during the initial mine construction and development. The new technology allows the mine owner to develop a safer and more efficient mine, which in turn leads to earlier draw bell initiation and production ramp up.

**10:05 AM**

## **Nevada Copper Corp. The Legend of Pumpkin Hollow: 1960 to 2018**

*T. Dyhr; Environmental, Nevada Copper Corp., Yerington, NV*

The Pumpkin Hollow property has been known since the 1960's. It is a cluster of large magnetite-rich copper skarn deposits located in western Nevada in the Yerington Mining District. The property hosts two near-term, permitted production mines -one underground and one large open pit. In addition to the considerable deposit size, several opportunities exist to increase mine life through resource expansion and exploration drilling. Based on the results of a November 2017 Technical Report, Nevada Copper secured financing to build the 5,000 ton per day underground mine. Mine development has been fast-tracked by re-engineering and construction commenced in August 2018. Production is anticipated in the second half of 2019. Additional technical studies are being performed on the open pit. The underground mine has an initial mine life of 13.5 years and open pit mine has an estimated 23-year mine life. The project also benefits from a federal land conveyance that resulted in an 11,500-acre private land position encompassing the entire planned and proposed underground and open pit mines. Because of the land conveyance, only Nevada state permits are required for the entire project.

**10:25 AM**

## **Managing Risk While Applying Lower Hoist Rope Safety Factors**

*J. Morrow; Stantec, Chandler, AZ*

As deeper ore deposits are considered, few single factors have as much impact on the economics of a shaft based project as the hoist rope static (or safety) factors. Globalization of the mining industry has exposed all of us to legislation from many different jurisdictions. Some companies standardize with their home legislation if the local regulations are less strict. It is tempting for all companies to apply lower static factors from different factors especially when they are from just over a border. It is critical to understand the context of these different factors. Applied correctly, additional shaft capacity can be achieved without increasing the risk to a project. Applied poorly, the opposite can be the result. This paper will explore the hoist rope legislation and standards of multiple regions including suggestions on some possible avenues in which improvements to standards can be made.

**10:45 AM**

## **Practical Application of Water Control Methods for Deep Shaft Construction**

*C. Linden; Frontier-Kemper Constructors, Inc., Evansville, IN*

There are many water control methods available for deep shaft construction. This presentation will describe the various methods of water control and the practical considerations needed for selecting the appropriate water control methods to incorporate during the shaft construction effort. Water control methods discussed will include dewatering, pre-excavation grouting, cover grouting, artificial ground freezing, alternative lining methods and various combinations of the aforementioned methods. In addition, guidelines will be discussed for developing safe and efficient working conditions within the shaft while mitigating impacts to the function and design of the final shaft lining, cost and schedule of the shaft construction and most importantly, the lifecycle costs of operating the shaft and managing residual water inflows.

**11:05 AM**

## **Shaft Electrical Cables: A Review**

*J. Fisher; Stantec, Tempe, AZ*

As underground mines become more dependent on electrical power it worth considering how we get that power underground through shaft access. This paper reviews and discusses how to size, select, install and maintain shaft power cables. Shafts will also have communication and control cables ranging from low voltage signals to fiber optic data cables. Shaft cables are often neglected because they just work: until they don't. This paper is aimed at raising awareness of shaft to ensure safer planning, maintenance and longer life of this critical infrastructure. It is also important to consider what future development we can expect for shaft cables.

**11:25 AM**

## **Unified Data Network for Tunnel Operations**

*G. Perez; Tunneling, MST Global, Golden, CO*

At present most underground developments have a fiber optic cable, and mostly it is used for data transfer (video cameras, signaling, etc). For communication, leaky coaxial cables are used, and VHF is the most used system. Very few tunnels take full advantage of having a fiber optic infrastructure. Having Wi-Fi platform underground brings among others: -Tracking by using RFID's tags, knowing the precise location of people while underground Communications by Voice over the Internet Protocol (VoIP) phones, radio or push-to-talk functions also compatible. Wireless data transfer, providing access to the internet and allowing the use of smart phones. For exceptional maintenance operations in locations where there is no infrastructure for communications or data transfer, Wireless Repeater Nodes (WRN) have a perfect fit. They are mobile self-meshing network extender/access point. Intended for the extension of an existing Wi-Fi network. The WRN are designed to enable multiple nodes in a redundant mesh implementation, effectively filling communication black spots or "gaps."

**TUESDAY, FEBRUARY 26**

*MORNING*

**9:00 AM | ROOM 210**

## **Valuation: Case Studies**

*Chairs: E. Mudd, Rock Associates, LLC,  
Overland Park, KS  
E. Moritz, Gustavson, Boulder, CO*

**9:00 AM**

### **Introduction**

**9:05 AM**

### **Valuation of Mineral Properties with Split Ownership**

*D. Hambley; Agapito Associates, Inc., Lakewood, CO*

Nowadays, the ownership of a mineral property may be split among multiple mining companies or, in some cases, multiple subsidiaries of a single company with differing percentages of ownership. Valuation of the resources and reserves of the property in the latter case must take into account the percentage ownership the company holds in each subsidiary as well as the subsidiary's cost structure. This situation becomes more complicated if mines in one subsidiary send their broken rock to the mill of a different subsidiary for processing for geographic reasons. This paper presents an example of a valuation for such a case for a hypothetical gold mining company with 7 mines and 3 concentrators within one operating unit that are split among three subsidiaries with different ownership percentages.

**9:30 AM**

### **Mineral Highlights from Uniform Appraisal Standards for Federal Land Acquisitions**

*J. Gustavson; Mineral Appraiser LLC, Boulder, CO*

The 2016 edition of the UASFLA, known as The Yellow Book, offers benefits over the 2000 edition. It contains excellent citations to landmark mineral appraisal cases and a special section on Valuation Approaches for Mineral Resources. This paper highlights when UASFLA standards are mandated (such as for appraisals touching on Federal land ownership incl. collateral in bank lending and 5th Amendment Takings). Also, the difficulties are described when needing to apply the Larger Parcel concept to minerals as part of the overall real estate (is there common use, ownership, propinquity?). The Unit Rule is discussed, showing how the overall property must be appraised, namely the whole "bundle of sticks" rather than the sum of the values of the various interests into which it may have been carved (such as landowner's mineral right versus operator's leased interest). Yet, this may also allow a minerals appraiser to form "bridges" for adjustment to market value from one to another "stick of the bundle". It is observed that the relative values change widely with Highest & Best Use of a mineral property.

**9:55 AM**

## **Observations of Discounted Cash Flow Models Used in Regulatory Filings**

*A. Jacobsen and R. Cameron; Behre Dolbear (USA), Denver, CO*

A mining company files various forms of discounted cash flow analyses for mineral projects to government agencies. Often these are developed for a particular purpose and many times were developed to address certain economic projections and milestones required by a government for license or permitting issues. It is important to note that these discounted cash flows may or may not represent a true fair market value of a project although, it may be presented as such in legal and arbitration hearings or proceedings. This presentation will explore a few different types of regulatory filings and outline what the mineral appraiser should evaluate when determining the true fair market value of mineral property.

**10:20 AM**

## **New Technology Boosts Industrial Minerals: A Valuation Perspective**

*E. Mudd; Rock Associates, LLC, Overland Park, KS*

In recent years, developments in technology have enabled mines to extract greater amounts of marginal and previously unmarketable resources than ever before. For industrial minerals, innovations in product sorting, advanced mine planning, and supply chain simulations are creating opportunities to develop new products, enhance operating efficiency, and reduce risk exposure. Case studies illustrate how technology implementation within the industrial minerals sector can enhance recovery of mineral resources, alter market dynamics, and, impact opinions of value.

**10:45 AM**

## **Definition of Rights Case History**

*E. Moritz; Gustavson, Boulder, CO*

A fundamental important step in the appraisal of a petroleum or mineral interest is the definition of rights. Although mineral appraisers typically rely on the Client for this information, there are often instances where the Client does not have complete information or does not even know details of their mineral interest. For oil and gas interests that generate income from production, sometimes the valuation is done by shorthand income multiples. This method while convenient may lead to an inaccurate market value determination depending on the future development potential. A case history is presented to show how taking the extra step to research the definition of rights had a material impact on the market value determination.

**11:10 AM**

## **Trends in Gold Property Transaction Values 2016-18**

*W. Roscoe, P. Chamois and G. Malensek; RPA Inc., Toronto, ON, Canada*

RPA has reviewed transactions globally from January 2016 to December 2018 on gold properties containing mineral resources and mineral reserves. The property values derived from the transactions have been normalized in terms of \$/oz contained gold or gold equivalent where gold is the dominant component. Trends in \$/oz values are examined over the 36-month period for producing versus non-producing properties, in different political jurisdictions, and with different resource and reserve sizes.

**TUESDAY, FEBRUARY 26**

*MORNING*

**9:45 AM – 10:30 AM | ROOM 710**

## **CMA: The Future for Coal Use in the U.S.**

*Eric Eddings; Department of Chemical Engineering,  
University of Utah, Salt Lake City, UT*

Colorado produces over 15 million tons of high quality, clean burning, low sulfur coal generating electricity for Colorado, the U.S. and the world. While a few environmental advocates wish to keep coal in the ground as a way to address climate change, communities that produce coal are eager to expand the ways Colorado coal can continue to generate electricity and be used for other purposes. Professor Eric Eddings of the University of Utah will present exciting new uses of coal communities can consider as they develop their economic development plans for the future.

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**TUESDAY, FEBRUARY 26**

*MORNING*

**10:30 AM – 11:30 AM | ROOM 710**

## **CMA: An Ephemeral Landscape: Traversing the Fractured Regulatory Dynamics Surrounding Abandoned Mines and Mining Districts**

*Anthony Edwards; Sholler Edwards LLC, Silverton, CO  
Paul Nazaryk; Ramboll US Corporation, Durango, CO*

The Bonita Peak Mining District Superfund site is located within the Upper Animas Watershed with approximately 400 abandoned mines in San Juan County near Silverton, Colorado. Through the lenses of the Gold King Mine spill, this presentation will explore the intersection of the 10th Circuit Chevron Mining Inc. v. U.S., decision and other contemporary regulatory developments including the Superfund Reform Plan and the White House Reform Plan with the nuances of the federal land ownership. The presentation will discuss their implications for mining companies and suggest proposed solutions for addressing legacy mineral waste in the West.

## TUESDAY, FEBRUARY 26

AFTERNOON

### 1:30 PM – 4:00 PM | ROOM 710 **CMA: Technology in Mining** *Sponsored by Wagner Equipment Co.*

#### **Moderator:**

**Ginny Brannon**

*Director, Division of Reclamation, Mining and Safety*

#### **Panel:**

**Christopher Bowles**

*Ramboll, Arlington, VA*

**Devin Castendyk**

*Golder, Denver, CO*

**Sean Hovorka**

*Trapper Mining, Inc., Craig, CO*

**Mike Rawitch**

*Ramboll, Overland Park, KS*

**Michael Scott**

*Propeller Aero, Denver, CO*

**Jim Stark**

*Colorado Division of Reclamation, Mining and Safety, Denver, CO*

The use of drone technology to assist mine operators and professionals has rapidly expanded in all aspects in mining. This session will feature the latest in application of drone technology along with technical developments that help strengthen Colorado's mining future.

**TUESDAY, FEBRUARY 26**

*AFTERNOON*

**2:00 PM | ROOM 507**

## **Bulk Material Handling: New Technology in Bulk Material Handling**

*Sponsored by: BEUMER Corporation*

**Chair:** *T. Burchett, Rexnord, Christiansburg, VA*

**2:00 PM**

### **Introduction**

**2:05 PM**

### **Gearless Drives for Medium Power Conveyors: Benefits and Operational Data Review from a Commercial Installation**

*U. Richter<sup>2</sup> and D. Andreo<sup>1</sup>; <sup>1</sup>Process Industries, Mining, ABB Inc., Littleton, CO and <sup>2</sup>Process Industries, Mining, ABB, Cottbus, Germany*

Two years ago, the material handling market has seen the introduction of an innovative combination of well-proven technologies to drive conveyors in the 800 – 4,000 HP range: Medium Power Gearless Conveyor Drive. By using a low-speed, high-torque, permanent magnets motor the need for gearboxes is eliminated. This is truly the lowest cost-per-ton drive solution for conveyors. Not only energy losses are reduced by over 30%, but also failure rate is decreased by over 50% thus allowing higher utilization. The compact design enabled by the use of totally enclosed permanent magnets motors is ideal for retrofit applications. The presentation, together with a general technology overview, provides a review of the operation and performance data from a real commercial installation where Medium Power Gearless Conveyor Drives have been chosen to retrofit an existing conveyor.

**2:25 PM**

### **New Trends in Material Handling: Autonomous Operation of Stockyard Machines & Smart Drive Applications**

*C. Dirscherl; Minerals, Siemens Industry Inc., Littleton, CO*

Digitalization for material handling applications In many parts of the world, deposits of ore content are decreasing while labor cost continue to rise. For mines to continue successfully, both operational costs must be optimized and the highest standards for Health, Safety, Security and Environment achieved. Autonomous operation of stockyard machines (e.g. stacker, reclaimer) and advanced material handling systems are accomplishing just that. These systems are paramount in helping mines reduce operational costs with the added benefit of increased safety. Digitalization of stockyards allows the following functions: Material Quantity tracking Material Quality tracking Real time material inventory Blending of desired qualities Simulation of storage Mine operators are also turning their attention to other aspects to improve conveyor operation; one of which is intelligent drive control. Proper drive control has the potential to limit wear and optimize the operation of mechanical components, such as gearboxes, belts and pulleys. This drive control is also likely to increase the lifetime of major mechanical gears.

**2:45 PM**

## **Bulk Solids Virtual Simulations vs. Real World Performance**

*C. Hartford and D. Craig; Jenike & Johanson, San Luis Obispo, CA*

Investigations reveal that the throughput difference between a perfect production day and an average is ~ 40%, and that bulk solids handling (BSH) system deficiencies are the largest (>50%) class of lost opportunity. To reduce or eliminate BSH problems requires an analysis of troublesome equipment – for example, a transfer chute that experiences plugging, excessive wear, unacceptable dust generation, high belt wear, and product spillage. These problems often lead to significant maintenance costs because of the need to unplug chutes, pick up spillage, or frequently replace wear liners. Further, the process may include a stockpile that only functions at 10% live capacity, or a bin that plugs causing unreliable flow. Simulation tools, such as calibrated Discrete Element Method (DEM) models, can be used to build a virtual model of material flow through the plant such as bins, stockpiles, and transfer chutes. Then changes can be made in these virtual numerical models, such as flowrate and material characteristics (e.g. higher clay/fines/moisture), to evaluate how the changes will respond in reality. Then design or operational changes can be planned for to ensure a successful change.

**3:05 PM**

## **New Generation Drum Motor Addresses Efficiency and Reliability of Belt Conveyors Operating in Extreme Environments**

*M. Lepp; Engineering, Van der Graaf, Shelby Township, MI*

The design and manufacture of drum motors to reliably operate in mining and aggregate applications has been a monumental task. Abrasive dust in the coal mine, fine powdery dust of the limestone quarry, and abrasive steel particles of the iron ore mine, combined with high belt tension, moisture and system vibration, requires a specifically engineered drum motor to meet the demands of belt conveyors to operate in these types of environmental conditions with minimized downtime. Essential design features of the Van der Graaf GrizzlyDrive™ drum motor has been developed exactly for these types of dusty and high vibratory conditions and to operate with efficiency, reliability and longevity. Drawing on over 30 years' designing and manufacturing drum motor experience, the new GrizzlyDrive™ is setting a new standard for motorized head pulleys. The GrizzlyDrive™ drum motor with patented IronGrip lagging, incorporates an advanced sealing system, bearings, shafts and motor technologies to provide years of safe and reliable operation in the harshest of conditions. This new line of drum motors has raised the expectations of belt conveyors' performance in the aggregate and mining industry.

**3:25 PM**

## **Critical Enabling Role of Overland Conveying in Electrification Initiatives in Mining**

*T. Barr; BEUMER Group, Somerset, NJ*

The efficiency of mining operations is heavily influenced by major mechanical and electrical installations. There is, accordingly, a progressively sharpening focus on mining electrification—with primary emphasis on processing and processing-related equipment and systems. Intra-operational handling of bulk, mined materials, paradoxically, receives less attention but represents a key opportunity for both sustainability and economic optimization in the broader context of electrification. This paper presents and validates a model of electrified bulk material transport that offers key advantages over diesel and fossil



fuel transport methods, as well as over conventional conveyor-based methods. Comparing lifecycle effects of a single-flight overland conveyor-based method with (a) multi-flight conveyor-based methods and (b) truck-based transport methods, this paper qualifies and quantifies single-flight conveying as a sustainable, economically optimized enabler of mining electrification initiatives.

**3:45 PM**

## **Case Study: Cuaajone High Capacity Coarse Ore Handling System**

*T. Mess; Project Management, thyssenkrupp Industrial Solutions, Greenwood Village, CO*

The newly commissioned coarse ore handling system for Southern Copper's Cuaajone Mine in Peru is an impressive crushing and conveying system that replaces the aging rail haulage that served the mine for 40 years. The heart of the new system is a 6.5 km overland conveyor that winds through the valley from the open pit to the plant location, powered by dual 6 MW Siemens gearless drives, the most powerful conveyor drives in operation in the world today. Multiple thyssenkrupp offices worked together with M3 to design, supply and construct the 120,000 ton per day coarse ore system that will significantly lower the mine's operating costs.

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## **TUESDAY, FEBRUARY 26**

*AFTERNOON*

**2:00 PM | ROOM 706**

## **Coal & Energy: Automation Innovation and Current Developments**

*Chairs: Z. Agioutantis, University of Kentucky, Lexington, KY*

*J. Sottile, University of Kentucky*

**2:00 PM**

### **Introduction**

**2:05 PM**

## **Opportunities and Challenges for Autonomous Shuttle Car Operation in Underground Coal Mines**

*V. Androulakis, Z. Agioutantis, S. Schafrik and J. Sottile; Dept. of Mining Engineering, University of Kentucky, Lexington, KY*

The repetitive nature of the current shuttle car operation exposes the operators to numerous hazards including fatigue related incidents and soft tissue injuries, poor visibility related incidents, noise and dust. To reduce the risks for all miners, the introduction of autonomous shuttle cars is essential. This paper introduces a project to demonstrate the feasibility of incorpo-

rating autonomous shuttle cars in the underground coal mining cycle. The autonomous shuttle car will be able to localize itself, map its surrounding and navigate in an underground GPS-denied environment. It will, also, navigate efficiently by fusing different on-board sensor modalities, autonomously planning the optimum path and traversing around the mine while avoiding collisions with humans and other obstacles. Lab scaled prototypes will be designed, as well as a full scale demonstration prototype will be created by retrofitting an active shuttle car. Moreover, a modified mining system will be demonstrated which will incorporate effectively the autonomous shuttle car into the underground coal mining cycle. Focus will be given in coal mines, where the room and pillars mining method is used.

**2:25 PM**

### **Why Integrate Power and Process for Mining Applications**

*D. Mazur and R. Entzminger; Rockwell Automation, Milwaukee, WI*

Coordination of large distributed measurement and control systems, such as SCADA and other process control system implementations, require robust networks that connect thousands of remote devices from multiple locations. The mining industry has increasing demands of their infrastructure to handle more network services and deliver a full spectrum of control and monitoring within their global operations. Conventional methods for mining applications provide two separate domains, infrastructure and process automation that typically do not communicate. With the advancement of the industrial communications and rising energy costs, these domains can provide value to mining applications when logically integrated. Unifying the power and process systems within an operation provides value by creating a single visualization and reporting environment. This paper will outline a method of providing a convergent use of the IEC 61850 standard, within process control networks, to provide enhanced process control, monitoring and energy management. The paper will discuss benefits of a unified power and process architecture with enhancements provided by visualization, archiving, and reporting.

**2:45 PM**

### **Mineworkers Perceptions of Mobile Proximity Detection Systems**

*J. Bellanca, L. Swanson, J. Helton and M. McNinch; CDC NIOSH, Pittsburgh, PA*

Accident data indicates that mobile haulage poses a significant risk. Proximity detection systems (PDS) have the potential to protect mineworkers. However, unintended consequences can undermine their safety. It is critical to understand how mobile PDS may hinder normal operations and endanger mineworkers. Researchers explored users' perspectives by conducting interviews with mineworkers from mines that have installed mobile PDS on some of their haulage equipment. Mineworkers reported that mobile PDS affects loading, tramming, section setup, maintenance, and general work on the section. Mineworkers discussed operational changes and increased burden, exposure, and risk. This paper gives recommendations for mobile PDS implementation.

**19-056**

**3:05 PM**

## **Feedback Control of Magnetic Proximity Detection Systems Used in Underground Coal Mines**

*J. Li, A. Smith, J. Carr and B. Whisner; The National Institute for Occupational Safety and Health, Pittsburgh, PA*

To reduce fatalities in underground mines, magnetic proximity detection system (PDS) has been recently introduced on underground mining equipment. It was observed that the accuracy of PDS is influenced by temperature and nearby metal masses. The magnetic field of PDS could be distorted by internal inductive components. A feedback system (FBS) was developed for a PDS in a laboratory environment. Test shows that the FBS can stabilize the performance against those disturbing factors and correct the field. The paper compares the performances of the PDS with and without the FBS to demonstrate the effectiveness and improvement of PDS performance.

**3:25 PM**

## **Using a Cognitive Work Analysis Framework to Introduce Automation in Room-and-Pillar Mining**

*A. Miller<sup>1</sup>, J. Engstrom<sup>1</sup>, E. Jong<sup>2</sup> and Z. Agioutantis<sup>3</sup>; <sup>1</sup>Virginia Tech Transportation Institute, Blacksburg, VA; <sup>2</sup>Mining and Mineral Engineering, Virginia Tech, Blacksburg, VA and <sup>3</sup>Mining, University of Kentucky, Lexington, KY*

A Cognitive Work Analysis (CWA) provides a framework for the organizational work domain and can be used to understand and outline the constraints in replacing manual roles with automated systems. A CWA was conducted on the individual, organizational, and social systems at a room-and-pillar coal mine in the Eastern US to assess the impact of introducing an autonomous shuttle car system within the work domain. Completion of the CWA involved conducting interviews of affected roles, discussions with subject matter experts, and collecting observational and written data, including safety training manuals, operational handbooks, and job descriptions. Analyses produced a detailed representation of underground personnel responsibilities and duties as well as individuals' interactions with materials, equipment, and other tools across the underground mining operation. This creates a formal structured description of the work domain that can be used as basis for addressing automation integration. Special focus is given to communication and safety protocols affected by introducing the autonomous shuttle car. Other domain priorities include maintaining compliance and productivity standards.

## TUESDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM 702

### Coal & Energy: Coal Mine Reclamation I

*Chairs: P. Conrad, Montana Tech, Butte, MT*

*J. Turner, Tetra Tech, Golden, CO*

2:00 PM

#### Introduction

2:05 PM

#### Intersection of Coal Mining and Alternative Energy

*A. Campoli; ECSI, Lexington, KY*

A selection criterion was developed to identify potential solar power sites on abandoned West Virginia Mine lands. Barrier and opportunity analysis from various stakeholder perspectives was combined with spatial evaluation of mine sites in the West Virginia permit database. Barriers: severed mineral ownership, possibility of future mining, perceived environmental liabilities, remote locations, potential subsidence. Opportunities: large tracts of underutilized land, early bond release, existing power infrastructure, landowner revenue, new industry, corporate and utility company sustainability goals. The potential of favorable sites was ranked. Development will be driven by falling solar costs. Large corporations are the necessary silver bullet to spur utilities to action. Factories powered by solar power on or adjacent to selected sites are the most probable developments.

19-031

2:25 PM

#### Developing Trees Tolerant to Degraded Mine Tailings and Soils in Butte, Montana

*F. Inkoom<sup>1</sup>, P. Conrad<sup>1</sup>, R. Pal<sup>2</sup>, C. Opoku-Ware<sup>3</sup> and M. Kukay<sup>4</sup>; <sup>1</sup>Mining Engineering, Montana Tech, Butte, MT; <sup>2</sup>Biological Sciences, Montana Tech, Butte, MT; <sup>3</sup>Barrick Gold, Elko, NV and <sup>4</sup>Retired, Butte, MT*

Researchers at Montana Tech are investigating the potential for developing trees tolerable to degraded un-reclaimed mine site tailings and soils as a solution to re-establishing long-term tree growth on those sites. This project involves growing tree seedlings from seeds planted in the degraded mine tailings and soils in which they will eventually be planted. The outcome of the project is expected to lead to a successful solution for re-establishing tree growth in degraded tailings and soils in Butte, Montana with minimal post-planting human intervention. Work conducted on the project to date has shown successful growth of seedlings in degraded tailings and soils.

19-030

**2:45 PM**

## **Activation of Seed Bank Can Lead to Better Restoration Success in Areas of Aeolian Contamination**

*A. Osabutey<sup>1</sup>, P. Marques<sup>2</sup> and R. Pal<sup>1</sup>; <sup>1</sup>Biological Sciences, Montana Tech of the University of Montana, Butte, MT and <sup>2</sup>Big Hole Watershed Committee, Divide, MT*

The Joiner Gulch area has been impacted by land-clearing and from aeolian contamination from copper smelting occurring from the late 1880's through the 1970's. Today the land is characterized by great erosive forces because of the lack of vegetation. Several restoration approaches have been applied in the area. However, before restoration efforts are widely executed it is recommended to evaluate the resiliency of the target environment. The scope of this project is to test the potential seed bank of the area that could be activated. Also we tested the effects of additional seed augmentation and of different amendments that have been utilized in earlier projects (bio and synthetic fertilizer, mycorrhizae). The approach is to use a greenhouse based seed bank test. Treating soils with different amendments significantly increased the grass and forb seedlins. Seed augmentation significantly increased the seedling number. Mycorrhizae application had no effect. Our results show that the soils of the area have a significant seed bank to be activated, however, the resulting diversity is rather low, therefore the augmentation of additional species is highly recommended.

**3:05 PM**

## **Coal in Ruhr, Germany: Industry in Transition. An American perspective**

*C. Suarez<sup>1</sup>, S. Moellerherm<sup>3</sup>, J. Kretschmann<sup>3</sup> and J. Brune<sup>2</sup>; <sup>1</sup>Student, Golden, CO; <sup>2</sup>Mining Engineering, Professor, Golden, CO and <sup>3</sup>Mining Engineering, Professor, Bochum, Ruhr, Germany*

The closure of the last deep bituminous coal mines in Germany's Ruhr region has triggered a major social and economic transition. When the last two mines close in 2018, a 200-year history of coal mining and steel production in Ruhr comes to its end. This paper will look into the economic, social and cultural transitions in the Ruhr region and how they affect the miners, their families and communities from the perspective of an American student. It will look into the roles of governments, labor unions, mining companies and service industries in mitigating the impact of the mine closures and the transition to "post-mining" life. The authors conducted interviews with influential stakeholders to examine the German cultural values and structural norms that help drive this transition and compare how they differ from American traditions and cultural standards.

**19-105**

**3:25 PM**

## **Unmanned Aerial Vehicle (UAV) Technology for Mine Planning and Reclamation Assessment**

*M. Maguire; Civil & Environmental Consultants, Pittsburgh, PA*

Unmanned Aerial Vehicle (UAV) technology provides several benefits to the “life cycle” of mine operations, from initial mine planning to eventual site reclamation. With minimal setup, short flight times, and quick delivery of topographic data, UAVs streamline aerial survey for stockpile and site balance calculations at mine sites. Going well beyond high-resolution photos and videos, drone-mounted sensors can capture thermal and infrared data for specialized analysis, benefitting facility inspection and environmental monitoring at reclaimed sites. This presentation will provide an overview of UAV sensor technology and data deliverables pertinent to mining operations, focusing on two key areas of the life cycle. First, a mine planning case study will be presented, describing UAV reserve estimation and asset retirement obligation (ARO) reporting at sites in central Pennsylvania. Second, related to post-mining activities, techniques for vegetation monitoring using near-infrared (NIR) drone sensors will be discussed. Key for assessing mine bond release, this method provides an efficient and safe alternative to extensive field survey for reclamation vegetation cover assessment.

**3:45 PM**

## **The Benefits of Concurrent Reclamation**

*J. Collyard; SLR, Lakewood, CO*

Concurrent reclamation is beneficial to all stakeholders and can be integrated into mine plans at nearly all stages of the mine life cycle. What are our goals as stakeholders in the mining industry? The mine owner(s) want to reduce risk, free up capital for this or other operations, and minimize the cost and duration of closure and post-closure activities. The mine operator wants to reduce risk, utilize freed up capital at the site, manage the mine as efficiently as possible, and reduce the level of effort and cost of closure and post-closure activities. The regulatory agencies want to reduce risk, have an up to date and effective closure strategy, and a sufficient financial assurance mechanism for closure. The community wants to reduce risk, maintain or increase property values, and maintain a high quality of life. The insurance brokers want to reduce risk, free up capital for other investments, and have more fluidity with their investments. The common goal for all stakeholders is risk reduction and although risk is defined differently between all stakeholders, risk is reduced for all stakeholders through successful concurrent reclamation planning and execution.

TECHNICAL PROGRAM: TUESDAY

**TUESDAY, FEBRUARY 26**

*AFTERNOON*

**2:00 PM | ROOM 708**

## **Coal & Energy: Research and Development I**

***Chairs:** M. Trevits, Xtraction Science and Technology, Inc, Pittsburgh, PA  
S. Schafrik, University of Kentucky, Lexington, KY*

**2:00 PM**

### **Introduction**

**2:05 PM**

### **A Case-study of Roof Support Alternatives for Deep Cover Room-and-Pillar Retreat Mining Using In-situ Monitoring and Numerical Modeling**

*G. Rashed<sup>1</sup>, M. Sears<sup>1</sup>, J. Addis<sup>1</sup>, K. Mohamed<sup>1</sup> and J. Wickline<sup>2</sup>; <sup>1</sup>NIOSH, Pittsburgh, PA and <sup>2</sup>Coronado, Beckley, WV*

To better understand the load shedding and the stress transfer on coal pillars due to room-and-pillar retreat mining in deep cover panels, researchers from the National Institute for Occupational Safety and Health (NIOSH) conducted a monitoring field study. Two sites, at overburden depths of 1,000 ft (304.8 m) and 1,500 ft (457.3 m), were selected in a room-and-pillar at a mine operating in Southern West Virginia. The deformation and stress changes in the roof and two adjacent pillars at each site were monitored during the retreat mining process. The monitoring results and field observations were used to calibrate large-scale FLAC3D models for each site. The calibrated model was used to assess different sizes of roof bolts installed in deep cover areas.

**19-076**

**2:25 PM**

### **Loading Characteristics of Mechanical Rib Bolts**

*K. Mohamed; NIOSH, CDC, Pittsburgh, PA*

Mechanical anchor bolt consists of a smooth bar threaded at the anchor end, a conical wedge, and a mechanical shell anchor. When the smooth bar is torqued, the conical wedge pushes the shell anchor against the borehole wall. Coal mines use mechanical bolts to control the deformation of coal ribs by stabilizing sloughed coal ribs. An engineering design for rib control requires the determination of the loading characteristics, stiffness, and capacity of the mechanical rib bolts. A standard pull-out test can provide enough information to define the loading characteristics of a mechanical rib bolt. Eighteen mechanical bolts of 5/8-in diameter and grade 75 from a single manufacturer were used for a pull-out study that was conducted at the NIOSH Safety Research Coal Mine of the Pittsburgh Mining Research Division (PMRD). Nine bolts were 4 ft long and the other 9 bolts were 5 ft long. Each bolt length was torqued for three levels—75, 100, and 120 ft·lb. The tri-linear load-deformation model obtained from tests was successfully tested in four active mines. It was found that the anchorage capacity depends on the coal strength and the anchorage stiffness depends on the applied torque.

**19-054**

**2:45 PM**

## **Satellite-Bound Monitoring of Abandoned Mine Sites**

*S. Moellerherm, P. Goerke-Mallet and C. Melchers; Research Institute of Post-Mining, Technische Hochschule Georg Agricola, Bochum, Germany*

In the Ruhr area in Germany the old mining sector creates special risks for the safety of the ground surface, the population and the environment. Unstable abandoned mine openings and sub-surface mine workings, uncontrolled methane emissions and acid mine drainage must be considered. At this point monitoring measures come into focus. The Research Institute of Post-Mining is working on the application of satellite data from the European project "Copernicus" for remote sensing and monitoring of current post-mining processes. Particular emphasis is placed on the hydrochemistry of water bodies, the soil water content, the land use and the land coverage. With respect to the potentials of the Copernicus-program and the reliability of the data provision, the connection between information provided by the satellites and terrestrial expertise will lead to an innovation of monitoring. Therefore, it will be able to reduce post-mining risks and increase post-mining chances like the valorisation of mining infrastructures for the recovery of renewable energy. This paper will discuss the various satellite monitoring components being used for post-mining risk assessment.

**19-115**

**3:05 PM**

## **Behavior of Full Scale Welded Wire Screen for Large Mine Roof Skin Falls**

*T. Batchler and T. Klemetti; CDC NIOSH - PMRD, Pittsburgh, PA*

A large number of documented injuries from ground falls in underground coal mines in the United States. The majority of these ground-fall injuries were not caused by a major roof collapse, but from falls of smaller rocks from the immediate roof. Roof screen can significantly reduce the number of these injuries and has been widely used in underground mines for surface control. Because of the potential of reducing ground-fall injuries, the National Institute for Occupational Safety and Health is further evaluating the performance characteristics of roof screen as used in underground mines by conducting a laboratory testing program using the Mine Roof Simulator (MRS) in Pittsburgh, PA. The load-displacement characteristics of an 8-ft x 12-ft panel of 8-gauge welded screen were evaluated using a large laboratory screen test frame with multiple pull point capabilities. This screen was tested in a configuration that simulates current installation practices in U.S. coal mines. In this study, isolated sections of screen were tested using a significantly greater pull point surface area to simulate the effects of larger roof falls and the screen reaction.

**19-028**

**3:25 PM**

## **An Improved Load Measuring Device for Underground Mining Standing Supports**

*B. Stables; Jennmar, Princeton, WV*

Standing support is often used in conjunction with underground retreat mining. Knowledge of the load-displacement behavior of a standing support, and loading induced by the mine opening is critical to proper support selection. The NIOSH STOP database contains load-displacement laboratory test data



for most commonly used standing supports. Hydraulic load cells currently used to measure in-situ loading of standing supports have exhibited leakage under load, producing irregularities within the dataset. An improved hydraulic load cell eliminates leakage and produces more consistent data.

19-128

**3:45 PM**

## **A Historical Summary of the Development and Diffusion of Proximity Detection Technology for Mobile Underground Coal Mining Equipment**

*J. Carr, C. Zhou, M. Reyes, J. Li and A. Smith; CDC NIOSH, Pittsburgh, PA*

Miners can be killed in underground coal mines when they are struck by mobile equipment. Proximity detection systems have emerged as a means of helping to prevent these types of accidents. This paper summarizes the roughly two-decade history of the development and diffusion of this technology, with a particular focus on the role that government research, led by the National Institute for Occupational Safety and Health (NIOSH), has played. This summary includes major technological and regulatory changes as well as challenges that have limited the success of the technology's diffusion. Finally, current research at NIOSH on proximity detection is summarized.

19-038

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## **TUESDAY, FEBRUARY 26**

*AFTERNOON*

**2:00 PM | ROOM 704**

## **Coal & Energy: Surface Mining: Advancement Through Innovation**

*Chair: J. Wientjes, Komatsu America Corp., Peoria, IL*

**2:00 PM**

**Introduction**

**2:05 PM**

## **Automated Operator Assistance for Loading Excavators**

*G. Danko; Mining and Metallurgical Engineering, Univ. of Nevada, Reno, Reno, NV*

Automation and robotics are needed for mine loading operations for increased productivity and grade control. Energy and machine wear must also be minimized for high loading performance. These are difficult tasks to fulfill simultaneously by the loading operator. Partial automation by human-robot machine control is developed to assist the operator in the digging and loading tasks. The human operator of a hybrid machine can adjust the pro-

programmable path of the loading bucket during operation while the automatic control executes the programmable path with continuous safety checks and the best machine motion parameters for optimal performance. Loading and excavating along adjustable trajectories at the face of the open-pit benches are discussed. Programming the path of the bucket by joystick control is easier and safer than controlling the individual joints of the excavator. Simulated and experimental loading examples with a hybrid excavator show that the human-robot control simplifies the loading job of the operator while reduces the loading cycle time and energy consumption. The efficiency of the operator can be increased for any given skill level.

## 2:25 PM

### 794 AC Performance Implementation

*A. Reid and A. Varela; Caterpillar, Washington, IL*

The GAN-Micare mine is located in the Rio Escondido basin. Micare produces coal for energy creation used in two thermoelectric plants, whose joint capacity provide almost 10% of Mexico's energy. Caterpillar together with dealer Madisa were awarded an 8 ultra-class mining truck deal with GAN-Micare in 2017. This introduced the 320 short ton 794 AC electric drive haul truck to the Mexican mining market. The 794 AC Performance Implementation project was a focused effort to support the high availability market introduction Caterpillar has had with the 794 AC. Fleet availability represents one of the key components of Cost per Ton. The improvement objective was the creation of a fleet uptime program in collaboration with the dealer and customer. The program included documentation of a time usage model, machine stoppage categorization, data reconciliation with customer, ongoing performance communication between Madisa and Caterpillar team, creation of a tailored KPI standard work, and the implementation and training of a fleet performance governance system through Caterpillar's proprietary machine uptime tracking system Digital Performance Plus.

## 2:45 PM

### Surface Coal Mining Incidental to Land Development for the Natural Gas Industry

*B. Faulkner; Environmental Department, Civil & Environmental Consultants, Inc., Princeton, WV*

Fossil fuel extraction activities often involve interaction between coal mining interests and natural gas exploration and transmission/distribution. In West Virginia, the removal of coal at construction sites is regulated by a special authorization for a general permit by the state regulatory authority (West Virginia Department of Environmental Protection). The "Incidental Coal Removal Permit" addresses all substantive requirements of a SMCRA surface mine permit, and those stormwater permits required under other Federal and State statutes. Challenges from previous mining, legacy underground mine discharges, potential to produce acid mine drainage and current marketability of the coal resource complicated the gas company's efforts to develop a compressor facility atop a small knoll in the heart of coal country. Extensive

testing of coal/overburden/underlayment was performed to characterize the marketability of the coal and special handling, neutralization and encapsulation of acid-forming materials was addressed in the permit application to preserve water quality.

**3:05 PM**

## **The Effect of Truck Bunching Due to Payload Variance on Productivity and Energy Consumption in Surface Mines**

*A. Soofastaei; Artificial Intelligence Center of Excellence, VALE, Brisbane, QLD, Australia*

Data collected from truck payload management systems at various surface mines shows that the payload variance is significant and must be considered in analysing the mine productivity, energy consumption, greenhouse gas emissions and associated cost. Payload variance causes significant differences in gross vehicle weights. Heavily loaded trucks travel slower up ramps than lightly loaded trucks. Faster trucks are slowed by the presence of slower trucks, resulting in 'bunching', production losses and increasing fuel consumptions. This study simulates the truck bunching phenomena in large surface mines to improve truck and shovel systems' efficiency and minimise fuel consumption. The study concentrated on completing a practical simulation model based on a discrete event method which is most commonly used in this field of research in other industries. The details of all components of the model have been presented in this study by various algorithms and related formulas. The simulation model has been validated by a dataset collected from a large surface mine in Arizona state, USA.

**3:25 PM**

## **Advanced Data Analytic: An Innovative Method to Decrease Fuel Consumption of Haul Trucks in Surface Mines**

*A. Soofastaei; Artificial Intelligence Center of Excellence, VALE, Brisbane, QLD, Australia*

This project aims to develop a comprehensive artificial intelligence model based on advanced data analytic methods to improve trucks energy efficiency in surface mines. Payload, truck speed and the haul road total resistance are critical parameters that affect truck energy efficiency. The relationship between the principal parameters and the truck energy consumption is estimated by using an Artificial Neural Network (ANN), method. The ANN model is trained and validated using real data collected from four large surface mines in The United States and Australia. The ANN model efficiently creates a fitness function for the truck energy consumption. This function is applied to develop a digital learning algorithm based on Genetic Algorithm (GA) and estimate the optimum values of effective haulage parameters to reduce the diesel fuel consumption by haul trucks in surface mines.

**3:45 PM**

## **Optimization of Shovel Cycles through Effective Truck Guidance**

*C. Orr; Machine Guidance, Modular Mining Systems, Tucson, AZ*

Many challenges are associated with optimizing the load cycle at open pit mines. The introduction of the first integrated operator assist, Guided Spotting technology, which leverages high-precision GNSS positioning data to guide truck operators as they reverse to a shovel's loading point, has already

addressed several of these challenges. This presentation will investigate detailed results of the first ever large-scale deployment of this new category of mining technology. Data analysis will show the potential productivity improvements that mines can attain by introducing double-sided loading, minimizing shovel hang time, virtually eliminating re-spotting, and optimizing operator performance.

## TUESDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM 711

### Coal & Energy: Ventilation Innovations

*Chairs: P. Tukkaraja, South Dakota School of Mines and Technology, Rapid City, SD  
M. Gray, MSHA, Washington, PA*

2:00 PM

#### Introduction

2:05 PM

#### Auxiliary Ventilation Layouts for Noise Control in Underground Coal Mines

*F. Calizaya; Mining, University of Utah, Salt Lake City, UT*

In coal mines, auxiliary fans are used mostly in exhaust configuration with rigid ducts, and equipped with flameproof motors. To comply with federal regulations, the ducts are extended frequently to keep the duct inlet within 3m of the face. Depending on the airflow requirements and duct diameters, the fan pressures could be as high as 3.75 kPa (15 in.w.g.). Usually, these fans are equipped with high speed motors, and therefore, they are noisy. Silencers are often not installed or if installed they are not maintained. This study presents the results of a set of sound level measurements carried out in three underground coal mines where auxiliary fans are used regularly. Sound levels as high as 98 dB(A) by the workings and 110 dB(A) by the fans were measured in these mines. These levels are quite high even for intermittent noise. Ventilation layouts and best practices used to overcome potential problems related to overexposure to fan noise in underground coal mines are presented. Factors such as fan type, rotational speed, duct diameter, and silencer-duct arrangement, and their effects on noise attenuation are discussed.

TECHNICAL PROGRAM: TUESDAY



**2:25 PM**

## **Gas Migration Behavior Near the Longwall Face: Experimental and Numerical Simulation Using PSU Scaled Mine Model**

*N. Gendrue<sup>1</sup>, S. Lu<sup>2</sup>, L. Fan<sup>4</sup> and S. Bhattacharyya<sup>3</sup>; <sup>1</sup>Penn State University, Graduate Student, State College, PA; <sup>2</sup>Department of Energy and Mineral Engineering, <sup>3</sup>Center and EMS energy Institute, The Pennsylvania State University, USA, State College, PA; <sup>3</sup>Associate Professor of Mining Engineering, State College, PA and <sup>4</sup>Penn State University, PhD Student, State College, PA*

Gas migration behavior near the longwall face controls the gas emission to the face, and bleeder system and it has not been thoroughly investigated. In the literature, the previous studies have focused on either physical model or computational fluid dynamics modeling. In this study, we will use our novel in-house scaled mine model to experimentally study the interaction of gob gas and ventilation air. Meanwhile, parametric study was conducted to investigate the influence of degree of compaction of gob on the gas emission through CFD modeling. The results demonstrate that the gob porosity, due to different degrees of compaction, has a significant influence on the gas emission rate.

**2:45 PM**

## **Synthesis and Characterization of Sprayable Thermally Insulating Material As Heat Regulators in Deep Underground Mines**

*P. Rao and M. Momayez; University of Arizona, Tucson, AZ*

Heat evolution in deep underground mines, although undesirable, is inevitable due to sources such as geothermal heat from rocks as well as heat released from operations performed in mines. This almost always creates a potential for hazards and tough working conditions for the miners. Currently, ventilation and cooling systems persist that may be inefficient economically as well as in performance. Thus, this research focusses in the development of low cost thermally insulating shotcrete material which is spray able along the mine walls to control heat transfer into interiors. We have been successful in fabricating a low density foam from aluminosilicates. This multipurpose foam utilizes mine tailings thus rendering potential to recycle mine wastes making it environmentally friendly. Thusfar, our foams have density as low as 0.22 g/cc with a promising insulating character. We have also pursued synthesis via additive manufacturing techniques thus demonstrating its feasibility in being a sprayable insulator. The material has been structurally characterized thoroughly. Moreover, its porosity can be further utilized into applications of absorbents in mine spills.

**3:05 PM**

## **Experimental Investigation of Gas Dilution Strategies in Block Cave Mines**

*Y. Pan<sup>1</sup>, A. Jha<sup>1</sup>, P. Tukkaraja<sup>1</sup>, K. Katzenstein<sup>2</sup> and D. Loring<sup>3</sup>; <sup>1</sup>Mining Engineering and Management, South Dakota School of Mines and Technology, Rapid City, SD; <sup>2</sup>Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, SD and <sup>3</sup>Henderson Operations, Climax Molybdenum, Empire, CO*

Block caving has been proven to be one of the most effective and efficient underground mining methods to extract low grade mineral deposits. However, during the caving and ore extraction phases trapped gases such as radon, hydrogen sulfide (H<sub>2</sub>S), sulfur dioxide (SO<sub>2</sub>), are released in to the working

areas. This paper focuses on the investigation of various strategies to dilute gas concentrations in the working areas of a typical block/panel cave mine using a 1:100 laboratory scale physical model. Gas dilution strategies include ventilating undercut and production drifts with relatively higher-pressure airflows and maintaining negative (relatively lower) pressures at the top and inside the cave. Experimental investigations from this study indicate that cave resistance plays a major role in the transportation and emission of trapped gases from the cave.

**3:25 PM**

### **Prediction of Airway Resistance in Panel Cave Mines Using a Discrete and Continuum Model**

*K. Ajay<sup>2</sup>, K. Shahbaz<sup>2</sup>, P. Tukkaraja<sup>1</sup> and K. Katzenstein<sup>3</sup>; <sup>1</sup>Mining Engineering and Management, South Dakota School of Mines and Technology, Rapid City, SD; <sup>2</sup>Mechanical Engineering, South Dakota School of Mines and Technology, Rapid City, SD and <sup>3</sup>Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, SD*

The configuration of an airway (or production drift) in panel cave mines is different from the typical (straight) mine airway designs. There are drawpoints connected to the airway (cross-cuts), which allow airflow from the cave into the airway or air loss from the airway into the cave due to the ventilation approach, and cave porosity. These affect airflow in the production drifts, but it is difficult to investigate these conditions from field or laboratory scaled studies. Therefore, this study develops discrete and continuum CFD models to study the effects of the ventilation approach and cave porosity on the airway resistance. Our findings show that: with active undercut ventilation, a unique resistance model is required for the airway in panel cave mines; and an increase in cave porosity decreases the drift's resistance. These findings provide essential tools for a panel cave ventilation design.

**3:45 PM**

### **Simulation of the Impact of Environmental Conditions in Underground Mines on Truck and Loader Engine Efficiency and Emissions**

*S. Nichols; Mechanical Engineering, Colorado School of Mines, Lakewood, CO*

Diesel equipment and auto compression are two leading factors that result in varying environmental conditions in underground mines. Small changes in ambient conditions can negatively affect the efficiency and emissions of trucks and loaders, consequently affecting the ventilation and refrigeration requirements. The objective of this study is to simulate the impact of the ambient air conditions, as well as the impact of fuel type on engine efficiency and emissions. The results from this model can be used to design, validate, and reduce the cost of ventilation and refrigeration systems as well as influence fuel-type selection for mining equipment.

**19-146**

**TUESDAY, FEBRUARY 26**

*AFTERNOON*

**2:00 PM | ROOM 104**

## **Environmental: Innovating Analytical Measurements and Procedures Creating Solutions in Mining and Processing**

**Chairs:** *T. Patten, Inter Mountain Labs, Sheridan, WY  
C. Bucknam, Au (Analytical Unlimited LLC),  
Parker, CO*

**2:00 PM**  
**Introduction**

**2:05 PM**  
**Metals Bioaccessibility Method to Support Ecological Risk Assessment at Mining Sites**

*A. Thatcher, C. Meyer and C. Day; Arcadis U.S., Inc., Broomfield, CO*

The bioaccessible fraction of a constituent is that fraction that dissolves or desorbs from its matrix (e.g., soil) in the gastrointestinal tract and is available for absorption. Currently, there are two main techniques: in vivo animal studies (time-consuming and often cost-prohibitive), and in vitro tests that simulate human digestion in a laboratory setting. While well-studied for humans for arsenic and lead, not as many studies apply the concepts to ecological receptors. At a legacy mine site, soil, sediment and invertebrate tissue were analyzed for 18 metals for bioaccessibility based on the USEPA Method 1340 developed by Drexler and Brattin (2007), with some modifications to reflect physiologic conditions of a bird and/or small mammal (based on Furman et al. 2006, Beyer et al., 2016). Depending on the metal, bioaccessibility ranged from 0.5 to 38% in sediment and soils and from 1 to 94% in soil or benthic invertebrates. This laboratory analysis was used to support reclamation decisions, but it could also be used to augment baseline studies for permits.

**2:25 PM**  
**Advances in Analytical Methods to Describe pH-Dependent Constituent Release from Mine Materials**

*P. Moran<sup>1</sup>, T. Patten<sup>2</sup> and D. Pasteris<sup>3</sup>; <sup>1</sup>Practical Geochemistry LLC, Incline Village, NV; <sup>2</sup>Inter-Mountain Labs, Sheridan, WY and <sup>3</sup>McGinley & Associates, Inc., Reno, NV*

Mine materials are subjected to a range of static and kinetic leaching tests to assess the potential to mobilize constituents. Testing using Meteoric Water Mobility Procedure (MWMP) and Synthetic Precipitation Leaching Procedure (SPLP) methodologies can be used in situations where the mine materials drive the pH of the system, such as meteoric water contact with weathered waste rock. However, these methods are not well suited for assessing constituent release for materials in an environment where the pH is constrained,

such as cemented tailings backfill (pastefill), where crushing can result in high pH conditions. Alternative methods are available to understand changes in solution chemistry under site-specific pH conditions. This talk describes the evolution of test methods to investigate pH-dependent constituents with a focus on parallel batch extraction methods, application of these methods to mine materials, procedures, and limitations.

**2:45 PM**

### **The Use of Biocompatible Polymers for Suppressing Dust Generation from Tailings Storage Facility**

*J. Park<sup>1</sup>, K. Kim<sup>1</sup>, T. Lee<sup>2</sup> and M. Kim<sup>2</sup>; <sup>1</sup>Mining and Geological Engineering, University of Arizona, Tucson, AZ and <sup>2</sup>Material Science Engineering, University of Arizona, Tucson, AZ*

One challenge the hard rock mining industry faces is controlling fugitive dust that is generated from large-scale tailings storage facilities (TSF). In an upstream TSF, most of the dust originates from two areas: the slope/dike and the dried zone on the TSF beach surface. With limited accessibility on the tailings beach surface, and with the large-scale accumulation of TSF, dust control management remains a consistent problem. While dust from the dried zones on the beach surface is controllable through consistent water saturation by discharging tailings (containing water), that type of TSF management could pose a serious problem because of the induction of undulated beach surface that reflects TSF instability. This study proposes a new method of ameliorating dust generation through the application of biocompatible and environmentally-friendly polymer formulations on the beach surface. Both field and laboratory test results of those polymers support as much as a 95% suppression of respirable dust.

**3:05 PM**

### **Interlaboratory Testing of Inductively Coupled Plasma Emission Analysis of Mining and Fracking Influenced Waters for Astm Standardization**

*C. Bucknam; Au (Analytical Unlimited LLC), Parker, CO*

Water treatment is dependent on comprehensive and accurate elemental characterization for some difficult matrices such as Mining Influenced Water (MIW) and Fracking Influenced Water (FIW). Inductively Coupled Plasma (ICP) Emission has been shown to work as a characterization tool for elements needed for geochemical modeling for major elements and for selection of optimum conditions for trace analysis by Inductively Coupled Plasma Mass Spectrometry. Standardization of the method was successful in the 1980s for 20 elements, but not for six elements Ba, Ca, Li, K, SiO<sub>2</sub>, and Na. The missing elements, plus P, S and Sr, were selected for standardization in the FIW matrix, since a method was needed to characterize MIW and FIW to judge potential impacts on drinking water in the vicinity of mining and oil and gas exploration, fracking, operation, closure and post-closure. Synthetic matrix solutions were used to cover the range of published concentrations in FIW, due to difficulty in obtaining actual FIW samples. Results of interlaboratory testing are presented in the paper.

**19-106**





**3:25 PM**

## **Overview of New Inter-Laboratory Validation Data for ASTM D7573 Standard Test Method for Total Organic Carbon, and D8083 Standard Test Method for Total Nitrogen**

*W. Lipps; Research and Development, Eurofins Eaton, Monrovia, CA*

Two inter-laboratory trials following ASTM D2777 have recently been conducted. One for a previously existing TOC method, ASTM D7573-09 (2017) and the other for a new method, ASTM D8083-16. Each of these method validations were in collaboration between ASTM Committee D19 on Water and Standard Methods for the Examination of Water and Wastewater. This presentation briefly covers the validation plans and the multiple laboratory data.

**3:45 PM**

## **Analysis of Solids for Polonium 210**

*T. Patten; Inter Mountain Labs, Sheridan, WY*

Performed a wet acid digestion on on a 100 mesh or finer solid samples. The wet acid digestion consisted of a nitric acid digestion refluxed overnight on a hot plate. The samples were then filtered and brought to a volume of 1 liter. A portion of the solution was then prepared for polonium 210 analysis. The samples were analyzed using procedures described by Eichrom OTW01-rev2. The heavy metals of the digest solutions were precipitated via an iron hydroxide precipitation procedure. Then the precipitate was separated and re-dissolved. Then the resulting solution was passed through a Eichrom Sr resin column and the polonium was selectively eluted. The elute containing Po210 was chemically plated onto a nickel disk. The disks were then alpha counted using a Gas Proportional Counter or alternatively an Alpha Spectrometer.

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## **TUESDAY, FEBRUARY 26**

*AFTERNOON*

**2:00 PM | ROOM 107**

## **Environmental: Innovations in Mining to Drive Sustainable Business Value**

*Chairs: A. Trippel, ERM, Minneapolis, MN*

*V. Seppala, Climax Mine, Climax, CO*

**2:00 PM**

### **Introduction**

**2:05 PM**

## **Common Sense for Use of Tailings Filtering Technology**

*J. Rogers and B. Ulrich; Stantec, Denver, CO*

To date, filtered tailings technology has only been successfully implemented at a limited number of relatively low production-rate mining operations. However, the technology may be poised to make a dramatic leap forward; it

is proposed for use at a number of high production-rate mines. Pressures ranging from increasing regulatory scrutiny to decreasing water availability are likely to drive additional adoption of the technology. Considering the current state of the industry, how should tailings professionals view filtered tailings and the selection of a disposal technology? This paper presents a recommended approach for selecting a tailings disposal method and summarizes several filtered tailings design concepts and considerations that the authors have found useful in their practical experience.

**2:25 PM**

## **Beyond Philanthropy: Key Areas of Social Responsibility Practice for Engineers**

*J. Smith; Colorado School of Mines, Golden, CO*

Based on interviews with over 70 industry professionals, this chapter identifies four key ways in which engineers can use their everyday work to foster social responsibility, moving beyond philanthropy and volunteering to encompass the professional practice of engineering itself. First is design for community acceptance, in which community concerns and desires are integrated into the design of mines infrastructure and processes. This area of practice is predicated on a second: listening-centered community engagement. This approach should also underline the third key area of education and outreach, which is often grounded in a deficit model of the public and one-way information flow. Finally, engineers working in the Global South, with support from organizations such as Engineers Without Borders – Canada, engage in local procurement to foster sustainable economic development in the communities closest to them.

**2:45 PM**

## **Incorporating Social Conflict Risk into Project Valuation: A Stochastic Modeling Approach**

*B. Teschner<sup>2</sup> and E. Holley<sup>1</sup>; <sup>1</sup>Mining Engineering, Colorado School of Mines, Golden, CO and <sup>2</sup>Mining Engineering, Colorado School of Mines, Golden, CO*

Company-community conflict at mining properties negatively affects stakeholders and companies. Stakeholders risk fractionalization of their communities, loss of cultural identity, and physical harm when they resist mining activities. Companies risk physical harm to employees and equipment, reputational costs, delays, or complete suspension of their projects. Yet, the conditions that lead to conflicts can be difficult to anticipate and even more difficult to quantify. This presentation will showcase a stochastic modeling method which incorporates the risk of project suspension from company-community conflict into the project's net present value (NPV). The approach combines qualitative risk indicators from the project with the project's cash flow model to determine a social-risk-adjusted NPV. Using this method, an investor can determine a project-specific 'risk cost' and how the risk is distributed over the life of the project. This approach could enable, companies, investors, communities, and host governments to better assess social conflict risks, how and if a site should be developed, and how the project might be managed to reduce the chances of company-community conflict.

TECHNICAL PROGRAM: TUESDAY



**3:05 PM**

## **Quantification of Environmental Impacts of Coal Mining in Samaleswari Opencast (surface) Mine of Ib Valley Coalfields of Odisha, India Using Life Cycle Assessment (LCA) Model**

*D. Khanda and M. Mahananda; P.G.Department of Environmental Sciences, Sambalpur University, Sambalpur, Odisha, India*

**Purpose:** This study's aim was to understand and assess the life cycle environmental impacts of water use, land use, energy use, abiotic resource depletion, and climatic change impacts. **Methods:** The study used the general principles of the ISO 14040-49 series Life Cycle Assessment(LCA) standards, modifying them whenever and wherever necessary. **Results and discussion:** For the studied mine, life cycle potential water use impact is 61.91 litres/tonne of coal produced at the mine gate. The potential land use and energy use has been assessed to be 9.48 m<sup>2</sup> -year/tonne, 107.66 MJ/tonne respectively. **Conclusions & recommendations:** LCA is a perfect and prominent tool for comparison of various systems based on the impacts. So, more mines needed to be included in the study and thereby compared further based on impacts. More impact categories could be considered for study to address more resource inputs and emissions to air, water and ground. **Keywords** Abiotic resource depletion. Climatic change. Coal Mining. Energy use. Land use, Life Cycle Assessment(LCA). Water use

**3:25 PM**

## **Use Cases of Sensor Based Sorting in Brazilian Mining Operations**

*A. Young<sup>1</sup>, C. Petter<sup>2</sup> and M. Veras<sup>3</sup>; <sup>1</sup>Student Member, Porto Alegre, Rio Grande do Sul, Brazil; <sup>2</sup>Mining Engineering, University of Exeter, Exeter, UK and <sup>3</sup>Mining Engineering, IFAP, Macapá, Amapá, Brazil*

This conference paper highlights case studies and test works as part of on-going research into Sensor Based Sorting (SBS) currently performed at the Federal University of Rio Grande do Sul. Materials which are showcased include coal, limestone, copper, zinc, iron, manganese, rare earths, gold and industrial aggregates. Dual Energy X-ray Transmission (DE-XRT) and Optical (CCD Camera) sensors were used for the studies, and the advantages and technical functionality of each sensor type is described in the paper. Economic impacts and return on investment for proposed industrial scale sorting equipment is also discussed, under the assumption that laboratory scale results scale well at the industrial level. Among the highlights summarized are the following results: SBS on an iron waste pile 46% recycled 46% of the material into saleable lump iron ore product. Zinc studies showed head grade increases of approximately 30% and recoveries of above 90%. Rare earth studies achieved a head grade of approximately 100Kppm HREE. Coal studies yielded an increase from approximately 15% floating at 1.6 g/cm<sup>3</sup> to approximately 60% floating at 1.6 g/cm<sup>3</sup> after preconcentration.

**3:45 PM**

## **Climate Risk Disclosure – Implications and Best Practices for Mining Companies**

*J. Wollmuth; Global Environmental Solutions, Jacobs, Chicago, IL*

The rise of supplier questionnaires from CDP, activist investor pressure, or the growing momentum of the Task Force on Climate Change Disclosure (TCFD) demonstrates that mining companies need to take an active approach to understanding the risks resulting from climate change. This prepares com-

panies for sustainable production and improves climate risk transparency to external stakeholders, which is increasingly becoming an expectation. This presentation will explore best practices in climate risk disclosure, the role of scenario planning, and the integration of climate risk disclosure into organizations existing processes and strategy for measuring, reporting, mitigating, climate impacts and adapting to its effects.

#### 4:05 PM

### **Creating Business Value Through Sustainability Reporting: Utilizing Sustainability Reporting Materiality Assessments to Ensure That Sustainability Reporting Topics Are Credible, Balanced, and Relevant to Stakeholders**

*C. Christopher; Sustainability & External Relations, Newmont, Greenwood Village, CO*

In the rapidly evolving landscape of sustainability reporting, balanced and credible sustainability reports create business value. With a rapidly growing interest in environmental, social and governance (ESG) performance, ESG investors, ratings and research firms, NGOs, communities and watchgroups are increasingly relying upon corporate sustainability reports as companion documents to corporate financial reports when evaluating a company's credibility and performance. One of the best ways a reporting organization can lend credibility to its sustainability reporting efforts is to perform an ESG materiality assessment, which identifies and prioritizes the needs and concerns of its external stakeholders alongside those of the reporting organization. By following the four GRI Principles for Determining Report Content – Sustainability Context, Stakeholder Inclusiveness, Materiality and Completeness – reporting organizations can create more business value through their sustainability report. This overview covers the materiality assessment process, key elements to ensure success, and discusses some common pitfalls to avoid for new and experienced reporters alike.

#### 4:25 PM

### **Reclamation as a Sustainability and Economic Value Proposition**

*D. Bieber; Rocky Mountain Division, Martin Marietta, Lakewood, CO*

Mining companies typically view reclamation as a nuisance at best and a liability at worst. However, the case can be made that reclamation can and should be managed so that the reclaimed site is a resource with an intrinsic sustainability and economic value. The outcome is better if reclamation is managed as an asset generating activity, and the end use and end user are part of the upfront planning. Practices that support this value proposition include a clear vision of what the end use will be, early involvement by stakeholders, and changes in how we account for reclamation costs.

**TUESDAY, FEBRUARY 26**

*AFTERNOON*

**2:00 PM | ROOM 108**

## **Environmental: Passive and In-Situ Water Treatment**

*Chairs: D. Kratochvil, BQE Water, Vancouver, BC, Canada*

*S. Benowitz, Water Engineering Technologies, Inc., Bozeman, MT*

**2:00 PM**

### **Introduction**

**2:05 PM**

### **In Situ Treatment of Contaminants in Groundwater Near Abandoned Mines: Is Natural Attenuation a Viable Option for Remediation?**

*S. Kuykendall and P. Roghanchi; Mineral Engineering, New Mexico Institute of Mining and Technology, Socorro, NM*

Discharge water from abandoned mining operations can contain high levels of toxic contaminants, often metals suspended in solution which can affect water quality. Using treatment systems, such as constructed wetlands and anoxic subsurface permeable reactive barriers, can enhance the environment's natural recovery process before mine water infiltrates groundwater resources. By implementing such passive treatment systems, metals suspended in mine effluent can be precipitated into sediments or compost-based media and removed from discharge water. Using the correct design parameters for each contaminant, such as determining the retention time of mine water in the treatment system along with kinetics and flow rates, are imperative for increasing the effectiveness of treatment. Passive treatment systems are ideal for reducing the impacts of contaminated mine water, as these techniques can be integrated into land near the abandoned mine and left unattended for long periods as they remove contaminants. As future costs for mining remediation will likely increase, passive treatment systems for mine water appear to be viable options that can effectively reduce impacts to groundwater.

**2:25 PM**

### **Performance Review of a Passive Treatment System for Fe, As, Mn at the Empire Mine State Historic Park**

*R. Schipper, N. Gallagher, T. Rutkowski, S. Lofholm and G. Leach; Golder Associates, Leo, IN*

The Empire Mine State Historic Park now operated by the California Department of Parks and Recreation contains 367 miles of now flooded underground workings. Following closure, mining influenced water (MIW) was discharged containing arsenic, iron, and manganese in excess of Federal and State standards. A full-scale passive treatment system (PTS), which has been in operation since

November 2011, was designed and constructed to treat MIW and meet the permit limits. PTS flowrate varies seasonally and has averaged 160 gpm with a peak near 1000 gpm. Metal removal results for the system have improved over time, corresponding with maturation of the PTS. Since February 2013, the PTS has provided effective removal of permitted metals to trace levels. In addition to metals removal, the PTS has also increased pH, increased dissolved oxygen, and reduced turbidity. A review of PTS performance is presented.

**2:45 PM**

## **Passive Metal Recovery and Mine Water Treatment Using Crushed Concrete**

*A. Brown; Adrian Brown Consultants, Inc., Denver, CO*

Mine waters contain dissolved metals which have value, but are too dilute to process and too concentrated to discharge. This paper reports a method of metal extraction from mine waters that is passive, simple, long-term, closable, cheap, and sustainable: passive metal recovery and mine-water treatment using crushed concrete. Metal extraction is achieved by the following process: 1) Metal-bearing water is introduced to a bed of crushed concrete particles; 2) The water slowly dissolves alkaline constituents from the cement in the concrete particles; 3) The released alkalinity neutralizes any acidity in the water and increases the alkalinity to levels where the dissolved metal impurities are insoluble; 4) The metal impurities precipitate as hydroxides; 5) The concrete particle bed traps the metal hydroxide precipitates by filtration; 7) The treated filtered water discharges; 8) When the concrete is exhausted, the metal precipitates are extracted and hydrometallurgically processed to produce metal; and 9) The remaining concrete aggregate is recycled. A patent for this invention has been applied for, and is available for use under license world-wide.

**3:05 PM**

## **Peat Sorption Media – Successful Treatment of Mine Drainage but How Does It Really Work?**

*P. Eger; Global Minerals Engineering, Hibbing, MN*

Peat sorption media has successfully removed both dissolved and suspended metals from mine drainage. Dissolved metal removal from mine drainage has exceeded 90% and five different removal mechanisms have been identified. The media has also successfully removed seventy to eighty percent of finely suspended copper and aluminum from mine drainage, but the exact mechanisms for suspended metals are not well known. Since the media has a size distribution similar to fine sand, some physical filtration would be expected. Sand filters generally remove particles in the 10-20 micron range but the peat media appears to remove particles down to about 3-5 microns. Over 90% of dissolved metals are retained on the media in extraction tests indicating that the metals are covalently bonded. Similar strong bonding has been observed with particulate metals. At one site the media successfully removed particulate chromium. Since chromium is a RCRA metal, TCLP tests were needed prior to media disposal. Over 99% of the chromium remained on the media suggesting that removal is not simple filtration. Possible mechanisms include microbial interaction or chemical bonding of the particulate.

**3:25 PM**

## **Enhanced Evaporation for Improved Fluid Management of Low pH/Super Saturated Drain Down Fluids**

*D. Bonner and T. Phelps; Arcadis, Reno, NV*

Arcadis manages the operations and maintenance of a fluid management system (FMS) to control drain down fluids associated with several Heap Leach Pads (HLP) at the Yerington Mine Site in Yerington, NV. The fluids in the FMS ponds are low pH (typically ranging from 1.9 to 2.7) and high TDS (with average values up to 381,000 mg/L). To improve removal of fluids from the system without off-site disposal, Arcadis installed an enhanced evaporation system on top of one of the HLP with operation occurring during the summer months of 2017 and 2018. Fluids are routed to one of several evaporation ponds where they are removed via active evaporation which is reasonably effective given the climatic conditions present at the site. This paper will discuss and present the design of the evaporation system; effectiveness of water removal, challenges associated with the low-pH/ high TDS water, decommissioning approach for the system after operations are complete, and mist/particulate migration monitoring. The objective of the paper will be to highlight the benefits and effectiveness of the system, applicability at similar sites, and any challenges encountered during operation.

**3:45 PM**

## **Bench-Scale Nitrate and Sulphate Biochemical Reactor Case Study, Amulsar Mine, Armenia**

*J. Gusek<sup>1</sup>, L. Josselyn<sup>1</sup>, A. Aghajanyan<sup>3</sup> and L. Breckenridge<sup>2</sup>; <sup>1</sup>Sovereign Consulting Inc., Lakewood, CO; <sup>2</sup>Global Resource Engineering, Denver, CO and <sup>3</sup>Lydian International Ltd., Yerevan, Armenia*

Bench-scale biochemical reactors (BCRs) filled with organic media successfully removed nitrate and sulphate in a laboratory setting in advance of field testing. The Armenian treatment goals are strict: 2.5 mg/L (nitrate as N) and 16 mg/L sulphate. Barrels filled with media were connected in series; three sets of barrels were tested simultaneously. Each barrel set included a denitrifying BCR, intermediate mechanical aeration and settling, and a sulphate-reducing BCR, which fed a sulphide scrubber. One stand-alone BCR was tested to determine if nitrate and sulphate could be removed simultaneously. Water pumped into the barrel sets contained 50 mg/L nitrate, up to 150 mg/L sulphate, and exhibited a pH of 3.6. The sulphide scrubbers contained different inorganic reactive media. The test results exceeded expectations; the effluents from two barrel sets satisfied the Armenian standards throughout 38 weeks of operation. The stand-alone BCR met the nitrate standard but was unable to fully treat sulphate.

**4:05 PM**

## **Arsenic and Antimony Removal from Mine-Influenced Water – Iron Oxyhydroxides and Beyond**

*D. Pasteris<sup>2</sup>, P. Moran<sup>1</sup> and J. Gillow<sup>3</sup>; <sup>1</sup>Practical Geochemistry LLC, Vail, CO; <sup>2</sup>McGinley & Associates, Inc., Reno, NV and <sup>3</sup>Geosyntec Consultants, Greenwood Village, CO*

Iron oxyhydroxides are strong sorbents that are commonly present in native ground and mine materials or can precipitate in surface and groundwater through both natural and engineered processes. Iron oxyhydroxides are frequently used to describe arsenic and antimony removal from mine-influenced water (e.g., groundwater, pit lakes, process water). Other sorbents can contribute to arsenic and antimony removal, although precipitation/dissolution of these phases may limit sorption to iron oxyhydroxides. This talk addresses incorporation of sorbents into hydrogeochemical evaluations, potential challenges and opportunities, and mine water applications.

## TUESDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM 709

### Fuerstenau Symposium: Comminution, Modeling & Flotation

*Chair: J. Herbst, Retired, Morgantown, WV*

2:00 PM  
Introduction

2:05 PM  
**The Evolution of Grinding Mill Power Models**

*R. Rajamani<sup>1</sup>, P. Kumar<sup>2</sup> and N. Govender<sup>3</sup>; <sup>1</sup>Metallurgical Engineering, University of Utah, Salt Lake City, UT; <sup>2</sup>Mining Division, PolyCorp Ltd., Elora, ON, Canada and <sup>3</sup>Chemical engineering, University of Surrey, Guildford, Surrey, UK*

Mill power models have been used in a variety of ways in industrial practice since power directly equates to throughput and fineness of ground product. We first start with Hogg-Fuerstenau Power Model and show how this model successfully predicted the power draw of many grinding mills in several mining operations. Then we show how this model was on the verge of being able to predict the influence of lifter design on power draw. Next, we describe the discrete element model and how it overcame the issues faced by the previous power model. Using a DEM software known as Millsoft, we show the influence of lifter design geometry on power draw and analyze the power draw of rubber lifters versus the steel lifters via several case studies. As years passed the two-dimensional discrete element model imbedded in Millsoft is superseded by three-dimensional discrete element method. Due to the gigantic computational power of Graphic Processing Units new computational codes that can do the tumbling motion along the entire length of the mill has come about. Here we show the predictive capability of Blaze-Dem for ball and SAG mills.

2:23 PM  
**A Curious Observation Relating to Product  
Grade and Particle Size in Comminution**

*G. Jameson and C. Emer; Center for Multiphase Processes, University of Newcastle, Callaghan, NSW, Australia*

Samples of ore were wholly crushed in a jaw crusher at a top size of 600  $\mu\text{m}$ , and the product was separated into size fractions by screening. The grade of each size fraction was then determined. As expected, the grades improved with finer size fractions. However, when the grades were analysed, an unusual effect was noted. At the upper end of the size range, the product grade is constant, but as the size decreases, the grade increases exponentially below a certain break point. The goodness of fit with an assumed exponential relation is very high, of the order of 99.91%. The precise alignment with the exponential curve suggests that there is some fundamental law that underlies the crushing operation. This effect has been found with a porphyry copper ore of head grade 1.01% Cu; a finergrained copper ore of head grade 1.26% Cu; and a copper-gold ore of head grade 0.09% Cu. The observations will be discussed with reference to the differences in hardness between the copper minerals and the gangue.





**2:41 PM**

## **Production Increase Through the Milling of the Phosphate Rock Flotation Middling**

*A. Silva<sup>1</sup>, M. Teixeira<sup>2</sup>, B. Milanez<sup>2</sup> and E. Silva<sup>1</sup>; <sup>1</sup>Mine Engineering, Federal University of Goiás, Catalão, GO, Brazil and <sup>2</sup>Copebras/CMOC, Catalão, GO, Brazil*

The Brazilian main P reserves are igneous, as that is the case of Catalão alkaline dome, where Copebras/CMOC International has operations. In order to increase the P<sub>2</sub>O<sub>5</sub> recovery the circulating load (or middling) of the Copebras' phosphate rock flotation circuit was submitted to bench scale flotation tests. Phosphate rock samples were collected at Copebras/CMOC mineral processing plant 76 before the apatite flotation in order to produce the flotation middling (the scavenger concentrate plus the cleaner tailings) using a lab scale Denver flotation cell. The middling was comminuted in a pilot scale rod mill in order to produce two different middling regarding their d<sub>95</sub>. The three samples were sent to rougher flotation tests, A and B immediately after milling. The industrial implementation of a milling stage for the flotation middling and a subsequent flotation stage of this material has the potential to increase the overall process efficiency by approximately 5.5%, resulting in a production increase of 62 kt/year of phosphate rock concentrate, with P<sub>2</sub>O<sub>5</sub> content similar to the one currently produced.

**2:59 PM**

## **Flotation Mass Pull Measurement Using Distributed Acoustic Sensing (DAS)**

*D. Finfer<sup>1</sup>, A. Muller<sup>2</sup> and M. Amir<sup>1</sup>; <sup>1</sup>Silixa Limited, London, UK and <sup>2</sup>Anglo American Platinum Limited, Johannesburg, South Africa*

Anglo American and Silixa have pioneered the use of Distributed Acoustic Sensing (DAS) for flow metering in challenging metals processing environments. In this application, metering zones are created by instrumenting flowing pipes with optical fibre in a non-intrusive fashion. Several metering zones can be spliced together in series, thereby making it possible to meter several flows within the process using only a single length of optical fibre. This paper will describe a pilot during which this process flow metering technology was applied to several flotation cells within a rougher bank at Mogalakwena North Concentrator, with the goal being estimation of mass pull on a cell-by-cell basis. Regression methods were used to compare the optical flow metering data with reference output from both cameras and sump flow meters. Using this approach, it will be seen that acoustic signal processing can be applied to obtain output which is comparable, or better, in quality to the output obtained using flotation cameras. In addition, practical considerations regarding the installation and use of this technology in closed-loop flotation control will be presented.

**3:17 PM**

## **Implications of the Frother Adsorption and Desorption on Flotation Modelling**

*Z. Jávör<sup>2</sup>, N. Schreithofer<sup>1</sup> and K. Heiskanen<sup>1</sup>; <sup>1</sup>Bioproducts and Biosystems, Aalto University, Aalto, Finland and <sup>2</sup>Research and Innovation Services, Aalto University, Espoo, Finland*

The paper argues that the deterministic equations used in flotation modelling do not form a consistent physical structure. The assumptions made in developing these equations, gives rise to doubts of their usefulness. These

models suffer from the long-standing issue of low predicting capability, while having a good curve fitting power. A major shortcoming is the treatise of the chemical potential effects. This relates to all physical and chemical boundary-boundary interactions. At the gas-liquid boundary the effect of different frothers is not well understood. The paper discusses in general terms the effects of frother adsorption and desorption kinetics to flotation.

**3:35 PM**

### Recent Advances in Studying Colloidal Interactions in Mineral Processing

*Z. Xu<sup>2</sup>, Z. Li<sup>1</sup> and Q. Liu<sup>1</sup>; <sup>1</sup>Chemical and Materials Engineering, University of Alberta, Edmonton, AB, Canada and <sup>2</sup>Southern University of Science and Technology, Shenzhen, China*

Colloidal interactions play a critical role in mineral processing, including grinding, physical separation, dewatering and tailings management. Despite great energy input in comminution to liberate valuables from gangues, hetero-coagulation between them would prevent separation of valuables from gangues. On the other hand, selective coagulation/flocculation to increase the size of fine particles could enhance physical separation and dewatering, while dispersion is needed for fine grinding. Measuring colloidal interactions in a relevant system conditions is therefore important to control the state of colloidal dispersions by creating favorable conditions. This review summarized recent advances in techniques of colloidal interactions measurements, including atomic force microscope, surface force apparatus, zeta potential distribution measurement, quartz crystal microbalance with dissipation, and our recently developed integrated thin liquid film force apparatus, to emphasize the use of complementary techniques to tackle a basic problem in mineral processing.

**3:53 PM**

### The Chemist's View of Mineral Processing

*B. Cousins; Solenis, Calgary, AB, Canada*

The chemistry that occurs in most mineral processes is not fully understood. Although mining processes have a long history, the development of modern chemical theory is more recent and we are only just beginning to understand key interactions. As a result, standard operations do not benefit from the advancement of the science. However, the ability to troubleshoot chemical imbalances in a mill can be increased tenfold by applying a simple principle outlined by three proven chemical mechanisms; reaction kinetics, solubility and equilibrium. This discussion will serve as an introduction to the benefits of managing the chemistry within a metallurgical plant.

**19-120**

**4:11 PM**

### Probing the Oxidation of Nickel Sulfide Minerals by the Surface Charge Measurements

*J. Liu, H. Wang, J. Han and Q. Liu; Chemical Engineering, University of Alberta, Edmonton, AB, Canada*

Nickel sulfide minerals, mainly including pentlandite  $[(\text{Ni}, \text{Fe})_9\text{S}_8]$  and millerite  $[\text{NiS}]$ , are the major source for producing nickel metal. Unfortunately, even though millerite has a potential to contribute a large amount of Ni, there is little research on millerite in terms of surface properties and flotation chemistry. A fundamental understanding of the surface properties of millerite is

critically important for the successful flotation or depression of millerite from chalcopyrite in the coppernickel separation. In this study, the surface charge of millerite was investigated by Atomic Force Microscopy (AFM) and zeta-potential measurements under various pHs coupled with acid-base titration methods. It was found that the surface charge of millerites was closely correlated to the oxidation of nickel sulfide minerals. The oxidation of millerite is faster and more severe than that of pentlandite. The oxidation products on the mineral surface were further determined by XPS. Our research provides more insights for the flotation chemistry of millerite.

**4:29 PM**

## **Column Flotation Using Oscillatory Air Supply**

*J. Wang, C. Li, H. Park, C. Ng and L. Wang; School of Chemical Engineering, The University of Queensland, Brisbane, QLD, Australia*

Flotation tests were conducted for coal particles and mineral particles, respectively, using a laboratory-scale column equipped with a sparger and supplied with oscillatory air flow. The oscillatory air flow was converted from steady air flow using a fast-switching solenoid valve. It was found that use of oscillatory air supply with a proper valve switching frequency and on/off time ratio to replace steady air supply could significantly improve the recovery of coals or minerals. The improved flotation recovery can be accounted for by enhanced gas dispersion and reduced axial mixing of fluid inside the column.

**4:47 PM**

## **High Profit Potential with Packed Column Flotation**

*D. Yang<sup>1</sup>, D. Zhang<sup>2</sup> and W. Xiao<sup>2</sup>; <sup>1</sup>Mineral Technologies Intl. Inc., Morgantown, WV and <sup>2</sup>Wuhan Institute of Technology, Wuhan, China*

The innovative Packed Column Flotation system has emerged as a highly efficient and cost-effective process capable of drastically improving product quality or recovery using a simple flowsheet. This was developed based on a multi-cell concept generating repetitive separation actions through a myriad of small cells created by the filled packing structure. Unlike the traditional, the packing perfectly distributes air and pulp flows counter-currently through these tortuous flow passages, thus a deep and stable froth can be supported and monitored automatically without spargers. Wash water addition on top of the froth bed almost completely eliminates the entrapped gangue into the overflow, further enhancing the product quality. Recent successful commercialization has unlocked the hidden value of the immense profit potential on a wide variety of applications. Major technical breakthroughs include a simplified flowsheet with significant savings in labor (fully automatic), energy (1/7) and water usage (1/20), lowering construction (1/5 total cell volume) and operating costs. This paper shows the progress made to date and provides a rare opportunity for much-improved plant performance.

**TUESDAY, FEBRUARY 26**

**AFTERNOON**

**2:00 PM | ROOM 610**

## **Health & Safety: Compliance is Not Enough! Safety Culture Transformation**

*Chairs: M. Savit, Jackson Lewis LLP, Denver, CO  
A. Rlchins, Salt Lake City, UT*

**2:00 PM**

**Introduction**

**2:05 PM**

### **Creating Personal Improvement Experiences to Drive Your Safety Culture Well Beyond Compliance**

*J. Wickizer; Health and Safety, Acknowlogy, Kaysville, UT*

Let us look at the safety experience from the eyes of an individual worker. Perhaps a field Electrician, line Supervisor, Operator or the CEO of an organization. Let us evaluate that experience. Each individual works for a company that has safety policies that have been developed by their company, based on type of work the company performs, the customers and facilities the company services, the industry the company works in and even the regulatory agency that regulates the overall compliance expectations. Individuals operate under the guise that each safety experiences is the exact same within the organization. From a compliance perspective this is foundationally true and the basic expectations are set. Realistically though this leads to frustration, complacency, poor information collection and safety effort that is without purpose. What if the experience and expectation was compliant AND specific to the individuals improvement? Is this even possible, and what would that look like? Let us discuss some examples of the future experiences we are going to create for individuals that lead to meaningful and purposeful safety improvement efforts.

**2:25 PM**

### **How to Identify and Control Fire and Explosion Hazards in Bulk Material Handling and Processing**

*V. Ebadat; Solent Process Safety, Princeton, NJ*

In the manufacturing and processing industries a flash-fire or explosion hazard can exist during the transfer, handling, processing, and packaging of liquids and powders. Ignition of a flammable atmosphere occurs if the ignition-source energy exceeds the minimum energy that is required to ignite the fuel/air mixture at the given process conditions. This presentation will discuss how both flash fire and explosion hazards arise in manufacturing processes, how they can be systematically identified and assessed, and how the most appropriate and practical basis of safety can be selected and implemented. The presentation will provide delegates with: 1. An understanding of explosion characteristics of vapor and dust cloud atmospheres 2. Methods to identify locations where flammable atmospheres could be present 3. Methods to identify potential ignition sources that could be present under normal and abnormal conditions, including electrostatic ignition sources 4. An understanding of practical

TECHNICAL PROGRAM: TUESDAY



measures to prevent flash fires and explosions and protect against their effect

5. Information on Codes and Standards for managing flammable gas, vapor, and dust cloud flash fire and explosion hazards.

19-113

**2:45 PM**

## **Mining Safety; Sharing Solutions**

*B. Ross; Geotechnical Center of Excellence, University of Arizona, Tucson, AZ*

The experience of the mining industry has been that, for various reasons, safety experience and innovations of one company have not been shared with others in the industry. The James E. Rogers College of Law's Third Annual Mining Law Summit, entitled "Mine Safety; Sharing Solutions" addressed this issue by reviewing a recent example of sharing learnings from the Bingham Canyon landslide, looked at the authority of the Mine Health and Safety Administration and experiences with self-audits and information sharing as well as having a panel discussion to illustrate the implementation of collective expertise in addressing a hypothetical mine disaster. The Summit concluded with a review of methods to providing mine safety expertise and a proposal for providing future mine safety assistance. This presentation will provide valuable insights into sharing safety solution and considerations for future policy initiatives based on learnings from this summit.

**3:05 PM**

## **Safety Controls for Leach Stockpile Gas Generation**

*B. Varela, P. Cook and S. Johnson; Freeport-McMoRan, Tyrone, NM*

This paper discusses the hazardous gas potential on leaching stockpiles and focuses on the critical controls needed to protect personnel. The generation of hazardous gas on a copper leach stockpile in 2014 led to a sampling campaign and investigation that identified the potential for NO<sub>x</sub> exposure to personnel from the dilution of sulfuric acid. Further testing has shown SO<sub>2</sub> evolution to be a regular occurrence during sulfuric acid dilution. Potential gas exposures downstream from sulfuric acid-carbonate mineral interactions are discussed, as well as the physical transport mechanisms through a leach stockpile. Associated controls for both reaction pathways are included.

**3:25 PM**

## **Safety Culture and High Reliability Organizations: Convergent Approaches for Smarter Mine Safety Management**

*M. Pillay<sup>1</sup> and M. Tuck<sup>2</sup>; <sup>1</sup>School of Health Sciences, The University of Newcastle, Callaghan, NSW, Australia and <sup>2</sup>School of Science, Engineering and Information Technology, Ballarat, VIC, Australia*

Mining is an important contributor to the social and economic fabric of a number of developed and developing countries. However, it continues to be regarded as one of the most hazardous industries because of the industry's inability to achieve zero harm or sustain high levels of safety performance. In addition, fatalities and serious incidents in the industry continue to be attributed to the same factors, suggesting that the sector is failing to learn from lessons of fatalities and serious incidents of the past, or on emerging theory on organizational performance. More innovative solutions are required, including those that take into account the complexities of the industry. Since the 1980s safety culture and high reliability organizational approaches have

been part of the safety management arena, but which have yet to be seriously embraced by many mining companies. This paper reviews and synthesizes published literature on these strategies, with the aim of identifying opportunities they provide for smarter mine safety management

19-103

3:45 PM

### **The Role of Supervisory Support in Fostering a Positive Safety Culture That Enhances Workers' Performance**

*E. Haas; CDC National Institute for Occupational Safety and Health, Pittsburgh, PA*

Leadership is part of an organization's safety culture and influences how H&S is enacted on site. Worker perceptions of management are shaped through consistent leader-employee interactions; however, little is known about the communicative support (emotional, informational, and tangible) offered by supervisors and its impact on workers' H&S outcomes. Using preand post-interview data with 20 supervisors and 48 workers, researchers identified positive and negative instances of supervisor support. This presentation highlights common support tactics offered by supervisors and desired by workers to help practitioners identify ways to improve their safety culture and subsequently, the performance of their workforce.

19-014

4:05 PM

### **The Steps to a Successful Safety Culture Transformation**

*J. Buenemann; Kiewit Mining Group, Englewood, CO*

The only SMART MINING is mining done safely. Kiewit Mining has experienced a dramatic shift in safety results with the successful transition from a compliance-based to a behavior-based safety program. Kiewit has learned that using "safety cops" to enforce company standards leads to ignored rules when supervision is out of the sight. Safety improvements resulted from miners running Kiewit's safety programs. Within Kiewit, we call this team CVIS, which is an acronym for the Craft's Voice in Safety. This team is empowered to bring up safety issues, solve problems, and communicate safety concerns with the mine manager and fellow miners. This empowerment fosters an environment where transformations in safety culture can occur because people accept and embrace constructive criticism about their safety behavior. With this safety culture, there is a whole team looking out for safety, not one person. Safety is a never-ending journey, but progress can be made, and results improved with a behavior-based safety program.

4:25 PM

### **Assessing the Quality of Incident Investigations and Its Effect on Safety Performance of the Ghanaian Mining Industry**

*E. Stemm<sup>1</sup>, D. Cliff<sup>1</sup>, M. Hassall<sup>2</sup> and C. Bofinger<sup>1</sup>; <sup>1</sup>Mineral Industry Safety and Health Centre, Sustainable Mineral Institute, The University of Queensland, Indooroopilly, QLD, Australia and <sup>2</sup>The School of Chemical Engineering, The University of Queensland, St Lucia, QLD, Australia*

This study examined the content of past incident investigation reports to determine the quality of the investigations using a semi-quantitative method. The assessment tool consists of 5 elements with several indicators and rating

scales for assessing the quality of an investigation report. The method was applied to 304 investigation reports of 3 Ghanaian large-scale mines, and the results correlated with incidence rates. Results showed that the mines differ significantly in the quality of their investigations, and the incidence rates negatively correlated with elements of the assessment tool. Overall, the method was found useful and revealed areas where improvement is needed.

19-003

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## TUESDAY, FEBRUARY 26

AFTERNOON

**2:00 PM | ROOM 110**

### **Industrial Minerals & Aggregates: Applications of Data Analytics & Artificial Intelligence in Industrial Minerals & Aggregate Industry I**

***Chairs:** E. Tarshizi, Michigan Technological University,  
Houghton, MI*

*J. Zdunczyk, Pike Industries, Inc., Westbrook, ME*

**2:00 PM**

**Introduction**

**2:05 PM**

### **Frequency Texture Map for Segmentation of Mining Site Model Using Machine Learning**

*R. Sahu; Strayos, Saint Louis, MO*

This work focuses on development invariant features for segmentation of 3D models of mining sites. The data is generated by stitching together geo-tagged images from the drone. The 3D model is then generated by applying stereo reconstruction using structure from motion. This reconstruction gives a dense 3D model with RGB data corresponding to the point cloud. In this paper we focus on segmenting this data for further analysis. We describe multiple features specific to aid in the classification of surface with random and repetitive texture like grass, sand and rocks. In the Frequency Texture Map (FTM) descriptor, we capture the roughness and frequency components both in Cartesian and RGB space. Providing high discriminability to the surface textures and in-variance to position, planar orientation of the surface. The features provide enough information to segment the scene into various geological components. Thus helping us understand the scene and analyse it. The high discriminability in features gives us high accuracy in segmentation. Enabling us to precisely measure and particle analysis of the muck pile in the blasted area.

## 2:25 PM

### Web-based Benchmarking in Today's Mining Industry

*J. Marston<sup>1</sup>, N. Hoffman<sup>1</sup>, T. Demorest<sup>2</sup>, H. Ednie<sup>3</sup> and Z. Lukacs<sup>3</sup>; <sup>1</sup>Golder Associates, St. Louis, MO; <sup>2</sup>Syncrude Canada Ltd., Edmonton, AB, Canada and <sup>3</sup>Global Mining Guidelines Group, Howick, QC, Canada*

Industry wide benchmarking of equipment performance has been challenging given the lack of standards. Golder and the Surface Mining Association for Research and Technology (SMART), launched a web-based benchmarking program in 2004 to assist participants in data standardization and monitoring performance metrics. This program allows participants to anonymously compare performance with similar operations. Canadian oil sand operators have used the program for over a decade. A partnership with the Global Mining Guidelines Group is resulting in collaboration on the adoption of standard performance definitions and extending the reach of the program to the worldwide mining community. The benefits of participation and the ongoing work to improve benchmarking methodology will be discussed.

19-124

## 2:45 PM

### The Application of Artificial Intelligence to Reduce Greenhouse Gas Emissions in the Mining Industry

*A. Soofastaei; Artificial Intelligence Center of Excellence, VALE, Brisbane, QLD, Australia*

Mining industry consumes a significant amount of energy and makes greenhouse gas emissions in various operations such as exploration, extraction, transportation and processing. A considerable amount of this energy and gas emissions can be reduced by better managing the operations. In surface mining operations, mobile equipment uses diesel as a source of energy. These equipment are haul trucks excavators, diggers and loaders, according to the production capacity and site layout and they use a considerable amount of fuel in surface mining operation; hence, the mining industry is encouraged to conduct some research projects on the energy efficiency of mobile equipment. Classical analytics methods that commonly used to improve energy efficiency and reduce gas emissions are not sufficient enough. The application of artificial intelligence and deep learning models are growing fast in different industries, and this is a new revolution in the mining industry. In this study, the application of artificial intelligence methods to reduce the gas emission in surface mines with some case studies will be explained.

## 3:05 PM

### A Computer Vision System for Terrain Recognition and Object Detection Tasks in Excavation Environments

*G. Somua - Gyimah, S. Frimpong, W. Nyaaba and E. Gbadam; Mining & Nuclear Engineering, Missouri University Of Science & Technology, Rolla, MO, UK*

Recent studies towards dragline excavation efficiency have focused on incrementally achieving automation of the entire excavation cycle. Initial efforts resulted in the development of an automated dragline swing system, which optimizes the swing phase time. However, the system still requires human operation for collision avoidance. For full dragline autonomy, a machine vision system is needed for collision prevention and big rock handling during the 'swinging' and 'digging' phases of the excavation operation. Previous attempts in this area focused on collision avoidance vision models which es-



timated the location of the bucket in space in real-time. However, these previous models use image segmentation methods that are neither scalable nor multi-purpose. In this study, a scalable and multi-purpose vision model has been developed for draglines. This vision system averages 82.6% classification accuracy and 91% detection in collision avoidance, 87.32% detection rate in bucket pose estimation tasks and 80.9% precision and 91.3% recall performance across terrain recognition tasks. With minimal modification, the proposed vision system can be adjusted for other automated excavators.

19-013

**3:25 PM**

## **Characterization the Flow Behaviour of Industrial Minerals and Aggregates With Convolutional Neural Networks**

*C. Aldrich; Curtin University, Perth, WA, Australia*

In this presentation, the use of deep neural networks to characterize the flow behaviour of industrial minerals and ores is discussed. This can be accomplished by recasting measurements obtained from the flow of the materials as images. These images can subsequently be used as primary inputs to a convolutional neural network model to predict the flow behaviour of the minerals and aggregates, as will be illustrated by a number of case studies. Since the approach is generic, it can be integrated with online models for use in the control of plants and a framework for this is also proposed.

**3:45 PM**

## **Development of a Windows Based Software for Industrial Application of Error Detection Algorithm**

*E. De Melo, R. Ganguli and R. Pothina; Mining Engineering, University of Alaska Fairbanks, Fairbanks, Brazil*

Sensors allow for real time monitoring and fine tuning of the mineral processing plant. This has extended the range of ores the processing plant can accept and has reduced waste. This represent savings and improvement in profits. It does come with drawbacks; great recovery rates demand finely tuned circuits that demand accurate data. Errors in the data cause decrease of optimization and in revenue also increasing waste. These errors might also become more than revenue issues. Sensitive operations, such as cyanidation, are safe only within certain aspects. Error in these operations lead to health hazards. Process knowledge and other tools are enough to detect gross errors, but they fail to detect small deviations. Small magnitude errors can only be detected by checking the sensor calibration. In this paper we present the progress in an algorithm that has allowed detection of low magnitude errors. We have developed a software tool that allows the monitoring of the data stream in a Carbon Stripping Circuit and detects small magnitude errors. This allows for a real time monitoring and industrial deployment of this system for error detection.

## TUESDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM 106

### Industrial Minerals & Aggregates: Digitization, Automation & Control Strategies, Part II: Geology and Mining

*Chairs: S. Chatterjee, Michigan Technological  
University, Houghton, MI  
M. King, Imery's*

2:00 PM

#### Introduction

2:05 PM

#### Stochastic Analysis of Block Failure for Improving Safety in Underground Limestone Mines

*J. Monsalve, J. Baggett, R. Bishop and N. Ripepi; Mining and Minerals  
Department, Virginia Tech, Blacksburg, VA*

According to the Pillar and Roof Span Design Guidelines for Underground Stone Mines proposed by NIOSH (2011), structural instability is one of the main failure mechanisms in underground limestone mines. Even though NIOSH design guidelines do not apply to all mining operations, an analysis methodology that allows engineers at each specific site to identify specific rock fall hazards is proposed. In order to prevent rock falls, engineers must have a clear understanding of the structural setting throughout the entire mine. A change in the structural setting or the direction of the excavation will be reflected in a change to the rock fall hazard. If these changes are not identified, reported or analyzed miners may be exposed to a ground failure. The integration of laser scanning and Discrete Element Modeling (DEM) propose an adequate methodology than can be applied to any mine in order to improve miner's safety. This work presents a stochastic discrete element numerical analysis approach to predict rock failure in underground excavations based on structural data extracted from Terrestrial Laser Scanning (TLS).

2:25 PM

#### A Comparison of Laser Scanning and Photogrammetry in Underground Limestone Mines

*R. Bishop, J. Monsalve, J. Baggett and N. Ripepi; Mining Engineering,  
Virginia Tech, Statesville, NC*

Technology plays an ever-increasing role in improving the safety and efficiency of mining operations. Laser scanning and photogrammetry are two useful methods for capturing 3D digital representations of real world objects. While both technologies have been applied to the mining industry in numerous ways, the practical applications in an underground mine environment have been tested, including for visualization and site characterization. Each technology is capable of creating highly detailed geospatial point clouds, but are all point clouds created equal? This work presents a comparison of the accuracy and density of their respective point clouds and addresses their strengths and limitations in surveying operating underground mines.

19-095

**2:45 PM**

## **Allocation-Based Operational Uncertainties for Haulage Dump Trucks By Using Parallel Simulation-Based Optimization**

*J. Sattarvand<sup>1</sup>, A. Moniri-Morad<sup>2</sup>, M. Pourgol-Mohammad<sup>2</sup> and H. Aghababae<sup>2</sup>; <sup>1</sup>Mining and Metallurgical Engineering, University of Nevada Reno, Reno, NV and <sup>2</sup>Mining Eng., Sahand University of Tech., Tabriz, eastern azerbaijan, Iran (the Islamic Republic of)*

Mining haulage system operates in uncontrolled and harsh environments, leading to major challenges in making strategic decisions about the optimum number of equipment to meet the production targets. Realistic determination of existing equipment capacity may not be captured through conventional techniques like mathematical programming, queueing theories and simulation alone. Parallel simulation-based optimization (PSBO) approach is proposed for determination of the most optimal quantity of equipment under uncertainties. A real case study is considered to validate the outputs of the proposed methodology and the results revealed that the algorithm precisely predicts the required fleet size subject to production targets for heterogeneous haulage operational systems.

**3:05 PM**

## **The Digital Twin Mine: A Concept and Proposed Experimental Facility at Virginia Tech**

*W. Lucero and E. Westman; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA*

Recent advances in technology have allowed equipment manufacturers to generate “digital twins” that are electronic replicas of actual pieces of working equipment. These computer-based replicas allow improved optimization of the use of each piece of equipment. One of the world’s largest mining companies recently saw a 30% improvement in equipment productivity and cost savings through the use of digital twins. This paper presents the concept of generating a digital twin for an entire mining operation, from blasthole drilling, fragmentation, loading, and mineral processing. This technology would allow the mining company to not only optimize each separate aspect of the mining process but also to optimize the entire process more readily. Construction on a new facility will begin within the Mining and Minerals Engineering Department at Virginia Tech that will foster the growth of digital twins research along with simulating real-world data modeling of industrial environments.

**3:25 PM**

## **Design and Implementation of Optimized UAV Flight Paths for High-Resolution Imaging at Open Pit Mines**

*R. Battulwar, J. Valencia, G. Winkelmaier, B. parvin and J. Sattarvand; University of Nevada, Reno, Reno, NV*

With the open pit mines becoming bigger and steeper around the globe, it has become essential to identify the cracks and monitor them for analysis of potential failures in a more efficient way. This NIOSH supported research work presents an energy efficient procedure to generate high-resolution 3-D maps of an open pit mine for tension crack detection using an Unmanned Aerial Vehicles. The battery of the UAV has been modeled by performing empirical studies in various flight scenarios and a flight path optimization algorithm has been presented. The implementation and performance of the algorithm have been evaluated for a real mine environment through multiple case studies.

3:45 PM

## Connected Mine – The Present and Future of Digital Technology in Mining

*P. Sobecke; Consulting, Accenture, Denver, CO*

Current mines generate data via many digital systems, from fleet management to fatigue monitoring. These data are generally stored in their respective departments, be it engineering, maintenance or IT. Any analysis is post-processed, meaning improvements to the operation occur slowly. Connected Mine is a single platform that integrates these disparate systems to provide near real-time data analytics, visualizations and alerts to the production supervisors. Actionable insights are provided directly to users in the field, allowing them to make immediate decisions and drive business value.

4:05 PM

## Vision-Based Automation for Rock-Type Classification in Cement Industry: A Machine Learning Approach

*A. Patel<sup>1</sup>, A. Gora<sup>2</sup> and S. Chatterjee<sup>1</sup>; <sup>1</sup>Geological and Mining Engineering and Sciences, MTU MI, Asst. Professor, Houghton, MI; <sup>2</sup>Department of Mining Engineering, NIT Rourkela, Associate Professor, Rourkela, Odisha, India and <sup>3</sup>Department of Computer Science and Engineering, K L University, Asst. Professor, Guntur, AP, India*

Proper quality planning of limestone raw minerals is an essential job of maintaining desired feed in cement plant. Rock-type identification is an integrated part of quality planning for limestone mine. In this research, a vision-based automated rock-type classification algorithm is proposed for fast and reliable identification without human intervention. A laboratory scale vision-based model was developed using machine learning algorithm. A support vector machine (SVM) was applied for rock-type classification where image features were used as input. A total of 280 features were extracted and selected 7 optimum feature using sequential forward floating selection (SFFS). These selected features are used for optimal classification model development by selecting cost and gamma judiciously. The developed SVM model is validated using the test data set and results reveal that the proposed visionbased model can perform satisfactorily for classifying limestone rock types. Overall, the error of misclassification is zero. When compared with other three classification algorithms, it is observed that the proposed method performs substantially better than all three classification algorithms.

**TUESDAY, FEBRUARY 26**

*AFTERNOON*

**2:00 PM | ROOM 603**

## **International II**

**Chair:** *M. Gavrilovic, GR Engineering Services,  
Denver, CO*

**2:00 PM**

### **Introduction**

**2:05 PM**

### **Meerschaum Mining and Processing Activities in Eskisehir, Turkey**

*M. Yavuz; Mining Engineering Department, Eskisehir Osmangazi  
University, Eskisehir, Turkey*

Sepiolite [ $\text{Mg}_4\text{Si}_6\text{O}_{15}(\text{OH})_2 \cdot 6\text{H}_2\text{O}$ ] is widely used in industry because of its adsorptive, rheological and catalytic properties. There are two genetic types of sepiolite around the Eskisehir, Turkey. The most common type is the so-called “Meerschaum” which occurs as nodules and concretions in Miocene-Pliocene conglomerate surrounding the magnesite deposits around Eskisehir. Meerschaum mining has been doing for centuries by local farmers in two different regions of Eskisehir. Traditional tunneling methods are used in production activities by local farmers. The produced raw meerschaum is processed by many artists in Eskisehir. The best nodules are carved into objects such as pipe bowls, bracelets, and necklaces. In recent years, various problems have encountered both processing and mining in sepiolite. Primarily, meerschaum production dramatically decreased. For this reason, artists cannot find quality meerschaum. So, domestic and external demand for processed meerschaum cannot provide by artists. In this paper, the studies for solving the problems are described. The solutions for meerschaum sector both production and processing processes have been developed.

**2:25 PM**

### **Regulatory Changes in Brazil in the Aftermath of Tailings Failures**

*K. Morrison; CMOC International, Phoenix, AZ*

On November 5, 2015, the Fundão tailings dam at the Samarco iron ore mine in the state of Minas Gerais (Brazil) failed with catastrophic consequences. By now, nearly three years later, most persons working in the mining industry are aware of this failure; however, few outside of Brazil know of the further reaching effects that this event (or previous tailings dam failures) has had on tailings management within the country. Failures and incidents are often the catalyst for change, with the Samarco failure effecting significant changes to the regulations and requirements surrounding tailings management in Brazil. This presentation outlines recent important changes to the regulations surrounding tailings dam safety in the country.

**2:45 PM**

## **Sustainable Change of Coal Mining Regions**

*J. Kretschmann; TH Georg Agricola University, Bochum, Germany*

According to the model of the product lifecycle, the global coal mining industry is in the stagnation phase. The coal demand of China has peaked in 2013 and is now decreasing. The Norwegian sovereign wealth fund excluded coal-related companies for ethical reasons. Important players have already begun to describe pathways to decarbonization. An increasing competition between the coal mining companies and the mining regions can be expected globally if they want to keep their positions on the markets. Non-competitive mining regions will decline and leave the market incrementally. European countries are forerunners of this development. The concept of Sustainable Development (SD) is based on a model of progress whose ecological, economic and social dimensions should be developed equally and positively. But without the idea of competition, the concept is incomplete. The lifecycle of German hard coal mining has ended in 2018 after 60 years of stagnation and decline. This paper describes what has been done to handle the decline in a sustainable way and what are the lessons learned. This can be useful for mining regions who will face a similar development in the future.

**19-080**

**3:05 PM**

## **Continuous Improvement Applications at the Palmarejo Mine**

*J. Díaz; Colorado, SME, Chihuahua, Chihuahua, Mexico*

The Palmarejo Mine (PJO) has changed significantly since 2013. At the time, the 6000 tpd process plant was fed by nearby OP and UG operations. Five years later, PJO is a 4000 tpd process plant feed by two UG operations in a growing exploration district delivering strong operative and business results. This transformation required a cultural change in the organization and constant monitoring and evaluation to identify and implement the necessary changes to keep PJO delivering at the highest performance of competitive industry standards. Continuous improvement is a key tactical function in any mining operation to help achieve the expected results. Through this function management, leaders promote cultural change by measuring current performance and establishing the necessary changes. In turn, operations are able to raise performance and standards in various business areas to new heights. This paper describes successful continuous improvement applications across of entire PJO organization, including the strategy and implementation process followed to support a successful transformation and how the PJO team is getting ready to overcome new challenges in an always changing environment.

**3:25 PM**

## **Blame Mining: A Brazilian Perspective of Current Social Trends in Mining**

*A. Young<sup>1</sup>, R. Pereira<sup>2</sup> and B. Villa Verde Revelles Pereira<sup>2</sup>; <sup>1</sup>Student Member, Porto Alegre, Rio Grande do Sul, Brazil and <sup>2</sup>Management, TERRA Engenharia em Mineração, Curitiba, Paraná, Brazil*

Harmonizing the environment with mining is critical in Brazil. Many claim to preserve biodiversity, but put no thought to the need for mineral resources. Environmental permits have taken the face of tedious bureaucracy, which only reinforces the attitude of some corrupt government officials who say, "write a report, pay and go ahead". Politicians and media are supportive of environmental activism but fail to defend the reality that our modern lifestyle depends

on mining and its products more than ever. When we talk about results, what are we talking about? To consider every aspect of life, and act accordingly, is a challenge that is set on each one of our choices and commitments. This conference paper looks at the social issues surrounding mining from the Brazilian perspective. It outlines some of Brazil's specific problems as well as solutions that could be beneficial for mining companies of any country.

**19-130**

**4:05 PM**

## **Understanding the Basements for a Good Planning & Scheduling**

*C. Mimica; Mining and Exploration, SME Professional Member, Santiago, Region Metropolitana, Chile*

The mining industry is currently facing up a huge challenge related with continue reducing people risk exposures, increasing productivity, increasing automation and as usual being far away from non-profit or marginal profit mining company group percentiles. The role of tactical planning & scheduling will stay as critical as now due to the reduction in field operational decision meanwhile the increment of quality of detailing planning and scheduling with just big one purpose ....not surprises. Premise: the production results in an open pit mine is not a decision any more. The planning, scheduling and execution for success is about to recognize what tasks are necessary to complete, how those tasks should be complete and when they should be completed. A good planning with enough detail will reduce extra tasks in field. The purpose of this presentation is to show how important is to do those 2 short term planning process to avoid surprises. What tools, skills and routines are necessary to ensure the highest quality of the process, and for sure, the quality of the mining compliance kpi.

**TUESDAY, FEBRUARY 26**

AFTERNOON

**2:00 PM | ROOM 501**

## **Mining & Exploration: Geosciences: Geology of Base Metals Deposits**

**Chairs:** *B. Tracy, SRK Consulting (U.S.), Inc.,  
Denver, CO*

*A. Schwarz, Freeport-McMoRan Inc., Phoenix, AZ*

**2:00 PM**

**Introduction**

**2:05 PM**

### **Identifying Key Processes on Mineralization at Khoemacau's Cu-Ag Deposit, Kalahari Copper Belt, North West District, Botswana**

*C. Knight<sup>1</sup>, O. Disang<sup>2</sup>, B. Muyoba<sup>2</sup> and M. Enders<sup>3</sup>; <sup>1</sup>Cupric Africa (Pty) Ltd., Bedfordview, South Africa, <sup>2</sup>Khoemacau Copper Mining, Gaborone, Botswana and <sup>3</sup>Mining, Colorado School of Mines, Golden, CO*

The Khoemacau and Boseto Copper Projects are sedimentary rock-hosted stratiform copper-silver deposits located in North West Botswana, within the Kalahari Copper Belt (KCB). The KCB is host to a number of copper-silver deposits and mining operations in Southern Africa. The lower D'Kar Formation is host to the majority of the high-grade copper showings (>1% Cu). Exploration and targeting efforts have led to the discovery of additional, undercover high-grade copper-silver deposits in the belt including Khoemacau's Zone 5 deposit. Recent geochemical analyses, structural modeling and stratigraphic reconstruction have highlighted how understanding the depositional environment and architectural basin evolution provide important insights on the location and distribution of economic mineralization including the following major ore controls: 1) sediment starved, organic rich, shallow water environments; 2) underlying oxidized and altered sandstones, bimodal volcanic and paleo-basement; 3) magnetic and gravity highs indicative of basement faulting, major structures and metal enrichment; and 4) regional litho-stratigraphic lineaments as copperbearing fluid traps.

**2:25 PM**

### **Copper Hosted in Red Beds At Tambomachay Deposit (Cuzco, Peru), Trapped By Bacterially Reduced Sulfur During Migration of Basinal Fluids**

*S. Rosas<sup>1</sup>, L. Fontboté<sup>2</sup>, C. Salcedo<sup>1</sup>, R. Misael<sup>1</sup>, J. Vallance<sup>1</sup>, J. Sáez<sup>1</sup> and J. Spangenberg<sup>3</sup>; <sup>1</sup>Geology Engineering Program, Pontifical Catholic University of Peru, Lima, Peru; <sup>2</sup>Department of Earth Sciences, University of Geneva, Geneva, Switzerland and <sup>3</sup>Institute of Earth Surface Dynamics, University of Lausanne, Lausanne, Switzerland*

The Tambomachay ore deposit (13°28'36.78"S, 71°57'35.98"W, about 6 km to the north of the town of Cuzco Peru) consists of Cu hosted in arkosic red beds of the Kayra Formation (Lower Eocene). Bornite, chalcopryrite, chalcocite, covellite, digenite, malachite, and chrysocolla occur disseminated in thin layers and in veinlets. The occurrence of the copper ores in a green reducing hori-

TECHNICAL PROGRAM: TUESDAY





zon intercalated in the red bed sequence, the presence of organic matter in interstices between the hypogene sulfides, and the sulfur composition of the copper sulfides ( $\delta^{34}\text{S}$  values between -16.9 and -12.4‰ vs VCDT) pointing to bacterial sulfate reduction, are strong arguments to propose that mineralization was caused by copper-bearing oxidizing saline basinal fluids that precipitate copper sulfides when they meet reduced sulfur in a organic matter-rich horizon. The “Falla Tambomachay” and other regional structures could have acted as feeders for oxidizing basinal copperbearing fluids that precipitated copper sulfides in reduced horizons of the Kayra Formation. Fluid migration was probably driven by tectonically-induced topography gradient.

19-094

2:45 PM

## **Black Butte Copper, a High-Grade Underground Movable Copper Deposit in Meagher County, Montana**

*E. LeLacheur; Sandfire Resources, America Inc., White Sulphur Springs, MT*

The Black Butte Project is a high-grade sediment-hosted copper deposit formed in a hot springs sedimentary exhalative setting in the Newland Formation along the northern margin of the Middle Proterozoic ‘Belt’ sea. The hydrothermal activity introduced large volumes of iron as well as copper, cobalt, lead, zinc, silver, gold into basin muds. Sandfire Resources America (Sandfire), doing business as Tintina Resources, began exploring the project in 2010, and has outlined a resource suitable for mining. Sandfire is planning an underground cut-and-fill mining operation at Black Butte. The anticipated mining rate of 3300 metric tons per day will produce about 400 metric tons of copper concentrate per day. Mining is designed to minimize environmental impacts by: 1) Placing surface activities on private lands, away from surface waters, 2) Waste rock and about 45% of the mill tailings will be returned underground as paste backfill, 3) Remaining tails will be placed as a cemented paste into a double-lined surface impoundment. 4) Water encountered on site will be treated using reverse osmosis and be returned to the groundwater via infiltration. There will be no surface discharge.

3:05 PM

## **The Soledad Project, Peru: High-Grade Cu-Au-Ag Hosted in Multiple Tourmaline Breccia Pipes**

*D. Kelley; Chakana Copper Corporation, Golden, CO*

The Soledad project is central Peru, 260 km north-northwest of Lima and 35 km south of Barrick’s Pierina mine. Previous exploration identified numerous highgrade quartz-tourmaline-sulfide breccia pipes that crop out at surface. Chakana initiated a definition drilling program in 2017 and has completed over 18,000m of diamond drilling in two of the fourteen known breccia pipes. Numerous additional targets exist on the property. Drilling to-date has focused on Breccia Pipe 1 (Bx1), where previous drilling confirmed a vertical extent of mineralized breccia from surface to 490m depth before the drill hole deviated out of the breccia pipe. Interpretation of geophysical data (IP and CS/NS-AMT) suggests the pipes extend much deeper. Highlights from drill results include 119m @ 3.36 g/t Au, 1.14% Cu, and 61.3 g/t Ag at Bx1 and 164m @ 1.68 g/t Au, 0.51% Cu, and 27.4 g/t Ag at Bx5. The breccias have dimensions of 25-60m diameter at surface with separation between the pipes of 250-500m. The sulfide assemblage includes chalcopyrite, chalcocite, digenite, pyrite, arsenopyrite, and silver-sulfide phases. Gold occurs as 20-100 um free blebs in pyrite and along sulfide grade boundaries.

### 3:25 PM

#### Ods Project a Sediment Hosted Copper Deposit in Neuquen and Mendoza Provinces, Argentina

*H. Vera; SME, Buenos Aires, Buenos Aires, Argentina*

The Neuquen Basin hosts examples of sediment-hosted copper deposit types that make huge company-forming mines in other basins, such as Dzhezkazgan, Kazakhstan and the Kupferschiefer at Lubin, Poland. Two of the world's great sediment-hosted copper deposit types are present in the Neuquen Basin; copper in failed oil reservoirs, and copper at the transgression of marine organic-rich fine clastics sediments over red beds. The ODS deposits occur as disseminations or porosity fillings of copper ( $\pm$ silver, cobalt, uranium, vanadium) minerals in porous and usually friable sandstone or conglomerate. The genesis of these deposits is intimately connected to the petroleum generation. The net effect is friable, light colored, porous sandstone. The polymetallic nature and broad lateral extent of sediment-hosted Cu deposits make them attractive. The deposits exhibit potential for large open pit mines. They require little or no use of explosive to be mined and are readily crushed by bulldozer tracks. Preliminary studies performed indicate the oxidized ores to be possible amenable to acid heap leaching and SX-EW recovery. The capital and operating costs for this type of mine are comparatively low.

### 3:45 PM

#### Geology and Discovery History of the Cukaru Peki Cu-Au Deposit, Serbia

*V. Canby; Exploration, Senior VP, Englewood, CO*

Cukaru Peki is Europe's largest high-sulfidation/porphyry copper-gold deposit, located in the southern Bor district, Timok complex, eastern Serbia, discovered by Freeport-McMoRan Exploration Corp. and Reservoir Minerals in early 2012, eleven years after FMEC's first visit to Serbia. In 2016, Freeport sold its interest in the Upper Zone (UZ) high-sulfidation portion of the deposit, retaining majority of the large Lower Zone porphyry (LZ) Cu-Au deposit. Nevsun Resources purchased Reservoir, and since 2016 advanced UZ studies, collared exploration declines, and announced LZ inferred resources of 1.659 Bt at 0.81% Cu, 0.18g/t Au (mid 2018). The deposit is concealed by post-ore Cretaceous and Miocene rocks, and a thin andesite unit, complicating its discovery. UZ transitions from a high-grade massive body, into lower-grade breccia/veinlet ore. Underlying LZ porphyry mineralization extends from ~700m to >2.2km. Late argillic/advanced-argillic overprint (cov-dig-py) adds Cu, and partially redistributes Au in the LZ. Part of the deposit likely cropped out prior to Miocene concealment. Post-ore compression, basin subsidence and regional uplift give the current topography and exposure

### 4:05 PM

#### Geologic and Geotechnical Data Collection of Resolution Copper UG development

*D. Stalling; Geology, Rio Tinto - Resolution Copper, Florence, AZ*

The Resolution porphyry Cu-Mo deposit in Superior, Arizona has presented several challenges for underground data collection through its early evaluation period. The primary means of geologic and geotechnical data collection is conducted by advanced core logging with the use of acoustical borehole imagery assisting in the identification and description of structures. During shaft and drift development, geological and geotechnical data was routinely collected from photogrammetry generated models, and face mapping by

hand and tablet based application. For further structural data collection, water inflow data was recorded from probe drilling during the shaft grouting campaign and during the underground core drilling. Additional challenges specific to the underground core drilling were in cuttings containment and contamination prevention into the shaft dewatering system. This data compiled during the geologic model revision provided additional details for refining lithology and structure within the initial development area.

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## TUESDAY, FEBRUARY 26

AFTERNOON

**2:00 PM | ROOM 506**

### **Mining & Exploration: Geosciences: Uncertainty & Risk in Resource Modelling**

*Chairs: A. Jewbali, Newmont Mining Corporation,  
Greenwood Village, CO  
M. Moore, Maptek, Lakewood, CO*

**2:00 PM**

#### **Introduction**

**2:05 PM**

#### **Managing Mineral Resource Risk**

*E. Ronald; SRK Consulting, Denver, CO*

Mineral Resources form the foundation of exploration and mining company value with risk management a critical function of business decision making. Mineral Resources are converted to Reserves, Reserves are the basis for the mine plan, while the mine plan the centerpiece of the business plan. A central responsibility of mining company Boards and Executive management teams is managing the inherent risky nature of Mineral Resources. Due to the dynamic nature of the business and the varying levels of technical staff experience, assurance can be challenging. Through effective internal validation, reviews, and systems, coupled with external auditing, Mineral Resource risk can be understood and managed. Documented programs and a transparent assurance program are key for company Boards to communicate adequate risk management of Mineral Resources to investors and stakeholders.

**2:25 PM**

#### **Data Spacing Design Based on Uncertainty with a Graphical User Interface**

*Y. Wang and J. Boisvert; Mr., Edmonton, AB, Canada*

A common problem in mining drill hole pattern design is to determine an appropriate data spacing value for classification. The target is to maximize data spacing while obtaining a reasonable level of uncertainty. This paper applies a workflow to facilitate data spacing design by assessing the uncertainty

that results from various data spacing's; the relationship between uncertainty and data spacing is quantified through a set of simulations. Practitioners can relate increasing data spacing to increasing uncertainty. Data spacing is not the only factor influencing uncertainty, uncertainty in the histogram and variogram is also important. A spatial bootstrap technique is implemented to consider the additional uncertainty resulting from histogram and variogram uncertainty. The workflow is nearly automatic, for a new data set the user provides data and a variogram and uncertainty for a range of data spacings is calculated; a Graphical User Interface (GUI) is provided to facilitate ease of use of the automatic methodology. The output is a plot of the relationship between drill hole spacing and uncertainty. The methodology is demonstrated on a small 3D realistic data set.

19-125

2:45 PM

### The Risks in Fundamentals of Recoverable Resource Models

*M. Rossi<sup>1</sup>, J. Bruna Novillo<sup>2</sup> and J. Bassar<sup>2</sup>; <sup>1</sup>GeoSystems International, Boca Raton, FL and <sup>2</sup>Patagonia GeoSciences, Ing. Jacobacci, Rio Negro, Argentina*

Data collection from the original drill holes, including field procedures and the quality assurance and quality control (QA/QC) of those samples are pillar one of a resource model. The second pillar of the model is the good use of the logged geological information, resulting robust geological interpretations, and the corresponding three-dimensional models of those interpretations. These models are partly subjective and mostly conditioned by the quality of logging and the geologist's experience. They are also conditioned by the quality of the three-dimensional models built, regardless of the modeling method employed, traditional or implicit. Knowledge, understanding, interpretation, and management of the model's fundamentals are critical, given that they directly affect its accuracy and predictive quality. The mitigation of related risks allows for the creation of opportunities, generating value and reducing the project's uncertainty. This paper discusses some of the key variables, uncertainties, and risks involved in the resource modeling process. It discusses possible risk mitigation alternatives, and proposes best practices to avoid or mitigate those uncertainties.

19-005

3:05 PM

### Optimizer: Drill Planning for the Modern Era

*M. Giebel; Newmont Mining Corporation, Elko, NV*

Newmont's Infill Optimizer allows geologists to make fast, educated decisions on how and where to invest drill dollars. The software helps to improve resource classification by optimizing drill pads, collar locations and targets while honoring constraints set forth by the geologist. Program applications include more precise budget planning, quick decisions regarding the effects of infill drilling on models and providing data to show impacts additional funding can have on a drilling program. Geologists and resource modelers across Newmont use the infill optimizer, in both surface and underground environments, to create drill plans which allow management to quickly quantify budgeting options, drill targets, and refine a projects scope of work.



**3:25 PM**

## **Reaching for the Stars**

*C. Wilson; Resource Modeling, SME, Elko, NV*

The Newmont Short Term Automated Resource System (N\*Stars) is part of Newmont's Smart Model Innovation Platform to deliver value by real time model automation leveraging all available data to improve model precision. N\*Stars, the first autonomous modeling system at Newmont, is designed to streamline short term decision making, minimize user error and optimize user productivity. This allows for efficient optimal near-term mine plans. Only a short-term window is updated near the new drilling with this information; the reserve model estimates are used for any regions beyond this short-term window. The software is specifically designed so that anyone within the technical services department can execute the software with minimal training.

**3:45 PM**

## **Decluster Weights as a Measure of Average Sample Spacing Applications in Mineral Resource Classification**

*D. Hulse; Gustavson Associates LLC, Aurora, CO*

Mineral resource classification is described in both the SME and CIM Standards for Mineral Resource Reporting. The CIM Standard states "... sampling ... is sufficient to assume geological and grade or quality continuity between points of observation", thus is a function of continuity and sample spacing. Continuity can be measured by use of a variogram model, but average sample spacing in three dimensions is more difficult to measure. The decluster algorithms provided with Geostatistics software, including GSLIB, are commonly used to weight data for statistical analysis due to the sometimes irregular spacing between drill holes during exploration. The weights are lower when data is closer, reflecting shared influence between samples, and higher for isolated samples reflecting independence. This paper will discuss the potential to use estimates of the average decluster weight as an inverse relative measure for average sample spacing to gauge the confidence of the estimate independent of the single nearest sample.

**19-047**

**4:05 PM**

## **Comparative Analysis of 3D Domain Modelling Alternatives: Implications for Mineral Resource Estimates**

*M. Tokoglu<sup>1</sup> and K. Dagdelen<sup>2</sup>; <sup>1</sup>General Directorate of Mineral Research and Exploration of Turkey, Ankara, Turkey and <sup>2</sup>Mining Engineering Department, Colorado School of Mines, Golden, CO*

The study constitutes a comparative analysis of four major domain modelling techniques; (i) explicit modelling, (ii) implicit modelling, (iii) indicator kriging, and (iv) conditional simulation. It involves comparison of outcomes for alternative scenarios in order to assess the implications of the modelling decision on resource estimates of a polymetallic massive sulfide deposit located in western Turkey. Furthermore, identical grade estimation method and parameters are considered in order to demonstrate the discrepancies arising only from the choice of the domain modelling approach and underlying assumptions. Economic implications are demonstrated in the form of range of outcomes for the extends of the ultimate pit, ore tonnages (min:37.0 Mt, max: 46.7Mt), waste tonnages (min:201.2 Mt, max: 251.2 Mt), stripping ratios (min:5.18, max: 5.71), and total pit values (min: \$1.05B, max: \$1.45B). Examination of solid models as well as cross-sections revealed that major

discrepancies are observed beyond outlying drillholes. Therefore, it has been proposed that assumptions regarding extrapolation distance is the main source of mentioned dissimilarities.

19-072

## TUESDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM 503

### Mining & Exploration: Geosciences: Underground Mine Geotechnical II

*Chairs: S. Warren, NIOSH, Spokane, WA  
M. Raffaldi, NIOSH, Spokane, WA*

2:00 PM

Introduction

2:05 PM

#### Identifying Loose Ground and Unfavorable Structures in Underground Workings Using Thermal, Multispectral, and Hyperspectral Imagery

*R. Turner<sup>1</sup>, R. Becker<sup>3</sup>, S. Iverson<sup>2</sup> and M. MacLaughlin<sup>3</sup>; <sup>1</sup>Underground, Barrick, Whitehall, MT; <sup>2</sup>NIOSH, Spokane, WA and <sup>3</sup>Geological Engineering, Montana Tech, Butte, MT*

Ground falls in underground mining are a significant hazard to mine personnel and equipment, particularly in areas without ground support or in need of rehabilitation. Portable thermal, multispectral, and hyperspectral imaging devices that can be carried by hand or mounted to a UAV can potentially be used to identify loose, unstable ground that occurs along geological structures with unfavorable orientations (e.g. Iverson and Signer 2014). The authors used these instruments underground at the Barrick Golden Sunlight Mine in Montana and the Underground Mine Education Center (UMEC) on the campus of Montana Tech of the University of Montana to investigate their ability to detect and quantify loose, unscaled ground or geological structures with clay-altered infill. The capture of hyperspectral and photogrammetric imagery has been used successfully to map regional and outcrop-scale geological features (Salehi et al., 2018), and this study tests the technique in an underground mine environment.

2:25 PM

#### Comparison of UAV Systems Equipped with LiDAR and Photogrammetry for Geotechnical Investigation in Underground Mining Environments

*R. Becker<sup>1</sup>, R. Turner<sup>2</sup> and M. MacLaughlin<sup>1</sup>; <sup>1</sup>Montana Tech of the University of Montana, Butte, MT and <sup>2</sup>Barrick, Whitehall, MT*

Autonomous systems are increasingly being implemented to improve the safety of underground miners. By combining unmanned aerial vehicles

(UAVs) with technologies such as photogrammetry and LiDAR, 3D point clouds can be created for inaccessible regions of a mine. These point clouds provide valuable geotechnical information including the ability to inspect the rock conditions, create a record of the geometry of an area, and measure discontinuities. In order to evaluate the performance of existing systems, five teams were invited to visit the Barrick Golden Sunlight Mine in Montana to demonstrate the capabilities of their UAV systems in an underground mining environment. The demonstrations consisted of autonomous drift and stope flights using obstacle avoidance technologies such as Simultaneous Localization and Mapping (SLAM). The data collected during the flights included LiDAR point clouds and, when possible, video footage that was used to build photogrammetric point clouds. An objective assessment and comparison of the accuracy and quality of the collected data was performed.

**2:45 PM**

## **Real-Time Hazard Monitoring System for Underground Mining Using Video Technology**

*A. DiRienzo; RESPEC, Rapid City, SD*

Video technology provides an exciting opportunity to enhance safety in underground mines by improving ground-control hazard recognition. Drawbacks of underground rock mechanics instruments are that they provide only a single measurement location, may not be installed in the area most likely to fail, and can be an obstruction. Alternatively, methods like photogrammetry require extensive post processing to create a scan of the area of interest, which then has to be compared to the previous state to determine movements. Video technology can monitor for hazards real-time, across a large field of view, at a lesser cost than installing a suite of extensometers. A real-time monitoring system for underground mines has been developed using a commercial, digital image correlation software that resolves displacement measurements of movements captured on video. The system can automate video collection and processing to export mine displacement measurements remotely. The system has been proven to accurately measure long-term closure at an active potash mine. Multiple cameras, each capable of monitoring a 350 ft length of mine drift, have demonstrated a measurement resolution of 0.005 in.

**19-142**

**3:05 PM**

## **A Numerical Modeling Investigation of Coupled-Mechanism Subsidence Over An Underground Carlin Trend Mine**

*A. Perry<sup>1</sup>, S. McKinnon<sup>2</sup> and K. Kalenchuk<sup>1</sup>; <sup>1</sup>Mine Design Engineering, Kingston, ON, Canada and <sup>2</sup>Department of Mining Engineering, Queen's University, Kingston, ON, Canada*

Subsidence was detected over a dewatered underground Carlin Trend mine utilizing longhole stoping methods, and there was evidence that it was caused by dewatering and/or underground mining. A numerical modeling study investigated the mechanism(s) producing subsidence, and InSAR data was used as the main calibration dataset. The findings of this case study include: deformation is likely the result of coupled mining-induced and aquifer deformation; geologic factors form controls on the subsidence; and rock mass yielding likely produced higher strain magnitudes over stoping. This case study has implications for understanding ground behavior and mine design at Carlin-style deposits.

**3:25 PM**

### Scanning the Oro Hondo Vent Shaft

*S. Schiele; Mine Vision Systems, Denver, CO*

Many mines utilize vent shafts to complete the fresh air circuit. When the Homestake mine in Lead South Dakota became the Sanford Deep Underground research facility, fresh air became critical to many experiments success. The Oro Hondo vent shaft is a key part of the ventilation circuit and the shaft was built in 1986 and is over 4,000 feet long. The shaft has undergone repairs as needed and, in 2010, underwent a significant rebuild as Sanford Lab prepared to install the first physics experiments on the 4850 Level. The main concern for the shaft is deterioration as it can inhibit airflow and cause the system to fail, it was critical for the lab to understand the integrity of the wall rock. The Sanford Lab Engineering team consulted a team that consisted of Professional Mapping llc and Mine Vision Systems a company focused on dynamically scanning underground environments utilizing proprietary SLAM (simultaneous localization and mapping) algorithms. Using the MVS technology the shaft data collection took less than one shift the data was then used to generate 3d maps and with mapping multiple times convergence and change can be detected at cm levels.

**3:45 PM**

### Interpreting Entry Stability and Geologic Hazards Utilizing Borescopes

*M. Van Dyke and W. Su; Ground Control, NIOSH, Pittsburgh, PA*

Entry stability is dependent on engineering controls and geologic conditions. Most engineering controls are predictable and standardized for typical geologic conditions. However, geologic anomalies do occur and can be difficult to detect with traditional core hole drilling. Most core holes are drilled to gather coal thickness and quality data rather than for ground control purposes. The core holes can be over 2000 feet apart which makes predicting geologic trends extremely problematic. Borescopes offer a cost-efficient way to gather more geologic data between core holes. Additional data obtained from borescope results provides a much clearer picture to enhance detection of hazardous conditions due to geologic anomalies. The equipment, methods, and analysis of borescope results provides geomechanical engineers with clear understanding of strata behavior and the best methods to implement roof control plans to enhance miner safety and health.

**19-022**

**4:05 PM**

### Localized Seismic Velocity Reduction Associated with Induced Seismicity in a Deep Narrow-Vein Mine

*S. Ghaychi Afrouz<sup>1</sup>, E. Westman<sup>1</sup> and K. Dehr<sup>2</sup>; <sup>1</sup>Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA and <sup>2</sup>Spokane Research Lab, NIOSH, Spokane, WA*

Rock bursts are a detriment to safety and productivity in deep mines, and as mines reach greater depths the related concern will grow. Passive seismic tomography is a potentially helpful tool for this purpose as it is promising the ability to generate images representative of the underground rock mass. This study investigates the seismic velocity changes within a localized region of an underground mine and examines the patterns of occurrence associated with three moderate magnitude seismic events (with local magnitude of less than 3). The goal of this approach is to identify the precursory conditions



associated with major seismic events so that required actions to mitigate the negative impacts on safety and production can be completed. In this study, the seismic wave velocity in highly-stressed zones is found to reduce before the occurrence of major events. This seismic velocity reduction is due to the formation of discontinuities in the rock mass, which inhibit the seismic wave propagation. The seismic data of a deep narrow vein mine is analyzed in two active mining sections as a case study.

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## TUESDAY, FEBRUARY 26

AFTERNOON

**2:00 PM | ROOM 502**

### **Mining & Exploration: Innovations & Technologies: Data Driven Innovation: Inspiration to Action**

***Chairs:** L. Walker, Freeport-McMoRan Inc, Morenci, AZ  
K. Tew, Doe Run, Salem, MO*

**2:00 PM**

**Introduction**

**2:05 PM**

### **Increasing Robustness and Predictability in the Mining Industry through Data Analytics and Integration**

*M. Risso<sup>2</sup>, M. Momayez<sup>1</sup> and K. Henríquez<sup>3</sup>; <sup>1</sup>Mining and Geological Engineering, The University of Arizona, Tucson, AZ; <sup>2</sup>Electrical and Electronics Engineering, Universidad del Bío Bío, Concepción, Bío Bío, Chile and <sup>3</sup>Electrical and Electronics, Universidad Tecnológica de Chile INACAP, Santiago, RM, Chile*

The era of big data and machine learning provides great opportunities for companies to take advantage of process information to make smart and competitive business decisions. In the mining industry the adoption of artificial intelligence becomes particularly relevant when developing strategies to improve safety, efficiency, and robustness to processes and stock fluctuations. Currently, several data infrastructures are deployed in the mining industry and carry the promise of paving the way for a full implementation of the Industrial Internet of Things. However, are companies truly taking advantage of the tools and technologies available today? In our research, we are set to develop validated design methods that could be easily adapted by technical staff and practitioners to achieve higher predictability and improved efficiency, without process delays. Within the realm of application development based on integration, we develop here a simple application using real data, in order to demonstrate the relative ease with which useful numerical models can be developed by taking advantage of the integration capabilities available in industrial data infrastructures, such as the PI System.

## 2:25 PM

### Mine to Mill 2.0 – A New Approach to Capturing the Potential of Higher Intensity Blasting to Improve Throughout

*D. La Rosa; CRC ORE, Brisbane, QLD, Australia*

Mine to Mill optimisation is a mature methodology that has demonstrated significant benefits to mines globally. One drawback to the approach is that the audits conducted to calibrate the blasting and comminution models only capture an instant in the operation's life. This can limit scenarios where there are complex ore paths or long-term schedules are to be considered. The authors have developed a methodology to simulate concentrator performance for each block in the Life of Asset model utilising different blast designs. This enables a site to understand where and when the potential for throughput increase can occur. The paper describes the approach taken and tools used in this project.

## 2:45 PM

### 5D Slope Steepening Oversight and Analytics

*J. Lyons-Baral and S. Gering; Mine Planning, Hexagon Mining, Tucson, AZ*

Interoperable 5D visualization and analytics is the next major step in advancing mining technology. There is an accelerating need to become more precise in mine designs and operations due to uncertain commodity prices, mineral scarcity, improved safety standards and an increasing need for sustainability. Steepening mining slopes is one significant method for reducing stripping ratios and maximizing NPV. However, to do this safely and consistently requires comprehensive oversight, understanding and control. Mines need the ability to visualize and analyze their geology, water, blasting, mining, terrain, and monitoring data in: 3D, with real-time and playback visualization, and temporal analytics.

## 3:05 PM

### Real-Time Access and Analytics of Your Machine Health Data, Your Way

*R. White; <sup>3</sup>D-P, Calgary, AB, Canada*

Real-time access of machine health data remains a challenge for many mining companies. Whether you're limited in the data you can access on-board your heavy equipment or forced into a specific analytics package, most miners still struggle to get the most out of their machine health data. Combination of the right 3rd party machine health software and edge computing platform has allowed numerous miners to not only access the data their business needs, when and how they need it, but also use the analytics package that truly makes sense to their business. In this presentation, we will discuss some of the alternative machine health solutions available in mining and cover the example of a large mining corporation in the US.

## 3:25 PM

### Automated Mine Haul Profile Extraction from GPS Data

*N. Priegnitz<sup>1</sup> and J. Yoo<sup>2</sup>; <sup>1</sup>Komatsu America Corp. / Bradley University, Peoria, IL and <sup>2</sup>Industrial & Manufacturing Engineering, Bradley University, Peoria, IL*

Productivity and operability of haul trucks, the primary transportation mechanism of material in open pit mines, are highly dependent on the roads on which they travel. An understanding of these roads is important to the simulation of the mine and to maintenance diagnoses. While routinely manually surveyed and planned, mine haul roads are ever changing as the mine con-

tinually evolves. Modern largescale mining equipment is generally outfitted with GPS devices to track machines in the pit and support the optimization of loading and dumping operations in the mine. With the continued development and implementation of improved data processing and transmission technology, there exists increased potential of the trucks to provide more contextual information regarding their activities that could assist mine operations and maintenance personnel. This research explores a methodology to automatically extract and report significant road information from fleet wide GPS data to add further context and detail to haul truck operation.

**3:45 PM**

## **On Budget but Losing Millions...a Two-Dimensional Problem with a 3-Dimensional Solution**

*K. Sever; Optimiz Consulting LLC, Gilbert, AZ*

Companies take pride in meeting budget, unaware of significant losses incurred along the way. These unreported losses are caused by the organization and corporate culture. Actual and budget data give a “two-dimensional view” of performance that includes these losses, so management never sees them! Cultural losses are worth millions of dollars when annualized; knowing these losses 1) gives engineers and managers a “three-dimensional view” of organizational potential, 2) exposes a hidden opportunity to maximize earnings without capital spending, and 3) enables an innovative method for shifting the culture into “loss reduction mode” (achieving “site-wide” optimization). Mining examples will be shared.

**4:05 PM**

## **UAV/Drone Data Implementation at a Mine Site**

*C. Nelms; Mining Division, RDOIC, San Antonio, TX*

Unmanned Aerial Vehicles UAV's or Drones are now in use at many mine sites. This abstract will cover: UAV types, what data is collected, ways it can be incorporated into your existing engineering software, and production reporting. Often times a UAV will be acquired for a specific reasons, typically volume calculations. When not being used at the end of the month for that purpose a mine can also gather reclamation base and topsoil information, individual project as-built status(ie. new ramps into pit areas), pond evaluations, and truck bed inspections. There are several report examples including a monthly “Production summary versus budget” and also an “Overburden production relative to operator hours”

## TUESDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM 504

### Mining & Exploration: Management: Mine Management in a Digital World: How Embracing Innovation has Challenged Management Systems

*Sponsored by: OceanaGold*

**Chair:** *T. Camm, Montana Tech, Butte, MT*

2:00 PM

Introduction

2:05 PM

#### The Challenge of Change in Organizations

*T. Camm; Montana Tech, Butte, MT*

Change is difficult for most of us. We particularly resist change when everything seems to be working just fine. With all the promise of ever-advancing technology, most of us have personal experience where the newest upgrade made things more inefficient. Understanding this dynamic is critical if we are to reap the benefits of the digital world.

2:25 PM

#### Innovation Or Shiny New Toy? An Old Far's Perspective.

*T. Arnold; Pershing Gold Corp., Lovelock, NV*

Many baby boomers still have a few good years left in us, and some of us are still making economic decisions at mines. As innovative tools appear, how can you judge whether they bring value to the workplace? More importantly, how can you communicate that value to a person that did dump design with a planimeter and a slide rule? This talk isn't going to answer any of those questions for you, but it may educate you into the inner workings of that mind you may need to convince.

2:45 PM

#### Agile Management in an Inflexible World: When Management Systems Collide

*J. Dwyer; Consultant, Elko, NV*

What happens when some of the sharpest minds in Silicon Valley are asked to assist a minesite that is at least an hour away from the nearest Starbucks with not a single Whole Foods in sight? As the flexible work hours, ping-pong tables and Google-esque workplaces of the software industry collide with the security gates and regulatory environment of a working mine, the two worlds can feel galaxies apart. For mining companies that want to gain that "high-tech" advantage, a bridge is needed between traditional management systems common at most minesites and the agile management systems common in the software development industry. This presentation introduces the advantages of waterfall versus agile management systems and provides tips for successful adaptation of technology while minimizing digital drama.



**3:05 PM**

## **Our Efforts to Modernize an Archaic Mine Project Cost Estimating Software System**

*S. Stebbins<sup>1</sup> and M. Masiar<sup>2</sup>; <sup>1</sup>Aventurine Engineering, Inc., Elk, WA and <sup>2</sup>UX, InfoMine Canada, Vancouver, BC, Canada*

Twenty years ago, the process of developing mineral project analysis software was handled by one or two scientists and the driving force of the design was their own expertise. In a more modern paradigm, software development is a team-oriented process focused almost entirely on the requirements of the user. This study details a recent modernization project of code written in the late 1980's and the process used today to manage a medium-scale software development venture. Part of this process is a reassessment of how this type of project evaluation software fits in with current client practices. In addition to an explanation of the purpose of the original program design, detailed in this document is the work of filling gaps in the original code as well as the method of translating that code to a newer web-based, data driven format, the tasks assigned to each member of the development team, and the management philosophy behind designing modern, innovative tools to evaluate the economic potential of proposed mineral development projects.

**19-088**

**3:25 PM**

## **Value Driven Mining Decisions: Top-down Approach to Mining Cost Reduction**

*A. Young and W. Rogers; Department of Mining Engineering, University of Utah, Salt Lake City, UT*

With productivity on a steady decline and new ore deposits becoming increasingly scarce, miners are looking to cut costs like never before. This conference paper looks at a top-down approach to cost savings for mining operations by adapting business intelligence and process improvement strategies currently implemented in other industries to mining. After categorizing the primary cost drivers of most mining operations, this paper outlines strategies for a top-down approach to their systematic and continuous reduction. Furthermore, as many other techniques have been presented and used within the mining industry as cost reduction strategies, this article reviews current cost reduction techniques and scores the effectiveness of different methods based on a newly presented rubric. Assessment of the various methods is presented along with the rubric used. The work showcases ongoing research efforts at the University of Utah for operational excellence in mining through the use of digital strategies.

**3:45 PM**

## **MWOPS – Digitising Mine Water Management in Mining**

*S. Szykarski; DHI Water & Environment, Brisbane, QLD, Australia*

Mine Water Operational Planning System (MWOPS) is a new approach for improving water operations across a mine site. It is based on the implementation of a modern digital software platform that integrates information and workflows relating to the management of water across a mine site. The importance of managing water at the mine site has only been recognised across the industry in recent times. It can be a key driving factor for the economic success for many mining operations. Water status across a mining operation is often overlooked due to lack of awareness and difficulties in accessing information from across the necessary silos that operate across a mining

operation. MWOPS address these key challenges by brining all the water data information, planning tools, models and workflows that impact water, into a single digital platform focused on improving “operational planning”. This paper will present the implementation of MWOPS to three mining operations in Western Australia including Fortescue Metals Group (FMG), Roy Hill Iron Ore and Rio Tinto operations. The paper will present some of the lessons learned in these implementations and future directions.

## TUESDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM 505

### Mining & Exploration: Operations: Blasting II

*Chairs: T. Worsey, Newmont, Lexington, KY*

*J. Silva, University of Kentucky, Lexington, KY*

2:00 PM

#### Introduction

2:05 PM

#### Innovative Method to Approach Velocity of Detonation (VOD) by Measuring Electromagnetic Pulse (Emp) of Blast

*M. Seo<sup>1</sup>, A. Torrance<sup>2</sup>, G. Cavanough<sup>3</sup> and C. Johnson<sup>1</sup>; <sup>1</sup>Nuclear and Mining Engineering, Missouri Science and Technology, Rolla, MO; <sup>2</sup>Kilmorie Consulting, Cooks Hill, NSW, Australia and <sup>3</sup>QMR Blasting Analysis, Pinjarra Hills, QLD, Australia*

Velocity of detonation (VOD) is an important variable when evaluating the performance of mine blasts. Typically, for a VOD measurement, individual probes have to be loaded into each blast hole that requires a measurement, increasing the loading time and is not representative of the whole blast. Experimental studies of electromagnetic pulse (EMP) from the detonation of explosives charges show that electric and magnetic field signals are observed when chemical explosions occur in the air, at the ground surface, and underground. EMP has the potential to evaluate VOD of the whole blast without impeding the loading process. Due to a variety of physical causes which make the electromagnetic effects complex, measuring EMP of the detonation of explosive charge has not been fully studied yet. This paper presents experimental results of a study of EMP generation during the detonation of explosive charges in holes at quarry with various types of antennae. This study will help to determine the most suitable antennae for capturing EMP data from the field so that EMP data can be used to monitor blasting performance.

19-042

**2:25 PM**

## **Vibration Considerations for a New Aggregate Operation Next to a Dam**

*G. Rigsby; Vibra-Tech Engineers, Inc., Austin, TX*

Technical challenges are often presented when proposing new blasting operations next to unique structures. This presentation will review techniques utilized for securing a new quarry permit next to a roller compacted concrete (RCC) gravity dam. There was a concern that the ground vibrations produced from rock blasting may induce excessive stress on the dam and deep concrete cut off wall. A study was conducted to measure the vibration effects on the structural integrity of these structures. Also, single hole attenuation and Multi-Channel Analysis of Surface Waves (MASW) studies were performed to understand the seismic characteristics of the local geology. In addition, a vibration criteria, monitoring plan, and blast design recommendations were developed to prevent damage from future production blasting.

**2:45 PM**

## **Cautious Blasting on Pinnacles Over Communities and Sensitive Infrastructure**

*N. Rouse and T. Worsey; Respec, Lexington, KY*

The authors worked with quarry operations and contractors at multiple mine sites in the Philippines to evaluate current blasting standards, improve blasting practices, and train blasting contractors. As part of this work, the authors worked with the client and its contractors to address elevated rock pinnacles and overhanging boulders sitting within meters of local community buildings and highly sensitive plant infrastructure. The client had historically avoided the pinnacles due to the potential to impact the community and the plant infrastructure; however, the remaining pinnacles sterilized much-needed reserves, so the client was forced to blast the pinnacles and boulders. The author's influence on the drilling and blasting operations allowed the operation to continue blasting in areas previously deemed unmineable. The mining operation will continue to use the best-practices identified by the authors to continue the cautious blasting operations required to continue mining the areas required to maintain cement production.

**3:05 PM**

## **Blasting Proximity to Local Communities and Structures in the Cripple Creek and Victor Mining District**

*R. Meany; Mine Tech Services, SME member, Colorado Springs, CO*

Newmont operates the Cripple Creek and Victor Mine (CC&V) located 2 hours south west of Denver and is named due to the close proximity to two towns; Cripple Creek and Victor. At its peak in the early 1900's nearly 50k residents occupied the area. Historic mining at CC&V was underground mining from the 1890's until the 1980's when open pit mining began. Because of CC&V's proximity to modern day mining operations, many considerations are taken into account to keep a positive and productive external relationship with the local communities. One of the key areas of consideration is blasting. Calculations regarding velocity and structure distance are not only regulated by permit, but are also monitored to avoid negatively impacting the relationship with the community in the form of fly rock and vibration damage. Some of the closest residents are located only 1,000' away from active mining. Blast timing, blast product, and vibration analysis are all utilized to help maintain a proper social license. The presentation will outline specific design changes and vibrations monitoring that have occurred in engineering and drill and blast to maintain proper metrics.

### 3:25 PM

#### Ground Vibration Control from Blasting in Saturated Deposits – Case Study in South Florida.

*J. Silva<sup>1</sup> and B. Lusk<sup>2</sup>; <sup>1</sup>Mining Engineering, University of Kentucky, Lexington, KY and <sup>2</sup>PhD, Rolla, MO*

The construction industry is one of the most important economic sectors in the state of Florida. It is estimated that this sector generates more than 15 billion dollars in wages and salaries annually providing more than 400,000 jobs. Florida is a leader in crushed stone production, contributing with over half of the total 1.3 billion tons of crushed stone produced annually in the United States. Paradoxically, the mining industry is subject to great pressure due to the need for construction materials and the occupation of areas near the quarries. These residential areas often include lake front property and homes constructed on previously mined quarry pits, with a considerable population living close to the quarries. This paper presents the particular characteristics of ground vibration where quarrying activity is ongoing in South Florida. Due to its particular geological and ground water conditions, low frequency waves are amplified when traditional initiation timing is used. The use of a waveform superposition technique developed by the authors allowed the control of such low frequency vibration waves.

### 3:45 PM

#### 3D Modeling of Predicted and Actual Blasting Vibrations

*J. Lyons-Baral; Mine Planning, Hexagon Mining, Tucson, AZ*

Velocity attenuation curves are used to predict blasting vibration potential in open pit mines. However, these predictions are rarely mapped out and especially not in 3D heatmaps with the underlying geology visible. Linear regression analyses consider the distance from the nearest hole in a blast scaled by the maximum instantaneous charge and how it relates to the peak particle velocity vibration at seismographs throughout a mine. For this study, because the analysis is being done in 3D mine planning software, correlations of the velocity attenuation curve fitting constants can be analyzed compared to block model rock types and RQDs.

### 4:05 PM

#### Optimize Comminution Using Shovel-based Fragmentation Analysis

*T. BoBo; Split Engineering, Tucson, AZ*

Comminution receives much scrutiny by cost controllers as the mining industry goes “back to basics” to reverse the decline in productivity during the mining super cycle from 2008 to 2012. Blasting is the first and lowest cost per ton stage in the comminution value chain. The basic principle that effective blast design can optimise fragmentation from the Run of Mine (ROM) ore muck pile to improve productivity through digging, loading and crushing to grinding and increase mine site profits has been well documented. Benefits of controlling fragmentation in the blast include reduced wear on equipment, faster loading, increased truck loads while detecting oversize rocks at the muck pile can reduce the frequency of a blocked primary crusher. A second basic principle is a measure of particle size distribution (PSD) at each unit operation in the comminution cycle allows engineers to manage blast design to produce fragmentation in the ROM ore most suitable to optimise downstream unit processes to improve mine site productivity and profits. This is “Back to Basics” paper will discuss the use of real time fragmentation analysis to measure each blast.

19-025



**TUESDAY, FEBRUARY 26**

*AFTERNOON*

**2:00 PM | ROOM 112**

## **Mining History**

*Chair: G. Luxbacher, NIOSH, Prosper, TX*

**2:00 PM**

**Introduction**

**2:05 PM**

## **The Beginnings of Mining and Metallurgy Literature in Early Modern Europe**

*I. Barton; Mining and Geological Engineering, University of Arizona, Tucson, AZ*

From ancient times through the 14th century A.D. there was very little scholarly or professional literature about mining and metallurgy. Western mining and metallurgy literature began to develop in the 14th-15th century A.D. owing to a renaissance in European mining, cultural changes in the perception of mining, the development of an analogous professional literature in medicine, and the printing press. This talk will trace the evolution of Western mining and metallurgical literature from unwritten miners' lore in the 15th century to a well-developed professional and scholarly literature 200 years later. The transition began with the Proberbuechlein metallurgical pamphlet series (15th century). The later Nuetzlich Bergbuechlein (c. 1505) fused prospecting and mining practice with then-current philosophical concepts of ore formation and the earth. Georgius Agricola (d. 1556) completed the development by including both technical details and advanced theory in a Latin form designed to add a scholarly air. Subsequent work was mainly practical, with further theoretical advances only after the development of chemistry and geology as sciences in the late 18th – early 19th century.

**2:25 PM**

## **Alaska Gold and Southwest Copper - How Daniel Jackling Brought Copper Know-How to the Juneau Goldbelt**

*T. Braun; SRK Consulting (U.S.), Inc., Denver, CO*

After the success of the Treadwell gold mine (1889 to 1916) on Douglas Island, a young mining engineer named Bartholomew Thane assembled a promising claim block 4 miles southeast of Juneau, Alaska. The deposit was lower grade than other mines or prospects in the area; however, the trend and size of the deposit made the project potentially economic. In 1911, Thane developed a business plan for the project and successfully attracted investor interest. In 1912, Daniel Jackling visited the site at the request of the investment group. Upon inspection, Jackling saw an opportunity to apply the low-grade/high volume milling technology which was widely adopted to the copper porphyry deposits of the southwestern U.S. With a design capacity of 6,000 tons per day, Jackling's mill would require the power of two new hydroelectric projects. By 1915, the mine was in full production. Between 1915 and 1919, the mine and mill set production records for haulage and throughput. Operational difficulties related to ore grade, refractory elements and labor shortages interrupted production on an increasing basis. In 1918, demands from other projects required Jackling to moved on. The mine shut down in 1919.

**19-011**

**2:45 PM**

## **300 Years of Lead Mining in Southeast Missouri (SEMO)**

*R. Bullock; Department of Mining & Nuclear Engineering, Missouri University of Science & Technology, Longview, WA*

Lead mining began in SEMO in 1719 at Mine LaMotte, at the southern end of the Old Lead Belt. It was not until 1864, when St. Joe came to Bonne Terre and introduced steam powered diamond drilling, that prolific lead ores were discovered in depth. Then, some 14 other companies rushed in to develop the 30-mile district. By the late 1940's St. Joe had acquired all competitors and by 1955 operated 22 mines. St. Joe mined there for 110 years. They discovered the Viburnum Trend in 1958, the west arm of the same deposits which surrounds an old igneous high. This leg is 42 miles long and five other companies rushed in to help develop the district. In 1981, the "cash cow" St. Joe company officers broke up the company and sold each of the diversified mining companies, lead, zinc, gold, coal, iron and oil to the highest bidder; the lead and gold went to Fluor. The lead company became Doe Run Company, which then acquired all competitors by 1992. St. Joe/ Doe Run have mined there for 155 years, mining about 570 M tons of ore, which has produced about 50 B tons of lead, plus zinc and copper, making it the world's leading lead producer. The history of mining technology will also be discussed.

**3:05 PM**

## **Anthony Lucas and the Development of the Louisiana Salt Mining Industry**

*W. Goodman<sup>2</sup> and C. Hocking<sup>1</sup>; <sup>1</sup>Mining and Energy, RESPEC, Rapid City, SD and <sup>2</sup>Sovereign, Leesburg, FL*

Louisiana has a history of salt production that dates to discovery of a brine spring at Avery Island in 1791. At the end of the 19th century and beginning of the 20th century, the salt mining industry in Louisiana expanded rapidly. Anthony Lucas helped pioneer mining engineering and exploration of southern Louisiana salt domes including at Avery Island, Jefferson Island, Belle Isle, Weeks Island, and Anse La Butte. Between 1893 and 1900, Lucas laid the foundation for significantly expanding the salt mining industry in Louisiana and molded an enthusiasm for oil exploration that would soon thereafter be his claim to fame.

**3:25 PM**

## **The Founders of the American Institute for Mining Engineers - 1871**

*G. Luxbacher; OMSHR, NIOSH, Prosper, TX*

On May 16, 1871, a group of 22 men met in the clubroom of the Wyoming Valley Hotel in Wilkes-Barre, Pennsylvania to establish the American Institute of Mining Engineers, in response to a call for a meeting that had been circulated and published over the preceding months. The next day the formal structure of the Institute was established, an additional 46 men, who were not present but had indicated their interest, were approved as Associates, and officers were selected. These 68 men, with a multitude of backgrounds and interest, many immigrants, few with formal mining education, laid the groundwork for what today we know as SME, the largest mining professional society in the world. This paper looks at that group of 68, who established a legacy now approaching 150 years.

**3:45 PM**

## **American Mining Engineers on a Global Stage: The Case of John Hays Hammond from the 1870s to the Great Depression**

*M. Hendrickson; History, University of California, San Diego, San Diego, CA*

Beginning in the last decades of the nineteenth century, American mining engineers fanned out around the globe to potential or existing mines in China, Mexico, Chile, Siberia, South Africa, and beyond. Hendrickson's paper will examine the rise and work of mining engineer John Hays Hammond and the mining engineers, geologists, and capitalists with whom he worked. The paper reveals ways that a segment of the investor class depended upon university-trained mining engineers for collaboration—and even inspiration—regarding possible sources of remunerative investment. This paper also describes how new developments in mining and ore processing (flotation and cyanidation among them) facilitated a dramatic increase in the production of materials key to economic growth in the period. The search for raw materials abroad opens up a chapter in the history of U.S. mining and foreign direct investment in which mining engineers like Hammond encouraged and facilitated a new phase of export of redundant U.S. capital and manufactured goods in a direction where investment would be secure, labor recruitable, and profits attractive and subject to repatriation.

**4:05 PM**

## **Zinc Mining in the Friedensville Mining District and the Birth of the U.S. Zinc Industry**

*L. Kaas<sup>1</sup>, M. Connor<sup>1</sup> and G. Lennon<sup>2</sup>; <sup>1</sup>Retired, Arlington, VA and <sup>2</sup>Civil and Environmental Engineering, Lehigh University, Bethlehem, PA*

In 1853, the small mining town of Friedensville, Pennsylvania, and Bethlehem, located 4 miles to the north, became the centers of commercial production of high-purity zinc oxide in the U. S. In the early 1860's, a new zinc smelter in Bethlehem, produced the first commercial zinc metal in the U. S. The mines operated until 1893 and again from 1958 to 1983. The largest of the historic Friedensville mines was the Uberroth. As the workings deepened, miners encountered an immense inflow of water. A unique mix of practical Cornish mining skills and American engineering and manufacturing expertise led to installation of "The President," the largest steam pumping engine in the world in 1872. The huge Cornish engine house, the only one remaining in the U. S., still exists on land now owned by Lehigh University. A team of Lehigh students is designing a mining heritage park at the site. They have developed a working 3-D digital model of The President. Preservation of the site is significant because of Lehigh's close relationship with the metals and mining industries since its founding in 1866, and the role that many of its faculty and alumni played in the founding of AIME in 1871.

## TUESDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM 703

### MPD: Chemical Processing: Hydrometallurgy

*Chairs: J. Lee, University of Arizona, Tucson, AZ  
B. Garcia, Freeport-McMoRan*

2:00 PM

#### Introduction

2:05 PM

#### Heap Leach Production Modeling – A Spreadsheet Based Approach

*M. Botz<sup>1</sup> and J. Marsden<sup>2</sup>; <sup>1</sup>Elbow Creek Engineering, Billings, MT and  
<sup>2</sup>Metallurgium, Phoenix, AZ*

A variety of modeling approaches can be utilized to forecast metal production at heap leaching operations. For many operators, a spreadsheet based modeling approach is attractive since the calculations are directly accessible, models can normally be developed by site staff and results are often easier to interpret. The authors have developed a spreadsheet based modeling technique that provides a high degree of flexibility, while still considering detailed operating information for ore properties, leaching kinetics, scale-up factors, lift height and in-heap metal inventories. The technique involves establishing kinetic leach curves for each ore type to characterize metal extractions, followed by application of separate metal recovery curves to define the rate at which metals exit the heap in pregnant solution. At any given point in time, the difference between total metal extracted and total metal recovered is the in-heap inventory of the metal. This paper describes the modeling technique in detail, including input data required, methods of defining kinetic leach curves and metal recovery curves, and the key model limitations.

2:30 PM

#### Comparative Oxidation Study of Gold Bearing Sulfide Ores By Microbial Assisted Processes

*J. Ahn, J. Wu and J. Lee; University of Arizona, Tucson, AZ*

Gold associated in refractory sulfide minerals can be liberated by oxidation of sulfide in the materials. Compared to other sulfide oxidation processes, bacterial oxidation technologies are promising regarding economic and environmental perspectives. In this study, oxidation of sulfidic gold ore by various microbial assisted oxidation technologies were demonstrated to increase gold extraction. Two sulfide gold ores were collected from one of active mines in Nevada. Sample A and B contained 2.25 and 8.38 ppm of Au, 1.23 and 2.47% of S, 1.29 and 2.76% of Fe, and 7.75 and 1.60 g/L of As, respectively. Gold extractions were compared by performing cyanidation of residues from 10 to 40 days biooxidation and 60 days Sand Farming. Direct cyanidation was carried out as a baseline. Significant increase of gold extraction was observed after 10 days biooxidation, achieving the increase from 32 to 75% on sample A and from 7.0 to 67% on sample B. Comparative metallurgical studies of biooxidation and Sand Farming tests will be discussed.

**2:55 PM**

## **Safford Deep Raffinate Injections**

*R. Crossman; Freeport-McMoRan, Thatcher, AZ*

High residual copper inventories remain in the Safford leach pad from early poor leaching practices. Using resistivity, a confining layer was identified and drill results confirmed that little raffinate solution was reaching the lower lifts. A pilot project was initiated to recover this copper by injecting raffinate into four deep wells. During well start up, resistivity was taken to monitor the area of influence while flow was increased slowly and piezometers were monitored closely to ensure there was no solution build up. Solution was injected over six months, and drill samples were obtained to evaluate recovery and feasibility for expansion.

**3:20 PM**

## **Freeport-McMoRan – Tyrone SX/EW Site Process Automations and Tank House Electrical Safety Best Practices**

*S. Dominguez; Hydrometallurgical, Freeport-McMoRan Copper and Gold, Tyrone, NM*

Freeport-McMoRan The challenges in copper electrowinning process involve high operating cost, safety risks, electric shock due to stray current, inexperienced personnel, poor production quality and quantity. The best methodologies are through automation, implementing best practices and process optimization. Tyrone recently completed automation of the starter-sheet fabrication process which has reduced safety risks and improved production quality and quantity. Crud infiltration negatively affects copper quality unless it is managed at the source. A new crud removal and conveying system (patent pending) designed by Tyrone operations optimizes the crud management process (cost savings/quality). Safety; Best practices to minimize fatal electric shock potential due to stray current have been implemented in the EW tank house. This paper presents details of the automation technology, design and operation of the crud management system and tankhouse best practices.

**3:45 PM**

## **Improving Physical SX Performance for Agitated Leach Feeds by Chemical Treatment of the PLS**

*B. Acton<sup>1</sup>, L. Moya<sup>1</sup>, T. McCallum<sup>1</sup>, T. Bednarski<sup>1</sup>, J. Dalton<sup>2</sup> and J. Dettamant<sup>3</sup>; <sup>1</sup>Metal Extraction Products, Solvay, Tempe, AZ; <sup>2</sup>Process Superintendent, Tamra Mining, Milford, UT and <sup>3</sup>Metallurgist, Tamra Mining, Milford, UT*

Two common challenges for agitated leach solvent extraction (SX) circuits are higher presence of colloidal silica (Si) in the pregnant leach solution (PLS) and elevated levels of suspended solids. Both can negatively impact the physical and metallurgical SX performance and lead to higher processing costs or reduced copper production. Colloidal Si can prolong phase disengagement times, resulting in elevated aqueous entrainment, impurity transfer, and in some cases cause stable emulsions requiring plant downtime. Elevated levels of suspended solids can lead to increased crud levels and mixer phase instability, resulting in higher entrainment. Operating in organic continuity is preferred to address Si or suspended solids challenges, but not always possible. Additional treatment options may be advantageous, and Solvay has recently introduced a new chemical additive for PLS treatment to address these concerns. Continuous addition to the PLS improved physical performance without negatively impacting Cu transfer or cathode quality. This paper will review results and benefits from pilot and commercial scale trials at Tamra Mining in the USA.

**19-139**

**4:10 PM**

## **Low Temperature Process for Production of Lead from Lead Oxide**

*R. Reddy, H. Yang and A. Liu; Met. Matls. Eng., The University of Alabama, Tuscaloosa, AL*

A low temperature and high energy efficiency process for production of lead from lead oxide using ionic liquids was investigated. Lead was produced by electrochemical method from lead oxide using ionic liquids at low temperatures. Lead oxide (PbO) was dissolved in ionic liquids (ILs) at different temperatures (70 to 100°C). The electrochemical behavior of Pb (II) ions in ILs was investigated. Cyclic voltammograms and chronopotentiograms indicate that the reduction of Pb (II) ions to Pb is a diffusion-controlled quasi-reversible process. The diffusion coefficient of Pb (II) ions and also activation energy were determined. The electrodeposit on a Cu substrate was pure Pb as confirmed by XRD and SEM-EDS. A uniform, dense, and non-dendritic Pb deposit was obtained. The current efficiency of > 96% was obtained. Industrial application of these results are discussed.

## **TUESDAY, FEBRUARY 26**

*AFTERNOON*

**2:00 PM | ROOM 707**

## **MPD: Flotation: Chemical Aspects of Flotation I**

*Chairs: R. Kappes, Newmont Mining Corp, Englewood, CO  
C. Young, MT Tech, Butte, MT*

**2:00 PM**

### **Introduction**

**2:05 PM**

## **Surface Interaction Mechanism of Orfom® D8 Organic Depressant on Copper and Molybdenum Sulfide Mineral Surfaces**

*S. Timbillah, A. Das, R. LaDouceur and C. Young; Metallurgical, Montana Tech, Butte, MT*

The adsorption of Disodium Carboxymethyl Trithiocarbonate (Orfom® D8) organic depressant on copper sulfide mineral surfaces is vital for the successful depression of copper in copper-molybdenum sulfide flotation separation. The mechanism of Orfom® D8, as reported elsewhere, shows adsorption analogous to potassium ethyl xanthate except that it occurs at lower potentials than xanthate. Orfom® D8 appears to co-adsorb with xanthate through its CS-group on the mineral surface. By coating the mineral surface, it enables depression. This study evaluates the surface chemical interaction of Orfom® D8 on chalcopyrite and molybdenite surfaces. UV-Vis and Zeta Potential studies are also reported for Orfom® D8 treatment on these minerals as well as possible decomposition products of the Orfom® D8 organic depressant.

**2:25 PM**

## **New Collector Chemistry for Sulfide Flotation – Tecflote**

*Q. Zhou<sup>1</sup>, A. Lewis<sup>2</sup> and H. Nordberg<sup>2</sup>; <sup>1</sup>AkzoNobel Surface Chemistry LLC, Brewster, NY and <sup>2</sup>AkzoNobel Surface Chemistry AB, Stenungsund, Sweden*

Sulfide flotation has relied heavily on xanthate, thiophosphate and thiocarbamate based collectors, all derived from sulfur chemistry. Tecflote™ is a new family of patented collectors based on nitrile chemistry which can supplement or replace thiol collectors, depending on the ore types. Using Tecflote™ as the main collector for the rougher and cleaner steps allows the steep grade-recovery curve typical of Tecflote™ collectors to give a better recovery compared to current thiol collectors at maintained grade. Examples of laboratory flotation with Tecflote™ collectors will be articulated to demonstrate the improved grade and recovery of metal sulfides in cleaning steps. Additional recovery increase has also been observed by the addition of scavenger step using Tecflote™ collector in combination with current thiol-based collector. The sulfide ores studied include copper, zinc and lead ores. The mechanisms for Tecflote's selectivity towards sulfides are currently under investigation and will be discussed. Results of TOF-SIMS analysis will be presented, demonstrating the collector's selective affinity to different mineral surfaces in flotation.

**2:45 PM**

## **A Study of the Adsorption of Collectors on Bastnaesite**

*J. Zhang<sup>1</sup>, D. An<sup>1</sup> and J. Withers<sup>2</sup>; <sup>1</sup>University of Arizona, Tucson, AZ and <sup>2</sup>ATS-MER, LLC, Tucson, AZ*

A nano-scale investigation has been carried out by applying an AFM (atomic force microscope) to study in situ the adsorption of various collectors, i.e., oleic acid, octanohydroxamic acid (HA), and salicylhydroxamic acid (SHA), on bastnaesite in aqueous solutions. The obtained AFM images show that the surface morphology of bastnaesite changes greatly after it contacts the solutions of the collectors, suggesting that all these collectors can effectively adsorb on bastnaesite. Increasing temperature can help increase the adsorption of oleic acid on bastnaesite. FTIR (Fourier transform infrared) results also show that all these collectors adsorb strongly on bastnaesite with a strong absorbance spectra being detected, which confirms with the results obtained with AFM imaging analysis. In general, hydroxamic acid collector (HA and SHA) adsorbs on bastnaesite mainly in the form of insoluble metal hydroxamate. This specific adsorption mechanism explains that a high selectivity with a moderate collectivity will be achieved with a hydroxamic acid collector for the flotation of bastnaesite.

**19-098**

**3:05 PM**

## **Effect of pH and Time on Hydrodynamic Properties of Dodecylamine**

*X. Zhou, Y. Tan and J. Finch; Department of Mining and Materials Engineering, McGill University, Montreal, QC, Canada*

Gas holdup and froth height are reported for dodecylamine (DDA,  $pK_a = 10.63$ ) at three pH values that reveal a strong time effect: at pH 3 stability was reached; at natural pH stability was not reached, for example, gas holdup declining to the water only value; and at pH 11 stability was reached quickly but gas holdup was now less than in water alone indicating coales-

cence. In the first two cases, the time effect is attributed to loss of amine from the system as molecular amine, observed at natural pH as precipitates on the column wall. An argument for precipitation at  $\text{pH} < \text{pK}_a$  is presented. At pH 11, coalescence is attributed to the oily nature of the molecular amine present as colloidal aggregates. Noting a difference in literature steady state gas holdup data at natural pH, it is speculated that varying steady states can be reached that corresponds to different levels of amine loss.

**3:25 PM**

### **Novel Depressant for Pyrite and Silica in Polymetallic Sulfide Flotation**

*J. Rutledge; Silvateam, Tucson, AZ*

Compelling research has been performed with Silvateam reagents, specifically Benefloat, on a Peruvian polymetallic sulfide ore. Studies were conducted on the zinc rougher and cleaner circuits, with the main goal to reduce silica and pyrite present in the final zinc concentrate. As one would expect of an effective depressant, the zinc grade of the concentrate was dramatically increased with the addition of Benefloat. Surprisingly, the zinc recovery also increased in the presence of Benefloat, an uncommon occurrence for a depressant. Results from these studies demonstrate that Benefloat shows great promise as a depressant in polymetallic sulfide circuits.

**3:45 PM**

### **The Role of Soluble Sodium Silicate for Enhancing Flotation Selectivity of Sulphides Towards Grade and Recovery Improvements: Example from a Copper Sulphide Ore**

*B. Hart<sup>2</sup>, D. Shaw<sup>3</sup> and V. Sidorkiewicz<sup>1</sup>; <sup>1</sup>PQ Corporation, Toronto, ON, Canada; <sup>2</sup>Surface Science Western, London, ON, Canada and <sup>3</sup>Consultant, Evergreen, CO*

Sodium silicates also known as “waterglass” are one of the oldest industrial chemicals. In grinding and flotation, silicate functions as a sulphide and non-sulphide gangue mineral dispersant, depressant and a modifier. Soluble silicate promotes selectivity of value sulphides against silicates. This paper seeks to link improved grade/recovery to the interaction of minerals and sodium silicate. A systematic study was performed with mineral species, model ore and the feed ore from a copper operation. The function of silicate was examined in the context of colloidal and mineral surface chemistry. Pulp rheology, settling and zeta potential tests shown that sodium silicate works as a dispersant. Results suggest that better dispersion reduced interaction of chalcopyrite with gangue. Improved Cu grade and recovery are likely due to a better accessibility to collector, improved particle bubble attachment, thus better separation efficiency. ToF-SIMS surface analysis of the flotation samples found a higher proportion of sodium silicate on minerals from the flotation tailings relative to the concentrates. The data indicates that sodium silicate favours the surface of gangue phases over value sulphides.

**19-085**





**4:05 PM**

## **A Novel Collector for Selective Fluorspar Flotation**

*A. Michailovski; Mining Solutions, BASF SE, Ludwigshafen, Germany*

The products of the fluorochemical industry are a crucial part of the modern industrial world and are in demand in all industrial branches from aerospace to petrochemical manufacturing to household appliances. Fluorspar ( $\text{CaF}_2$ ), the main fluorine-bearing raw material, typically occurs in metamorphic and magmatic rocks and is typically recovered by flotation utilizing fatty acids as collectors and tannins as depressants. However, unlike many other industrial minerals, the requirements to the purity of the concentrate are very stringent; acid-grade fluorspar must contain at least 97,5%  $\text{CaF}_2$  but also very low levels of other impurities such as silica, sulfur and heavy metals. This is achieved by a long series of cleaner stages which sacrifice a significant part of fluorspar to achieve the necessary purity of the rest. With DP-OMC-1234, BASF is introducing a new collector system with a significantly higher affinity to fluorspar over other calcium minerals as well as heavy metal impurities. As a result, the necessary number of cleaning stages is strongly reduced, leading to a significantly higher recovery of salable acid grade fluorspar concentrate.

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## **TUESDAY, FEBRUARY 26**

*AFTERNOON*

**2:00 PM | ROOM 705**

## **MPD: Plant Design II**

*Sponsored by: thyssenkrupp*

***Chairs:*** *J. McDonald*

*H. Haselhuhn, Michigan Technological  
University, Houghton, MI*

**2:00 PM**

**Introduction**

**2:05 PM**

## **Lessons Learned Implementation Process for Successful Delivery of a Desalination Expansion Project With Aggressive Schedule Targets**

*R. Roldan, A. Tafrá and R. Dominguez; Mining, Black & Veatch, Santiago, Chile*

The project consists of expanding a desalination plant and water conveyance system capacities of a mine in Chile to meet client's future water demands. Black & Veatch's scope of work included Engineering and Procurement. Some of the project challenges included an aggressive completion schedule and the requirement for an effective implementation of lessons learned from the original project. The presentation will focus on the practical methodology for implementing lessons learned based on the following 4 steps: Quantify/Evaluate, Propose Resolution, Implement Solution and Monitor/Verify Implementation. Results show that the methodology was successful and that it helped the project to remove several execution risks.

**2:25 PM**

## **A Reliable Solution for Pumping Mineral Froth with Challenging Froth Volume Factors.**

*M. Webb, P. Loderer and A. Roudnev; Weir Minerals, Madison, WI*

Pumping mineral froth has always been a challenge, often magnified by incorrect pump selection and suction tank design, manifesting from insufficient information on the froth volume factor. The limits of the flotation process are being continually stretched to increase recovery and improve efficiency, often leading to an increasing and more changeable froth volume factor. In these conditions, traditional froth pumps can fall over. A new technology from Warman® pumps called the 'Continuous Air Removal System' (CARS) can reliably operate in these more challenging, variable conditions whilst maintaining pumping performance, efficiency and wear life. The enhanced froth pumping technology is successfully operating in a number of Gold, Phosphate, Potash, Copper, Molybdenum, Silver, Zinc, Lead, Coal and Oil Sands applications around the world.

**2:45 PM**

## **Automated Plant Design for Optimizing Comminution Circuit in Feasibility Phase**

*S. Nazari; ANDRITZ, Richmond, BC, Canada*

This paper describes application and results of the usage of IDEAS process simulation software for designing and optimizing a mineral processing plant through a case study. During the feasibility stage of a mineral processing project (disclosing of the name is pending approval), comminution circuit's operating cost (including power and water consumption) and performance (particle size distribution) have been optimized. In this paper, a comparison results between alternatives including HPGR, SAG Mill and Ball Mill, screens and hydrocyclones configurations is reported. The novelty of this approach is to use high fidelity dynamic models in an automated simulation execution platform that allows running multiple simulations over the range of scenarios of variations in the operating conditions including ore grade and capacities through alternative process equipment configurations. Additionally, this approach allows us to perform automated sensitivity analysis for abnormal conditions which results in automated generation of equipment specific characteristics.

**3:05 PM**

## **Operation and Process Control Development for a Leaching and Solvent Extraction Circuit Recovering Rare Earth Elements from Coal-Based Sources**

*D. Addo<sup>1</sup>, J. Werner<sup>1</sup>, D. Threlkeld<sup>2</sup>, R. Bratton<sup>2</sup> and R. Honaker<sup>1</sup>; <sup>1</sup>Mining Engineering, University of Kentucky, Florence, KY; <sup>2</sup>Mining and Minerals Engineering Department, Virginia Tech, Blacksburg, VA and <sup>3</sup>Alliance Coal LLC, Providence, KY*

The US Department of Energy in 2010 identified several rare earth elements (REEs) as critical materials needed for the manufacturing of clean energy technologies. As part of ongoing research in REE recovery from coal-based sources, a pilot plant has been designed, developed and demonstrated with the capability of treating material from multiple coal-based sources. To accomplish process control, PLC systems design/deployment, overall operational design and the utilization of Six Sigma design methodology was implemented. The paper will provide additional details into the application of the control design, both procedural and electronic, data management and analysis, and integration into databased decision-making.

**3:25 PM**

## **The Chapada Story, Increasing Recovery Using APC and SFR Technology**

*M. Schaffer; Woodgrove Technologies, Toronto, ON, Canada*

Chapada is a mine located in Alto Horizonte GO, Brazil that processes 2,840 tph of ore, producing 127Mlbs of Copper and 119,000 Oz's of Gold per year. An opportunity to increase the plant performance was recognised with a plan put in place to first stabilise the operation through APC and then open up the cleaning circuit and finally, once the cleaners had the capacity, to increase rougher performance. Chapada selected Woodgrove Technologies as a partner and the projects began in 2016. The APC components were completely installed in early 2017 and the cleaner expansion in late 2017. The increase in flotation capacity on the rougher circuit is now underway. This paper will review the metallurgy and operational approach that drove the process design with the ultimate results and lessons learned. It will outline the next steps and why they make sense from a process perspective as well as the metallurgical results that drove the justification. The Chapada base case illustrates the opportunity that exists in many facilities to re-examine their operation and leverage advances in technology to unlock potential.

**3:45 PM**

## **Optimization of Mineral Processing Circuit Design Under Uncertainty**

*S. Amini; Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA*

The estimation and analysis of uncertainty propagation in separation circuits are essential and significant, but challenging, aspects of a comprehensive optimal circuit design procedure. Owing to the complex modeling requirements, many of the current circuit optimization tools rely on deterministic models, despite the ubiquity of uncertainty in the techno-economic input parameters (e.g., mineral price, plant feed grade, and process kinetic coefficients). Neglecting the data uncertainty phenomenon in the circuit design procedure may lead to ambiguity in the design and optimization process, as certain solutions may only be optimal under specific input scenarios. This presentation describes the novel implementations of various mathematical strategies (e.g., Law of Propagation of Error), simulation tools (e.g., Monte Carlo Simulation), and stochastic approaches (e.g., Sample Average Approximation) to the design and optimization of separation circuits under uncertainty. Given the large flow volumes, high capital costs, and relative rigidity of the final flowsheet, findings of this study will guarantee that a suitable separation circuit is selected relatively early in the design process.

**TUESDAY, FEBRUARY 26**

*AFTERNOON*

**2:00 PM | ROOM 605**

## SME Young Leaders: Panel Discussion: Things I Wish I Had Known in School and at the Beginning of My Career

**Chair:** *Q. Huang, West Virginia University,  
Morgantown, WV*

This session will feature a panel discussion by senior-level professionals. They will share what they wish they had known when they were in school and at the beginning of their careers. Based on panelists' long-term experiences, they will discuss things that have or would have made a tremendous positive impact on their careers and life today. Questions and discussions are welcomed and invited among panelists and attendees.

### Panelists:

**Michelle Ash**

*Chair of GMG*

**Steven Gardner**

*President/CEO of ECSI, LLC, and 2015 SME President*

**Keith Hainer**

*President, Spearfish Engineering, Consulting & Development PLLC*

**Heather Trexler**

*Proj. Manager, Tetra Tech, 2016 Chair of SME Pittsburgh,  
2018 SME Coal & Energy Div. Program Chair*

**Thomas Novak**

*Department Chair of Mining Engineering, University of Kentucky,  
Alliance Coal Academic Chair*

**TUESDAY, FEBRUARY 26**

*AFTERNOON*

**2:00 PM | ROOM 612**

## **UCA of SME: Tunnels**

*Chairs: R. Brock, Brierley Associates, Denver, CO  
R. Gjerde, Epiroc, Bozeman, MT*

**2:00 PM**

### **Introduction**

**2:05 PM**

### **Oslo Follo Line – Project Challenges and TBM Solutions, 4 Double Shielded Hard Rock TBMs**

*D. Bäßler and S. Dube; Herrenknecht, Etobicoke, ON, Canada*

Until recently, all rail tunnels in Norway were excavated using drill & blast technology. The Follo Line project is a new 22 kilometers long double track rail line that is currently under construction between Oslo Central Station and Ski. Four double shield hard rock TBMs with an excavation diameter of 9.96 meters excavate a total of about 36 kilometers of predominantly Precambrian gneisses with banding and lenses of amphibolite and pegmatite. The tunnelling concept is based on using four TBMs, two of each operating in opposite directions from two access tunnels that are located near the midpoint of the alignment in a remote, rural location. When finished, the tunnel will be Norway's longest and largest rail tunnel. The paper highlights the project challenges in particular the abrasive and strong rock mass, the large diameter in combination with the possible risk of high water pressures (12 bar) that require a well-adapted TBM concept.

**2:25 PM**

### **Predicting TBM Utilization Factor Using Simulation Approach**

*A. Khetwal, O. Frough and J. Rostami; Mining Engineering, Colorado School of Mines, Golden, CO*

Estimation of TBM performance in terms of rate of penetration (ROP) and utilization factor (U) is one of the challenges in mechanized tunneling. Utilization factor is determined by combined effect of tunnel geology, unexpected breakdown, maintenance, utility extension, transportation, site set up, workers/contractor experience, site management, and other unforeseen downtimes. In this study, several tunneling activities and downtimes are modelled using Arena, a discrete event simulation software, to predict the TBM utilization factor. The model was developed using data from selected recent tunneling projects and verified by using data from other tunnel projects to assess its reliability and validity. The comparison of the actual and predicted TBM performance showed good correlation among themselves. This paper will discuss the background of challenges in estimation of utilization rate for TBMs and explains the advantages of the proposed approach, along with the review of the results of the preliminary models developed for this study.

**2:45 PM**

## **Feasibility of Using Microwaves to Break Hard Rock for Underground Tunneling and Excavation**

*R. Kaunda, J. Martinez Calvo, R. Megaptche Kouteu and S. Arora; Mining, Colorado School of Mines, Golden, CO*

As unprecedented demand for mineral resources continue, deeper mines in difficult environments can be anticipated. Therefore, more efficient rock excavation techniques will become valuable to create access to underground workings. The main challenge with current rock excavation techniques is the high cost to break up and move large volumes of rock during blasting, drilling or mechanical excavation. Large openings in hard rock are typically excavated with drill-and-blast or mechanical excavation. Concurrent with concerns regarding excavation costs are more efficient rates of excavation for smoother underground excavations. There is thus need for improved concepts for rock drilling and excavation. In this study, the emerging concept of using microwaves for excavation in hard rock is investigated. Cubic blocks of hard rock subjected to microwave pre-conditioning are used to conduct full-scale linear cutting tests. Specific energy values are calculated using cutting forces for specified spacing and penetration values. The results suggest that microwave preconditioning of hard rock can lead to more economic means of mechanical excavation than for non-preconditioned hard rock.

**3:05 PM**

## **Face Stability Analysis in Earth Pressure Balance Tunneling on Layered Soil – A Case Study**

*J. Shahmoradi<sup>1</sup>, H. Salar<sup>2</sup> and P. Roghanchi<sup>1</sup>; <sup>1</sup>Mineral Engineering, New Mexico Institute of Mining and Technology, Socorro, NM and <sup>2</sup>Amirkabir University, Tehran, Iran (the Islamic Republic of)*

Determining the minimal support pressure in the tunnel face is one of the most critical steps in tunneling using the earth pressure balance method. The purpose of this research is to study a particular tunneling case in great depth by Earth Pressure Balance. In the Dez-Ghomrod water transmission tunnel bored by EPB-TBM, the machine encounters to very weak rock mass similar to alluvial zone. Considering the depth of the tunnel and also the layering of the field, calculating the support pressure of the tunnel face involves significant complexity. In this paper, analytical and numerical methods were utilized to investigate the stability of the tunnel face. The analytical method is based on the slope of layers relative to tunnel face and limit equilibrium of forces. The results demonstrate that the formation of soil arching, distribute the weight of upper levels, and therefore the pressure on the tunnel face is reduced. Geomechanics parameters of the field, shield geometry, and field convergence in the excavated section are essential factors in the calculating the support pressure of the tunnel face. Besides, layering slope and failure mechanism in the tunnel face should be considered.

**3:25 PM**

## **Probability-Based Uncertainty Analysis of Rock Mass Quality in Underground Excavations**

*H. Lu<sup>1</sup>, E. Kim<sup>1</sup> and M. Gutierrez<sup>2</sup>; <sup>1</sup>Department of Mining, Colorado School of Mines, Golden, CO and <sup>2</sup>Department of Civil and Environmental Engineering, Colorado School of Mines, Colorado School of Mines, Golden, CO*

Uncertainty in rock mass quality exists due to the inherently heterogeneous nature of rock mass itself. Traditional deterministic assessment lacks a complete understanding of significant uncertainty involved and may have an adverse impact on the overall design performance. To address this problem, a



probability-based uncertainty analysis approach was proposed to quantify the uncertainty in the rock mass quality Q-system. The proposed probabilistic approach has been successfully applied in a water tunnel in Vancouver. In this study, sensitivity analysis has been conducted to identify the most sensitive input parameters of Q-system. The effect of RQD distribution pattern on the Q-value has also been investigated to select the most representative distribution, which is helpful in realistic prediction and uncertainty evaluation. Moreover, the negative correlation between RQD and  $J_n$  was reported and its effect on Q-value has also been studied. The proposed probabilistic approach can be useful in characterizing the uncertainty in rock mass quality before construction and providing insightful information for assessment of ground response and support performance of underground structures.

**3:45 PM**

## **Optimization Oriented Work Preparation for Sub-Surface Construction Work Under Special Consideration of Construction Logistics and Explicit Choice of Technique and Equipment**

*J. Herhold<sup>1</sup>, H. Mischo<sup>1</sup> and S. Plaum<sup>2</sup>; <sup>1</sup>TU Bergakademie, Freiberg, Sachsen, Germany and <sup>2</sup>University of Applied Science Wiesbaden, Wiesbaden, Germany*

The focus within the economical optimization of projects, which are conducted underground, shifts more and more towards the conduction of construction work underground. Underground operations can be defined in a wide range of various projects, from underground mining tasks to the construction of engineering structures. Within these projects the conduction of construction work cannot only be defined as absolutely necessary, but sometimes also as optimizing for underground processes (e. g. installation of workshops underground to support the mining processes). Even though the conduction of underground construction might cause positive outcomes concerning the productivity, it also tends to be challenging due to local (sub-surface) conditions and influences. To minimize the risk of failure and sudden events within in the conduction of construction work underground, the tool “work preparation” shall be used. Under the given constraints, such as local influences, expected construction work and set time frame, the conduction of the construction work will be planned in advance by consideration of the construction logistics as well as the selection of a fitted construction technique.

**19-075**

## TUESDAY, FEBRUARY 26

AFTERNOON

2:00 PM | ROOM 210

### Valuation: Lessons Learned

*Chairs: T. Knobloch, AIMA, Marietta, OH  
E. Moritz, Gustavson, Boulder, CO*

2:00 PM  
Introduction

2:05 PM  
**The Role of Commodity Futures Markets  
in Mine Planning and Valuation**

*G. Davis<sup>1</sup> and F. Dorobantu<sup>2</sup>; <sup>1</sup>Economics and Business, Colorado School of Mines, Golden, CO and <sup>2</sup>The Brattle Group, New York, NY*

Mine planning and valuation often require the projection of metal prices decades into the future. While no projection will be accurate, it should at least be unbiased, meaning that on average it is correct. In some cases the projected price is taken to be the same as the current price. This is called naïve forecasting. A similar approach is to use the average price over some prior period. Some practitioners suggest that analyst forecasts are the best predictor of metal prices. The firm Consensus Economics surveys these analysts and sells their forecasts to subscribers. Economists tend to prefer the use of futures prices, which are the result of current trades on regulated exchanges for the purchase and sale of metal at some future date. In this presentation we review the theoretical and empirical support for these types of forecasts. We suggest that practitioners consider the use of futures prices in mine planning and valuation exercises since these may be the least biased measure of prices over the short term. We show how projections based on futures prices can be extended beyond the relatively short horizon for which futures trade by using empirically calibrated price models.

2:30 PM  
**Highest and Best Use Analysis and Its Application  
in Appraising Undeveloped Mineral Properties**

*A. Stagg; Stagg Resource Consultants, Inc., Cross Lanes, WV*

There is a continuing debate in the mineral appraisal community regarding the appropriate technique to use in valuing an undeveloped mineral property when using the Income Approach to Value, with the alternatives being the use of either a royalty income or an operating income. As background, it is noted that a lease of mineral rights creates two new estates in a property: the Leased Fee and the Leasehold. In those instances in which a lease exists for an undeveloped property, the valuation approach will be reflective of which of these two estates is being valued. For properties that are not under lease at the date of the appraisal but for which the Income Approach to Value is being used, the issue becomes which of the two estates should be the basis for the appraisal. In the author's experience, this decision is best approached as part of the Highest and Best Use analysis. Support for this concept and a hypothetical example are provided in this presentation.



**2:55 PM**

## **Appraisal Education: An Overview and Recent Experiences**

*D. Werthessen; Mineral Engineering, New Mexico School of Mines, Rehoboth, MA*

Mineral appraisal is a specialization within the larger valuations industry. Licensure, regulations, and the myriad of professional organizations may confuse those new to the discipline or matriculating from other industries. Instruction is currently provided by a number of different entities. The Appraisal Institute (AI), American Society of Appraisers (ASA), and American Society of Farm Managers and Rural Appraisers (ASFMRA) are some of the primary providers of introductory and advanced coursework in appraisals education. EduMine is a primary resource for mining and geologically focused material, available through the web and short courses. The International Institute of Minerals Appraisers (IIMA) is the presiding body within the United States for minerals appraisal and efforts to organize international chapters continues. This presentation will provide novices with some guidance towards licensing structures found throughout the United States as well as what may be expected from state licensing boards. Experiences and examples from the author's recent coursework with the Appraisal Institute and assignments completed with a commercial real estate appraisal firm will be presented.

**3:20 PM**

## **International Valuation Problems – Solutions by IMVAL**

*J. Gustavson<sup>1</sup> and F. Pirkle<sup>2</sup>; <sup>1</sup>Mineral Appraiser LLC, Boulder, CO and <sup>2</sup>Gannett Fleming, Jacksonville, FL*

These are standards AFTER reserves have been estimated. What is fair value, market value, investment value? International Mineral Valuation (IMVAL) Committee, founded 2012, developed strategies for conducting those mineral asset valuations. The strategies have been combined in a template, the "International Mineral Property Valuation Standards Template", linked to the SME Standards website. IMVAL works toward consistent international standards for mineral asset valuation and reporting. The Template deals with Valuation -putting a cash value on minerals in the ground, -which is distinctly different from the much broader Evaluation. This template is a living document, based on three fundamental principles: Competence, Materiality, and Transparency. The Template is a base on which countries and appraisal associations may harmonize the standards in their own countries for valuation of minerals as real estate. It represents a consensus of current good practices. It is not a stand-alone reporting code and does not claim to supersede existing national reporting standards. To put cash value on minerals, be it land, at feasibility stages, during development or producing: you need IMVAL!

**3:45 PM**

## **Three Pillars of Mineral Valuation**

*F. Pirkle and W. Bagby; Gannett Fleming, Inc., Jacksonville, FL*

The International Mineral Valuation (IMVAL) Committee, founded in 2012, develops strategies for conducting mineral valuations. These strategies, have been developed into a mineral asset valuation template called the International Mineral Property Valuation Standards Template and is part of IMVAL's work to establish consistent international standards for mineral property valuation and reporting. This template is a living document that is updated from time to time and is based on three core values or pillars (fundamental principles): Competence, Materiality, and Transparency. Objectivity, Independence, and Rea-

sonableness may be applied as required by national codes or standards. The Template harmonizes international standards for valuation of mineral assets as real estate and represents a consensus of current good practices. It is not a stand-alone reporting code and does not supersede existing national reporting standards. The Template deals with Valuation, which is distinct from Evaluation.

19-012

4:10 PM

### Eminent Domain Mineral Property Valuations: When Self-Proclaimed “Latitude” Falls Somewhere South of Competence and Ethical Obligations

*J. Beck; J. M. Beck & Associates, Lakewood, CO*

Mineral property appraisers in eminent domain actions on properties where mining is the highest and best use must be competent in all phases of mineral project development (or retain competent assistance), and eminent domain appraisal requirements (USPAP Competency Rule). Failure to ensure such triggers the issue of appraisal competence, and demonstrates a disregard of the code(s) to which the appraiser is subject. The assertion of “latitude” in the valuation process does not exonerate the appraiser from a disregard of the USPAP Competency Rule. Lack of independence (i.e., “advocacy”) in mineral property appraisal is the usual result of a weak background in mining and/or appraisal theory. While it is apparent to those able to recognize it, judges and juries cannot be expected to detect purposefully misleading valuations. Deception by the appraiser can lead to either over-compensation or failure to provide just compensation. Yet, the purpose of eminent domain proceedings is to leave the property owner no richer or poorer as a result of the taking. Deceptive practices encountered in litigation settings are discussed in context with competency, ethics, and professional certifications.

19-024

TECHNICAL PROGRAM: TUESDAY

**TUESDAY, FEBRUARY 26**

*AFTERNOON*

**3:00 PM | ROOM 601**

## **Barrick Operators Session Leading Through Challenging Times**

*Sponsored by: Barrick*

*David Rabiner, Leadership and Work/Life Balance Expert*

Ultimately, leadership is all about helping people and organizations develop and reach their potential. This powerful program explores the principles of achievement and the leadership practices critical to achieving organizational results and a resilient, spirited workforce especially during challenges times. Since 1993, David Rabiner has helped audiences become better leaders, perform at a higher level, and create stronger teams and organizations. His programs are fun, substantive, and have practical application. Audiences relate to David's common-sense approach and real-world examples. In the end, they are motivated to change and they know how to do it – the hallmark of speaking excellence. Averaging over 90 programs each year, David is one of the most experienced speakers in America. In 2003, he earned the coveted Certified Speaking Professional (CSP) designation, an honor awarded to a small percentage of speakers worldwide.

## WEDNESDAY, FEBRUARY 27

MORNING

8:30 AM | ROOM 709

### Fuerstenau Symposium: Technology & Innovations

*Chairs: Pradip, Tata Consultancy Services Ltd  
J. Herbst, Retired, Morgantown, WV*

8:30 AM  
Introduction

8:35 AM  
**A Step Change for Carbon Dioxide Capture –  
Enhancement with Frothing Agents**

*S. Root, S. Valluri and S. Kawatra; Chemical Engineering,  
Michigan Technological University, Houghton, MI*

In the United States, 6.6 billion metric tons of CO<sub>2</sub> are released into the Earth's atmosphere annually. The increasing levels of atmospheric CO<sub>2</sub> have been linked to climate change. Carbon dioxide capturing technologies are expected to slow and even reverse the effects of climate change. Reagents used in common technologies, like amine absorption, are expensive and energy intensive to regenerate. Aiming to make carbon dioxide capture a profitable venture, researchers at Michigan Technological University have designed a packed bed scrubbing column which uses aqueous sodium carbonate rather than amines as a scrubbing medium. In flotation, we use frothers to create finer and uniform bubble sizes. We have applied this same strategy to CO<sub>2</sub> capture to increase the available surface area for CO<sub>2</sub> transport within the packed bed. This novel enhancement of a relatively inexpensive carbon dioxide capture-regeneration cycle shows potential to allow plants to turn a profit by sequestering a waste product.

19-071

8:50 AM  
**Carbon Dioxide Capture Utilization and Storage (CCUS):  
Sustainable Solution for Climate Change Mitigation**

*J. Ahn<sup>1</sup> and T. Thenepalli<sup>2</sup>; <sup>1</sup>Climate change mitigation and sustainability division, Korea Institute of Geoscience and Mineral Resources(KIGAM), Daejeon, Daejeon, Korea (the Republic of) and <sup>2</sup>Research Department, Hanil Cement Co Ltd, Daejeon, Daejeon, Korea (the Republic of)*

Currently, the global warming trend is of notable significance because most of it is immensely likely to be the result of anthropogenic activities since mid of the 20th century. Responding to climate change involves two possible approaches: one is mitigation and the second one is adaptation. Adapting to the climate change, CCUS technologies will play a major role in the CO<sub>2</sub> emission reduces and it can deliver solutions to major environmental challenges. The carbonation of alkaline material is an inexpensive and safe process that leads to the formation of thermodynamically stable products. The use of the carbonation can be an advantageous solution for overcoming



problems associated with coal ash and the emissions of several thousand tons of CO<sub>2</sub> from coal power plants each year. The role of convergence technologies for the utilization of coal ash, bauxite residues to manufacture green cement called “Calcium Sulfo Aluminate” and simultaneous CO<sub>2</sub> capture and utilization. Convergence technologies offered a lot of benefits and opportunities to overcome the environmental challenges.

**9:05 AM**

## **Linear Circuit Analysis: A Tool for Addressing Challenges and Identifying Opportunities in Process Circuit Design**

*A. Noble, G. Luttrell and S. Amini; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA*

The linear circuit analysis (LCA) technique, originally conceived by Meloy (1983) nearly four decades ago, provides fundamental insights regarding how unit operations interact and respond when arranged in multi-stage processing circuits. Researchers at Virginia Tech have successfully utilized this tool to improve the operating performance of industrial processing circuits incorporating coal spirals (Luttrell et al., 1998), magnetic separators (Luttrell et al., 2002), mineral spirals (McKeon and Luttrell, 2005) and eddy current separators (Shuttleworth et al., 2015). More recently, advanced versions of this tool have also been developed to provide a standardized framework for circuit mass balance calculations (Noble and Luttrell, 2014), to output exact analytical solutions to mass yield and value-based efficiency expressions (Noble and Luttrell, 2015), and to estimate uncertainty propagation in separation circuits (Amini and Noble, 2017). This article reviews the historical development of LCA, describes how the technique has evolved to address more complex circuit design problems, and presents industrial case studies that highlight the importance of this process engineering tool.

**9:20 AM**

## **Mapping Flotabilities on Mineral/Ore Cross Sections**

*M. Rudolph, B. Babel and E. Schach; Department of Mineral Processing, Helmholtz Institute Freiberg for Resource Technology, Freiberg, Saxony, Germany*

The wettabilities of particle systems play a crucial role for the separation efficiency of flotation processes. While the characterization of reagent-mineral interactions of finely intergrown ores is limited in the applicability of standard techniques like microflotation tests and contact angle experiments or renders them impossible due to a lack of sufficient samples in terms of quality and quantity, the colloidal probe atomic force microscopy technique proofed its value to characterize wettabilities on a microscale. We are presenting a novel methodology to study flotation characteristics based on embedded mineral/ore specimen and colloidal probe atomic force microscopy with a hydrophobic particle probe. It enables us to map hydrophobic interactions on process relevant sample surfaces and how it is correlated to the flotation behavior of the phases in froth flotation separation processes. The realization as a tool for fast flotation reagent screening is as well shown on various mineral and ore specimen. In addition our results contribute to the understanding of hydrophobic interactions, a still diverse topic in fundamental flotation science.

**9:35 AM**

## **Panel-Technology & Innovation**

*J. Gebhardt; FLSmidth Inc, Midvale, UT*

A panel of industrial and academic experts will discuss current and future issues facing the mineral processing industry. Will flotation be replaced? Are we at the limit of super-sized equipment? How do we ensure sustainable growth for the minerals industry? How do we reduce energy and water requirements for processing? How do we leverage advances in digital technology to meet the challenges facing us? Panel members John Marsden (Metallurgium LLC), P. Somasundaran (Columbia University), Robin Batterham (University of Melbourne), Mikael Lindholm (FLSmidth Inc) and D.R. Nagaraj (Solvay) join John Herbst (retired – formerly with Metso) for a discussion about imminent issues and future opportunities in the minerals industry.

**9:45 AM**

## **Break**

# **WEDNESDAY, FEBRUARY 27**

*MORNING*

**9:00 AM | ROOM 707**

## **Coal & Energy: Atmospheric Monitoring Systems in Underground Coal Mines**

**Chairs:** *J. Kohler, Penn State University,  
University Park, PA  
G. Barclay, Contura Energy Services*

**9:00 AM**

## **Introduction**

**9:05 AM**

## **Safety, Health and Cost Benefit Optimization with Accident Intervention Assistance**

*G. Danko and W. Asante; Mining and Metallurgical Engineering,  
Univ. of Nevada, Reno, Reno, NV*

An Early-Warning System (EWS) is described to interpret automatically the signal trends from the Atmospheric Monitoring Sensors (AMS) in underground mines in the real and the near-future time for assessing continuously safety and health conditions; and for supporting cost saving decisions. The EWS continuously processes AMS data and compares the trends with the results from a fast-running, Dynamic Model of the Mine (DMM). The signals are evaluated for the recognition of any upcoming accident scenario by pattern recognition, root-cause analysis, and fast-forward prediction using machine

learning and artificial intelligence components. The DMM simulation over long, normal conditions represents a mine operating within the acceptable variation boundaries. If and when the signal patterns in the AMS data deviate too much and too consistently from the output data of the DMM, the root cause is recognized by the EWS and the DMM is run in forward-prediction mode to check possible outcomes: whether it is either harmless or potentially harmful for the safety of the mine. Evaluation of the safety margin is used to advise the operators for avoiding possible over-ventilation for cost savings.

**9:25 AM**

## **Corrosion Monitoring of Roof Bolts in Underground Mines with Half-Cell Potential Technique**

*G. Bylapudi, A. Spearing and K. Mondal; Mining and Mineral Resources Engineering, Southern Illinois University Carbondale, Carbondale, IL*

Corrosion of roof support systems in underground mines can be a serious threat to rock related safety with direct negative impact on the workforce and then production. The majority of research related to corrosion of roof bolts used in underground mines are focused on identifying the factors responsible for the corrosion and testing the commonly used bolt material in different conditions. Corrosion monitoring work to identify the corrosion severity of roof bolts in the field is novel to the underground mining industry and could be a possible solution for the mentioned problem. Corrosion potential methodology was developed in the past by the researchers at SIUC and that methodology is purely based on spot readings which tell the reader only the chance of corrosion activity at that time and doesn't tell the reader the severity of it. To assess the roof bolt corrosion severity, the longterm corrosion monitoring of the bolts corrosion potential and its' shift with time is necessary and hence recorded in situ using the half-cell potential technique. Hence, this preliminary research is significant to the underground mining industry in assessing the roof bolt corrosion severity.

**9:45 AM**

## **AwAir Gas Detection System for Refuge Alternatives Uses Gas Extraction and Includes Automatic Calibration**

*A. Ketter; Rel-Tek Safety Technology Center, Monroeville, PA*

The AwAir™ gas detection system manufactured by Rel-Tek Corporation monitors four gases (CH<sub>4</sub>, CO<sub>2</sub>, CO and O<sub>2</sub>) inside and outside a Refuge Alternative (RA) using gas extraction means via four tubes. A data viewing window displays sensor values and status. Intrinsically Safe external alarm and switches are provided for occupant controls. Enclosed in two XP boxes, one housing the four sensors and computer electronics, and another holding a 96-hour battery backup. The MSHA approval issued (18-A150009-0) covers the complete AwAir system, including the fully automatic sensor calibration utility which maintains sensor accuracy throughout a five-year hot standby period. A data viewing window displays sensor values and status. Intrinsically Safe external alarm and switch circuits are provided externally for occupant alerts and controls. Redundant air pumps draw sample gases from as far as 500 ft (152m) so can accommodate Built-in-Place RA's as well."

**10:05 AM**

## Using an Atmospheric Data Management System for Decision Making

*Z. Agioutantis<sup>1</sup>, K. Luxbacher<sup>2</sup> and S. Schafrik<sup>1</sup>; <sup>1</sup>Mining Engineering, University of Kentucky, Lexington, KY and <sup>2</sup>Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA*

The goal of our research atmospheric data management system is to collect data from a variety of disparate sensor systems and displaying them in a manner that a human operator can monitor the conditions. Monitoring of atmospheric conditions by both human and computer based operators makes ventilation systems more efficient and responsive. The layout of the sensors in each mine depends on regulatory requirements, mine geometry, the design of the ventilation system, the availability of power and communication lines to each sensor location and other parameters. In many mines the sensor packages are in proprietary data forms and do not intercommunicate. Currently, several real-time monitoring techniques are available that allow mine operators to monitor all ventilation parameters including, air flow, air velocity, pressure drop, and gas concentration at various locations throughout a mine. This paper presents an atmospheric data management system that demonstrates the techniques that should be adopted for informed decision making by operators. The system can be used to identify developing critical conditions, which can then be mitigated safely, timely and effectively.

**10:25 AM**

## Strategic Location of Sensors in Atmospheric Monitoring Systems

*J. Kohler, S. Lu, L. Fan and E. Zeglen; Energy and Mineral Engineering, Penn State University, University Park, PA*

Advances in technology have made it easier than ever to acquire real-time information from all parts of the mine and the operations within the mine. Our ability to collect vast amounts of data has outstripped our ability to utilize, or otherwise gain a benefit from the information embedded in that data. Moreover, there are significant ongoing costs associated with this data collection. While a good case can be made for the use of atmospheric monitoring systems to improve mine safety, there is little evidence of sustained efforts to do this. One barrier that must be overcome can be stated as a simple value proposition: the value of the acquired data must exceed the cost of the data acquisition. The goal of the research presented in this paper was to formulate a strategy for placing a minimum number of sensors throughout the mine to help identify developing ventilation conditions that could lead to hazards. A generalized strategy was developed and tested, and the strategy, along with the underlying research, are summarized in this paper.

**10:45 AM**

## Monitoring Gases in Remote and Access Challenged Areas of Underground Mines

*D. Snyder, G. Luxbacher and J. Burr; NIOSH, Pittsburgh, PA*

Under the MINER Act, NIOSH has been given the responsibility for awarding contracts related to the development and implementation of new mine technology and equipment. The extension of Atmospheric Monitoring Systems (AMS) have been an ongoing focal point, providing the opportunity to identify disruptions in the mine ventilation system before they become serious and,



in the event of a disaster, providing critical information for escape and rescue. Often the locations that could benefit from monitoring are in difficult or not routinely access areas. This paper summarizes the work that has been done to develop systems that extend the monitoring of gases to these areas on a real time and/or on demand basis.

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## WEDNESDAY, FEBRUARY 27

MORNING

**9:00 AM | ROOM 711**

### **Coal & Energy: Coal Preparation and Advances in Clean Coal Technologies**

**Chairs:** *T. Ghosh, University of Alaska Fairbanks, Fairbanks, AK*  
*Q. Huang, West Virginia University, Morgantown, WV*

**9:00 AM**

**Introduction**

**9:05 AM**

### **A Robust Optimization Approach for the Coal Blending Problem Under Uncertainty**

*S. Amini<sup>1</sup>, C. Vass<sup>2</sup>, M. Shahab<sup>3</sup> and A. Noble<sup>3</sup>; <sup>1</sup>Mining & Minerals Engineering, Virginia Tech, Blacksburg, VA; <sup>2</sup>Mining Engineering, West Virginia University, Morgantown, WV and <sup>3</sup>Civil and Environmental Engineering, University of Michigan, Ann Arbor, MI*

Coal blending, as a critical element of the coal supply chain, plays an integral role in attaining the financial and strategic objectives of the mining operations. In many cases, the blending problem is incredibly complex, as some large mining complexes process materials from numerous sources while trying to fulfill several distinct sales contracts. To assist in this task, many operators will use sophisticated blend optimization software packages that specify which coal sources should be blended into specific products to maximize the overall profit. While these tools are very helpful in setting blend specifications, they often neglect the various sources of uncertainty that may reduce the validity of the optimization results. As a result, operators usually apply arbitrary safety factors on top of the model results to ensure that the desired specifications are met. The current study describes and demonstrates an alternative optimization approach that rigorously accounts for these uncertainties while outputting a robust blending solution. The proposed strategy can help decision makers achieve the economic and strategic goals of the operation at acceptable risk levels.

9:25 AM

## Enhanced Bio-Weathering of Alaskan Coal for REE Extraction and Concentration

A. Sachan<sup>1</sup>, T. Ghosh<sup>1</sup>, R. Ganguli<sup>1</sup>, F. Dehghani<sup>1</sup>, S. Aggarwal<sup>2</sup> and B. Briggs<sup>2</sup>;

<sup>1</sup>Department of Mining and Geological Engineering, University of Alaska Fairbanks, Fairbanks, AK; <sup>2</sup>Department of Biological Sciences, University of Alaska Anchorage, Anchorage, AK and <sup>3</sup>Department of Civil and Environmental Engineering, University of Alaska Fairbanks, Fairbanks, AK

The rare earth elements (REEs) are a group of seventeen elements which include scandium, yttrium, and fifteen elements of the lanthanide series and are vital components in modern electronics, consumer goods, navigation and defense equipment. Securing a profitable domestic supply source is thus a critical national need. Some Coal deposits are rich in REEs and can serve as an alternative source as demonstrated by the fact that some of the Alaskan coal deposits contain REEs in concentrations as high as 950 ppm. Microbes have profoundly affected Earth's surface over geologic time periods by playing critical roles in weathering of minerals, and microbial weathering rates are very high compared to abiotic reactions. Several mechanisms of microbial weathering have been identified such as acid production (organic and strong acids), physical disruption, siderophore or chelator production, and electron transfer. In this study, bacteria were utilized to separate the REEs from certain Alaskan coal samples and the efficiency was compared to the conventional methods of REE extraction. Keywords: Rare earth elements, Coal, Microbes

9:45 AM

## Conception of a Coal Preparation Flowsheet for Minimizing Potential Environmental Impacts of Associated Waste Materials

M. Rezaee<sup>1</sup> and R. Honaker<sup>2</sup>; <sup>1</sup>Energy and Mineral Engineering, The Pennsylvania State University, University Park, PA and <sup>2</sup>Mining Engineering, University of Kentucky, Lexington, KY

An environmental concern at coal preparation operations is the release of elements resulting from the oxidation or dissolution of certain minerals contained in the process waste streams. Using a standard conductivity test, the electrical conductivity (EC) of the water samples obtained from mixing with various particle size and density fractions of a given plant waste material were measured as an indicator of total dissolved solids. The net neutralization potential (NNP) of the fractions were also measured to predict the pH of the supernatant upon disposal. As a result, the particle size and density fractions contributing to high EC levels and also acid generation were identified with the objective of potentially extracting and isolating the fractions to reduce the potential for negative environmental impacts. Based on the obtained results, modifications to the coal preparation plants was proposed. The proposed flowsheet not only minimizes the generation of acid mine drainage, release of trace elements and EC of the discharged water, but also enhances the recovery and quality of the final clean coal product.



**10:05 AM**

## **Separation Characteristics and Performance of Large-size Coal (50-150 mm) with a Deep Air Dense Medium Fluidized Bed**

*L. Guofeng<sup>1</sup>, C. Duan<sup>1</sup>, Y. Zhao<sup>1</sup>, C. Sheng<sup>1</sup> and Q. Liu<sup>2</sup>; <sup>1</sup>School of Chemical Engineering & Technology, China University of Mining and Technology, Xuzhou, Jiangsu, China and <sup>2</sup>Department of Chemical and Materials Engineering, University of Alberta, Edmonton, AB, Canada*

The deep air dense medium fluidized bed (DADMFB) was established in this study with attempt to separate the large-size coal (+50mm) and investigate the separation efficiency. The separation performance of a DADMFB separator for large-size coal (50-150 mm) beneficiation was studied. Experiments, involving factors of fine coal content ( $\varphi$ ), superficial air velocity ( $U$ ), and static bed height ( $H_s$ ) were conducted to analyze the influence of each factor on the separation characteristics of large-size coal separation with DADMFB. The clean-coal ash content ( $A_d$ ), yield ( $\gamma_p$ ), separation efficiency ( $\eta$ ), and Ecart probable moyen ( $E$ ) were implemented to evaluate the separation efficiency. The optimum operating conditions were determined to be  $U = 12.8$  cm/s,  $\varphi = 8\%$ , and  $H_s = 600$  mm, leading to optimum ash content and  $E$  values of 15.7% and  $0.045$  g/cm<sup>3</sup>, respectively.

**10:25 AM**

## **Research on the Uniformity of Density in a Deep Air Dense Medium Fluidized Bed**

*L. Guofeng, Y. Zhao, L. Dong, C. Duan and Z. Enhui; School of Chemical Engineering & Technology, China University of Mining and Technology, Xuzhou, Jiangsu, China*

The feasibility of optimizing the density distribution of the deep air dense medium fluidized bed (DADMFB) was explored by changing the air chamber to a new type one, with the local pressure drop fluctuations throughout bed space used to characterize the nonuniformity of bed density. Experiments shows that, when the new type air chamber was used, the region of high density is changed from central axis of the bed to periphery, and the uniform area of density is also increased obviously, with the increase of fluidizing gas velocity, the radial distribution of bed density decreases at first and then increases, and the minimum value of the standard deviation is  $0.1035$ g/cm<sup>3</sup>.

**10:45 AM**

## **Applications of Portable XRF Technology in Coal Mining: Essential Hard Rock Tool Moves to Soft Rock**

*J. Caban; Analytical Instrumentation, Olympus, Waltham, MA*

In recent decades, portable x-ray fluorescence (pXRF) technology has become an accepted and well-proven technique for the elemental analysis of hard rock mining samples in base metal, precious metal, iron ore, and light rare-earth deposits. Historically, XRF was only considered to be a “reliable” technique for elements Ti and heavier. In the past five years, advancements in pXRF hardware including Rh anode x-ray tubes, silicon drift detectors, graphene detector windows, and improved signal processing, have made it possible to analyze elements as light as Mg in the field at ppm concentration levels. Recent work completed at the University of New South Wales as part of the Australian Coal Industry Research Program (ACARP) has shown that pXRF can be used not only for whole-rock geochemistry, but also for direct sulfur analysis and to estimate ashing content and calorific value. For ashing

content, a proxy comprised of several elements including Mg, Al, Si, P, S, Ti, K, Ca, and Fe, shows excellent correlation with lab-calculated ash yield. This research has been successfully applied to the Sebuk and Jembayan Thermal Coal Mines in Indonesia, where pXRF is now being utilized.

## WEDNESDAY, FEBRUARY 27

### MORNING

#### 9:00 AM | ROOM 704

### Coal & Energy: Dust Control-II

*Chairs: R. Reed, NIOSH, Pittsburgh, PA*

*E. Sarver, Virginia Tech, Blacksburg, VA*

#### 9:00 AM

#### Introduction

#### 9:05 AM

### Roof Bolter Canopy Air Curtain Effects on Airflow and Dust Dispersion in An Entry Using Blowing Curtain Ventilation – A Computational Fluid Dynamics Evaluation

*Y. Zheng<sup>1</sup>, W. Reed<sup>1</sup>, M. Shahan<sup>1</sup>, P. Zhang<sup>2</sup> and J. Rider<sup>1</sup>; <sup>1</sup>Dust, Ventilation and Toxic Substances Branch, National Institute for Occupational Safety and Health, Pittsburgh, PA and <sup>2</sup>National Institute for Occupational Safety and Health, Pittsburgh, PA*

Roof bolter operators may frequently experience significantly high respirable dust concentrations on continuous miner sections that use blowing face ventilation. The canopy air curtain (CAC) using a filtered blower fan to deliver clean air directly to the miner underneath may be a solution to reduce the high respirable dust concentrations. In this study two scenarios are considered; 1) a roof bolter machine located in the center of the entry bolting the fifth row of bolts, and 2) a roof bolter machine located closest to the face while drilling the last row of bolts. In both scenarios, the bolting machine is placed in an environment comprising 6 mg/m<sup>3</sup> of respirable dust using a blowing curtain with 3,000 cfm ventilation. Two operation positions are considered in the simulation: dual drillheads inward position or outward position which the bolting machine is drilling either two inner or two outer bolts in the same depth of the mining face. The influence of the CAC on airflows and dust dispersion will be evaluated with the CAC operating at 250 cfm. The results of the study can help the mining engineer and miners to improve their working practice accordingly.

19-021

**9:25 AM**

## **Optimizing Continuous Miner Blowing Face Ventilation Parameters for Reducing Shuttle Car Operator Dust Exposure**

*S. Klima and J. Organiscak; CDC NIOSH, Pittsburgh, PA*

CDC NIOSH performed testing to optimize airborne dust capture and methane removal performance of flooded bed scrubbers on continuous miners using blowing face ventilation to reduce shuttle car operator respirable dust exposure. Curtain-to-face setback distance (30-ft vs. 50-ft), face ventilation airflow (8,000 vs. 12,000 ft<sup>3</sup>/min), and operating side body blocking sprays (on vs. off) were compared, along with slab vs. box cuts and shuttle car location (behind the continuous miner vs. not present). Scrubber airflow was maintained at 7,000 ft<sup>3</sup>/min. The resulting optimal blowing face ventilation setup uses blocking sprays with a 50-ft setback and 12,000 ft<sup>3</sup>/min face ventilation.

**19-078**

**9:45 AM**

## **Assessment of a Two-Component Foamed Rock Dust**

*C. Brown, I. Perera and M. Harris; CDC NIOSH, Pittsburgh, PA*

The application of rock dust can limit miners' visibility and increase exposure to respirable dust. The solution, wet rock dusting, results in caked rock dust no longer effectively dispersing to suppress a coal dust explosion. Researchers focused on a foam rock dust formulation which can be applied wet to mine surfaces and remain dispersible once dried. A series of lab tests were conducted to examine the effects of humidity, submersion in water, overloading and under-loading the formulation with rock dust as well as foam components, alterations to the rock dust size distribution, and varied rock dust types on dispersion.

**10:05 AM**

## **Feasibility Study of Selected Face Ventilation Layouts for Extended Cut Continuous Mining in Low Coal Mining Height**

*T. Petrov<sup>1</sup>, B. Mackellar<sup>2</sup> and D. Turner<sup>2</sup>; <sup>1</sup>Engineering Consultant, PhD, Lexington, KY and <sup>2</sup>Professional Engineer, Lexington, KY*

A study of selected face ventilation scenarios for the conditions of a coal mine with a 5.5 ft height of the entry has been performed. The purpose of the study is to investigate the feasibility of several face ventilation design variants to meet the safety standards for 40-45 ft extended cut. The study involves Computational Fluid Dynamics modeling, in-mine measurements, and full-scale lab testing. The paper discusses the specifics of the mining conditions, the findings of the study and presents options for dust control improvement.

**19-134**

**10:25 AM**

## **Evaluation of PDM Sample Tube Cleaning Techniques and Particle Re-Entrainment from Sample Tube Manipulation and Pinching and Pdm Inversion**

*S. Mischler and T. Lee; PMRD, NIOSH, Pittsburgh, PA*

CDC NIOSH has completed extensive testing of the personal dust monitor (PDM) and will continue to assist the mining industry and MSHA with research questions regarding PDM use. As part of CDC NIOSH's continued commitment to successful continuous personal exposure monitoring, CDC NIOSH investigated several questions that were raised by our mining stake-

holders including; 1) effectiveness of different methods for sample tube cleaning and 2) potential for re-entrainment of particles resulting from sample tube pinching or PDM inversion. The results of this testing show that tube pinching and PDM inversion create insignificant re-entrainment and standard cleaning procedures are adequate.

## WEDNESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM 708

### Coal & Energy: Research and Development-II

*Chairs: M. Trevits, Xtraction Science and Technology, Inc, Pittsburgh, PA  
L. Ackah, Southern Illinois University at Carbondale, Carbondale, IL*

9:00 AM

#### Introduction

9:05 AM

#### Evaluating Performance of Real Time DPM Monitors for Quantifying Airborne EC and OC

*K. Raj, D. Parks, M. McNinch and A. Miller; NIOSH, Spokane, WA*

Diesel particulate matter (DPM) has been shown to contribute to various adverse health effects on underground miners. In order to reduce worker exposures, it is critical to measure the levels of DPM in the active work settings and in real time. However, the National Institute for Occupational Safety and Health (NIOSH) 5040 method, which quantifies the mass of “elemental carbon” (EC) and “organic carbon” (OC) in the samples, is based on full-shift samples and can take days or even weeks for results, which can risk miner exposure to DPM. Use of real time monitors could significantly reduce the risk of DPM exposure to miners, and available monitors have been shown to quantify DPM, mainly using the EC and other surrogates. NIOSH Spokane Mining Research Division is conducting research aimed at developing a field portable DPM monitor that is able to quantify both EC and OC. One part of that work is to understand the effect of OC on currently available real time DPM monitors. This paper will present the results from experiments that were designed to observe the effect of high OC on real time monitors and compare the results with the NIOSH 5040 method.

19-087

**9:25 AM**

## **Infrared Spectroscopy for Quantifying Diesel Particulate Matter**

*D. Parks and A. Miller; Spokane Mining Research Division, NIOSH, Spokane, WA*

Diesel particulate matter (DPM) has been classified as a carcinogen to humans by the International Agency for Research on Cancer. DPM exposure is regulated by the Mine Safety and Health Administration. Currently diesel emissions in the workplace are monitored by way of collecting the aerosol onto filters, which are then sent to a lab for thermal-optical analysis using the NIOSH 5040 method. This process can take days or even weeks, and workers can potentially be exposed to excessive levels of (DPM) before the problem is identified. To remedy this, researchers from the National Institute for Occupational Safety and Health are seeking to develop a field-portable method for measuring elemental and organic carbon in DPM aerosols. In the current study, we investigated the use of Fourier transform mid-infrared spectrometry, which lends itself more readily to implementation in a real-time system than do the thermal-optical analysis methods. We have demonstrated a method for measuring organic and elemental carbon in DPM for a broad range of organic carbon to elemental carbon ratios. The method has been applied to laboratory generated samples and to mine samples with success.

**19-112**

**9:45 AM**

## **Large-Scale Screen Testing: More Realistic but What Changes?**

*T. Klemetti and T. Batchler; Ground Control Branch, NIOSH, Pittsburgh, PA*

How representative are small-scale screen tests of the in situ response of screen to roof and rib deterioration and displacements? Can a more representative test procedure improve the utilization and effectiveness of screen as a roof and rib support? This paper details a new large-scale screen test procedure and initial results. The test frame was designed to test an 8 by 16 feet screened area with bolt spacing as small as 1 foot increments. The initial design was planned for testing up to 6 pull points, but additional locations can be added to produce a more uniform loading. The test frame was developed to capitalize on the capabilities of the Mine Roof Simulator at the Pittsburgh Mining Research Division of the NIOSH. The initial tests included a baseline test using the original 4 by 4 feet test frame, a 4 by 4 feet test in the large-scale test frame, and two multiple pull point tests. The large-scale 4 by 4 tests produced a peak load 6% higher and a yield load 30% lower than the original test frame. The multiple pull points of the large frame produced variable yield, peak, and intermediate loads, but on average were lower than the single pull point tests.

**19-048**

**10:05 AM**

## **Study of Airflow Patterns During the Advancement of the Face in Extended-Cuts Using Particle Image Velocimetry**

*K. Mayfield, T. Novak and S. Schafrik; Mining Engineering, University of Kentucky, Lexington, KY*

The effectiveness of face ventilation systems in underground coal mines is crucial for the health and safety of mineworkers. Its primary role is to dilute potentially harmful contaminants as they are produced by the coal-cutting

process. To provide effective dilution, an adequate quantity of intake air must reach the active face. This challenge increases with the distance between the end of the curtain and the active face, particularly when extended cuts, up to 40 ft, are used. Air currents become unpredictable in a dead-ended entry, and the complexity worsens with the presence of machinery. Furthermore, safety issues and lack of accessibility limit the means for making airflow measurements during coal-cutting operations. To circumvent this problem, researchers use various techniques, such as physical models and computational models, to study airflow behavior in face ventilation systems. A 1:12 reduced-scale physical model of a continuous miner operating in an extended-cut entry was constructed for investigating airflow patterns using PIV. The results of this study are presented with the intention of providing insights for creating improved face-ventilation strategies.

**10:25 AM**

### **Dispersibility of Rock Dust for Coal Dust Explosion Prevention**

*R. Gilmore and J. Brune; Mining, Colorado School of Mines, Golden, CO*

Underground coal mines apply finely powdered limestone rock dust to inertize explosive coal dust deposits created during the mining process. Rock dusting creates a cloud of nuisance dust downwind, preventing other work in the area. Applying a wet or foam mix of rock dust eliminates the nuisance dust, but may impact the dispersion and explosion prevention capability and thus, may render the rock dust ineffective. Dispersibility tests were conducted in a full-size mine explosion test drift at the Colorado School of Mines. Tests include dry, wet, dry-misted, and foam applications using three types of rock dust: conventional, hydrophobic, and rock dust meeting stricter German specifications. Results show that dried dust forms large, agglomerated particles that may not be effective in suppressing coal dust explosions. Hydrophobic rock dust maintains better dispersibility even when applied wet or applied dry then misted. German specification dust disperses better than U.S. conventional rock dust.

**19-133**



**WEDNESDAY, FEBRUARY 27**

*MORNING*

**9:00 AM – 11:05 AM | ROOM 710**

## **CMA: State and Federal Mining Policy Update**

*Sponsored by: Climax Molybdenum, a  
Freeport-McMoRan Company*

Every federal agency has implemented the administration's objectives to ease regulations in the energy and environmental arena. EPA, BLM, the Forest Service, Fish and Wildlife Service and others have embraced the plan. Colorado state agencies are dealing with these changes in various ways. A panel will review some of the more critical regulatory actions taken over the last two years at the federal level which impact the coal, energy and hardrock mining industries.

### **Moderator:**

**John Watson**

*Spencer Fane LLP, Denver, CO – Waters of the United States*

### **Panel:**

**James Sanderson**

*Ryley, Carlock & Applewhite, Denver, CO – 2019 Colorado legislative update and results of 2018 ballot measures affecting mining*

**Paul Seby**

*Greenberg Traurig, LLP, Denver, CO –  
Update on the Clean Power Plan (Obama Administration)  
litigation and President Trump's Affordable Clean Power Plan*

## WEDNESDAY, FEBRUARY 27

MORNING

9:00 AM – 11:05 AM | ROOM 712

### CMA: Safety and Health: From the Nation's Capital to CMA Membership's Operations

Meet and hear from National Mining Association's Senior Director of Safety and Health, Thomas Harman, and Stacy Kramer, Vice President Corporate Safety and Occupational Health at Freeport-McMoRan, Inc. on the NMA's CORE safety program and its impacts on an operational level. The panelists will also break down where we have been since the Trump Administration took office and what to expect after the 2018 mid-term elections. Changes affecting agency personnel moves, congressional committee composition and political appointments will be covered. Find out what is going on (or not) at the Federal Mine Safety and Health Review Commission and get an update on potential Congressional oversight topics for the Mine Safety and Health Administration.

#### Moderator:

**Laura E. Beverage**

*Jackson Kelly PLLC, Denver, CO*

#### Panel:

**Thomas V. Harman**

*CSP, National Mining Association, Washington, D.C.*

**Stacy L. Kramer**

*Freeport-McMoRan, Inc., Phoenix, AZ*

**WEDNESDAY, FEBRUARY 27**

*MORNING*

**9:00 AM | ROOM 107**

## **Environmental: Abandoned Mine Lands – Closure and Reclamation**

*Chairs: J. Pepe, Golder, Lake Oswego, OR  
H. Lammers, Colorado School of Mines,  
Denver, CO*

**9:00 AM**

### **Introduction**

**9:05 AM**

### **Geochemical Modeling of Monitored Natural Attenuation for Coal Combustion Residuals**

*P. Nolan and R. Verburg; Mine Environment, Golder Associates, Redmond, WA*

Coal combustion residuals (CCR) present a unique and global challenge due to their geochemical characteristics and vast production since the industrial revolution. Numerous concepts widely used in closure and remediation in the mine environment are directly applicable to developing CCR corrective action plans. One strategy, Monitored Natural Attenuation (MNA), represents an attractive option for long-term management of CCR leachates. The mobility of CCR-derived constituents depends heavily on site-specific geochemical conditions, including pH, redox conditions, and the sorption capacity of the receiving groundwater or surface water environment. Geochemical modeling allows for an early determination of MNA as a potential management strategy and can be used for further refinement of design alternatives, leading to long-term site stability. This paper describes the general geochemical characteristics of CCR leachates, presents the regulatory MNA framework, and discusses the geochemical modeling approach for evaluation of MNA options.

**9:25 AM**

### **Closure Adaptive Management – SGC's Reclamation Activities Case Study**

*S. Lange; Geochemistry and Hydrology, Knight Piesold and Company, Denver, CO*

Metals loading in the Animas River has limited aquatic life, including the trout fishery downstream from Silverton. The metals loading in the Animas River is due to acid rock drainage formed from both natural weathering of mineralized rocks and residues from over 100 years of historic mining. Sunnyside Gold Corporation (SGC) was formed and acquired the Sunnyside Mine in the Upper Animas basin in 1985. SGC operated the mine from 1986 until 1991 using modern techniques and under the modern era of environmental regulation and has engaged in more than 30 years of reclamation and remediation in the Silverton Caldera. Actions included removal of mine waste from owned and area mines, treatment of water discharged from mine portals, seasonal treatment of the flow in Cement creek, installation of bulkheads in mine workings, and stabilization of tailings deposits. Evaluation of the results of SGC's mining, reclamation and remediation demonstrates that the actions of SGC have substantially reduced acid rock drainage and metals loading in the Animas compared to what would have otherwise been the case.

9:45 AM

## Voluntary Reclamation and Remediation of the Former Garfield Vanadium Mine Site, Rifle, Colorado Part I: Remedial Investigation, Remedy Selection, and Reclamation

*B. Nielsen<sup>1</sup>, C. Beu<sup>2</sup>, J. Rusch<sup>2</sup> and L. Santisteban<sup>1</sup>; <sup>1</sup>Environmental and Sustainable Development, Freeport-McMoRan Inc, Phoenix, AZ and <sup>2</sup>Golder Associates Inc., Lakewood, CO*

The Garfield Mine is a legacy vanadium mine in western Colorado that consisted of multiple mine openings, waste rock piles, and adit seepages that Cyprus Climax Metals Company (a Freeport-McMoRan Inc. subsidiary) voluntarily remediated through the Colorado Voluntary Cleanup Program (VCUP). The steps taken to obtain a no further action determination from the VCUP is presented. The process included performing the site investigation under the supervision of a licensed radioactive materials handler and involving the VCUP and the state's Radiation Management Unit. The remedial action objectives (RAOs) under the VCUP included preventing direct human or biotic exposure to the waste rock and radiation emitting from the waste rock; maintaining the existing undeveloped character of the surrounding landscape. The site-wide design included regrading, installation of an infiltration barrier and rock cover, a diversion channel, and a biologically-based passive remediation water treatment system. After 12 years of site investigations, the remedial action was completed in 2016 and 2017 with all RAOs met and a no further action determination granted in 2018.

10:05 AM

## Hydrogeologic Investigations to Evaluate Source Control Options at an Extensive Abandoned Underground Coal Mine at the Missouri River Headwaters

*T. Henderson<sup>1</sup>, S. Morford<sup>2</sup>, C. Kelley<sup>2</sup> and C. McCoy<sup>2</sup>; <sup>1</sup>Abandoned Mine Lands, Montana DEQ, Helena, MT and <sup>2</sup>Tetra Tech, Helena, MT*

The Montana DEQ is designing a water treatment plant to mitigate one of the state's most severe mine water discharges. The former Anaconda Copper Mining Company Belt Mine discharges approximately 275 acre-feet of acidic water each year containing 120 tons of dissolved metals to the headwaters of the Missouri River. The source of the majority of the mine impacted water is a pH-neutral pool in the abandoned mine workings located approximately 275 feet below ground surface and two miles from the mine adit. Stratigraphic modeling indicates the mine water pool elevation is controlled by spill-over points in the underground workings; water discharging from the pool is significantly degraded as it travels through the unflooded mine workings to the adit. We are evaluating source control measures through hydrogeologic investigations incorporating downhole video logging, mine pool pumping, and adit flow monitoring. The investigations are concurrently evaluating the potential for injection of treatment plant sludge into the mine pool. We summarize our investigation results and their application to fundamental design decisions for this complex water treatment and source control project.

**10:25 AM**

## **McCracken – A Collaborative Approach to Mine Closure**

*D. Enos<sup>1</sup>, D. Abranovic<sup>2</sup> and J. Hilker<sup>3</sup>; <sup>1</sup>Manager, Dormant Properties, Spokane, WA; <sup>2</sup>Partner, Scottsdale, AZ and <sup>3</sup>Geologist, Scottsdale, AZ*

Teck American Incorporated (Teck) implemented closure activities at the legacy McCracken silver mine in Arizona. Teck acquired the property through a merger in the mid-1980s. They determined that historical mine features and waste in an arroyo on Bureau of Land Management (BLM) managed land could pose a risk to human health and the environment. This session will discuss the project, which closed over 50 mine features including open adits, portals, stopes, shafts, trenches, and historical mine structures categorized as physical hazards. Teck introduced a program to limit land disturbance, and preserve local bat, plant, avian, and reptilian communities. The cleanup removed mining waste, and placed it in an engineered repository on adjacent patented Teck property. Surveys identified and protected historical and cultural assets in the district, and the cleanup considered local stakeholder concerns. This public-private partnership serves as a model to address safety and environmental impacts at other legacy mine sites located on or adjacent to public lands. This project received the BLM's national 2011 Fix-A-Shaft-Today (FAST) and 2017 Hardrock Mineral Environmental awards.

**10:45 AM**

## **Nearly Three Decades Later, What Closure Learnings Have We Observed: A Montana Series of Mine Closures**

*R. Bullock; EDS, CSM, Golden, CO*

Over the past few decades, the US has seen significant changes in its mine closure operations. The primary changes have been the inclusion of more stringent environmental regulations, some technological advancements, and the inclusion of social dimensions into final closure plans. This presentation provides an overview of multiple closure case studies in Montana for certain mine and smelting facilities under Superfund. While Superfund is generally not necessarily the preferred regulatory mine closure method, it is one that is in use today at certain mines. The presentation will discuss differing regulatory, cost sharing and community input processes.

**11:05 AM**

## **Using FMEA to Manage Risks in Abandoned and Flooded Underground Workings: A Case Study from the Vermont Copper Belt**

*T. Hadj-Hamou<sup>1</sup>, A. Boeckeler<sup>2</sup> and E. Hathaway<sup>2</sup>; <sup>1</sup>SLR International Corporation, Irvine, CA; <sup>2</sup>New England Region, US Environmental Protection Agency, Boston, MA and <sup>3</sup>Nobis Engineering, Concord, NH*

Failure Mode and Effect Analysis (FMEA) were performed at three abandoned copper mines within the Vermont Copper Belt in Orange County Vermont to evaluate the potential for uncontrolled and catastrophic releases of mine impacted water (MIW) associated with flooded underground workings that could subsequently impact the downstream environment or community, or pose other health and safety risks. A multi-disciplinary team was used for the FMEA, including a mining historian with expertise in the Vermont Copper Belt, a rock mining geologist familiar with the site lithologies and fracture regimes, a hydrogeologist with expertise in groundwater flow within the abandoned mines, and other mining experts, geotechnical engineers, and government agencies representatives. The FMEA outcome was a document that identified the potential failure modes, assigned a general probability, and

assessed the potential consequences. This document is a site planning tool to support an evaluation of future monitoring and cleanup actions.

**11:25 AM**

## **Bringing Life Back to an Historic Mine**

*T. Thompson; Ecological Resource Consultants, Inc., Evergreen, CO*

The Swan River has a long history of mining. Using turn of the century methods in the early 1900s, dredge boats unearthed gold that existed 80 feet below the ground. An historic mill existed and deposited tailings through the valley. Scars from these practices are glaring as sterile rock dominates the landscape. As a result, the Swan River, its riparian corridor and surrounding uplands ceased to exist. The large-scale restoration project sought to reestablish the Swan River (which had long been flowing subsurface) and reclaim the valley. Studies were conducted to understand groundwater and estimate pre-mining hydrology. The design involved significant site grading to create a new, meandering stream channel below groundwater. The result was a stream mimicking natural conditions. Aquatic habitat was created by constructing a natural riffle/pool system. The valley was transformed to create riparian and upland habitat in place of the barren dredge rock. Historic tailings were removed from the corridor, capped and vegetated. Within one year the restoration work reclaimed the valley from an example of mining's historic impacts to an example of what creative reclamation can achieve.

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## **WEDNESDAY, FEBRUARY 27**

*MORNING*

**9:00 AM | ROOM 104**

## **Environmental: Holistic Mine Water Management**

*Chairs: D. Ramey, Freeport-McMoRan*

*R. Furey, Stantec, Broomfield, CO*

**9:00 AM**

### **Introduction**

**9:05 AM**

## **Siting, Design, Installation and Operation of a Submerged Diffuser for the Managed Discharge of Mine Water**

*S. Rasmussen; Environmental, Civil & Environmental Consultants, Inc, Pittsburgh, PA*

Faced with the challenge of economically managing a major mine water discharge with a chloride concentration 30 times the expected permit limit, the Buchanan deep mine in western Virginia retained Civil and Environmental Consultants, Inc. to evaluate alternatives and develop the preferred option. After considering treatment, reuse, and deep well disposal, a managed discharge located approximately 14 miles downstream in the same watershed

was chosen. This presentation will examine the in-depth biological, flow and water quality monitoring which allowed for detailed modelling and design of a diffuser system, and timely approval by regulatory agencies. The presentation will also discuss the history of the diffuser's operation including how a law suit regarding the use of closed deep mines for mine water management complicated and limited the use of the diffuser and resulted in the construction and operation of an advanced wastewater treatment. We will also highlight the resolution of those issues resulting in the idling of the advanced water treatment system and full time use of the diffuser since 2013.

**9:25 AM**

## **Water Balance Model Benefits and Results During the Reclamation Phase of a Mine**

*M. Reginato<sup>1</sup>, J. Stefanoff<sup>1</sup> and R. Reisinger<sup>2</sup>; <sup>1</sup>Jacobs, Irvine, CA and <sup>2</sup>ARCADIS, Highlands Ranch, CO*

Water balance models are powerful tools to facilitate mine water management decision making. A water balance model used to guide water management activities on a reclamation project is described. The model allowed rapid and cost-effective evaluation of multiple reclamation options and what-if scenarios prior to design, including stream diversions, waste rock covers, and passive and active water treatment. The model was also used to study the cumulative effects of reclamation activities on future surface water, groundwater, and pit lake water quality. Predicted model results and actual measurements after reclamation are compared.

**9:45 AM**

## **Alternatives to Evaporation for Managing Positive Water Balances**

*R. Bryce; Freeport-McMoRan, Oro Valley, AZ*

Many of Freeport-McMoRan's large integrated mine sites are in arid climates, yet some of these mines have positive water balances in certain unit operations due to precipitation and groundwater inflow. Evaporation is one important tool to manage this excess water particularly for highly impacted waters. While evaporation is relatively low-cost, the water is lost for potential reuse. Alternatives to evaporation could result in either discharging clean water or reusing the excess water at other mine unit operations. Alternative water management strategies include water segregation, reverse osmosis, neutralization and storm water shedding. Evaluation of any strategy is site specific and requires a thorough understanding of the site water balance and the water chemistry of both the source water and receiving water. Examples will demonstrate the successful application of alternative water management strategies.

**10:05 AM**

## **Groundwater Supply Development: Practical Methods to Develop, Design and Maintain a Ground Water Supply System**

*J. Koreny; HDR Engineering, inc., Seattle, WA*

Groundwater is used as a water supply for most mines world-wide for a variety of industrial processing applications. The development of a groundwater supply system involves a strategic, planned approach from identifying the source of water, securing water rights and permits, installing test and production wells, designing a water conveyance pipeline, pumping and stor-

age system and providing power and a control system. A properly designed groundwater supply system can reliably deliver a long-term water supply that operates with few headaches. This presentation will identify techniques to effectively plan and design a ground water supply system. The presentation will include information on 1) source water assessment (identifying a source water aquifer with the needed water quantity and quality) and water rights, 2), well layout, design, installation, maintenance and rehabilitation and 3) design and maintenance of well infrastructure (pumps, connector pipelines, controls. The presentation will emphasize practical information using real-project case studies from mining and water supply projects completed in the Western U.S.

**10:25 AM**

### **Mitigating Storm Water Surge Through a Holistic Water Treatment Strategy**

*S. Anderson, M. Yingling and D. Dattoli; The Doe Run Company, Viburnum, MO*

Storm water management is a large and variable contribution to a facility's overall water balance and can pose significant challenges from both operational and risk perspectives. While a facility's water treatment plant is designed to effectively manage typical operational volume as well as storm water surge, significant rain events can still pose a risk to the facility. Doe Run has taken a holistic approach to water management at its Viburnum, MO facility by utilizing non-contact storm water diversions, storm water retention, appropriate blending and proper scaling of the water treatment plant to manage this risk.

**10:45 AM**

### **Best Practices in Acid Rock Drainage (ARD) Characterization and Management for Reduction of Long-term Environmental Risks and Liabilities**

*M. RagHAV<sup>1</sup> and S. Doyle<sup>2</sup>; <sup>1</sup>Environmental Technology - Oro Valley, Freeport-McMoRan, Tucson, AZ and <sup>2</sup>Department of Civil & Environmental Engineering, Colorado School of Mines, Golden, CO*

Acid rock drainage (ARD) is estimated to contribute over \$100 billion in total worldwide liability associated with current and future remediation. A robust ARD characterization program can provide benefits far beyond regulatory compliance. It can provide an early understanding of potential environmental risks and guide the planning and implementation of effective ARD control/management strategies for long-term liability reduction. Best practices for ARD characterization and management include: early and ongoing ARD characterization and revision of ARD block models to match changing mine plans; refinement of scoping-level water quality using field analog data; scale-up of lab elemental release rates using field-scale testing (barrels or test pads); and establishment and use of site-specific ARD criteria for operational materials management. This paper presents recommended best practices for ARD characterization and management through examples from the authors' experiences in the mining industry, as well as from case studies available in literature.





**11:05 AM**

## **Acid Water Source Control Measures at the Block P Mine, Barker/Hughesville Mining District, Montana**

*R. Huffsmith; Mining, Wood Environment and Infrastructure Solutions, Helena, MT*

The Block P Mine Complex is located in the Barker/Hughesville Mining District, approximately 45 miles southeast of Great Falls, Montana. Between 2008 and 2015, Doe Run conducted removal actions under CERCLA to reduce the threat to public health, welfare, and the environment posed by the release of metals-contaminated water resulting from interaction of mine waste and water. In 2016, 2017, and 2018, Doe Run, with approval and review of USEPA, USFS and MDEQ, completed additional source removal actions to reduce the volume of water discharging from springs and seeps that are poor quality. This reduction included three primary objectives 1) reduce the volume of impacted water that discharges from seeps to Galena Creek and 2) Flood workings that are partially open to the air so that less acid is generated and discharged to the seeps and springs and 3) stabilize the workings to reduce erosion from Galena Creek. Early water quality results from this effort show a very positive impact and future measures may include a bulkhead and other water management techniques.

**11:25 AM**

## **Voluntary Reclamation and Remediation of the Former Garfield Vanadium Mine Site, Rifle, Colorado Part II: Treatment of Adit Water Seepage**

*B. Nielsen<sup>1</sup>, L. Santisteban<sup>1</sup>, R. Schipper<sup>2</sup> and C. Beu<sup>2</sup>; <sup>1</sup>Environmental and Sustainable Development, Freeport-McMoRan Inc, Phoenix, AZ and <sup>2</sup>Golder Associates Inc., Leo, IN*

The Garfield Mine is a legacy vanadium mine in western Colorado that consisted of multiple mine openings, waste rock piles, and adit seepages that Cyprus Climax Metals Company (a Freeport-McMoRan Inc. subsidiary) voluntarily remediated through the Colorado Voluntary Cleanup Program (VCUP). As part of a sitewide reclamation and remediation plan, a biologically-based passive remediation treatment system was chosen to reduce metal concentrations and radionuclides in adit seepage and prevent discharge from the site. The adit seepage is circumneutral, discharges at <5.5 gpm, and contains several constituents of potential concern that exceed Colorado surface water standards: sulfate, selenium, zinc, uranium, radium, and gross alpha and beta particles. An initial lab-scale evaluation provided design criteria for the full-scale system, which consists of a sulfate-reducing biochemical reactor and post-treatment aerobic polishing cells. Results from both systems are presented. The system has been operational since construction was completed in 2017, providing year-round operation and zero discharge of effluent.

**19-007**

## WEDNESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM 210

### Ethics

**Chair:** *D. Abbott, Brian Research Institute,  
Melbourne, VIC, Australia*

9:00 AM

### Assessing and Mitigating Risk to Mining – Can We “Future Proof” the Industry?

*K. Dingley; WSP, London, UK*

Mining operators throughout the world, and those looking to invest in mining, are exposed to risk on a daily basis. Analysts reflect on the “top 10 risks to mining” on an annual basis, and generally these are consistent year on year, albeit the order influenced by immediate political and/or economic forces. Realistically however, how many of these really are tangible risks that could (and should) hamper an appetite for investment? Can the industry navigate its way through inevitable uncertainty that comes with global macro-economic change, political will (or lack thereof), and predicted longer term changes to our climate? Building on our extensive global mining footprint, we reflect upon the appetite that we see for accepting risk across the junior, mid-tier and major operator base, and international investors. We consider the options for sensibly mitigating risk, and we look into the future to gauge how the industry might improve not only its own resilience to change, but at the same time protect the communities, the customers, and the environment that is directly impacted by mining.

**WEDNESDAY, FEBRUARY 27**

*MORNING*

**9:00 AM | ROOM 610**

## **Health & Safety: Emergency Management and Response Planning**

*Chairs: E. Haas, NIOSH, Pittsburgh, PA*

*M. Poulton, University of Arizona, Tucson, AZ*

**9:00 AM**

### **Introduction**

**9:05 AM**

### **Development of an Integrated Command Center for Improved Mine Rescue Operation**

*A. Jha, Y. Pan and P. Tukkaraja; Mining Engineering and Management, South Dakota School of Mines and Technology, Rapid City, SD*

Despite the detailed planning and execution, accidents have occurred in underground mines all around the world. In a typical rescue operation, in majority of the cases, critical decisions should be taken very quickly; however, based on the current rescue practices, the decision-making process is tedious. Several researchers have conducted investigations on this topic, however, the literature review reveals that a thorough step by step computer-based approach to deal with an emergency situation was missing. This paper discusses the development of a comprehensive GIS-based command center equipped with a data management tool for improved mine rescue operations. GIS based command center can aggregate data generated from various sources and provide meaningful analysis of the data gathered that would help in taking a better decision in a typical rescue operation. It is observed to be a viable option to overcome the challenges associated with the traditional rescue operations. Furthermore, a database management module developed in GIS is crucial for the mandatory rescue activities include command center, activities center, and multifunctional group.

**9:25 AM**

### **Effect of Text Message Guidance on Miners' Evacuation Decisions in An Emergency**

*T. Lyche<sup>2</sup>, A. Ur Rehman<sup>1</sup> and K. Awuah-Offei<sup>1</sup>; <sup>1</sup>Mining Engineering, Missouri University of Science and Technology, Rolla, MO and <sup>2</sup>Granite Mountain Quarries, Little Rock, AR*

Increasingly, underground miners have access to personal transponders capable of two-way text messaging. However, we could find no previous work that evaluates how effective text messages could be in providing early guidance to miners during an emergency. This preliminary work evaluates the effectiveness of text message guidance on miners' evacuation decisions during the early stages of an emergency. We used a survey based on real-life emergency scenarios to evaluate miners' response to directions relayed by text messages versus by a human. We recruited 37 miners from three shifts in an underground coal mine to participate in our survey. The results indicate that, while miners are likely to respond to the warning of imminent danger,

their actions may not necessarily be consistent with the guidance contained in the text message. Rather, our respondents responded better to verbal cues from human interaction. This work provides insights into the response patterns for endangered miners in emergency situations and can be used to develop emergency response plans that make mine safer.

19-102

9:45 AM

### Emergency Evacuation Guidance System for Underground Miners

*A. Ur Rehman<sup>1</sup>, K. Awuah-Offei<sup>1</sup>, D. Baker<sup>2</sup> and D. Bristow<sup>3</sup>; <sup>1</sup>Department of Mining and Nuclear Engineering, Missouri University of Science and Technology, Rolla, MO; <sup>2</sup>Department of Psychological Science, Missouri University of Science and Technology, Rolla, MO and <sup>3</sup>Department of Mechanical and Aerospace Engineering, Missouri University of Science and Technology, Rolla, MO*

While a body of work exists on intelligent systems for guiding occupants out of buildings during an emergency, the problem of guiding miners out of a mine during an underground emergency has not been explored. Underground evacuation fundamentally differs from building evacuation because of differences in the regulatory regime and uncertainty regarding number of occupants. The potential for implementing an intelligent miner guidance system is buttressed by the fact that miner tracking systems, along with communication and sensor networks, already exist in underground mines. This work presents a method based on a local positioning system, in the form of a network of “nodes” at major “intersections,” which can then be used to guide miners to safety. We have developed a path-planning algorithm, based on Dijkstra’s algorithm and the local positioning system that can provide miners with the optimal escape path in an emergency. The algorithm is validated with scenarios at the Missouri University of Science & Technology Experimental Mine demonstrating the potential to include smart technology in mine emergency management and response planning.

19-100

10:05 AM

### Examining Trends in Individual Risk Factors: Organizational Approaches to Emergency Management

*C. Hoebbel<sup>2</sup>, E. Haas<sup>2</sup>, M. Ryan<sup>1</sup> and B. Eiter<sup>1</sup>; <sup>1</sup>CDC National Institute for Occupational Safety and Health, Pittsburgh, PA and <sup>2</sup>CDC National Institute for Occupational Safety and Health, Pittsburgh, PA*

Since Congress passed the 2006 MINER Act, structural and technological advancements are observable, but levels of worker preparedness remain difficult to ascertain. It has been suggested that effective disaster prevention and response requires that emergency management be incorporated into everyday operations, planning, and decision-making, potentially in the same way the industry approaches routine risk management. To begin exploring whether measurable indicators of emergency preparedness can or should be addressed within a risk management framework, researchers examined data sets from three separate efforts in the areas of self-escape competence, safety climate, and hazard recognition.

19-059

**10:25 AM**

## **Mine Emergency Risk/Readiness Self-Assessments: An Effective Use of Group Dynamics**

*W. York-Feirn<sup>1</sup>, D. Stalfort<sup>2</sup> and J. Kravitz<sup>3</sup>; <sup>1</sup>Colorado Department of Natural Resources, Colorado Division of Reclamation Mining & Safety, Denver, CO; <sup>2</sup>ABS Group, Inc., Arlington, VA and <sup>3</sup>JHK and Associates Consulting, LLC, Pittsburgh, PA*

This session provides an overview of a pro-active set of tools for underground and surface coal and metal/non-metal mine operators. You will learn about these tools, originally developed through a partnership between the mining industry, states, MSHA Tech Support, and the ABS Group, Inc. You will understand how mine management teams participate in facilitated self-assessments to (1) identify mine-specific risks and evaluate (2) the mine's overall preparedness to respond to an emergency, (3) readiness of mine rescue teams to respond, and (4) readiness of responsible persons or designated competent persons (DCPs) to execute the emergency plan.

**10:45 AM**

## **Quick-Erect Stopping System for Radiation Protection and Mine Rescue**

*J. Dehnert<sup>1</sup>, J. Stopp<sup>2</sup>, P. Windisch<sup>3</sup> and B. Schönherr<sup>3</sup>; <sup>1</sup>Department <sup>53</sup>Radiation Protection, Saxon State Office for Environment, Agriculture and Geology, Dresden, Saxony, Germany; <sup>2</sup>Aluminiumbau und Verwaltungs GmbH Stopp, Schneeberg, Saxony, Germany and <sup>3</sup>Bergsicherung Schneeberg GmbH & Co. KG, Schneeberg, Saxony, Germany*

A new Quick-Erect Stopping System (QESS) for miners was developed to reduce the radon exposures of miners at small construction sites of old mining in Germany. The QESS is a lightweight, modular, and reusable construction kit of interlocking telescopic aluminum tubes, plastic foils, and glue foam to shut off radon rich parts of galleries in only a few minutes. The QESS was originally developed for the radiation protection of miners. Then the QESS was discovered at a German mining conference by some mine rescue teams. First mine rescue drills were carried out in Freiberg and Schlema by the Student Mine Rescue of the Technical University Mining Academy of Freiberg and the Wismut Mine Rescue. Additionally, a mine rescue drill was carried out in the Edgar Experimental Mine of the Colorado School of Mines by the Front Range Mine Rescue. All experiences were collected and used to improve the system. Now the Quick-Erect Stopping System (QESS) works well. The QESS can be used in mines to shut off galleries in only a few minutes to protect miners against radon exposures and for mine rescue.

**19-126**

## WEDNESDAY, FEBRUARY 27

### MORNING

#### 9:00 AM | ROOM 605

### Health & Safety: Industry Discussion of Practices to Understand and Improve Miner Health

**Chairs:** *E. Lutz, NIOSH, Spokane, WA*  
*M. Poulton, University of Arizona, Tucson, AZ*

#### 9:00 AM Introduction

#### 9:05 AM

### A Mine-Level Leading Indicator of Interstitial Lung Diseases: Findings from 20 Years of MSHA Data

*S. Moore<sup>2</sup>, P. Yorio<sup>2</sup>, A. Laney<sup>1</sup>, C. Halldin<sup>1</sup>, D. Blackley<sup>1</sup>, K. Wizner<sup>2</sup>, L. Radonovich<sup>2</sup> and L. Greenawald<sup>2</sup>; <sup>1</sup>Respiratory Health Division, National Institute for Occupational Safety and Health, Morgantown, WV and <sup>2</sup>National Personal Protective Technology Laboratory, National Institute for Occupational Safety and Health, Pittsburgh, PA*

Given the recent increase in dust induced lung disease among U.S. coal miners and the respiratory hazards encountered across the U.S. mining industry, it is important to enhance an understanding of lung disease trends and the organizational contexts that precede these events. In addition to exploring overall trends reported to the Mine Safety and Health Administration (MSHA), the National Institute for Occupational Safety and Health (NIOSH) used MSHA's enforcement database to examine whether or not compliance with health regulations resulted in fewer mine level counts of these diseases over time. This presentation will be geared towards a mining stakeholder audience and will provide an overview of the study findings, which were recently published in Risk Analysis. The findings suggest that mines that followed a relevant subset of MSHA's health regulations were less likely to report a lung disease over time. The findings will be discussed from a lung disease prevention strategy perspective.

#### 9:25 AM

### Inventive Methods for Evaluating the Translation of Hand-Arm Vibration to the Ear Canal in Miners – A Pilot Study

*W. DuBose, C. Sunderman, S. Finley and G. Poplin; Spokane Mining Research Division, National Institute for Occupational Safety & Health, Spokane, WA*

The prevalence of hearing loss among miners has not improved substantially despite decades of research, the widespread availability of hearing protection, and implementation of hearing conservation programs. Other postulated causative mechanisms must also be evaluated when attempting to remedy this problem. The impact of mechanically induced vibration on human hearing is unclear. However, research suggests that this vibration type can potentially contribute to hearing loss in miners operating heavy-duty mining equipment. This proof-of-concept study attempts to demonstrate

whether hand-arm vibration (HAV) can be translated to the hearing anatomy and analytically measured. NIOSH researchers have developed a preliminary monitoring system designed to capture tri-axial accelerometry data on jack-leg drill operators performing drilling and bolting tasks. This is a wearable device with sensors positioned at the wrist, shoulder, and behind the ear (i.e. mastoid bone) to depict the progression of HAV. The data gained from this study could have implications with respect to the prevention of hearing impairment, should results suggest the presence of a mixed exposure pathway.

**9:45 AM**

## **Patterns of Heat Strain Among a Sample of U.S. Miners**

*K. Yeoman; NIOSH, Spokane, WA*

Heat strain, which is the physical strain experienced from heat exposure, is a growing issue in U.S. mining. Few studies of heat strain have been performed among U.S. miners. A better understanding of patterns of heat strain among U.S. miners would be beneficial in determining the relevance of national heat exposure guidelines to the U.S. mining industry and in guiding future research relevant to mining. A pilot study performed by NIOSH's Spokane Mining Research Division to evaluate physiologic effects of heat exposure demonstrated a novel way to evaluate heat strain, expanding on previous research that focused primarily on characterizing maximum and mean core body temperatures. Core body temperature measured during subjects' normal work shifts was categorized into temperature zones. On average, subjects changed temperature zones 13.8 times per shift. Temperatures increased above the recommended limit of 38 °C nearly 5 times per shift for an average of 26 minutes each episode. Substantial variability was demonstrated between and within subjects. Further research is needed on the impact of multiple short-term, intermittent heat exposures on miners.

**10:05 AM**

## **Your Brain on Stress and Fatigue: Impacts of Stress and Fatigue on Decision Making**

*K. Vault and M. Reiher; Colorado School of Mines, Golden, CO*

Fatigue and stress are so common in today's society that they are not viewed as a problem. Everyone experiences fatigue. Everyone has stress. But, can your brain fight against these stressors to keep you safe? In this presentation you will gain a basic understanding of your brain function, understand the effect of stressors on your ability to process information in order to make sound decisions, and learn practical strategies that will counteract known stressors and improve brain function.

**10:25 AM**

## **Protecting Lungs in Mining Environment**

*M. White; Inventor, Nunawading, VIC, Australia*

A unique personnel de-dusting device has been invented by Mideco specifically for workplaces where dust is a hazard. The system is called Bat Booth™. It can permanently remove up to 80% of dust in seconds and is effective against the smallest dust particles such as silica. It uses compressed air to blow the dust off, which is then captured and contained in HEPA filters. The process takes only 10 – 12 seconds and tests have shown a 50% improvement in dust removed from clothes over other methods. The competitive solutions where a single point air hose method is used usually

provide only temporary relief. Since its launch in 2014 Bath Booth™ won “Highly Commended” award in the category of “Best Practice in Work Health & Safety” at the “Australian Bulk Handling Award” in Sydney in 2016. The Bath Booth™ has been included in the Dust Control Handbook 2018 produced by the U.S. National Institute for Occupational Safety and Health. It was presented as one of the best examples of removing dust from personnel uniforms thus helping prevent dust related diseases, in particular those caused by silica exposure.

## 10:45 AM

### Nanometer Sized Particles Generated from Drilling Activity

*C. Tsai<sup>1</sup>, D. Theisen<sup>1</sup>, J. Brune<sup>2</sup> and M. Schreiner<sup>2</sup>; <sup>1</sup>Colorado State University, Fort Collins, CO and <sup>2</sup>Colorado School of Mines, Golden, CO*

Traditional gravimetric based methods for exposure assessment may not effectively characterize the respiratory insult experienced by miners due to exposed small particles. An on-site evaluation of particle emissions from the feed-leg drilling activity was conducted to characterize particle size and elemental composition. Air quality was monitored using direct reading instruments for sizes of 10nm to 10 µm and particles were collected using a novel nanoparticle sampler side by side with a respirable cyclone sampler. The nanoparticles and respirable particles were directly collected onto a transmission electron microscope (TEM) grid and polycarbonate filter for microscopic analysis. The filter and TEM grid were discovered to have a multitude of particles in the nanometer to micrometer size range, and were consistent with instrument measurements. They were mostly silica rich stone, spherical iron oxide, and carbon rich soot particles according to elemental composition analysis. This study demonstrates the need for nanoparticle exposure assessment in a mining workplace.

19-020



**WEDNESDAY, FEBRUARY 27**

*MORNING*

**9:00 AM | ROOM 110**

## **Industrial Minerals & Aggregates: Applications of Data Analytics & Artificial Intelligence in Industrial Minerals & Aggregate Industry II**

*Chairs: J. Zdunczyk, Pike Industries, Inc., Westbrook, ME  
A. Kendir, Lehigh Hanson, Inc.*

**9:00 AM**  
**Introduction**

**9:05 AM**  
**Using Import/Export Data to Track  
Developments in Mineral Markets**

*E. McCarthy; Performance Minerals LLC, Morgan Hill, CA*

For many years mineral markets were local or regional but increasing specialization of both consumers and users along with declining seaborne freight costs has changed the landscape; now it is often less expensive to serve a Japanese paper plant from Georgia or Brazil than from another location within Japan and product quality is usually better as well. This paper will review export/import data for major producing and consuming countries to explore the evolving nature of industrial mineral markets for kaolin, feldspar, talc and borates.

**9:25 AM**  
**Effective Operational Conditions on the  
Whole Body Vibration of Mining Truck Driver**

*J. Sattarvand<sup>1</sup>, M. Rahimide<sup>2</sup> and M. Mirzaei<sup>2</sup>; <sup>1</sup>Mining and Metallurgical Engineering, University of Nevada Reno, Reno, NV and <sup>2</sup>Mining Eng., Sahand University of Tech., Tabriz, eastern azerbaijan, Iran (the Islamic Republic of)*

Long time exposure to vibrations of mining machinery has adverse effects on operators and leads to skeletal disorders in long-term. Among all types of mining machinery, haul trucks expose their drivers to the most dangerous level of wholebody vibrations because of their various working cycles and also passing on roads with different qualities. This paper studies an experimental research to find the effects of working conditions on the whole body vibration of truck drivers during open pit mining. To achieve this goal, first, the root mean square of vibration at different operational condition are measured in a case study; 60-ton truck as Sungun Copper Mine, Iran. Then, the health risk levels of vibrations at different operational conditions of the mine are analyzed and discussed according to ISO 2631-1 standard. Results of this paper are helpful for designers to represent the practical solutions for low back pain health risk reduction in mining trucks.

**9:45 AM**

## **Leveraging Technology Innovations to Bolster Large Mine and Process Facility Construction and Operations Efficiency, Profitability, and Risk**

*C. Barnett and B. Calcote; Jacobs Engineering, St. Louis, MO*

The tight timelines and narrow cost margins of large construction projects are spawning new approaches to managing inventory and choreographing the multitude of interconnected activities happening each day at a large construction sites. Advanced analytics for construction include tools for real-time tracking of personnel, supply-chain, and tools integrated into a single platform for enhanced visualization of the work environment. This information can be further used to create comprehensive workflow simulation models to analyze the feasibility of alternative courses of action. In this session, we will cover how the Internet of Things (IoT) sensors and advanced analytics are being used on major construction projects and how those same approaches can be adapted to mine site construction and operations to maximize efficiency, enhance productivity, and ultimately increase profitability.

**10:05 AM**

## **Distribution of Local Porosity in Direct Shear Specimens Using Digital Image Processing**

*M. Razavi<sup>2</sup> and s. amirrahmat<sup>1</sup>; <sup>1</sup>Civil Engineering, University of Tennessee, Knoxville, TN and <sup>2</sup>Mineral Engineering, New Mexico Institute of Mining and Technology, Socorro, NM*

Understanding the micro-scale behavior of granular materials and its effects on their strength is crucial for safe designs in different geotechnical applications. One of the most common and easiest ways of characterizing the micro-scale behavior of granular materials is quantifying local void ratio or porosity. In this study, digital image processing methods and thin sectioning are employed to quantify the distribution of local porosity in direct shear test specimens. The specimen preparation, thin-sectioning methods and the necessary image processing steps are explained in more detail. The results from a direct shear test are also discussed briefly as an illustration.

**10:25 AM**

## **Comparison of the Particle Size Distribution in Marble and Granite Rock Samples Subjected to Ball Milling Process**

*B. Kunar; Mining Engineering, Assistant professor, Mangalore, Karnataka, India*

Rock or particle size has a very important significance in the mining industry, starting from blasting till the mineral processing. The present study was carried out to understand the particle size distribution in various sieves after conducting the ball milling process. The time of the grinding process was varied at different intervals. It was observed that 80% of the particles of both granite and marble rock samples passed through the 4800 mm sieve when subjected to grinding time of 40 minutes. Also, it was observed the number of particles that were retained in the smallest sieve of <75 mm was higher in the case of granite sample when compared to a marble sample.

**19-017**

**10:45 AM**

## **Stepping Stones for Implementing Data-Intensive Analysis in Modern Mining**

*V. Tenorio and O. Palomino; Mining and Geological Engineering, University of Arizona, Tucson, AZ*

Mining in present times is facing challenges that go beyond productivity goals, safety, and environmental considerations, all this in a context of economic sensitivity and market fluctuations, which in turn affect the expected financial results of a project. The implementation of new technologies appear to be a new trend in the industry, announced as a long-awaited aid for controlling risk and performance variability in complex operations. Many of these technologies are by themselves innovative and undeniably effective in their own niches, however when an integrated solution is implemented at the site, some systems may not talk smoothly to others. This paper presents a fresh perspective of how to start a comprehensive solution in modern mines, covering the newly available technologies and the scope of their capabilities. A step-by-step roadmap is provided to help project managers to choose the suitable technology to implement for their magnitude of operations, all this while complying with the requirements of maximizing production, controlling productivity of assets, thus keeping the continuity of operations and reaching the highest standards for safety and eco-friendliness.

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## **WEDNESDAY, FEBRUARY 27**

*MORNING*

**9:00 AM | ROOM 106**

## **Industrial Minerals & Aggregates: Innovations in Industrial Minerals & Aggregates Industry II**

**Chairs:** *G. Tomaino, Minerals Technologies Inc, Easton, PA  
B. Li, Michigan Technological University,  
Houghton, MI*

**9:00 AM**

### **Introduction**

**9:05 AM**

## **Geologic Comparison of Regionally Derived Hydraulic Fracturing Sands versus Traditional Northern White Sources**

*K. Anderson and J. Zoellmer; Kraemer Mining & Materials Inc, Burnsville, MN*

Sands located near producing oil fields in the United States are starting to replace traditional Northern White sands as sources for hydraulic fracturing. These regional sands generally differ in percentage of monocrystalline quartz, percentage of potentially deleterious particles, roundness, sphericity, and acid

solubility. A geologic analysis of the depositional environments and resultant sand characteristics will be presented. Reference of these parameters to API specifications for hydraulic fracturing sand will be provided from the presenter's experience in conducting exploration and mining work in various areas.

**9:25 AM**

### **Vermiculite in China: Resources, Market, and Applications**

*K. Zhao<sup>2</sup> and B. Li<sup>1</sup>; <sup>1</sup>Materials Science and Engineering, Michigan Technological University, Houghton, MI and <sup>2</sup>Xinjiang Xinlong Vermiculite Ltd, Korle, Xinjiang, China*

Vermiculite is a magnesium-rich aluminum silicate mineral with 2:1 typed layer structure. Currently, the major applications of vermiculite are in its form of exfoliated state. In China, vermiculite deposits are broadly distributed in the northern regions, including Xinjiang, Hebei, Inner Mongolia, Liaoning, Henan, Shanxi. The total mineral reserve of vermiculite is over 110 million metric tons. Having 100 million tons of vermiculite reserve, Yuli vermiculite is the largest vermiculite deposit in China and the second largest deposit in the world. In China market, vermiculite is only used in the exfoliated form. The major applications are lightweight construction (lightweight aggregates, etc.), insulation, fire retardant, and horticulture. It's also used as agricultural agent such as soil modifier, poultry feed additive, chemical carriers, and wastewater absorption, etc.

**9:45 AM**

### **The Role of Minerals in Paint and Coating Formulations**

*T. Dombrowski; SMI Performance Minerals, Specialty Minerals Inc., Bethlehem, PA*

Minerals perform three major functions in paint and coating formulations. They are either whitening agents, pigment extenders or fillers. Many different types of minerals are used to perform these functions. Key properties invoked in their utilization are whiteness/brightness, particle size and the ability to interact with the film forming binder as measured by oil absorption. Examples will demonstrate how these properties impact paints and coating in formulations that are both above and below the critical pigment volume concentration of a paint/coating.

**10:05 AM**

### **Classification of Mining and Processing By-products from the Viewpoint of Materials Science**

*B. Li; Materials Science and Engineering, Michigan Technological University, Houghton, MI*

There are numerous types of mineral-based by-products generated from mining, mineral processing, and metallurgical activities. Traditionally, these by-products were classified by the types of mineral industries (such as gold mine tailings, iron ore tailings), or the stages of processing/manufacturing (such as tailings and slag). However, there are many similarities in the chemical, physical, mineralogical, and material characteristics of that among these by-products and also comparing them to natural mineral deposits and soils. For efficiently recycling and reuse these by-products, this paper is aimed to propose a method for the classification of these by-products by determining their commonality based on the viewpoint of secondary mineral resources and materials science.

**10:25 AM**

## **Sloping Sand Bed for Mineral Sand Plant Effluent Clarification**

*J. Gusek<sup>1</sup>, J. Renner<sup>2</sup> and D. Settles<sup>2</sup>; <sup>1</sup>Sovereign Consulting Inc., Lakewood, CO and <sup>2</sup>Southern Ionics Minerals LLC, Saint Simons Island, GA*

Zircon and rutile-bearing ore at a heavy mineral sand operation in Georgia contains a naturally-occurring, low-density organic humate fraction. Mineral separation process water contains abundant suspended and dissolved humate, but traditional settling ponds are a long term environmental liability. Discharge of process water blowdown onto a sloped sand bed allows coagulated humates to settle sub-aerially, dry, and be easily disposed. After bench testing, a full scale 0.57 ha "sloping sand bed" was designed and built in 2017. The sand bed reduces a 400 ppm TSS load to <10 ppm TSS at a flow rate of about 800 m<sup>3</sup>/day.

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## **WEDNESDAY, FEBRUARY 27**

*MORNING*

**9:00 AM | ROOM 112**

## **Industrial Minerals & Aggregates: Sustainable Developments Including Environmental Remediation & Water Management Resources**

**Chairs:** *K. Kosloski, Luck Stone, Richmond, VA  
S. Gaillard, Virginia Tech, Blacksburg, VA  
F. Heivilin, HGPS LLC, Thomasville, GA*

**9:00 AM**

**Introduction**

**9:05 AM**

## **Air Quality Permitting and Regulatory Compliance for Aggregate Mines and Processing Plants in Mid-Atlantic U.S. States**

*K. Macoskey and A. Lashgari; Civil & Environmental Consultants, Wexford, PA*

The economics of aggregate mining and processing depend heavily on the proximity of the mine to the point of use. For this reason, aggregate mines and processing plants are located in every state and in close proximity to the urban areas. This increases public attention on adverse environmental and health impacts of aggregate operations. One of the most recognized environmental and health hazards from aggregate mining and processing involves airborne particulate emissions. This presentation will review the federal and state air quality permitting requirements in several Mid-Atlantic States of the United States. Federal and state air quality regulations will be summarized in

this presentation. The most recent air quality requirements applicable to aggregate mining and processing facilities in this region will also be discussed. In addition, best practices for addressing the most common air quality challenges for the industry will be reviewed. This presentation will help stakeholders better understand air permitting and compliance requirements in Mid-Atlantic States for new and modified sources of atmospheric Emissions.

**9:25 AM**

### **Endangered Species – A Moving Target**

*J. Wallgren; Westward Environmental Inc., Boerne, TX*

The regulations and the list of protected species is constantly changing. The large scope and public perception of mining can put projects in the crosshairs. Developing a conservation strategy that works for your project, the species, and the reviewing public can be challenging. However, mining projects can provide some of the biggest opportunities in sustainable development and provide a lasting, large-scale benefit to the ecosystem. This presentation outlines how to plan for the moving targets of species and their regulations, and when and how to get creative when looking for sustainable solutions that keep your project moving forward.

**9:45 AM**

### **Hydrogeologic Characterization and Mining Impact Analysis of a Low-Yield, Fractured Granite Deposit**

*M. Day<sup>1</sup>, P. Kos<sup>2</sup> and S. Brinton<sup>2</sup>; <sup>1</sup>Hydro-Logic Solutions, Inc., Denver, CO and <sup>2</sup>Stantec, Denver, CO*

A hydrogeologic characterization and impact analysis was performed for the proposed Hitch Rack Ranch quarry located in the Little Turkey Creek watershed southwest of Colorado Springs, Colorado. Continuous multiple channel tubing, nested piezometers; stream flow measurements; and seep mapping were used to define the three-dimensional potentiometric distribution and areas of groundwater recharge and discharge. Water balance considerations, geochemistry, and potentiometric response to earth tides confirmed that the granite fracture system in the in the proposed mining area has an extremely low bulk hydraulic conductivity and contributes minimal groundwater discharge to the base flow of Little Turkey Creek. This conclusion has significant implications with respect to projected mining impacts and recharge to downgradient Denver Basin sedimentary deposits.

**19-108**

**10:05 AM**

### **Flood Attenuation Opportunities: Mining in the Floodplain**

*C. Campbell; Westward Environmental, Boerne, TX*

Surface mining for sand and gravel has long been a critical part of our economy and is a critical component of the upstream supply chain for infrastructure development. Due to the recent hurricane flooding mining in the floodplain has been targeted as a strain on the water bodies in which the activity is performed. This presentation looks at how these facilitates relate to the water bodies they are in proximity to and the adaptive reuse of these sites as flood attenuation facilities and the potential benefits to the environment around them.

**WEDNESDAY, FEBRUARY 27**

*MORNING*

**9:00 AM | ROOM 603**

## **International III**

**Chair:** *M. Gavrilovic, GR Engineering Services,  
Denver, CO*

**9:00 AM**

### **Introduction**

**9:05 AM**

### **Working for the Sinergy Between Mining and Agriculture in Peru**

*R. Mucho; Pevoex Contratistas SAC, Lima, San Borja, Peru*

The objective of this work is to reduce social conflicts that don't allow the development of mining projects that are very important for the Peruvian economy; demystifying the concepts that mining and agriculture compete for water and territory. We have found that the more mining has developed, the more agriculture has advanced with an excellent performance, as per the brief description of the Peruvian economy growth.. This study shows that both sectors are not exclusive, on the contrary there is a synergy between them, And no real conflict between mining and agriculture for water resources; it is needed by both, however the mining sector uses a small percentage of this resource.

**9:25 AM**

### **“Our Gold Is Dirty, but We Want to Improve”: Formalization and Mercury Use in Artisanal and Small-Scale Gold Mining in Peru**

*N. Smith; Mining Engineering, Colorado School of Mines, Golden, CO*

Peru is the world's fifth largest gold producer with an estimated 15% of the gold coming out of the artisanal and small-scale mining (ASGM) sector. While ASGM provides a source of income for more than 60,000 people in rural areas of Peru, it often takes place in the informal sector and is associated with practices that pose environmental and human health risks, such as the use of mercury. Efforts to formalize the ASGM sector have addressed mercury use by focusing on awareness campaigns and cleaner technologies; however, this focus obscures other barriers that stand in the way of broad-scale change. This paper examines the perspectives and practices of artisanal and small-scale gold miners in a community in southern Peru. It highlights some of the challenges they face in becoming formalized and addressing mercury use and demonstrates that efforts to formalize the sector must apply an approach where the mercury problem is situated within the multiple and dynamic socio-economic, environmental, and health-related challenges in ASGM communities.

**9:45 AM**

## **South American Tailings Management Update**

*M. Moncada and M. Fuller; Tierra Group International Ltd., Lakewood, CO*

The presentation discusses regulatory changes and their impacts to tailings operations, management and engineering in South America, following the Samarco Fundão Tailings Dam failure.

**10:05 AM**

## **The Importance of Socio-Economic and Socio-Political Factors in Due Diligence for Acquisitions**

*D. Malhotra; Resource Development Inc., Wheat Ridge, CO*

The Author has been involved in reviewing several failed / wounded projects. He highlights some of the deficiencies in socio-political and socio-economic factors revealed as a result of the due diligence process.

**10:25 AM**

## **Cerro Verde Concentrator Optimization – Crushing, Grinding, Flotation and Water**

*L. Roman and H. Benavente; Sociedad Minera Cerro Verde, Arequipa, Arequipa, Peru*

The C2 Concentrator commenced operation in Spetember 2015. Crushing, grinding and flotation operations have undergone continuous optimization to improve processing rates and copper and molybdenum recoveries. Installation of a waste water (sewage) treatment plant for the city of Arequipa was an integral part of the project, and provides both make-up water and a significant social benefit for the community. Maintaining a strong community relations program is an essential part of Cerro Verde operations. The presentation discusses the social and technical elements of the optimization process.

**10:45 AM**

## **Artisanal and Small-Scale Gold Mining in the Puno Region of Peru: A Comparison of Formalized ASGM Operations**

*G. Martinez<sup>1</sup>, M. Schwartz<sup>2</sup> and N. Smith<sup>1</sup>; <sup>1</sup>Colorado School of Mines, Inglewood, CA and <sup>2</sup>University of Texas at Arlington, Arlington, TX*

Formalizing artisanal and small-scale gold mining (ASGM) is a priority for governments around the world. Prior studies have shown that there are significant challenges for artisanal and small-scale gold miners to become formalized, such as complicated procedures and fluctuating policies. Peru has made considerable efforts to formalize the sector, and in the Puno Region of southeastern Peru, there are several companies that have undergone the formalization process. This study examines two ASGM companies and demonstrates that even though both of these companies are working within a legal framework, there are significant differences in the mining operations, the mineral processing methods, and the organization of labor. We argue that there can be significant variation among ASGM companies that operate formally, and we highlight the need for further investigations that explore the nuances in formal ASGM operations.



**11:05 AM**

## **Why Filter Plant Tailings?**

*J. Ventosilla Shaw<sup>2</sup> and L. Harris<sup>1</sup>; <sup>1</sup>Director, Cardero Resources, Lone Tree, CO and <sup>2</sup>JVS Ingenieros, Lima, Peru*

Peru is a major mining country. There are several very large open pit and underground mines located throughout the country. All of these mines are milling their ores deposit their tailings in tailings ponds. This is a dangerous practice as many tailing pond installations have suffered failures. The benefits of filtering the tailings overcomes this serious problem, provides for maximum return of water to the plants and allows for dry stacking of the tailings or disposition of the material underground. Both plate and frame pressure filters for filter belts can be used which will be provided in some detail in the presentation.

**11:25 AM**

## **How to Reduce the Number of Recommendations in a Mineral Reserves Audit**

*L. De Freitas Leite<sup>1</sup> and A. Cerda<sup>2</sup>; <sup>1</sup>Mining Engineering, Golder Associates, Lima, Peru and <sup>2</sup>Mining Engineering, Golder Associates, Santiago, Chile*

Annual audits of Mineral Reserves are required by mining companies for various reasons: second opinion on a detailed audit; third party requirements (investors); signing off on Mineral Reserves as part of a Stock Exchange listing/IPO or financial transaction. Mineral Reserves audits are carried out by an organization external to the mining company, most likely a Competent/Qualified Person from a third-party consultancy, who is member of a "Recognized Professional Organization" (RPO) and has relevant experience in the style of mineralization or type of deposit under consideration. Numerous varied findings have been raised during Mineral Reserves audits such as insufficient information; unsubstantiated assumptions regarding modifying factors; and, lack of cost consolidation by technical areas. Based on audits carried out in Latin America, the author presents a sample of findings arising from Mineral Reserves audits performed in past few years. Recommendations on how to reduce the number of such recommendations are made, which the author believes will make the audit process more efficient and assist in complying with international mineral resource/reserve reporting codes.

## WEDNESDAY, FEBRUARY 27

### MORNING

9:00 AM | ROOM 501

## Mining & Exploration: Geosciences: Microanalytical Techniques in Mineral Exploration

*Chairs: E. Holley, Colorado School of Mines,  
Golden, CO*

*K. Pfaff, Colorado School of Mines*

9:00 AM

### Introduction

9:05 AM

### Distinguishing Fibrous Minerals from Asbestos in a Serpentinite Ore Body

*M. McGrath-Koerner, L. Solotky and B. Bandli; RJ Lee Group,  
Monroeville, PA*

An investigation was performed to determine if asbestos minerals are present in a serpentinite hosted ore body. Field and laboratory examinations were performed using polarized light and scanning electron microscopy, Raman spectroscopy, and x-ray diffraction. Several fibrous minerals, including asbestos, were observed. The presence of both asbestos and non-asbestos fibrous phases is mineralogically interesting. This assemblage is a useful case study for how regulated methods to identify asbestos in bulk materials could potentially fail to identify these non-asbestos fibrous phases correctly, and could over-estimate the amount of asbestos present within the core.

9:25 AM

### Hunting Elephants with Microanalyses – LA-ICP-MS Geo- and Thermochronology Applied to Carlin Exploration

*D. Huff<sup>1</sup>, E. Holley<sup>2</sup> and W. Guenther<sup>3</sup>; <sup>1</sup>Geology and Geological Engineering, Colorado School of Mines, Golden, CO; <sup>2</sup>Mining Engineering, Colorado School of Mines, Golden, CO and <sup>3</sup>Geology, University of Illinois at Urbana-Champaign, Champaign, IL*

Although Carlin-type gold deposits in Nevada have produced nearly 200 Moz since 1965, better understanding of mineralizing processes would help refine exploration efforts. The critical question is whether these deposits formed from magmatic hydrothermal fluids or circulating meteoric/metamorphic fluids. While difficult to test directly, geochronology and (U-Th)/He thermochronology allow us to determine the timing of magmatism and thermal events such as hydrothermal fluid flow, respectively. If thermal events in mineralized zones and magmatism are consistently contemporaneous, this implies magmatism is a necessary control on Carlin-type deposit formation. This presentation will discuss the role of LA-ICP-MS in obtaining geochronology and thermochronology ages for deposits in the Battle Moun-



tain district. Apatite (U-Th)/He ages from mineralized dikes at the Marigold deposit recorded late Eocene thermal events, which are contemporaneous with igneous intrusions at the Lone Tree deposit. Apatite and zircon He ages for the Valmy, North Peak, Trenton Canyon, and Brooks deposits are reported here. The relative timing of thermal events between deposits within the district will be discussed.

**9:45 AM**

## **Pentlandite-Bearing Quartz Veins in Kambalda, Western Australia**

*I. Simon<sup>1</sup>, K. Pfaff<sup>1</sup>, S. Staude<sup>2</sup> and T. Monecke<sup>1</sup>; <sup>1</sup>Colorado School of Mines, Arvada, CO and <sup>2</sup>Universität Tübingen, Tübingen, Germany*

During recent exploration, unusual pentlandite-bearing quartz veins have been recognized in the host rocks of the Archean komatiite-associated magmatic sulfide deposits at Kambalda, Western Australia. We present the results of detailed micro-analytical investigations on the quartz veins which allowed for characterization of the sulfide and associated gangue mineral assemblages and their geochemical footprint. The results of this study are significant in allowing exploration geologists to distinguish between sub-economic hydrothermal Ni deposits and highly economic Ni-enriched magmatic sulfide deposits, potentially enhancing the effectiveness of mineral exploration initiatives for Ni.

**10:05 AM**

## **Characterization of Rock Microcracks Using Thin Section Petrography, SEM Automated Mineralogy, and MicroCT**

*M. Nicco<sup>3</sup>, E. Holley<sup>3</sup>, K. Pfaff<sup>2</sup>, p. Hartlieb<sup>1</sup> and P. Nelson<sup>3</sup>; <sup>1</sup>Chair of Mining Engineering and Mineral Economics, Montanuniversität Leoben, Leoben, Austria; <sup>2</sup>Geology and Geological Engineering, Colorado School of mines, Golden, CO and <sup>3</sup>Mining Engineering, Colorado School of Mines, Golden, CO*

Understanding how rocks fracture is important for numerous fields, from structural geology to civil and mining engineering. This study describes a novel approach for examining how rock microfractures form and propagate, using a combination of destructive (optical and Scanning Electron Microscopy) and non-destructive (Micro Computed Tomography) microanalytical techniques. The results from each technique are incorporated in a global method resulting in the statistical characterization of the mineralogy of the hosting minerals and the location (intra or inter-grain). The method is presented using data from a case study on the generation of micro-fractures in granitic rocks from the Pike's Peak complex in Colorado. The micro-fractures were generated using microwave heating (3kW for 60 to 300 seconds), which is a potential method of pre-treatment in mineral processing of ores. A similar microanalytical approach could be applied to studies on the mineralogy of fractures in civil engineering (foundation, building failures etc.) and investigations of geological processes such as fluid migration during mineralizing events.

## 10:25 AM

### The SOLSA (Sonic on Line Drilling and Sampling Analysis) Project for on-Line-on-Mine-Real-Time Analyses: Key Parameters Definition and Field Tests on a Bauxite Mine in Southern France

A. Kanzari<sup>1</sup>, C. Rodriguez<sup>1</sup>, B. Orberger<sup>2</sup>, A. Prudhomme<sup>1</sup>, S. Blancher<sup>1</sup>, T. Bu<sup>3</sup>, S. Delchini<sup>4</sup>, A. El Mendil<sup>5</sup>, T. Lefevre<sup>5</sup>, H. Piliere<sup>5</sup>, A. Vaitkus<sup>6</sup>, A. Merkys<sup>6</sup>, S. Grazulis<sup>6</sup>, A. Bourguignon<sup>4</sup>, L. Capar<sup>4</sup>, N. Maubec<sup>4</sup> And M. Le Guen<sup>7</sup>; <sup>1</sup>Mineralogy, ERAMET Research, Trappes, France; <sup>2</sup>CATURA Geophysics, Paris, France; <sup>3</sup>ERAMET Research, Trappes, France; <sup>4</sup>BRGM, Orléans, France; <sup>5</sup>Thermofisher INEL, Artenay, France; <sup>6</sup>Vilnius University Institute of Biotechnology, Vilnius, Lithuania and <sup>7</sup>Geology, ERAMET SA, Trappes, France

On-line-on-mine-real-time analysis of drill cores is a real challenge for quick mining and processing decisions on the field. The SOLSA ID system analyses mineralogy and chemistry by combining hyperspectral cameras (VNIR, SWIR), an X-ray fluorescence spectrometer, an RGB camera and a profilometer in order to define regions of interest on undisturbed drill cores with a speed of about 80 m/day. To test the device at a bauxite mine, a study was conducted on representative samples with SOLSA ID, portable Infrared spectroscopy and laboratory XRD and XRF analyses, on powders and beads, respectively. The mineralogy obtained by SOLSA VNIR and SWIR cameras is confirmed by XRD laboratory analyses, and has proven to be more accurate than the portable device. SOLSA ID provided mineralogical and chemical data for the construction of a comprehensive database of key parameters (such as lithology, texture, mineralogy, etc.) based on the descriptions of experienced geologists using the ISO standards 14688-1:2017 and 14689:2017. The description of the preliminary tests will be used to develop smart algorithms capable of defining regions of interest in real time as required by the mining company.

## 10:45 AM

### Development Feasibility of a Multi-Sensor Probe Using LIBS and Raman Spectroscopy for in-Situ Elemental Rock Testing

S. Lee; South Dakota School of Mines, Gillette, WY

There is a common need among various mineral industries for a down-hole probe to conduct in-situ elemental (compositional) testing. Laser-Induced Breakdown Spectroscopy (or LIBS) is a technology supporting this need but requires specific calibrations for elements within a confined range. When LIBS is paired with a deterministic variable, such as Principle Component Analysis (PCA) of a Raman spectroscopy result, the quantitative analysis of multiple mineral types can be accomplished using multiple calibration curves. This presentation will focus on the propensity of data correlation of multiple sample specimens, the results of predictive analysis, and how LIBS when coupled with Raman Spectroscopy can provide greater predictive accuracy of elemental composition.

**WEDNESDAY, FEBRUARY 27**

*MORNING*

**9:00 AM | ROOM 502**

## **Mining & Exploration: Innovations & Technologies: Advances in Space Mining: Maturing Markets and Technology Readiness Levels**

***Chairs:** B. Blair, Planetary Resource Engineering LLC,  
Denver, CO  
G. Baiden, Penguin Automated Systems Inc.,  
Naughton, ON, Canada*

**9:00 AM**

**Introduction**

**9:05 AM**

### **Evaluating Regoliths' Propagation Effects During Drilling in Low-Gravity Environments**

*J. Crowell<sup>1</sup>, H. Patel<sup>2</sup>, P. Suermann<sup>2</sup> and J. Kaczmarek<sup>3</sup>; <sup>1</sup>Crow Industries,  
Inc., Tempe, AZ; <sup>2</sup>Department of Construction Science, Texas A&M  
University, College Station, TX and <sup>3</sup>Department of Astronautical  
Engineering, United States Air Force Academy, United States Air Force  
Academy, CO*

Regolith is a highly abrasive material that has the potential to cause significant problems to engineered systems during future exploration missions beyond Earth, especially those missions focused on high levels of interactions with the regolith of the target body (i.e. mining). Understanding how regolith behaves during drilling processes in low-gravity environments of asteroids, the Moon, and Mars is a critical component in determining best-practices in dust mitigation and asset protection strategies. Leading up to a November test mission, a team from Texas A&M University's Department of Construction Science, the United States Air Force Academy's Department of Astronautical Engineering, and Crow Industries conducted generative design and computer-based simulations for virtual mock-ups of predicted behavior. In November, the team conducted a low gravity flight experiment aboard a Zero-G research flight to study propagation effects of asteroid, lunar, and martian regoliths during drilling in their corresponding gravitational environments. This paper and presentation discuss the results of the test flight and offers dust mitigation recommendations.

**9:25 AM**

### **Lunar Soil Simulation: Effects of Grain Shapes on Mechanical Behaviors**

*Z. Khademian<sup>1</sup>, E. Kim<sup>1</sup>, M. Nakagawa<sup>1</sup> and R. Garvey<sup>2</sup>; <sup>1</sup>Mining Engineering  
Department, Colorado School of Mines, Golden, CO and <sup>2</sup>Blue Shift LLC,  
Broomfield, CO*

One of the challenges to overcome in moon mining operations such as soil handling, drilling, excavation, and wheeled movement is understanding mechanical behaviors of lunar soil, comprising grains characterized by highly

irregular shapes. This paper uses a Particle Flow Code and describes a procedure for simulating lunar soil grains with specific size distributions and shapes. We adopt data from soil 64501 retrieved in Apollo 16 and simulate lunar soil samples as assemblies of different shapes of grains consisting of elastic spheres connected through bonds. We classify grains into four categories based on their shape: agglutinate, breccia type A, breccia type B, and plagioclase. We perform angle of repose and triaxial compression tests to investigate behaviors of samples, respectively. The largest angle of repose and the highest strength values are found to correspond to the sample with 100% agglutinate content. Results show the significance of simulating irregularly shaped grains for understanding mechanical behaviors of lunar soil. The modeling procedure demonstrates a robust means of approximating soil mechanics across a range of potential lunar soil mixtures and particle sizes.

**9:45 AM**

### **Mars Colony in-Situ Resource Utilization**

*S. Saydam; School of Minerals and Energy Resources Engineering,  
UNSW Sydney, Sydney, NSW, Australia*

This paper reports on our effort to develop an ensemble of specialized models to explore the commercial potential of mining water/ice on Mars in support of a Mars Colony. The resulting database is then linked to a variety of “downstream” analytic models. In particular, we integrated a mining model, a simulation of the colony’s environmental control and life support infrastructure known as HabNet, and a risk-based economics model. The mining model focuses on the technologies associated with in situ resource extraction, processing, storage and handling, and delivery. This model computes the production rate as a function of the systems’ technical parameters and the local Mars environment. HabNet simulates the fundamental sustainability relationships associated with establishing and maintaining the colony’s population. The economics model brings together market information, investment and operating costs, along with measures of market uncertainty and Monte Carlo techniques, with the objective of determining the profitability of commercial water/ice in situ mining operations.

**10:05 AM**

### **Update on the OSIRIS-REx Asteroid Sample Return Mission**

*R. Witherspoon; Lockheed Martin, Idaho Springs, CO*

OSIRIS-REx is a NASA asteroid study and sample-return mission to asteroid 101955 Bennu, returning a sample to Earth in 2023 for detailed analysis. OSIRIS-REx proximity operations around Bennu is setting records for the smallest body orbited in space. At only ~500 meters across, Bennu provides numerous challenges for a spacecraft to operate near and contact. Learn the latest about this unique mission and what we’ve learned about Bennu including: operating with a small gravity field, selecting a site to sample collect, unique topography challenges, and spectral makeup. In addition, an overview of the Touch-And-Go-Sample Acquisition Mechanism (TAGSAM) designed by Lockheed Martin to collect up to 2kg of regolith will be covered.

**10:25 AM**

## **The Viability of Space Resources for Investors and Entrepreneurs**

*K. Galla and J. Kemeny; Mining and Geological Engineering, University of Arizona, Tucson, AZ*

The current understanding of space resources and the production costs associated with it is helping to build technology for space mining. However, the space resource market is the least known aspect for investors and entrepreneurs. To establish a commercial space market, we need to understand the demand and how it can help the investors to have confidence in return on investments. The demand for the space resources can be generated when we can have public-private partnerships, relaxed space policies, efficient and economical methods to extract resources. We are performing market analysis to understand the viability of space resources. These resources are vital and integral part for building the infrastructure and exploring space. This presentation will discuss the design and model for market analysis to create flexible and feasible conditions for entrepreneurs to invest in space resources.

**10:45 AM**

## **A Commercial Architecture for Mining Propellant from Water on the Moon**

*G. Sowers; Mechanical, Colorado School of Mines, Morrison, CO*

On the order of 2 billion tons of water exist frozen in the permanently shadowed polar craters of the Moon. Water, composed of hydrogen and oxygen, is the propellant that will open cislunar space and beyond to regular traffic for commerce and people. United launch alliance and other commercial space transportation companies are developing vehicles that could refuel from propellant mined on the Moon. If propellant derived from the lunar water is cheaper than that launched from Earth there is a business case for the emerging lunar mining industry. The Colorado School of Mines, ULA and the University of Central Florida and with inputs from experts across the industry has recently conducted a study to determine if we might reliably expect to be able to purchase lunar water derived propellant. This paper will describe the challenges and opportunities of mining lunar water for propellant.

**11:05 AM**

## **Lunar COTS Concept: A Public/Private Partnerships Approach for Lunar Resource Mining and Infrastructure Development**

*A. Zuniga; NASA Ames Research Center, Moffett Field, CA*

A new concept study was initiated to gradually develop an economical and sustainable lunar infrastructure system to facilitate lunar resource prospecting and mining. A public-private partnership approach was used to establish partnership agreements between NASA and industry teams to develop cislunar capabilities, such as, power stations, communication relay satellites, and autonomous rover operations. The public/private partnerships approach for this study leveraged best practices from NASA's Commercial Orbital Transportation Services (COTS) program. Similar to the NASA COTS program, the goals of this current study, named Lunar COTS (Commercial Operations and Transport Services), are proposed to: 1) demonstrate commercial and affordable cislunar capabilities and services; 2) encourage creation of new space markets to share cost and risk with industry; and 3) enable development of a sustainable and economical lunar infrastructure to support lunar resource prospecting and mining. This presentation will describe the Lunar COTS concept goals, objectives and approach as well as a plan for lunar mining and testing of new extraction techniques.

## WEDNESDAY, FEBRUARY 27

### MORNING

9:00 AM | ROOM 503

## Mining & Exploration: Innovations & Technologies: Technology Implementations: The Field Experience

*Chairs: C. Smith, Caterpillar, Perth, WA, Australia  
S. Lolon, Colorado School of Mines, Golden, CO*

9:00 AM  
Introduction

9:05 AM  
Sonic Drilling for Smart Exploration and Mining

*B. Orberger<sup>1</sup>, H. Eijkelkamp<sup>2</sup>, H. Nolte<sup>2</sup>, M. Buckland<sup>3</sup>, M. Le Guen<sup>4</sup> and  
M. Buxton<sup>5</sup>; <sup>1</sup>Catura Geoprojects, Paris, France, France; <sup>2</sup>Eijkelkamp  
SonicSampDrill, Giesbeek, Netherlands; <sup>3</sup>Btopenworld, Sheffield, UK;  
<sup>4</sup>Eramet, Trappes, France and <sup>5</sup>Resources, TU Delft, Delft, Netherlands*

Exploration challenges are unconsolidated ore deposits (e.g. alluvial gold, diamond, Ni, Mn laterites, bauxites), as heterogeneous in grain size and ore deposit scale. Diamond drilling (DD) often losses economic material, leading to erroneous geomodels. In difficult environments, sonic drilling (SD) rapidly provides coherent cores (~ 80 m/day), reduces water consumption and waste at lower project costs compared to DD. In E-Siberia, SD recovered for the first time, clay layers with fine Au. Gold location forecasting, reliable mine planning at reduced OPEX, increased the production by ~50 %. In NE Angola, alluvial diamonds of variable grades and quality are mined in gravel layers (0-5 m) beneath clay and sands. SD sampling allowed to evaluate high-grade diamond layers, while increasing the productivity and mining block life. For Nickel laterites, the EU project SOLSA develops new technologies and smart software for SD coupled with a mineralogical and chemical core scanner to define regions of interests on SD cores. Cloud-connected data converted into actionable data will contribute to short-time decision making to speed-up exploration and designing smart mines and processes.

9:25 AM  
The Use of 3D Photogrammetry through Unmanned Aerial  
Vehicles (UAVs) to Map Geology at the Bingham Canyon Mine

*D. Sorensen and N. Vetz; Geology, Rio Tinto Kennecott, Eagle Mtn, UT*

Bingham Canyon Mine has commenced the implementation of 3D photogrammetry through UAVs to improve mapping, safety, and data gathering of geologic features on the pit highwall. Traditionally, this task has involved a geologist working in close proximity to the highwall in order to determine lithology, structures, and alteration, while a partner matches geology to a measurement tape extended between GPS locations on the bench and acts as a safety spotter. With UAV 3D photogrammetry, the geologists can now fly a pit bench and map geology in the field on a georeferenced base map, and



then confirm data in the office using 3D computer modeling software. This new process decreases highwall exposure, increases identification of structural features, and improves measurement accuracy. Mapping with UAVs permits geologists to access previous benches that have gone unmapped due to failures or loss of access. Also, this technology allows the geologists to quickly obtain extensive overviews of pit walls for tracing and modeling of geologic structures throughout the pit. Through the use of UAVs and 3D photogrammetry, Bingham Canyon hopes to gain a better understanding of the deposit's geology.

**9:45 AM**

## **Implementation of Deswik CAD, Scheduler, and File Manager in a Real World Application**

*K. McCoy; Member, Spring Creek, NV*

Recently an underground gold mine has made the transition to exclusively use Deswik as its mine design software and has incorporated Deswik File Manager as its file management tool. This has greatly improved the planning process which had previously used Deswik for its scheduling capabilities. While the transition had some challenges the resulting ease of workflow, improved organization, and information sharing has been extremely beneficial.

**10:05 AM**

## **Information Overload (How Much Data Is Too Much Data?)**

*B. Olewinski; Barrick Nevada Goldstrike Operations, Spring Creek, NV*

In this time of increasing technology, we find ourselves with more and more data at our fingertips. As an industry we have made strides in automated data collection. Instead of having to go out to the field and spend hours collecting the data it is automatically collected at a set time interval. Depending on the time interval that you set versus the frequency of the manual collections this can lead to a large increase in data. So, what do we do with all this additional data? Unless we spend our time and resources analyzing this data, it is wasted. This means that our geotechnical groups need to become more efficient at their day to day duties and make the time to analyze the increased amounts of data. Data storage also can become an issue, which means that increasing cooperation and communication with the IT groups needs to occur. In this presentation we will go through the sources of data, storage of data, need for analysis, staffing issues, training, and some key takeaways.

**10:25 AM**

## **Performance of a 6,000 gpm Ultrafiltration System Retrofit on a Difficult Mine Wastewater**

*J. Felicetti, L. Linton and D. Dye; WesTech Engineering, Salt Lake City, UT*

Advances in membrane materials and operation understanding have widened the range of feed sources and expanded possibilities for the use of ultrafiltration (UF). In mining, UF applications can include wastewater treatment for reuse, water remediation, and surface water treatment for process water. This project involves a critical application requiring reliable treatment of process and mine wastewater using UF as pretreatment to RO. The source can reach temperatures in excess of 100°F, has extreme scaling potential, and is highly variable. Due to these complexities, the system was customized to include added redundancy, cross-flow, antiscalant dosing, and a clean-in-place system to clean multiple units concurrently. In addition to challenges

with the feed source, this project included a complex and time-sensitive retrofit of an existing spiral-wound UF system. Design, fabrication, and installation occurred in roughly 16 weeks with final commissioning was completed in May 2017. After a year of operation, plant performance with regard to capacity, cleaning intervals, membrane replacement frequency, and filtrate water quality have significantly improved and will be discussed.

**10:45 AM**

### **To Flitch or Not to Flitch: Using Post-Blast 3D Optimization to Make the Decision**

*W. Hunt; Principal, OreControl Blasting Consultants, Denver, CO*

Flitch or multi-pass mining (multi-pass mining) is as contentious a subject as is politics. On paper, it looks like a viable method to reduce dilution and increase grade. Why then, do some operations steer clear of avoid it? Reduced production efficiency, implementation aggravation, and poor grade recovery results have caused some mines to stick with adhere to traditional bulk mining methods, even though their ore bodies appear to be ideally suited for flitch mining methods. Is there a way to improve grade recovery, thereby soothing the operational pain flitch mining can bring? This paper examines this question by presenting analysis on of several blasts from a variety of narrow-vein gold mines.

**19-148**

**11:05 AM**

### **In-Situ Testing of a New Backfill Material in Salt Mining; Challenges of the Upscaling Process**

*S. Poetzsch<sup>1</sup>, G. Barakos<sup>1</sup>, T. Popp<sup>2</sup> and H. Mischo<sup>1</sup>; <sup>1</sup>Chair of Underground Mining Methods, TU Bergakademie Freiberg, Freiberg, Germany and <sup>2</sup>Institut für Gebirgsmechanik GmbH, Authorized Representative, Leipzig, Germany*

Backfilling of underground openings is essential for operation and developing sealing concepts for radioactive waste repositories in salt formations. A new long-term stable microstructure-stabilized backfill material based on crushed rock salt has been developed over the past five years. The stabilization is achieved by adding a binder consisting of three natural salt minerals and brine. Initially the material can be characterized as a granular bulk aggregate and in the long-term as a solid saliferous rock formation. In the first stage of the R&D project, appropriate salt mixtures were developed and tested regarding their suitability as backfill material. In the current second stage different backfill methods are being tested in-situ to find the most appropriate approach to achieve the laboratory-confirmed material behavior also in-situ. This paper deals with the challenges of the upscaling process from lab to in-situ application. Because of 8 different components the 1st challenge was the underground production of up to 80 t of this material. This paper presents approaches for the unprecedented mixing procedure and the experimental test layout for monitoring in-situ properties.

**WEDNESDAY, FEBRUARY 27**

*MORNING*

**9:00 AM | ROOM 504**

## **Mining & Exploration: Management: Slide Rules to Big Data: The Evolution of Technical Knowledge in Mining**

*Sponsored by: OceanaGold*

***Chairs:** S. Rosenthal, Montana Tech, Butte, MT*

**9:00 AM**

**Introduction**

**9:05 AM**

### **Visualizing and Quantifying Uncertainty in Mine Planning**

*C. Roos; Mining Engineering, Montana Tech, Butte, MT*

Uncertainty exists in all aspects of mine design and planning. While many of the sources of uncertainty are difficult to quantify and manage, modern geostatistics has provided many tools to understand the uncertainty in a resource estimate. As mining engineers, we have had a difficult time embracing this uncertainty and producing mine plans that utilize this information. Stochastic optimization techniques will someday be common practice, however in the interim, mine planning practices should be adapted to account for uncertainty. Communication methods should also be adopted to allow the results to be understood by decision makers. The author is developing a multifaceted model of embracing uncertainty that will allow the mining industry to work toward understanding this uncertainty and eventually embracing it. This paper includes a case study demonstrating the possible ways that mine planners can utilize geologic uncertainty to improve their mine plans and also introduces novel visualization techniques that could aid in quantifying the effects of that uncertainty and communicating it to company leadership.

**9:25 AM**

### **Mathematical Methods for Complex Underground Design and Scheduling Problems**

*P. Nesbitt, L. Sipeki and A. Newman; Mechanical, Colorado School of Mines, Colorado Springs, CO*

Underground mine design is often accomplished by selecting a single mining method to detail an engineering plan and estimate investment and production. This approach to industrial process design does not allow efficiencies gained considering hybrid methods. We contribute an optimization-based heuristic that considers multiple and hybrid methods with engineering constraints considering multi-mode and mode dependent precedence to create viable extraction sequences and operational scheduling to maximize profit. This approach provides a consistent means to design multi-mode industrial processes, immediately benefiting the mining industry by better informing strategic plans.

**9:45 AM**

## **Optimizing the Production Schedule at Barrick's Turquoise Ridge Operation Using a Deterministic Method**

*A. Chowdu<sup>1</sup> and R. Williams<sup>2</sup>; <sup>1</sup>Mining Engineering & Management, South Dakota School of Mines & Technology, Rapid City, SD and <sup>2</sup>Turquoise Ridge, Barrick Gold Corporation, Golconda, NV*

Underground mine production scheduling is a multifaceted and time-consuming job. In modern underground mining, industry practice is to use genetic algorithms and other heuristics for creating feasible production schedules. This paper presents an alternative to this approach and discusses the implementation at Barrick's Turquoise Ridge operation in Nevada. We present the process of converting the mine design to an equivalent mathematical model and the solution method used to generate a 10-year production schedule at daily fidelity. The result showed a significant increase in NPV over the 10-year period, while achieving ore production targets within current resources, e.g., processing capacity, equipment. The paper also highlights the operational benefits of utilizing these tools and methodology.

**10:05 AM**

## **Montana Tech's Underground Mine Education Center**

*P. Knudsen; SME, Butte, MT*

In 2010, Montana Tech acquired ownership of a parcel of land west of campus and received an industry gift that allowed Tech to initiate development of an Underground Mine Education Center (UMEC). The UMEC complements courses in mining engineering, geological engineering, environmental engineering and occupational safety and health. It also serves as a research facility. One of the first research projects was to demonstrate the feasibility of using the geothermal energy found in the warm mine water at the Orphan Boy Mine to heat the 55,000ft<sup>2</sup> Natural Resources Building at Montana Tech. Initial development consisted of 1000 ft. decline to reach the 100 ft. level of the mine and access the Orphan Boy Shaft. The 100 ft. shaft station became the centerpiece of the geothermal project. Next a 1000ft drift was driven to connect with the Orphan Girl Mine and provide secondary escape. The UMEC comprises existing underground workings of the Orphan Boy and Orphan Girl Mines plus new workings developed for specific training purposes. Students in the practical mining class have driven over 1100 additional feet of workings.

**19-057**

**10:25 AM**

## **Comparing Drone Survey to GPS Rover Survey at Coeur Rochester**

*J. Hoover; Coeur Rochester, Fernley, NV*

Drones are quickly becoming a standard tool across a host of industries; Mining professionals are constantly looking to innovate by improving or replacing inefficient processes and technologies which has led to mining quickly becoming one of the industries at the forefront of this technology. Currently, Drone Technology and Photo Telemetry is sold to the mining industry as a way of delivering safe, efficient, and effective high quality data that can be used to supplement or in some instances replace traditional mine surveying. In 2018 Coeur Rochester implemented a drone survey program with the goal of achieving the above mentioned benefits. This presentation is a summary of how Coeur Rochester implemented their drone program and how the drone survey results compared to the sites traditional surveying methods.

**10:45 AM**

## **Mining in the Future: Mind Matters**

*M. Javier; EnviroMINE, Denver, CO*

Mining is most vital to our civilization. The current model of extraction technologies was designed without an expiration date and therefore generates environmental effects that are severe. Mining results-effects have been traditionally accepted & promoted around the world since Agricola described mining. Mining's extractive technology is outmoded & standardized & inflicts negative results-effects on nature. Those results are liabilities dimensioned in legacy & type of nature able to provide to the next generation. In order to design, build, & transform mining effectively we must ask: What is the vision of mining? Mining has exhausted its antiquated mindset of over 200 years. Now it merely pilots us into crisis. The challenge today is to resolve the socio-environmental conflicts globally with a radical transformation of mining business at its core. This paper illustrates that old mindsets must be radically updated or the concept of mining will continue to be trapped. Changing the mindset will enable discourse toward a new destiny. We are able to evolve & get different results than in the past by pursuing a new legacy to live in harmony with nature for many more years.

**19-073**

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## **WEDNESDAY, FEBRUARY 27**

*MORNING*

**9:00 AM | ROOM 505**

## **Mining & Exploration: Operations: Efficiency Gains Through Automation and Innovation**

*Chair: J. Oxborrow, Barrick*

**9:00 AM**

**Introduction**

**9:05 AM**

## **Improving the Safety and Lowering the Cost of Ground Support Operations by Using LiDAR to Measure the Thickness of Sprayed Shotcrete**

*K. Smillie; Non-Member, Bingham, Nottinghamshire, UK*

Details of a new method of real-time, non-contact, thickness measuring of applied shotcrete during underground ground support operations are given. The solution, based on LiDAR technology, uses a laser scanner affixed to mechanised shotcrete sprayers. The system improves safety by ensuring required minimum thicknesses are applied, allows accurate, non-contact remote measurements without endangering personnel, and improves operational economics by reducing materials wastage through over-spraying. Manual measuring methods have suffered from reduced safety, inconsistency and traceability issues. Details of the technology, implementation, benefits and future improvements will be given, as well as digital output for reporting and QA purposes shown.

**9:25 AM**

## **The Roll of Unmanned Aircraft Systems (UAS) in Mining**

*L. DuPlessis, E. Fretheim, J. Hernandez, S. Winger and J. Snipes;  
Technology Center Mining, Freeport-McMoRan, Tucson, AZ*

In recent years, there have been an explosion of unmanned aircraft in the personal and commercial space. With the promises of the technology come a host of potential promises. Aside from the potential promise, the question remains “How can this technology best be used to improve the business of mining today?” This presentation discusses the various use cases of Unmanned Aerial Systems (UAS) in the mining environment. Although the technology has significant automated capabilities, the equipment also must operate within the regulations of the National Airspace under existing limitations. We seek to define the best use cases for the technology, and where automated technology can enhance the safety, operating awareness, and efficiency of the mine.

**9:45 AM**

## **How to Use Heave, 3D Movement, and Ore Block Optimization to Increase Grade and Decrease Dilution**

*W. Hunt and D. LaRosa; Principal, OreControl Blasting Consultants,  
Denver, CO*

To take a giant leap forward in ore control, a sophisticated approach to post-blast ore control is required. It must incorporate a ‘smart’ vector-field, heave knowledge, vectors of displacement, in-situ geology, and production opportunities. Based on dozens of studies, the gain is very-much worth the effort.

**19-137**

**10:05 AM**

## **How Deep Learning Will Revolutionize Blast Optimization: Using Artificial Intelligence to Measure Fragmentation in Shovel Buckets**

*J. Davies<sup>1</sup> and C. McKinnon<sup>2</sup>; <sup>1</sup>Editor, Vancouver, BC, Canada and  
<sup>2</sup>Marketing, Author, British Columbia, BC, Canada*

Efficient blasting is an integral part of any mining operation, and fragmentation analysis can help mining operators optimize blasting efforts to realize significant time and cost savings. This paper presents a shovel bucket monitoring solution that provides accurate, actionable particle size distribution data. The system outperforms traditional computer vision techniques by harnessing the latest deep learning techniques and field data collected from installed systems. A selection of case studies will be presented to support the accuracy and reliability of the solution. Compared to traditional image-based analysis, the fragmentation analysis solution presented here provides a safer and more efficient alternative.

**10:25 AM**

## **Autonomous Hauling System – Command for Hauling**

*A. Reid and T. Hawkins; Caterpillar, Washington, IL*

MineStar Command for Hauling (CfH) is a combination of on-board sensors and software, and off-board code that optimizes the performance of a customer’s load and haul system. The technology has been developed in conjunction with multiple eco-system partners, and has been awarded 20 patents. This solution provides mining customers with a system that can

work with any make or model of truck, loading tools, and support equipment. Autonomous operation of mining trucks, interaction with other equipment, and integration with customer mining processes and systems. Delivery of this technology required a large and diverse team internally and externally. Key project results: -Enabled our customers to move nearly one billion tons of material, at a rate higher than the manned production it replaced. -With an active fleet of 100 AHS trucks around the world, that have hauled 360 million tonnes safely with 0 lost-time injuries.

**10:45 AM**

## **Digitization of Daily Project Planning at Barrick Pueblo Viejo**

*K. Pena Pena; Drill and Blast, Barrick Pueblo Viejo, Distrito Nacional, Santo Domingo, Dominican Republic*

Auxiliary Projects allow Mining Operation Projects to be executed through activities such as construction roads, drainages, slopes stabilization and topographic surveys. At the open pit mine Barrick Pueblo Viejo, in Dominican Republic, we have identified that the lack of planning of these, lead to considerable delays in mining projects, and consequently, monetary loss for the mine. Our general strategy is the automation of the process so that planning engineers focus more on production projects instead of auxiliary projects. The MinePro Manager Project, through the Jira platform, will allow mining engineers to improve planning due to the integration of technology and digitization of daily tasks, users will keep effective communication, retain the same focus between work shifts, continuous planning and Business Improvement.

**11:05 AM**

## **Haul Truck Pass Match vs Payload Targets for Loading Optimization through Technology**

*R. Riggle; Cat Global Mining, Menomonee Falls, WI*

Numerous papers and, presentations have been written on Mining Haul Truck Payload management and the effects of payload on haul truck availability. Mining operations around the world understand the value and concept of haul truck payload optimization. This article will discuss loading from the electric rope shovel perspective. Electric rope shovels dippers are engineered for optimal pass match loading with 3-4 passes as the ideal loading system to produce the lowest cost per ton. With real time data systems and, equipment performance monitoring technology on both haul trucks and shovels, field studies at large mining operations reveal that haul truck payload optimization may be hindering shovel performance. The haul truck payload optimization, the 10-10-20 payload rule and technology at some operations have led to some questionable operational practices of trucks waiting for the payload to register while waiting under the shovel, taking very valuable production time away from the shovel loading time. This article will explore the advantages and disadvantages of shovels loading to a pass match verses loading to a payload.

**19-067**

## WEDNESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM 506

### Mining & Exploration: Operations: Mine Scheduling and Optimization II

*Chairs: R. Diaz, Centennial, CO*

*A. Ashok Parmar, Freeport-McMoRan Inc.,  
Tucson, AZ*

9:00 AM

Introduction

9:05 AM

#### Ultimate Pit Size Selection – Where Is the Optimum Point?

*A. Ebrahimi; Mining, SRK Consulting, Vancouver, BC, Canada*

Ultimate pit size selection is among the most fundamental decision-making processes for a project, because it shapes many aspects of mining. Yet, many mining companies select the pit shell with the highest NPV as the ultimate pit. When NPV is the only evaluating criteria, long-term / low-production rate projects cannot compete with short-term / high-production rate projects. This is due to the time value of money reflected by a project's discount rate. However, complex, multivariable factors (including technical, economic, social, and operational) should be accounted for in the ultimate pit selection process—although they can be difficult to quantify in the early stages of a project. These factors include outlook of longterm prices, power and water supplies, human resources, capital requirements, size and shape of orebody, location, mining method, and interests of communities and other stakeholders. Failing to evaluate any of these in depth might hurt the health of project. By using robust, plausible examples, the author demonstrates the challenges that many mining projects are facing in this regard.

9:25 AM

#### Unlocking Project Value: A Mine Planner's Perspective

*R. Vivas, C. Calderon-Arteaga and L. Gutierrez; Technical Services,  
Hexagon Mining, Tucson, AZ*

Each project presents unique opportunities to unlock and realize project value. For this reason, mine planners use scheduling and optimization tools for preparing their life of mine plans and budget plans. There are many aspects that mine planners look to improve in a project and the impact to the business and operations can be significant. In this paper we will review some practical examples that show how mine planners evaluate and uncover project value. More specifically, we will discuss how mine planners evaluate and optimize important aspects of the schedule such as total mine capacity, phase productivity, truck requirements, cutoff grade, etc... and how these schedules guide important capital investment decisions and have a significant impact on the value of the project.

19-150



**9:45 AM**

## **Mine Scheduling Optimization Using Floating Truck Concept Integrated With Forward Looking Approach – Freeport-McMoRan Sierrita**

*A. Ashok Parmar, A. Soderman and J. Cordova Fuentes;  
Mine Superintendent, Freeport-McMoRan Inc., Tucson, AZ*

Freeport-McMoRan is a leading international natural resources company that operates large, long-lived, geographically diverse assets with significant proven and probable reserves of copper, gold and molybdenum. This technical presentation discusses the concept of floating trucks integrated with forward looking optimization in the context of mine planning at Sierrita. In a traditional mine planning process, a constant or uniform truck requirement is utilized. As a result, the mine schedule is determined by the trucks, which, due to changes in truck destinations and cutoff grades, has a negative effect on project value. Alternatively, a dynamic or floating truck concept allows the mine plan to dictate the optimal truck requirement. This concept, integrated with a forward-looking approach, improves the economics of a mine plan, resulting in higher operational flexibility and project value. This paper will discuss the methodologies and procedures, as well as the optimization techniques, used to integrate a dig, haul and dump plan. It will also provide mine planners a better perspective of how truck requirements influence a mine plan and the value gained by implementing this new approach.

**10:05 AM**

## **Optimization of the Extraction Rate in Room and Pillar Mining**

*S. Döppenschmitt; Faculty of Geo-Resources and Process Engineering,  
Georg Agricola University Bochum, Bochum, Germany*

Room and Pillar Mining is subject to optimization between extraction rate and ground control. Required pillar sizes are mainly influenced by UCS, depth and seam height, thus the pillar size changes, if the influencing factors vary. A common approach is to design the panel with a unified size of the square pillars, which is equivalent to maximum needed pillar size in the panel. This leads to oversized pillars in some parts of a panel and a decreasing extraction rate. With the concept of elongated pillars with equivalent pillar width, it is possible to vary pillar size in a panel and to optimize the extraction rate significantly. Advantages of the elongated pillar concept are shown in a case study for an underground gypsum mine.

**10:25 AM**

## **Open Pit Mine Optimization with Maximum Satisfiability**

*M. Deutsch; Maptek, Lakewood, CO*

A common casualty of modern open pit mine optimization is the assurance that the resulting design is actually achievable. Optimized mine plans that consider value and a bare minimum of precedence constraints do not, in general, translate into practical, operational mine designs that can really be used in the field. Ultimate pits may come to a sharp point at the bottom. Schedules may require taking small parcels of material from many disparate areas of the pit in a single period. And grade control polygons may be ragged, narrow, and not minable with realistic equipment. In this paper all of these problems are addressed by encoding these three fundamental open pit mine optimization problems as maximum satisfiability problems. Maximum satisfiability provides a useful framework for problems that are non-linear, and may guarantee the optimality that metaheuristics cannot.

**19-074**

10:45 AM

## Simulation for Productivity Prediction of Life of Mine Plans Using Historical Data

*S. Upadhyay and H. Askari-Nasab; Civil and Environmental Engineering, University Of Alberta, Edmonton, AB, Canada*

Equipment planning for life of mine plans is critical to meet the production and budgeting requirements of the mine. However, the inherent uncertainties, especially that of truck travel times, hinder accurate estimations of truck cycle times and thus productivity. Existing software/methods mostly rely on rimpull characteristics of the trucks to estimate travel times and completely neglect the operating environment. A simulation tool is thus developed to estimate the productivity by combining the use of historical data, rimpull data and road network for the schedule. The proposed simulation method involves sampling distributions for predicting various cycle time components except truck travel times. Historical average velocity sampling distributions are used to sample velocities which is then adjusted using rimpull characteristics and the road network for the schedule to predict truck travel times. A validation study of the developed model at an operating open pit mine provided 94% improvement over the existing method at the mine site with -2% error in productivity estimation.

## WEDNESDAY, FEBRUARY 27

MORNING

9:00 AM | ROOM 705

## MPD: Chemical Processing: POX

*Sponsored by: thyssenkrupp*

**Chairs:** *R. Frischmuth, Hatch, Mississauga, ON, Canada  
B. Mota, Freeport-McMoran, Safford, AZ*

9:00 AM

Introduction

9:05 AM

## Development of a Pressure Oxidation Flowsheet to Treat Copper and Gold Ores from the Yanacocha Sulfides Deposits

*M. Jeffrey<sup>1</sup>, S. Shuey<sup>1</sup>, H. Arevalo<sup>1</sup> and R. Frischmuth<sup>2</sup>; <sup>1</sup>Newmont Mining Corp, Englewood, CO and <sup>2</sup>Hatch, Mississauga, ON, Canada*

During peak production, Yanacocha was one of the world's largest heap-leach gold mines, producing approximately 3M oz/a. However, as the remaining oxide reserves continue to decline, the future of the operations is dependent on treating refractory sulfide deposits. Newmont commenced studies treating Chacabuco and Verde sulfide deposits independently and determined that neither is viable as a standalone project at the time. In 2015, an integrated study



was initiated to explore synergies between all the remaining sulfide deposits at Yanacocha, including Chaquicocha, a refractory gold underground deposit with high elemental sulfur; and Verde which is an open-pit enargite-dominant copper deposit containing gold and silver. This presentation will describe the development of the process flowsheet, including laboratory and pilot testing in 2016, and a feasibility study completed in 2018.

**9:25 AM**

## **Commissioning and Early Operating Experience at the Coper Sulfide Expansion Project**

*V. Ketcham<sup>1</sup> and J. Ebbett<sup>2</sup>; <sup>1</sup>Operational Excellence Center, Alacergold, Denver, CO and <sup>2</sup>CESP Project Director, Alacergold, Ilıc, Erzincan, Turkey*

Anagold's Coper Sulfide Expansion Project, a two autoclave refractory gold processing plant in eastern Turkey, commenced operation in 2018. A summary of the successes and challenges experienced in construction, commissioning and early operation of this facility will be presented.

**9:45 AM**

## **PLCC Project – Autoclave Technology Applied to Complex Copper Concentrates**

*N. Parra Werth; none, Santiago, Chile*

In recent years arsenic content in copper concentrates has increased along with environmental restrictions for their transport and processing. Under this scenery is being developed the Complex Concentrate Leaching Project (PLCC), which allows the treatment of copper concentrates with high arsenic content (>0.5%) through a high pressure leaching within an autoclave. Through the addition of high purity oxygen and cooling water to control the temperature in the autoclave is possible to dissolve over 99% of copper and arsenic compounds. Dissolved arsenic is then precipitated as ferric arsenate, which is a stable compound that meets TCLP/SPLP tests. The oxidized slurry from the autoclave is depressurized, cooled and afterwards sent to a solid/liquid separation stages generating a PLS solution and an arsenical residue which is stored on a deposit.. The PLS is mixed with heap/dump PLS solutions and then sent to a SX/EW plant to produce copper cathodes. The gases from the autoclave, slurry depressurization and slurry cooling are sent to a gas cleaning system before they are released to the atmosphere. The purpose of this work is to describe the progress to date of the PLCC project.

**10:05 AM**

## **Freeport-McMoRan Morenci Operations: Concentrate Leach Plant (2015 to Present)**

*K. Schaub and B. Mota; Freeport-McMoRan Morenci Operations, Safford, AZ*

The Concentrate Leach Plant (CLP) at Freeport-McMoRan's Morenci Operations successfully restarted in May 2015. Since startup, the plant has processed over 400,000 tons of Morenci concentrate. This presentation will review plant operating challenges and major accomplishments. The presentation will also give an overview of the current strategies and tools being used for continuous operational improvement.

10:25 AM

## Industrial Scale-up of Pressure Oxidation for Refractory Gold Ores: From Bench Scale to Operations

*D. Dyson and K. Seto; Hydrometallurgy, AuTec Innovative Extractive Solutions, Vancouver, BC, Canada*

Predicting oxidation chemistry can be challenging when scaling up from batch autoclave processes to continuous operations. Batch experiments are typically used as an indicator as to whether pressure oxidation (POX) is a viable processing route after examining the gold recoveries downstream. Programs are then conducted to observe the effects of changing variables independently, but they may not reveal the actual POX behavior that will occur during continuous operations. Incomplete understanding and interpretation of aqueous chemistries and precipitates in bench top and pilot operations can cause recovery losses at the commercial scale. In addition to recovery losses, process challenges are also encountered with continuous campaigns; precipitate scaling can accumulate within the autoclave creating enhanced risks of operation failures and could impact plant production targets due to unplanned shutdowns. Mixing kinetics and short-circuiting also play a larger role in comparison to smaller batch experiments. Hence, it is critical to consider these changes when progressing through feasibility studies to minimize gold losses during POX.

10:45 AM

## Gold Extraction from Mulatos Mine Sulfides Concentrate Using Oxidative Acid Pretreatment

*J. Valenzuela<sup>1</sup>, M. Bracamontes<sup>1</sup>, P. Guerrero<sup>1</sup> and J. Parga<sup>2</sup>; <sup>1</sup>Chemical Engineering & Metallurgy, University of Sonora, Hermosillo, Sonora, Mexico and <sup>2</sup>Materials Science and Metallurgy, Institute Technology of Saltillo, Saltillo, Coahuila, Mexico*

Currently the gold and silver found in ores with low grade either where they are occluded in the ore, which are known as minerals refractory for its difficulty to extract them, causing that conventional methods of extraction are not economically feasible. Treating to increase the recovery of these values, extraction of gold from refractory of matrix sulfide concentrate was studied, ore samples were collected from Mulatos Mine, located in municipality of Sahuaripa, Sonora, Mexico, for which oxidation takes place in acid medium using ferric sulfate and sulfuric acid as oxidizers (pretreatment), followed by leaching with cyanide. The concentrate has a grade of 97 g/ton Au, 0.25% Cu and 15% Fe. XRD is confirmed the presence of the species of silica and pyrite. In experiments conducted so far was found to be the extraction of gold without using any prior pretreatment as low 24%, while making the acid pretreatment 0.5 M H<sub>2</sub>SO<sub>4</sub> Fe<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub> at conditions T = 50° C, PO<sub>2</sub> = 0.35 MPa, followed by neutralization with lime and leaching with cyanide (0.5%) NaCN, T=25°C and P= 1 atm. Gold extraction increased to 90%.

**WEDNESDAY, FEBRUARY 27**

*MORNING*

**9:00 AM | ROOM 706**

## **MPD: Flotation: Chemical Aspects of Flotation II**

*Chairs: O. Basuer, Osisoft*

*B. Vaziri Hassas, Pennsylvania State University,  
University Park, PA*

**9:00 AM**

### **Introduction**

**9:05 AM**

### **Natural Fatty Acids and Biocollectors: Eco-Friendly Collectors for Apatite**

*A. Silva and E. Silva; Mine Engineering, Federal University of Goiás,  
Catalão, GO, Brazil*

Froth flotation deserves special attention among the concentration methods for mineral processing due its great selectivity for different minerals and high efficient for fine particles. Bioflotation encompasses the principles and methods used in mineral flotation using microorganisms as reagents. In order to use sustainable and eco-friendly reagents, oils extracted from three different vegetable species were studied and tested as apatite collectors. *Saccharomyces cerevisiae* was chosen as biocollector due to its relatively easy industrial grow, absence of biological risk, and availability. Blue crystals of igneous apatite from Ipirá-BA, Brazil, were comminuted and characterized. Microflotation tests were carried out with different collectors dosages and pHs. Flotigam 5806 from Clariant was used as benchmark. Since the oils are water-insoluble, an alkaline hydrolysis (or saponification) was necessary before their contact with the mineral sample. The saponification was performed at room temperature. Commercial dried baker's yeast cells and spent yeast cells from a local brewery were tested. The results showed a high potential for some of the new collectors (flotability above 95%).

**9:25 AM**

### **Development of a New Starch Based Depressant: Study of Sorghum Starch Adsorption on Apatite Surface**

*E. Silva and A. Silva; Mine Engineering, Federal University of Goiás,  
Catalão, GO, Brazil*

Igneous deposits mostly compose Brazilian phosphate rock mines (in operation or prospection), with  $P_2O_5$  grades above sedimentary deposits and simultaneous occurrence of several gangue minerals. Currently, the most used technology for processing igneous ores is anionic flotation at alkaline pH (around 10) using saponified fatty acids (collector) and cornstarch (depressant, mainly because its effectiveness for different minerals. Studies were carried out using a sorghum's graniferous variety cropped in the State of Goiás/Brazil in order to verify its efficiency as depressor in mineral flotation. Sorghum starch interaction with apatite surface has been investigated through microflotation tests, adsorption studies, electrokinetic measure-

ments, and FTIR spectroscopy. Microflotation tests results demonstrate that sorghum starch interacts with apatite, but it was less intense than observed for cornstarch. The addition of sorghum starch resulted in an electronegativity increase at alkaline pH. The maximum adsorption density obtained on the apatite surface was 0.06 mg/m<sup>2</sup> at a dosage of 3.75 mg/L and pH 9. The FTIR results confirmed the sorghum starch adsorption on the apatite surface.

**9:45 AM**

### **Predicting Bubble Coarsening in Flotation Froth: Effect of Contact Angle and Particle Size**

*S. Park, K. Huang and R. Yoon; Virginia Tech, Blacksburg, VA*

A model has been developed to predict the bubble size enlargement in froth phase. It is based on predicting the kinetics of film thinning using the Reynolds lubrication theory with the hydrodynamic pressures corrected for the local capillary pressures around the particles adsorbed in the lamella films and the disjoining pressures in the free film without particles. The former varies with contact angle ( $\theta$ ) and particle size, while the latter varies with the disjoining pressures controlled by frother addition. At  $\theta < 90^\circ$ , the local capillary pressure presents a resistance to film thinning, which in turn varies with particle loading. The model shows that a froth acquires a kinetic stability when film thinning slows down due to the presence of particles despite the negative disjoining pressures of the free film. A series of flotation tests conducted with 35 mm glass spheres in the presence of 10-5 M MIBC show that bubble coarsening is minimum at  $\theta = 70^\circ$ , which corresponds to the experimental data obtained in the present work and by others. The model can also predict the effects of particle size in bubble coarsening.

**10:05 AM**

### **Improved Understanding of Starch Adsorption and Its Role in Iron Ore Flotation**

*S. Yang and L. Wang; School of Chemical Engineering, The University of Queensland, Brisbane, QLD, Australia*

This paper reports the amylose (AM) and amylopectin (AP) fractions of different starches in aqueous solutions before and after interaction with hematite particles as measured using size exclusion chromatography (SEC). The results were then used to determine the adsorption densities of am and AP on hematite surface, which were compared with the degrees of depression of hematite flotation (D). It was found that D had a strong correlation with the adsorption density of AP. Further studies using SEC and <sup>1</sup>H nuclear magnetic resonance spectroscopy suggest that adsorbed AP with longer, more branches could be more effective for depression of hematite.

**10:25 AM**

### **High-Efficiency Flotation Collectors for Magnetite Ores**

*Q. Zhou<sup>1</sup>, J. Gustafsson<sup>2</sup>, H. Nordberg<sup>2</sup> and N. Smolko Schwarzmayr<sup>2</sup>;  
<sup>1</sup>AkzoNobel Surface Chemistry LLC, Brewster, NY and <sup>2</sup>AkzoNobel Surface Chemistry AB, Stenungsund, Sweden*

Reverse flotation of iron oxides using cationic collectors to remove silica / silicate gangue materials is widely practiced by the iron ore industry in order to provide high-grade iron feed to the steel industry. The two most commercially important iron oxide ores are hematite and magnetite. In our current study of the reverse flotation of magnetite ores, new, highly efficient

collectors have been developed resulting in better froth profiles than the traditional ether diamines. In one particular case, it was observed that a new ether monoamine collector surprisingly gave a 20% higher dosage efficiency when compared with the standard ether diamine collector. Another series of collectors have been developed by introducing spacers of varying length between the hydrophilic head-group and hydrophobic tail of the surfactant collector. These spacers have been found to provide the resulting collectors ready biodegradability and lower toxicity than the traditional cationic collectors used in the reverse flotation of iron oxides. Details of the flotation performance of these new, high-efficiency collectors and the properties of the resulting flotation froths will be discussed.

**10:45 AM**

## **Chemistry of Rare Earth Mineral Flotation with Salicyl Hydroxamic Acid**

*S. Trant, A. Das and C. Young; Metallurgical, Montana Tech, Butte, MT*

Results are presented for a collector, salicyl hydroxamic acid (SHA), adsorbing on Rare Earth Minerals (REMs). Various REMs were examined and include the rare earth oxides (REOs), carbonates (RECs), phosphates (REPs) and silicates (RESSs) of a suite of Rare Earth Elements (REEs). SHA adsorption follows an ion-exchange process that leads to chemisorbed and surface-precipitated states, depending mostly on pH. Differences in adsorption density are attributed to both solution and surface chemistry as well as coordination number and ionic diameter, all of which are influenced by lanthanide contraction.

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## **WEDNESDAY, FEBRUARY 27**

*MORNING*

**9:00 AM | ROOM 612**

## **Research: Geometallurgy**

*Chairs: I. Barton, UA Lowell Institute for Mineral Resources, Tucson, AZ  
M. Enders, Colorado School of Mines*

**9:00 AM**

## **Introduction**

**9:05 AM**

## **Mine-Site Mineralogy Labs – Optimizing Ore Control and Processing**

*W. Baum; ORE & PLANT MINERALOGY LLC, San Diego, CA*

Geo-Metallurgy programs have become essential for competitive mining. Process-related mineralogy data represent a priority for better ore profiling, modeling, process and metallurgy diagnostics, and related improvements. Yet, modern, automated mine-site mineralogy labs remain the exception in

an industry which is confronted with a multitude of challenges. Recently, several new plants had long ramp-up times, under-performing flowsheets, costly retrofitting or de-bottlenecking to reach nameplate capacity. A major cause for these problems is the lack of robust “up-front” process mineralogy. It will be illustrated that 24/7 mineralogical analyses via automated lab modules may significantly improve blasting, comminution, agglomeration, leaching, reagent use, or flotation to name a few. Better and more cost-efficient mine geology, planning, ore control, models, production forecasting and continuous metallurgical optimization can be realized via smart investment in mine-site mineralogy labs.

**9:25 AM**

### **Applied Geometallurgy – A Common Sense Approach**

*M. Enders; Geology and Geological Engineering, Colorado School of Mines, Golden, CO*

It just makes common sense for the geological and mineralogical characteristics of ore deposits to be fully integrated with metallurgical properties and mineral processing indices. At the 2003 AMIRA Exploration Manager's Conference, I urged AMIRA to initiate research projects that benefited the mine geologists and operators, particularly geometallurgy, rather than focus solely on exploration. AMIRA project P843 (2005-2009) was their most successful single project ever and resulted in major advances in the development of tools and tests that can be used to better characterize the geometallurgical characteristics of ore deposits. Geometallurgy is simply a holistic description of ore deposits relating physical, chemical and mineralogical characteristics of ore types to metallurgical, mining and geophysical properties. The objective of these studies is to build deposit models and production forecasts based on the concept of “delivering the right material, to the right place, at the right time” such that mining and processing operations can be optimized to yield the highest metal recoveries at the lowest cost, which maximizes the profit from and extends the life of a mining operation

**9:45 AM**

### **The Boundary Phase Problem in Automated Mineralogy**

*I. Barton; Mining and Geological Engineering, University of Arizona, Tucson, AZ*

Automated mineralogy (QEMSCAN, MLA, TIMA) is a group of scanning electron microscope-based techniques used for quantitative evaluation of grain size, liberation, and mineralogy in mining, geometallurgy, and process samples. A major, largely unresolved source of error arises from boundary phases, where two or more touching minerals both contribute to backscatter and X-ray readings, leading to an ambiguous or incorrect identification of the boundary area. Monte Carlo modeling of electron trajectories near phase boundaries shows that the width of the boundary phase is distinct from the activation volume of the electron beam. Major determining factors in boundary phase width are boundary angle, electron beam accelerating voltage, and the ionization potentials of the minerals. Low ionization potentials and low stopping power yield wide potential boundary phases. Problematic minerals include feldspars and metal sulfides and oxides, which routinely form with fine intergrowth and replacement textures that can create disproportionately large boundary phase areas. Boundary phase error can be mitigated by crosschecking automated mineralogy results against optical microscopy or manual SEM.



**10:05 AM**

## **Mineralogy Characterization for Copper Bearing Gangue**

*R. Saulters; Material Characterization, Freeport-McMoRan, Vail, AZ*

In automated scanning electron microscopy (SEM) testing, the ability to detect and quantify the copper content in gangue mineralogy is important in metallurgical production analyses. More accurate recovery assessments are predicated on incorporating this often overlooked copper contribution. This presentation discusses the benefits of improved copper bearing gangue characterization while also touching on some of the challenges inherent in automated SEM testing. Additionally, opportunities to leverage insight into the composition of copper bearing gangue minerals will be explored for potential production gains.

**10:25 AM**

## **Next Steps in Innovation: Connecting Value Points for Financial Gain**

*K. Olson Hoal; Karin Olson Hoal Consulting, LLC, Golden, CO*

Many innovative developments have emerged in the minerals industry over the past decade, including data integration, quantitative geology, modular plants, sustainability, and geomet. Each has incrementally advanced the business, but potential financial benefits remain on the table when value points are not connected. Geomet is pivotal to integrating projects for value optimization. By linking knowledge of the subsurface to flexible operations uncertainty and downside risks are reduced, impacts are better predicted, and new value opportunities are uncovered through more informed decision making. Connecting the value points requires an innovative team committed to value generation for shareholders and stakeholders alike.

**10:45 AM**

## **Utilization of High Silica Iron Ore in Iron Making Process – A Case Study**

*D. Mukherjee, S. Shekhar, R. Kumar and M. Mishra; Mining Engineer, Jamshedpur, India*

A typical haematite deposit of Iron Ore consists of high siliceous material. Excavation of such material is required in order to ensure sustainable mine development. The high siliceous material mainly comprises of banded haematite jasper and banded haematite quartzite. Conservation of mineral is essential for mining industry worldwide. A typical steel plant imports pyroxenite as a flux material in sinter plant. The idea conveyed through this paper is to partially replace pyroxenite with high siliceous iron ore in sinter plant. High siliceous material has the ability to act as a flux in iron making process in sinter plant. Banded haematite jasper and quartzite are presently not used as a useful ore in manufacturing industry. Generating value out of waste is the main objective of this project. This idea has proposed to reduce the consumption of pyroxenite by 15 % and limestone by 7%. A reduction on overall 5 % cost has been targeted with the implementation of this idea. The utilization of high silica Iron ore has added a new dimension in iron making process and mining industry as a whole.

**11:05 AM**

## **Constraints Regarding Geomechanics of Degradation**

*P. Moreira Coutinho, J. Kemeny and I. Barton; Department of Mining and Geological Engineering, University of Arizona, Tucson, AZ*

This project aims to better understand how major mineralization and hydrothermal alterations affect slope stability in porphyry systems. This project focuses on samples from three mine sites in Arizona: Morenci, Miami, and Bagdad. I will investigate fresh and hydrothermally altered rock pairs through geotechnical tests and characterize how they behave under different stresses. The mineralogy, microfractures, textures, and alteration grades will be analyzed through petrographic thin sections. Hyperspectral Imagery will identify altered zones across the pit wall and the band spectrums for each alteration type. The terrestrial laser scanning will point the slope displacement and velocity as well as orientation, roughness, and joint spacing. This project aims to develop a geomechanics of degradation model using the Damage Mechanics Model to predict how factor of safety shifts through time due to hydrothermal alterations. The data collected so far regarding sericitic and argillic alterations shows that the factor of safety decreases after the alteration. The motivations behind this project are related to the pushback management, slope optimization, and mine safety in mine operations.

## **WEDNESDAY, FEBRUARY 27**

*MORNING*

**9:00 AM | ROOM 108**

## **Smart Mining Complexes and Mineral Value Chains**

***Chairs:*** *M. Godoy, Newmont Mining Corp, Greenwood Village, CO*

*R. Dimitrakopoulos, COSMO Lab, McGill University, Montreal, QC, Canada*

**9:00 AM**

### **Introduction**

**9:05 AM**

## **Developing a Dynamic Model to Optimize Mineral Value Chains under Uncertainty**

*M. Del Castillo and R. Dimitrakopoulos; COSMO Laboratory, McGill University, Montreal, QC, Canada*

This study presents a dynamic global production scheduling optimization approach for strategic planning of mineral value chains. Given the related uncertainties, it has become a priority to advance current stochastic optimization approaches and develop a dynamic model which provides flexibility, allowing a project to adapt to change over time. This work presents a strategic planning model based on a new multi-stage stochastic optimization approach, where

dynamic decisions are made sequentially over time, based on possible new information. The application of the proposed approach at a copper-gold mining complex shows an increased NPV of the dynamic model compared to the traditional two-stage stochastic formulation and includes options to invest over trucks and a secondary crusher, as well as operational alternatives that allow choosing between processing configurations and blasting patterns.

## 9:25 AM

### **Production Schedule for an Open-pit Mine Using Maximum Flow and Genetic Algorithm**

*A. Paithankar and S. Chatterjee; Department of Geological and Mining Engineering and Sciences, Michigan Technological University, Houghton, MI*

Production scheduling is a critical activity for any long-term production planning of the open pit mining operations. It deals with the effective management of resources and maximizes cash flows to generate higher revenue over the life of mine. The production scheduling problems determine the blocks to be mined and processed over the number of periods subjected to mining and processing constraints, making the problem more complex. In this study, we are using maximum flow algorithm with the genetic algorithm to generate the long-term production schedule. The graph structure for maximum flow is created for multiple time period under uncertainty and the flow in the arcs is controlled by the genetic algorithm to develop a production schedule. Numerical results for the realistic instances are provided to indicate the efficiency of the solutions.

## 9:45 AM

### **Digital Transformation, Delivering Results in Mineral Processing**

*R. Jonas; Process Solutions, Honeywell, Phoenix, AZ*

Digital Transformation has become an immense driver to generate business value. Many mineral processing plants are considering advanced technologies and services to enable their digital transformation that ensures their competitiveness in the foreseeable future. The technologies can include Industrial Internet of things (IIoT), big data, cloud computing, and virtualization. Many of these technologies are already being used in mineral processing by leading producers and these leaders have realized step changes in performance and production. This paper will discuss the digital technologies and solutions that are available today and discuss the value that they deliver to mineral processors. Honeywell is a leading provider of these technologies, having deployed on a large-scale basis across more than 15 mineral process sites, and are sustaining these for more than 5 years. The paper will discuss the proven technologies and methods they use to ensure success of digital transformation program, their long-term sustainment, and the delivery of business value.

10:05 AM

## Self-Learning Mining Complex: A Fast Mechanism Using Search Trees and Reinforcement Learning

*A. Kumar and R. Dimitrakopoulos; Mining and Materials Engineering, McGill University, Montreal, QC, Canada*

Smart digital technologies including the development of advanced sensors and monitoring devices have enabled a mining complex to acquire new information about the performance of its different components. Existing technologies are computationally expensive and more importantly cannot integrate such new digital information to adapt the short-term production plan. This work presents a smart framework based on the AlphaGo program from Google DeepMind that continuously learns and adapts the short-term production plan with the new digital information collected in a mining complex, to better meet the different production targets. The smart framework combines Monte Carlo tree search with the deep neural network in a self-play reinforcement learning algorithm. The algorithm makes decisions based on Monte Carlo tree search simulations and the deep neural network. The framework is applied at a copper-gold mining complex which shows its ability to adapt the short-term production plan with new digital information to consistently produce more metal and better meet the different production targets.

10:25 AM

## Simultaneous Stochastic Optimization of a Gold Mining Complex Focusing on Waste Management and Cut-Off Grade Optimization

*Z. Levinson and R. Dimitrakopoulos; Mining and Materials Engineering, COSMO Stochastic Mine Planning Laboratory, Montreal, QC, Canada*

Simultaneous stochastic optimization of a mining complex captures the unique interactions that occur through the mineral value chain where materials are transferred between mines, processors, stockpiles, and waste facilities. Production scheduling typically focuses on the optimal extraction of valuable minerals and tends to ignore the environmental impact of waste material. This work presents a simultaneous stochastic optimization of an open-pit gold mining complex while incorporating waste management and cut-off grade optimization. The simultaneous stochastic approach results in a 6% increase in NPV when compared to conventional methods while minimizing the likelihood of deviating from production targets and environmental constraints.

10:45 AM

## Simultaneous Stochastic Optimization of an Open-Pit Gold Mining Complex with Supply and Market Uncertainty

*Z. Saliba and R. Dimitrakopoulos; COSMO Lab, McGill University, Montreal, QC, Canada*

This work presents an application of a stochastic framework that simultaneously optimizes mining, destination and processing decisions for a multi-pit gold mining complex with strict blending requirements. The application explicitly accounts for supply and market uncertainty via stochastic orebody and commodity price simulations. This work assesses the impacts of integrating market uncertainty as an input that influences all components of the production schedule. This approach generates solutions that capitalize on the synergies between extraction sequencing, cut-off grade optimization, blending and processing to maximize value and manage risk in strategic plans.

**11:05 AM**

## **Incorporating Geological and Equipment Performance Uncertainty While Optimizing Short-Term Mine Production Schedules**

*M. Quigley<sup>1</sup> and R. Dimitrakopoulos<sup>2</sup>; <sup>1</sup>Osisko Gold Royalties, Montreal, QC, Canada and <sup>2</sup>COSMO Stochastic Mine Planning Laboratory, Montreal, QC, Canada*

An effective short-term mine production schedule will ensure compliance with the targets and restrictions imposed by the long-term plan. The method proposed herein outlines a new approach to simultaneously optimize the short-term production sequence with the mobile equipment allocation plan while incorporating both grade, and equipment performance uncertainty. A new simulation methodology is introduced to generate more realistic equipment performance scenarios, and ramp positions are incorporated to facilitate feasible extraction patterns. The results show improved production target compliance by delivering more consistent material quantity and quality to each processing destination, and a more reliable extraction sequence in the face of shovel performance and truck cycle time uncertainty.

**11:25 AM**

## **Mining Complex Optimization with Supply Material Uncertainty**

*L. Montiel Petro; Technical Services, PROMINE INC, Montreal, QC, Canada*

Mining projects are subject to different sets of uncertainties including technical, financial, environmental and social. From the technical standpoint, one of the major challenges geologists and engineers face is the ability to represent the distribution of grades and minerals within the deposits with limited information obtained from exploration drillholes. Conventionally, interpolation methods are used to estimate the deposits ignoring the large uncertainty associated with its grades and material types which is referred to as geological uncertainty. Geological uncertainty and related risk play a key role in the viability of mining projects. New methods for mine planning optimization have been developed to incorporate various sources of uncertainty and manage risk, demonstrating substantial improvements in terms of increasing expected cashflows and reducing the risk of deviating from operational and production targets. This presentation outlines the benefits of implementing risk-based optimizers that allows integrate and manage risks in mining complexes comprised of multiple pits, material types, stockpiles, blending properties and processing plants.

## WEDNESDAY, FEBRUARY 27

### MORNING

9:00 AM | ROOM 601

## SME Young Leaders: My Internship Experience

**Chair:** *D. Mason, Guy F. Atkinson Construction,  
Seattle, WA*

9:00 AM

### Introduction

9:05 AM

## The Two-Way Value of Rotational Internship Programs: Newmont Mining Co. Carlin Surface Operations Case Study

*M. Hetherington, Mining Engineering, Colorado School of Mines, Golden, CO*

My internship program with Newmont Mining Co. at their Carlin Surface operation was structured so interns performed two main projects with long and short-range planning, and smaller projects or shadowing opportunities in the ore control group, drill and blast, geotechnical department, operations, and survey crew. A project-based internship is a common practice within the mining industry. I worked on mapping and surveying projects, time studies, and spreadsheets in my time with the company. Rotationally structured internships are becoming more and more popular within the industry and have benefits for both the student and the company. Exposure to several different departments on site gives the student a well-rounded experience of how a mine is run. The opportunity to shadow employees in metallurgy, environmental, or operations will contribute to a more knowledgeable young engineer after graduation. Rotational internships also give the company a better idea of potential full-time candidates as the intern gets opportunities to meet and network with employees from different aspects of the business.

9:20 AM

## Internships in the Mining Industry: Operational vs Engineering

*J. Holl, Mining and Minerals Engineering, Colorado School of Mines,  
Golden CO*

As part of my presentation over internships in the mining industry, I would highlight the differences in working as an operational field hand and undertaking engineering work as an intern. Martin Marietta is the source of my experience from an operational perspective and duties on-site included such tasks as: machinery operation – CAT 769 haul truck, Hitachi Euclid R35 haul truck, CAT skid steer, plant trucks, water truck, JLG man lift; introduction to industry safety standards and implementation of safe working procedures; and installation of an air ventilation curtain, electrical lines, and water lines. Lafarge-Holcim is the source of my engineering-based industry experience with such assignments as: verification and digitalization of conveyor belt system data into AutoCAD databases for reference by the foreman; safety audits and installation of safety features including man-overboard alarm system; and preparation for nonprofit 5K company sponsored race. Upon introduction of these stark differences in job functions, show how they are both important

as “industry experience” and how they make students better engineers – either by understanding an operation from a field hand perspective, or actually undertaking engineering work for the site.

**9:35 AM**

## **Internship Report: Short Term Mine Planning Applied to a Limestone Quarry**

*N. Santa, Mining Engineering, Universidad Nacional De Colombia, Medellin, Columbia*

The application of the GEOVIA MineSched™ software as a support tool for mine planning allows greater control of the operation and a practical guide for production activities. The short-term mining planning has been refined, thus obtaining a more solid plan and a practical work guide. Greater quality control and optimized production rates are also obtained after implementing this software.

**9:50 AM**

## **The Value of Internships: My Growth from Student to Professional**

*Thomas J. Greene, Mining Engineering, The Pennsylvania State University, State College, PA*

Internships offer students excellent opportunities to learn skills that they otherwise might not during their academic career. Through each of my internships, I have learned this firsthand. In four internships covering a wide range of facets of the mining industry, the soft skills I have acquired along the way have proven just as helpful as the industry experience I gained. The ability to communicate effectively is a core competency that is required in all areas of business. Through effective communication, ideas can be conveyed, people can be directed, and problems can be solved. Each of my internships has helped to shape the way I communicate with others in and around the mining industry.

I have spent time working with mining's neighbors, engineering consultants, as well as miners themselves, and through these interactions, I have grown into a young leader confident in my ability to thrive and succeed as a professional in the mining industry.

## **Internship Overviews**

**10:05 AM**

*J. Glead, Mining Engineering, University of Utah, Salt Lake City, UT*

Trapper Mine in Craig Colorado has implemented a new business model based around technology and data. As a summer intern I had a unique experience to build a business intelligence platform that transformed data from all their fleet management system, into an insightful dashboard with Microsoft PowerBI. The dashboards provide process performance and efficiency reports, autonomously, to engineers and management allowing them to make data driven decision. The dashboards also provide insight to time usage and production delays identifying key areas of focus. The technology based internship was manifest of the adapting industry and the demand for technology and data integration.

## 10:20 AM

*S. Seitz, Mining Engineering and Geology, West Virginia University, Morgantown, WV*

I interned for Newmont Mining Corporation at their Leeville Underground gold mine in Elko, NV. I was the summer ventilation intern so I was able to spend my summer learning from and assisting the ventilation engineers. I also had the opportunity to spend time with the other mine engineers and the survey crews to experience the different aspects of an underground gold mine.

## 10:35 AM

*K. Patrick, Mining Engineering and Civil Engineering, West Virginia University, Morgantown, WV*

I was fortunate enough to intern with Peabody Energy in Australia at their Wambo Open Cut and Underground Operation. While there I spent the first half of my summer with the open cut engineers learning operations as well as drill and blast, the second half of my summer was spent Underground as a hand on the longwall move. While there I was able to tour 8 of 9 operations as well as take part in the a 2-week mine rescue course. Overall it was a fantastic opportunity to live and work in a new country and make friends and connections a world away.

## 10:50 AM

*R. Shipe, Mining Engineering and Civil Engineering, West Virginia University, Morgantown, WV*

This summer I had the opportunity to work for Warrior MET Coal in Tuscaloosa County, Alabama. It was a great experience that allowed me to be active in a number of crucial facets of the underground coal industry encompassing: section and longwall operations, surveying and CAD, coal processing and analysis, structural analysis of steel members in prep plants, pH testing and balancing of ponds, efficiency studies on dozer production at rock dumps, and planning for the implementation of a new portal site with brand new facilities.

## 11:05 AM

*J. Diehlmann, Mining Engineering, West Virginia University, Morgantown, WV*

This past summer I followed an untraditional Mining Engineering path and worked sales. I was a Sales Engineer intern with Nalco Water mining group. I was given many responsibilities such as participating in water treatment sales and services to West Virginia and Pennsylvania coal preparation plants. I was tasked with updating department's sales catalog system. Researching and establishing a database of potential mining sales clients throughout Maryland. I also assisted Mining Sales Specialists with onsite visits to monitor equipment. This summer taught me how important sales and services are to the mining industry and solidified my goal of becoming a Mining Sales Engineer.



**WEDNESDAY, FEBRUARY 27**

*MORNING*

**9:00 AM | ROOM 507**

## **The Power of Engagement in Building Organizational Strength**

*Sponsored by: BEUMER Corporation*

**Chair:** *E. Muteb, Freeport-McMoRan, Morenci, AZ*

**9:00 AM**

### **The Power of Engagement in Building Organizational Strength**

*S. Koon and J. Cross; Freeport-McMoRan, Phoenix, AZ*

Strong leadership is necessary for an operation to overcome challenges and to optimize results. Finding the best solution requires input and consensus across the organization. Why do teams struggle to come together and tackle issues in consensus? Is this an issue of technical knowledge, or could asking the right questions empower operating sites to find the best path forward? Management professionals from the industry will demonstrate the effectiveness of this approach through case studies and facilitated discussions. The session will focus on developing the skill of inquiry and incorporating it into a daily routine.

## WEDNESDAY, FEBRUARY 27

### MORNING

#### 11:00 AM | EXHIBIT HALL LANDING

### MPD: Physical Separation II: Gold Process Flowsheets – Gold Recovery with Adsorption (Desorption Recovery (ADR) Circuits

**Chairs:** *M. McCaslin, WesTech Engineering, Murray, UT  
T. Rauch, Kappes Cassiday & Associates,  
Reno, NV*

#### 11:00 AM

### Mobile Session – Carbon in Leach (CIL) Flowsheet on Exhibit Hall Floor

*M. McCaslin<sup>1</sup> and T. Rauch<sup>2</sup>; <sup>1</sup>International Sales, WesTech Engineering,  
Murray, UT and <sup>2</sup>Kappes Cassiday, Reno, NV*

Physical Separations II will be SME's first mobile session, visiting select technology providers in the Exhibit Hall. We will meet at the SME Resource Center in the Exhibit Hall and visit our presenters at their booths. The session will follow a carbon in leach (CIL) flowsheet from carbon columns to refining. Experts in the field will talk about their latest technology and services, and how the processes are impacted by their work. CIL is an agitated cyanide leach process used for the recovery of gold. It is one of the main processes utilized in gold processing today, an example of Adsorption-Desorption Recovery (ADR). Milled ore passes through agitated leach columns where gold is dissolved with cyanide. In the same columns, activated carbon collects the gold from the pregnant cyanide solution. The goldloaded carbon is then screened from the slurry, undergoes an acid wash, and is "stripped" of gold to produce a highly concentrated gold solution. The solution then goes to electro-winning cells, producing gold for melting and pouring. After stripping, the activated carbon is regenerated and reused, while carbon fines are captured for eventual recovery. To ensure that they can easily hear, attendees should bring a mobile phone with headphones or earbuds. A call-in phone number will be provided along with an access code. Also, the co-chairs will be there 10 minutes before start time, so arriving early will give attendees time to set up their phones before the session begins.

**WEDNESDAY, FEBRUARY 27**

*AFTERNOON*

**2:00 PM | ROOM 702**

## **Coal & Energy: A Review of Refuge Chambers in Underground Coal**

*Chairs: D. Yantek, CDC NIOSH, Pittsburgh, PA  
D. Alexander, University of Pittsburgh,  
McMurray, PA*

**2:00 PM**

**Introduction**

**2:05 PM**

### **Cryogenic Air Supplies for Cooling Built-in-place Refuge Alternatives in Hot Mines**

*L. Yan<sup>2</sup>, D. Yantek<sup>2</sup>, M. Reyes<sup>2</sup>, B. Whisner<sup>2</sup>, J. Bickson<sup>2</sup>, J. Srednicki<sup>2</sup>,  
N. Damiano<sup>2</sup> and E. Bauer<sup>1</sup>; <sup>1</sup>Cryo Life Support Systems, LLC, Titusville,  
FL and <sup>2</sup>CDC NIOSH, Pittsburgh, PA*

To minimize the risk of heat stress, the Mine Safety and Health Administration (MSHA) mandates a maximum allowable apparent temperature (AT) of 95°F (35°C) for an occupied refuge alternative (RA). Heat mitigation systems are one way to meet this requirement, especially in mines with elevated temperatures. This paper will provide the test methodology, findings, and guidance to improve the performance of prototype cryogenic air system based on in mine tests. The information in this paper is useful for manufacturers and mines to use cryogenic air systems to mitigate heat inside RAs.

**19-055**

**2:25 PM**

### **Effect of Ventilation System Configuration on Purging of Harmful Gases in a Built-in-place Refuge Alternative with a Borehole Air Supply**

*J. Bickson, D. Yantek and M. Reyes; CDC/NIOSH, Pittsburgh, PA*

Federal laws mandate the installation of refuge alternatives (RAs) in underground coal mines. Harmful gases can follow miners into an RA. NIOSH used sulfur hexafluoride tracer gas to investigate the time to purge from 1000 ppm to 25 ppm for a 60-person built-in-place RA. Tests were conducted with 12 ventilation system configurations (VSCs) at two flow rates. Except for one configuration, the purge time varied from 26 to 29 min at a flow rate of 750 SCFM and from 18 to 23 min at a flow rate of 1000 SCFM. Mines can use this information to design BIP RA VSCs.

**19-058**

2:45 PM

## NIOSH Research Toward the Implementation of Refuge Alternatives in Underground Coal Mines

*M. Reyes, N. Damiano and D. Yantek; CDC NIOSH, Pittsburgh, PA*

The Mine Safety and Health Administration mandates the installation of refuge alternatives to enhance protections for mineworkers unable to escape after a mine disaster. The NIOSH Mining Program took up efforts to characterize the industry, in terms of the number and types of RAs used, to develop program initiatives and promote the safe use of RAs. NIOSH is actively conducting research to advance the knowledge and technologies available for use in the implementation of RAs through laboratory and field investigations. This paper provides an overview of the industry profile and present some of the impacts that have been achieved.

3:05 PM

## Considerations for Blast Survivability of Built-in-place Refuge Alternative Stoppings and Doors

*D. Yantek, J. Homer and C. Jobes; CDC NIOSH, Pittsburgh, PA*

In 2008, the Mine Safety and Health Administration (MSHA) mandated refuge alternatives (RAs) in underground coal mines. For RAs, federal regulations specify a design pressure of 15 psi. This paper will discuss blast response of built-in-place RA stoppings and doors. NIOSH performed linear static finite element (FE) analyses on a BIP RA door using two loading conditions: the 15-psi design pressure and a 3-psi negative pressure. Both of the FE analyses showed that the door yielded. The information presented in this paper can be used to ensure that BIP RA stoppings and doors can withstand survivable explosions.

19-109

3:25 PM

## A Mine Refuge Chamber Model for Supporting Permit Application

*G. Danko<sup>1</sup>, D. Bahrami<sup>1</sup>, C. Stewart<sup>2</sup> and M. Mohanty<sup>1</sup>; <sup>1</sup>Mining and Metallurgical Engineering, Univ. of Nevada, Reno, NV and <sup>2</sup>Chasm Consulting, Capalaba, QLD, Australia*

Refuge chambers are needed to shelter miners underground after an accident. The refuge chambers, commonly Refuge Alternatives (RA), may be a built-in space, a metal container, or a tent-type enclosure. The RA may come with factory specifications regarding the required ambient thermal conditions in the mine for acceptable internal air temperature (T) and relative humidity (RH) for the safety time period of 96 hours. The performance of any RA depends on the actual conditions at the site. These conditions may differ from those given by the RA manufactures. Built-in RA may also need individual verification. A Universal, Thermal, Humidity and Airflow (UTHA) model is presented for applicability to any given RA to be used at any mine site. The UTHA model is useful to check T, and RH parameters in any RA without the need for experimental verification. The UTHA model has been tested against 10 different sets of measurements of real, metal and tent-type RAs under various mining conditions and occupational capacity conducted by NIOSH. Numerical examples with the UTHA model are shown to meet the 95°F apparent temperature limit in various RA configurations to support permit applications.

**3:45 PM**

## **Finland Shelter Design Principles and Critical Components Related to Mining Refuges**

*B. Hillukka; TemetUSA, Clearwater, MN*

Protective shelters developed for Civil and Military applications utilize technology which can be applied for mining safety. Finland has a well-developed Civil Defense Shelter System in place. The current Finnish legislation defines situations where civil defense shelters are mandated and specifies the shelter size, occupancy, critical components and life sustaining items required. All critical components are thoroughly tested and must pass the approval/certification process conducted by an independent testing laboratory in Finland. The Finnish Civil Defense legislation has been studied and adapted for local conditions and applied to several other countries. Finland currently has shelter space constructed for more than 70% of the Finnish population. Temet Oy (Helsinki, Finland) is the leading designer, manufacturer and provider of these critical shelter components in Finland and also the world leader providing solutions for the complete package of shelter critical component requirements. Temet exports to Military, Government, Industrial and Private customers in more than 40 countries around the world including USA, Saudi Arabia, South Korea, Canada, Kuwait, UAE, Jordan and Canada.

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## **WEDNESDAY, FEBRUARY 27**

*AFTERNOON*

**2:00 PM | ROOM 711**

## **Coal & Energy: Coal and Energy Innovation: Thinking Forward**

*Chair: J. Wientjes, Komatsu America Corp., Peoria, IL*

**2:00 PM**

### **Introduction**

**2:05 PM**

### **Automation in Room and Pillar Equipment**

*J. Haughey; Underground Mining, Komatsu Mining Corporation Group, Warrendale, PA*

As mine operators work towards removing personnel from harm's way, reducing operating costs and increasing production, automation can play a role in achieving these goals. This paper will discuss the technologies used in bringing automation features to Room and Pillar equipment, including continuous miners and continuous haulage equipment. Further, it will discuss the improvements demonstrated with the introduction of these features in specific applications.

**2:25 PM**

## Using Data Analytics to Optimize Performance of Underground Soft Rock Extraction Equipment

*J. Hirschi; Smart Solutions, UG, Komatsu Mining Corp, Marion, IL*

In the dynamic mining industry, constant attention must be given to efficiency and safety for an operation to be successful. With those two core areas of focus, Komatsu Smart Solutions is working to bring mining performance to the next level. We help customers solve their toughest challenges using data-driven intelligence, collaborative partnerships, and experience-based service execution. Case studies are presented illustrating how “smart” mining equipment delivers data to Komatsu’s experts, who use sophisticated analytics to identify productivity trends and opportunities for improvement. This information is utilized by both Komatsu and the customer in a shared effort targeting operator training, machine performance optimization, and pro-active equipment maintenance. Highlighted results include examples of increasing equipment utilization, reducing production cycle times, improving maintenance planning, and lowering parts usage costs. Also discussed is how Komatsu incorporates “smart” machine data into future developments. Examples include automated mining cycles and dynamic chain tensioners on longwall systems.

**2:45 PM**

## Active Barrier Systems Concepts for Underground Coal Mining in the USA

*J. Silva; Mining Engineering, University of Kentucky, Lexington, KY*

Underground coal mine explosions can be addressed in two ways, through prevention or mitigation. The United States mining industry practices have emphasized the prevention of explosions in underground coal mines, with little being done to mitigate the explosion once it occurs. Despite successful practices for the prevention of underground coal mine explosions in the USA, the threat of an explosion does still exist. Other mining countries around the world have developed and implemented mitigation systems such as active explosion barriers in their underground mines. Active barriers will detect the arrival of the shockwave or flame in front of the explosion and release inert material to suppress or extinguish the flame. The technology required for active barrier systems is readily available based on their presence in other mining countries but must be adapted for their use in the USA coal mines. The University of Kentucky Explosive Research Team (UKERT) is developing research to review the principles of active barrier systems and explore the applicability for the USA.

**3:05 PM**

## Characterisation of Rare Earth Elements from South African Coal and Coal By-Products

*G. Akdogan<sup>1</sup>, S. Bradshaw<sup>1</sup>, C. Dorfling<sup>1</sup> and C. Bergmann<sup>2</sup>; <sup>1</sup>Process Engineering, Stellenbosch University, Matieland, Western Cape, South Africa and <sup>2</sup>Mineral Beneficiation, Mintek, Randburg, South Africa*

South Africa is a noteworthy participant in the global coal market. In 2009 South Africa produced an average of 251 million tons of marketable coal and exported 25 % of that coal, making it the fifth largest coal exporting country in the world. This article reports the characterisation study in terms of mineralogy and elemental composition of REE’s in coal from the Vlakfontein mine as well as fly ash samples from Kendal and Kusile Power Plants in South Africa. The results from ICP-MS, SEM and XRD revealed that main minerals associated with the coal were kaolinite, muscovite, quartz, and calcite. SEM results indicated that of both LREE and HREE were present in the coal sam-

ples with an average total REE content varying from 90 to 100 ppm. The surrounding elemental composition apart from carbon primarily consisted of O, Si, S and Fe with minor quantities of Al, P and Ti. The average total REE content of both power plant ash samples were above the global average of 445 ppm. The REE's in the coal ash samples in decreasing order of abundance were Ce> La> Nd> Y> Sc which was in line with the coal analysis.

**3:25 PM**

## **Flexible Conveyor Trains (FCTs) in Gate Road Development**

*T. Cressman; Komatsu, Franklin, PA*

As longwall systems continue to mine faster and faster, there is a large demand to improve gate road development rates to match the pace of these systems. Komatsu Mining Corp. (KMC) has continued to develop the flexible conveyor train (FCT) and entry driver (ED) in the gate road development application to support the needs of the industry. This system provides a cut, bolt, and haul solution that can result in an increase of over 75% in advance rate over traditional batch haulage sections. As development of the products continues to move forward, there is a sustained focus on the delays associated with development sections to understand how these can be engineered out in future generations.

**3:45 PM**

## **Has BACT for Mine Methane Emissions Been Defined?**

*B. Apple; Environmental Commodities Corporation, Kensington, MD*

Following years of regulated reporting of mine methane emissions, industry has demonstrated multiple safe and successful mitigation technologies. As state and federal climate programs evaluate the economic value of voluntary emission mitigation, air quality regulators are considering recognition of Best Available Control Technologies for mine methane emissions. Coal mines are now in a race to implement projects that reduce emissions in order to generate saleable offsets. Mines that move before regulations are rewarded with the ability generate additional profits. Mines that ignore the race will soon be required to adhere to regulations imposed by MSHA and air quality regulators. ECC's projects across North America have generated over \$20 million for mines. We have deployed a mobile mine gas emission control system on the active Bailey Coal Mine in PA. As the first and only system approved for remote, unmanned operation on underground coal mines, the technology has received attention across North America. Barring recognition of BACT for the implementation of state-level regulations, the voluntary emission reduction market is expected to triple in size over the next three years.

**4:05 PM**

## **Risk Analysis in Production Phase – Design Based on Price, Volume, and Calorific Value: An Application from Indonesian Coal Mine**

*F. Suparno<sup>1</sup> and S. Chatterjee<sup>2</sup>; <sup>1</sup>Civil Engineering, University of Jember, Jember, Jawa Timur, Indonesia and <sup>2</sup>Department of Geological and Mining Engineering and Sciences, Michigan Technological University, Houghton, MI*

The optimization of open pit mine design under uncertain factors is one of the most crucial and challenging jobs in the mine planning. Complex geological structures and volatility of coal price are the important factors in mine planning. The coal price was simulated using Ornstein-Uhlenbeck (OU) mean reversion process combined with Monte Carlo simulation to

generate 50 simulations of coal prices for the next 10 years. Volume was simulated using a multiple-point geostatistical method, Single Normal Equation Simulation (SNESIM) to generate 20 equiprobable coal body models. The CV was simulated by generating 50 simulations within each coal body using sequential Gaussian simulation. The results show that the coal model from OU can be applied with a confidence interval of 5%. The deviation of the simulated coal bodies varies -0.07 to 5.48% compared to the training image. The average generated CV for all simulations is 5920.29 kcal/kg, with a standard deviation of 586.54 kcal/kg, but average CV from different simulations varied from 5305.26 to 6526.55 kcal/kg. All these factors were used to generate ultimate pit limit and production phase-designs with minimum cut maximum flow algorithm.

## WEDNESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 706

### Coal & Energy: Coal Mine Health & Safety II

*Chairs: S. Bealko, GMS Mine Repair, Oakland, MD  
K. Musick, Virginia Tech, Blacksburg, VA*

2:00 PM  
Introduction

2:05 PM  
Arbeitsgemeinschaft (AG) Grubenwehr  
Students' Mine Rescue Team

*A. Grubenwehr; TU Bergakademie Freiberg, Freiberg, Germany*

At the University of Freiberg mining students founded the first student working group in the field of mine rescue in Germany. There are three main tasks, which will be clarified in our presentation. Currently we are twenty active members. Our working group is organized by students for students. We are supported by our mining institute and the industry. At the same time, we establish a connection to other European mining universities. In the "Reiche Zeche", one of the oldest training mines, we simulate many different scenarios to be prepared for the worst case. The main topic of our presentation is about our practical exercises, so you can get an insight to the work at the Reiche Zeche. GLÜCK AUF!



**2:25 PM**

## **The Resilience of Underground Communication System Components Subjected to Explosions and Impacts**

*J. Silva; Mining Engineering, University of Kentucky, Lexington, KY*

Underground coal mining requires the use of communication systems to guarantee the safe operation of the mine. The design of most of the communication systems is based on principles of redundancy to keep communication in the event of a mine accident. Although there is a harsh environment that the communication system elements (antennas, nodes, gateways) need to bear, physical testing of such elements are limited to drop testing without any relation to the forces and pressures that can be generated in an underground coal mine accident. The University of Kentucky Explosive Research Team (UKERT) is testing various elements of explosive forces and dynamic impacts to find the best practical shielding technique to enhance the resilience of the communication system components. The results will improve the safety of underground coal miners and will be useful for the companies that produce underground coal mine communication systems to enhance the resilience of the elements.

**2:45 PM**

## **Foundations for a Mine Fire Classification System**

*M. Barros Daza and K. Luxbacher; Virginia Tech, Blacksburg, VA*

Although there have been great advances regarding the understanding of mine fires in underground mines in the last century, fires have occurred and always will occur in underground mines. During fire scenarios, many crucial decisions and actions can be made that greatly influence the final outcomes. Underground workers decisions are mainly based on their training and firefighting experience. For this reason, through numerical analysis this paper simulate different fire scenarios in a longwall mine in order to propose the foundations for a mine fire classification system allowing for the categorization of the fire events and the selection of response actions that can increase the probability of getting the mine back in balanced or reduce the amount of negative outcomes based on numerical parameters. Different fire simulations with various fire locations and ventilation schemes were conducted using a mine fire software. Parameters such as visibility, radiation, toxic gases, ventilation control damages, location of refugee chambers, evacuation time and approaching time to the fire were carefully examined.

**19-041**

**3:05 PM**

## **Oxygen Delivery System for Closed – Circuit Escape Respirators**

*R. Fernando; NPPTL, NIOSH, Pittsburgh, PA*

The National Institute for Occupational Safety and Health National Personal Protective Technology Laboratory is leading an effort to develop the next generation Closed-Circuit Escape Respirators (CCER) for use to egress from confined spaces in the case of an emergency. As part of this research, a unique oxygen delivery system (ODS) for these breathing apparatus was developed through contract agreements with the United States Navy (USN) and industry. To minimize the physical size while retaining the performance characteristics required, 3-D metal printing and very high oxygen pressures were employed. This paper outlines the design, function, testing and performance of the ODS. After a thorough analysis, initial prototypes were built and subjected to various tests by the USN and with third parties. After design improvements, final prototypes were made and successfully tested. This ODS applied in a future design, should contribute to development of smaller CCERs than current devices and deliver oxygen according to 42CFR84 requirements including sub-part O for escape purposes.

3:25 PM

## Assessment of IoT Devices, Analytics and Real Time Workflow in “Permit to Work” in Decision Making

*N. Sharma; Mining Engineering, Indian Institute of Technology, Dhanbad, India*

Industrial revolutions over the period has also shaped up the operations and maintenance practices as per the technical know-how and availability of resources. Safety being an important aspect in mining have to reinvent itself from proactive to cognitive to avoid near misses and incidents. The platform which Industry 4.0 provides can be utilized for the supervisors and workers to take decision based on evaluated analytics. As per OSHA analysis maximum injuries happens due to moving objects and energized electrical parts. The concept of this solution provides to have the digital switches for lock out/ tag out, camera visuals i.e. visual status of energy isolation for visual analytics (dual certification), weather insights which can help that equipment can be operated during lightning, thunder or rain. The text analytics and machine learning can guide through the previous provisions or risks associated during the PTW approval process. The outcome will be a workflow with all the data flowing from integrated sensors to take decision making insightful for the supervisor to issue PTW. This will in real time and also will provide all the requisite audit trail as a single version of truth.

## WEDNESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 708

## Coal & Energy: Research and Development-III

**Chairs:** *M. Trevits, Xtraction Science and Technology, Inc, Pittsburgh, PA*  
*L. Yuan, NIOSH, Pittsburgh, PA*

2:00 PM

### Introduction

2:05 PM

## Development of an Underground Aerial Reconnaissance System to Assist in Mine Rescue and Recovery

*S. Cotter<sup>2</sup>, M. Trevits<sup>1</sup>, J. Urosek<sup>3</sup> and M. Whoolery<sup>4</sup>; <sup>1</sup>Xtraction Science and Technology, Inc, Bethel Park, PA; <sup>2</sup>Subsurface Problem Solutions, Lockport, NY; <sup>3</sup>John Urosek Mine Consulting, LLC, Connellsville, PA and <sup>4</sup>United Mine Workers of America, Prosperity, PA*

In response to a major underground mine emergency, mine rescue and recovery personnel require timely, accurate, and reliable information upon which to base their actions. An Underground Aerial Reconnaissance (UAR) system would convey sensors and/or communication equipment prior to or ahead of entry by rescue personnel to provide detailed measurement of atmospheric and ground conditions, assess the condition of mine ventila-



tion controls, advance or re-establish wireless communication or monitoring systems, and possibly locate trapped miners. Four major subsystems were identified as necessary for an effective UAR system: (1) Aerial Vehicle Platform, (2) Underground Navigation, (3) Data Communications, and (4) Sensor Payload(s). In August 2017, a project was initiated through funding by the Alpha Foundation for the Improvement of Mine Safety and Health, Inc. to develop and demonstrate the feasibility of an appropriate design for the Aerial Vehicle Platform (AVP). This paper presents the technical approach to this project and is founded upon a thorough understanding and analysis of actual UAR mission requirements to develop a safe, mission-specific proof-of-concept AVP design.

## 2:25 PM

### **Preliminary Assessment of the Relationship of Pillar Load and Opening Convergence Response**

*R. Ray, C. Newman and Z. Agioutantis; Mining Engineering, University of Kentucky, Lexington, KY*

Originally developed for the civil tunneling industry, the Ground Reaction Curve (GRC) has provided a robust methodology for evaluating ground support installed in both tunnels and underground mining scenarios. This paper will present a preliminary assessment in the utilization of the GRC for the evaluation and design of the pillar-support system with respect to overburden stress and displacement. This initial assessment is based on measurements provided by instrumentation installed at an underground longwall mine with the Appalachian coal field.

19-062

## 2:45 PM

### **Use of Nearby Weather Data to Predict Changes in Underground Mine Gas Conditions**

*M. Trevits<sup>1</sup>, K. Luxbacher<sup>2</sup> and H. Dougherty<sup>3</sup>; <sup>1</sup>Xtraction Science and Technology, Inc, Bethel Park, PA; <sup>2</sup>Virginia Tech, Blacksburg, VA and <sup>3</sup>NIOSH, Pittsburgh, PA*

In this study, atmospheric monitoring data was analyzed from a cooperating underground mine located in the United States. The mine is positioned above the water table and consists of multiple continuous miner sections, sealed areas, and uses a surface fan for exhausting ventilation. Weather information for the study was provided from a station that was installed on the surface at the mine site. Methane gas emissions, though low, were correlated to instances when changes in barometric pressure occurred. To predict gas changes in the mine, weather data was collected from several nearby weather stations and correlated to the data from the mine site weather station. Wind rose diagrams were created to identify the prevailing wind direction and were useful in identifying which weather station data (specifically barometric pressure data) could best be used as a predictor of the weather at the mine site. In addition, time correlation studies were conducted to determine which data best aligned with the local weather station data. The results of this study suggest that nearby weather data can be used as an advanced warning of approaching changes in the gas conditions at the local mine.

**3:05 PM**

## **Optimizing CM Cut-sequence as the Chinese Postman Problem**

*A. Anani<sup>2</sup>, M. Klapp<sup>3</sup> and W. Nyaaba<sup>1</sup>; <sup>1</sup>Mining, Missouri University of Science and Technology, Rolla, MO; <sup>2</sup>Department of Mining Engineering, Pontificia Universidad Catolica de Chile, Santiago, Chile and <sup>3</sup>Department of Transportation and Logistics Engineering, Pontificia Universidad Catolica de Chile, Santiago, Chile*

The continuous miner (CM) travel times given a cut sequence typically makes up over 10% of the production time and has been a major contributor to low productivity and hikes in coal production cost. The study aims at developing a novel algorithm that optimizes the CM cut sequence as an Open-Hierarchical Chinese Postman Problem to minimize the total CM travel time and distance subject to geotechnical, ventilation, and operational constraints. This research demonstrates the use of graph theory to optimize coal productivity as a function of CM cut sequence and provides a holistic tool for CM cut sequence optimization.

## **WEDNESDAY, FEBRUARY 27**

*AFTERNOON*

**2:00 PM | ROOM 107**

## **Environmental: “Walk Away” Pit Lake Closure; Successes and Failures**

*Sponsored by: Piteau Associates*

*Chairs: D. Castendyk, Hatch, Lakewood, CO  
J. Vandenberg, Golder*

**2:00 PM**

**Introduction**

**2:05 PM**

## **Beneficial Use of Springer Pit Lake at Mount Polley Mine**

*J. Vandenberg; Golder, Kelowna, BC, Canada*

While pit lakes can pose potential risks to the environment and liabilities to mining companies, they may also present opportunities for sustainable end uses, if managed appropriately. The Springer Pit Lake and Mount Polley Mine provided an opportunity to store mine waste such as tailings and mill process water while the mine repaired its tailings storage facility after a breach in its perimeter embankment, which released tailings to the downstream environment in 2014. One year after the breach, a water treatment plant was installed so that the pit lake could be drawn down. Frequent monitoring of water quality in the pit, combined with a calibrated and verified water quality model, shows that water quality is improving. Based on the observations that tailings, suspended solids, and associated constituents are being removed efficiently by the pit, the treatment plant was reconfigured to a “passive” mode, which did not entail the use of reagents or mechanical energy – only in-line instrumentation.

**2:25 PM**

## **Is River Flow-Through a Sustainable Closure Option for Acidic Pit Lakes and the Downstream River?**

*M. Lund and M. Blanchette; Science, Edith Cowan University, Joondalup, WA, Australia*

WO5B coal pit lake (Lake Kepwari) was to be closed as a water ski park in Collie, Western Australia but low pH (<4) stalled relinquishment. Following an accidental breach of the diversion channel containing the Collie River South Branch (diverted to allow mining), which appeared to improve the lake and have no impact on the downstream river, a trial river flow through was approved. We investigated the impact of the trial on the water quality and biological endpoints in the lake and downstream river. We undertook detailed sampling of the lake (2010–2016) and river (2014/15) for a broad range of water quality parameters and biotic indicators. Significant ( $P < 0.05$ ) improvements were noted for most water quality indicators in the lake post river inflow, improvements in biota were less obvious. Significant ( $P < 0.05$ ) differences between above and below the lake were found for river sediment quality, water quality, riparian zones and bacterial (16S) communities but not for macroinvertebrates. We discuss the successes and issues with this closure strategy and the inevitable tradeoffs between particularly the social amenity of the lake and the impacts on the river.

**2:45 PM**

## **Long-Term Subaqueous Solute Generation in Pit Lakes: Implications for Modeling and Closure**

*C. Newman<sup>1</sup>, T. Cluff<sup>2</sup>, G. Beale<sup>2</sup> and T. Gray<sup>1</sup>; <sup>1</sup>Bureau of Mining Regulation and Reclamation, Nevada Division of Environmental Protection, Carson City, NV and <sup>2</sup>Piteau Associates, Reno, NV*

Predictive geochemical and limnologic modeling of pit lakes is an important aspect of modern permitting. One of the key assumptions of many predictive pit-lake models is that highwalls and pit backfill become unreactive once submerged by the filling pit lake. Existing pit lakes provide useful data to test this assumption. The Sleeper pit lake (northwestern Nevada) is near hydrologic equilibrium and contains good-quality water that generally meets regulatory standards for pit lakes. Despite the overall stable geochemical composition, seasonal trends in the hypolimnion indicate the potential generation of solutes and fluctuations in pH. This work applies mass balance, analysis of subaqueous pyrite oxidation, and trends in solute concentrations to evaluate the potential causes of long-term solute generation in the hypolimnion of the Sleeper pit lake. Results will aid in refining the effect that inundation of highwalls and waste rock has on ultimate pit lake chemistry and long-term closure planning. In the case of the Sleeper pit lake ongoing solute loading does not substantially change the closure plan however, as influent groundwater contains abundant alkalinity.

**19-045**

**3:05 PM**

### **The Transformation of Quarry Lake, Alberta, from Open Pit to Recreational Lake**

*G. Stephenson<sup>2</sup> and D. Castendyk<sup>1</sup>; <sup>1</sup>Golder Associates, Denver, CO and <sup>2</sup>Terra Cognita Resource Consultants, Canmore, AB, Canada*

Quarry Lake in Canmore, Alberta was an open pit coal mine which was reclaimed to form a recreational lake by closing the outlet, partially back-filling the pit, and allowing spring water to build up while stabilising and revegetating the spoil piles. This work began in 1972 and was completed in 1980 when the Town of Canmore took ownership. The Alberta Environment Conservation Authority has described this site as “The best mine reclamation in Western Canada.” Today, Quarry Lake is visited by up to 400 people on summer days. This presentation discusses lessons learned and the potential to similarly restore other pits.

**19-093**

**3:25 PM**

### **Managing Stratification in Mine Pit-Lakes: Risks and Opportunities**

*R. Pieters<sup>1</sup>, A. Huang<sup>2</sup>, D. Hasanloo<sup>2</sup> and G. Lawrence<sup>3</sup>; <sup>1</sup>Earth and Ocean Sciences, University of British Columbia, Vancouver, BC, Canada; <sup>2</sup>Tetra Tech, Vancouver, BC, Canada and <sup>3</sup>Civil Engineering, University of British Columbia, Vancouver, BC, Canada*

With sufficient salinity stratification, pit-lakes may become permanently stratified (meromictic) with the deep water isolated from the surface. On the other hand, with little salinity stratification, pit-lakes can mix seasonally. However, many pit-lakes end up between these extremes. We focus on understanding these intermediate cases by using both extensive data from a variety of existing pit-lakes with ice-cover, and by using two numerical lake models (GLM and CE-QUAL-W2). Data from existing pit-lakes with intermediate salinity provide specific illustrations of the evolution of the stratification. The models, calibrated to data from Colomac Zone 2 Pit-lake, are used to investigate the potential for meromixis and for isolation of the deep water over a wide range of salinity stratification. At small salinity stratification, the surface layer deepens significantly, mixing water from depth into the surface layer. We characterize the balance between the salinity stratification and the fraction of water from depth that is mixed into the surface layer, as well as the effect on the water quality of the surface layer.

**3:45 PM**

### **Outcomes of Two Predictive Geochemical Models for a Backfilled Pit, 20 Years Later**

*A. Haus; Foth Infrastructure and Environment, Lake Elmo, MN*

Initial geochemistry models predicting pore water chemistry within the back-filled pit at the Flambeau mine were developed in the late 1980s. Prior to backfilling with waste rock, models were re-developed in 1997. Groundwater chemistry within the backfilled pit has been measured quarterly since 1998, providing an opportunity to reevaluate and reassess the veracity of initial predictive models. Observations suggest initial model re-evaluating the reassess the veracity of initial predictive models. Observations suggest that inassumptions were largely correassumptions regarding the identity of secondary mineral precipitates were correct. This presentation will evaluate and assess the differences between model predictions and actual observed data.

**WEDNESDAY, FEBRUARY 27**

*AFTERNOON*

**2:00 PM | ROOM 104**

## **Environmental: Mine Waste Profitability**

**Chairs:** *V. McLemore, NMBGMR/NM Tech, Socorro, NM*

*G. Sutton, The Doe Run Company, Viburnum, MO*

**2:00 PM**

**Introduction**

**2:05 PM**

### **Making Mine Wastes Profitable**

*V. McLemore; NMBGMR/NM Tech, Socorro, NM*

Abandoned mine lands (AML) are lands that were excavated, left unreclaimed, where no company has responsibility, and where there is no closure plan in effect. Many AML sites have potential for additional commodity production. The growing market for technologies like solar panels, wind turbines, batteries, electric cars, desalination, and carbon storage require nontraditional elements for their manufacture. Characterization of mines and mine wastes will help identify those that are appropriate for potential commodity recovery in the future. Some of the critical minerals identified by Presidential EO 13817 are found in AMLs and mining districts. For example, vanadium and molybdenum, by-products of uranium mining, as well as commodities such as selenium and rare earth elements, are associated with sandstone uranium deposits in the Grants uranium district and could be recovered from those wastes during reclamation. Potash is currently mined in the Carlsbad potash district. Potential mineral recovery from mine wastes has the potential not only to support cleanup efforts financially, but to remove metals that could be part of the environmental and public safety hazards.

**2:25 PM**

### **From Waste to Resource: Extracting Valuable Elements from Mining Solutions Using Bio-Based Surfactants**

*D. Hogan<sup>1</sup>, C. Boxley<sup>1</sup> and R. Maier<sup>2</sup>; <sup>1</sup>GlycoSurf, LLC, Park City, UT and*

*<sup>2</sup>Soil, Water and Environmental Science, University of Arizona, Tucson, AZ*

Mining and mining-impacted solutions are often enriched in non-target metals during typical operations. These solutions must be treated or managed to ensure elevated metal concentrations do not pose human or environmental health risks. One management option is metal recovery using ion flotation. The green, bio-based surfactant rhamnolipid is known to be selective for valuable elements, including the rare earth elements, but has not been screened for efficacy in ion flotation of mining solutions. Thus, rhamnolipids were examined as a collector in ion flotation for the treatment of mining solutions to achieve environmental and economic benefits.

**2:45 PM**

## **Biominerall Soil Amendment Production – A Novel Approach for Reprocessing of Hardrock Mine Waste: Bench and Pilot Scale Data Update**

*A. Harley; Duraroot, LLC, Keensburg, CO*

The application of microorganisms have gained importance in the field of applied environmental microbiology. Amongst them, biomineral processing of metal mining from ores, concentrates, industrial wastes, and overburdens with microorganisms and/or their metabolites. Microorganisms are also gaining importance in agriculture, accessing nutrients that are locked in soil minerals as well as supporting additional beneficial outcomes in agricultural soils. This paper describes a novel technique that uses advances in biomineral processing to reprocess mine waste as a feedstock to produce a bioavailable, nutrient dense, biomineral soil amendment. This process results in a zero-waste facility and multiple revenue streams for waste material. Bench-scale and pilot test data will be presented.

**3:05 PM**

## **Mining Wastes a Secondary Resources**

*L. Alakangas; Civil, Environmental and Natural resources Engineering, Luleå University of technology, Luleå, Sweden*

The amount of stored mining waste in Europe is estimated at more than 1.0 billion tons. Storage facilities can pose environmental impact because of its potential for dam accidents and as a source of pollution. The main concept of waste management in Sweden has largely been to cover the waste or treat the contaminated water. Demand for critical raw materials and elements in Europe forces research against recovery/extraction of secondary sources like mine wastes. A remediation concept which include re-mining of Skarn tailings for extraction of toxic and valuable elements and minerals and utilization of the remnants as resource will be presented.

**3:25 PM**

## **Converting CO<sub>2</sub> to Useful Products: An Opportunity for Coal and Steel Industry**

*S. Valluri, V. Claremboux and S. Kawatra; Chemical Engineering, Michigan Technological University, Houghton, MI*

With increased CO<sub>2</sub> emissions from steel and coal industry, there is great opportunity to capture CO<sub>2</sub> and utilize the captured CO<sub>2</sub> for economic advantage. The primary goal is to develop energy-efficient processes that reductively couple CO<sub>2</sub>, an abundant and renewable carbon source, for the production of value-added chemicals such as methanol, ethanol, and oxalic acid. These chemicals can be used elsewhere in the refining process or sold as valuable by-products. Geological sequestration, in comparison, has no economic return. Current CO<sub>2</sub> utilization research at Michigan Technological University focuses on electrochemical reduction of CO<sub>2</sub>. Electrochemical reduction of CO<sub>2</sub> to hydrocarbons and other chemicals is a complex multistep reaction with adsorbed intermediates. The exact reaction mechanisms leading to various products are not clear from the literature to date and will likely change over the range of conditions like pH, electrode potential, electrolyte medium, catalyst, etc. This paper will present different ideas and their viability to utilize CO<sub>2</sub> as a feedstock to produce several value-added compounds.

**19-069**



**3:45 PM**

## **Paving with Chat**

*G. Sutton; Environmental, The Doe Run Company, Viburnum, MO*

The Old Lead Belt of Southeast Missouri produced millions of tons of lead during its heyday. The first step of processing produced a material known as chat. Large piles of dry, sandy chat dotted the landscape of these towns, marking the former mine and mill sites. The Missouri Department of Transportation approved the use of this material which has good construction material characteristics for use in paving mixes where fully encapsulated by the asphalt oils. One asphalt producer has had great success with marketing a pavement that is very popular with MODOT due to good surface characteristics. Presentation will detail a little history on themaking and historical use of chat, its physical characteristics, challenges of working with a highly variable material, and the environmental challenges.

**4:05 PM**

## **Factors Affecting the Electrochemical Recovery of Metals from Mining-Impacted Waters**

*S. Doyle and L. Figueroa; Colorado School of Mines, Lakewood, CO*

Electrochemical methods have potential to treat waters impacted by abandoned mines, while simultaneously producing a recoverable metal product to off-set treatment costs. However, current knowledge of the types of metal solids formed is limited. This paper will present results of bench-scale testing of electrochemical metals recovery from mining-impacted waters. Results will include the effects of operating conditions and water composition on the metal solids formed during treatment. Potential benefits and challenges of applying electrochemical metals recovery to mining-impacted waters will also be presented.

**19-036**

**4:25 PM**

## **Applying Fly Ash As a High Strength Water- Resistant Precast Construction Material Through Geopolymerization**

*J. Zhang and Q. Feng; University of Arizona, Tucson, AZ*

Study has been carried out to apply fly ash as a high strength, water-resistant precast construction material through geopolymerization. Experiment results show that the working conditions such as water content, the concentration of NaOH, curing temperature and curing time, significantly affect the mechanical property of geopolymer matrix. Through optimization, an above 100 MPa compressive strength has been achieved with the geopolymerization products. Water soaking tests show that the geopolymerization product has a very high water resistance without losing noticeable compressive strength even after a one month soaking time. To elucidate the geopolymerization mechanism, microscopic and spectroscopic techniques such as SEM/EDS and XRD are also applied to investigate the microstructure, the elemental and phase composition of geopolymerization products. The findings of the present work provide a novel method to apply fly ash as a high strength water-resistant precast construction material.

**19-036**

## WEDNESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 709

### Fuerstenau Symposium: General Session

*Chair: B. Moudgil, University of Florida, Gainesville, FL*

2:00 PM  
Introduction

2:05 PM  
**Professional Formation for Mineral Process Engineers –  
Sharpening Technical Capability in the Workplace**

*D. Drinkwater; Mineralis Consultants Pty Ltd, Brisbane, QLD, Australia*

'Apprentice' mineral process engineers have the fundamental skills to operate mineral processing plants. Workplace experience emphasises high throughput and recovery, high quality products, and minimising energy, water and reagents. 'Practitioner' mineral processing professionals are facing new challenges such as data management, changing work practices and rapid social change. To deal with these requires further skills. The transformation from 'apprentice' to 'practitioner' requires professional formation. This paper first establishes a set of required skills and capabilities that have been identified with industry and academia. These are acquired and developed through both a foundation degree and on-the-job learning. A clear professional formation pathway ensures progression. Second, we present a professional formation partnership between operators, suppliers, universities, consultants and specialists, who share an interest in the career success and industry retention of graduate engineers. Training young engineers is an industry wide challenge. The approach proposed will address many of the skill needs of both industry and its professionals.

2:23 PM  
**Developing Capacity and Capability – Experiential  
Based Learning from the Lab and Beyond**

*J. Werner; Mining Engineering, University of Kentucky, Lexington, KY*

This presentation will cover the work performed over the last year utilizing students, both graduate and undergraduate as key project members for the successful design, construction and operation of a rare earth pilot plant. This work will discuss key techniques and principles which were utilized to develop a high performing team of students to accomplish professional level results. The results of this work will address critical challenges experienced across all levels of a mining organization. These are identification and recruitment of talent, building individual capacity and performing well as a team. The context of these learnings is provided as a team of teachers and students construct a first of its kind rare earth extraction pilot plant, meeting and exceeding project deliverables.



**2:41 PM**

## **Practical Options for Solving the Dolomite Problem with Florida Phosphate Resources**

*J. Zhang<sup>1</sup> and B. Moudgil<sup>2</sup>; <sup>1</sup>Florida Industrial and Phosphate Research Institute, Bartow, FL and <sup>2</sup>University of Florida, Gainesville, FL*

Separation of dolomite from phosphate is the most challenging problem in phosphate mineral processing. Over 50% of the future phosphate reserves in Florida contains too much dolomite to process using the current industry practice. The FIPR Institute has collaborated with worldwide experts in the field to address this issue. As a result, the industry is now offered with three feasible options. Optional 1 involves crushing and grinding of high-dolomite phosphate pebbles followed by dolomite flotation at slightly acidic pH using a new collector that does not require phosphoric acid as a phosphate depressant, achieving a final concentrate analyzing less than 0.9% MgO at about 87% P<sub>2</sub>O<sub>5</sub> recovery. Option 2 offers three methods for reducing MgO content in the concentrate from the Crago process, including adding a dolomite depressant in the rougher flotation step, dolomite flotation of the cleaner concentrate, and scrubbing the cleaner concentrate in quartz sand. These methods could reduce MgO content in the final concentrate by 20-40%. Option 3 is a gravity separation technique using an innovative separation jig, and may well be the ultimate solution to the problem.

**19-099**

**2:59 PM**

## **On the Mechanisms of Silica Recovery in Magnetite Ore Low-Magnetic-Drum Concentration**

*M. Llamas-Bueno<sup>2</sup>, A. Lopez-Valdivieso<sup>1</sup> and M. Corona-Arroyo<sup>3</sup>; <sup>1</sup>Instituto de Metalurgia, UASLP, San Luis Potosí, San Luis Potosí, Mexico; <sup>2</sup>Gerencia de Procesos, Gerente, San Nicolas de los Garza, Nuevo Leon, Mexico and <sup>3</sup>Departamento de Minas, Metalurgia y Geologia, Universidad de Guanajuato, Guanajuato, Guanajuato, Mexico*

Magnetite is concentrated by low-magnetic field drums to recover a concentrate low in silica (SiO<sub>2</sub>). The magnetite concentrate is for steel production. Its silica content increases the steel processing cost. For the iron direct reduction-electric furnace process, silica increases the consumption of energy, refractory, electrodes, additives and iron losses in slags. This work is aimed at presenting the studies, carried out on the removal of SiO<sub>2</sub> from magnetite concentrate at both plant and laboratory scales. Studies were performed using a plant magnetic 36x96" three-drum unit processing 40 ton/h rougher magnetite. It is shown that silica in the magnetite concentrate appeared by three mechanisms: entrainment in magnetite chains, heterocoagulation between magnetite and silica-bare minerals and locking between magnetite and silica-bare minerals. Entrainment had the highest contribution. Several routes have been investigated to remove the trapped silica, namely sonic energy application, magnetite agglomeration in low-magnetic-external uniform fields and silica reverse flotation in a low magnetic external uniform field. Results of these three processes are presented.

3:17 PM

## Dry Beneficiation of High Silica Blue Dust – Turning Waste to Wealth

*S. Gaekwad<sup>1</sup>, N. Nanda<sup>3</sup> and R. Kumar<sup>2</sup>; <sup>1</sup>R&D Centre, Mineral Processing Laboratory, NMDC Limited, Hyderabad, Telangana State, India; <sup>2</sup>R&D Centre, NMDC Limited, Hyderabad, India and <sup>3</sup>NMDC Limited, Hyderabad, India*

The pockets of high silica blue dust across the entire high grade hematite deposits in the Bailadila sector bothers the excavation activity due their iron content, which is higher than the threshold value specified by the Indian Bureau of Mines and the agony of stacking them separately due to their fragile & powdery nature. The physical nature of blue dust and its negligible alumina content makes these a potential source of hematite, which is a blessing in disguise. As most of the particles are in the form of an independent grain making it appropriately suitable feed for dry magnetic separation and thus the dry beneficiation has turned a bane into boon by enabling to produce concentrate either suitable for using as DSO or amenable for blending. The emphasis on carrying out dry beneficiation studies in the present context serves the purpose of mineral conservation, mitigates the issues of excavation and stacking as well as conservation of water resource. This paper describes the laboratory and pilot scale dry beneficiation studies carried out on blue dust of 48 – 60%Fe and Silica up to 30% at 25 Kg/hour to 400 Kg/hour, resulting in production of concentrate assaying 60 – 65%Fe.

19-066

3:35 PM

## Effect of Anions on the Solubility of Rare Earth Element-bearing Minerals in Acids

*K. Han; Mat & Met Eng, SD School of Mines & Technology, Portland, OR*

The effect of anions such as sulfate, chloride, and nitrate on the solubility of rare earth element bearing phosphates and fluoro-carbonates has been examined using relevant thermodynamic data. The study has found that these anions have significant influences on the overall dissolution of rare earth elements (REEs) from various 118 SMENET 2019 Annual Meeting sources in the aqueous media. The thermodynamic calculations in this study have indicated that the speciation of REEs with the anions tend to increase the overall solubility of the REE-bearing minerals. However, in some cases, strong precipitation of REEs with some of these anions causes an adverse effect on the solubility of these elements. It has been found that sulfate ion has the most pronounced effect on the solubility compared to nitrate and chloride, in which the latter two acids exhibited almost identical results. The calculated results have indicated that REE-oxide (hydrated) is the easiest compound to dissolve, followed by carbonate, phosphate, fluoride, sulfate, fluoro-carbonate and oxalate in that order.



**3:53 PM**

## **Interfacial Phenomena in the Performance of Proton-Conducting Nanoparticulate Oxide Films for Clean Energy Technologies**

*G. Ong<sup>1</sup>, L. Reimnitz<sup>2</sup>, D. Milliron<sup>2</sup> and F. Doyle<sup>1</sup>; <sup>1</sup>Materials Science and Engineering, University of California, Berkeley, Oakland, CA and <sup>2</sup>Chemical Engineering, University of Texas at Austin, Austin, TX*

Proton-conducting membranes and solid electrolytes are critical components in many clean energy technologies, particularly fuel cells. However proton-conducting polymers such as Nafion perform best below 80°C, while ternary oxides such as doped BaZrO<sub>3</sub> and BaCeO<sub>3</sub> have poor conductivity below 350°C. Proton conductors that can operate in the 200-500°C range would be desirable for energy conversion and fuel cells. Freshly prepared mesoporous, nanocrystalline CeO<sub>2</sub> and TiO<sub>2</sub> display significant proton conductivity below 200°C in humidified atmospheres, although the densified and bulk oxides have poor conductivity. This is due to dissociative adsorption of water on surface defects of the nanocrystals. However the conductivity of CeO<sub>2</sub> deteriorates rapidly at temperatures <200°C. We report work that demonstrates this to be due to the surface formation of the more stable cerium hydroxycarbonate. Attempts to address this challenge by altering the surface affinity for carbonate were unsuccessful. In contrast, titania maintains its conductivity over time, reflecting the lower propensity of TiO<sub>2</sub> to form the passivating hydroxycarbonate.

**4:11 PM**

## **Interfacial Concentrative Effects in Hydrometallurgy: Surface pH and Dissolution/Precipitation Processes**

*K. Osseo-Asare; Materials Science & Engineering and Energy & Mineral Engineering, Penn State University, University Park, PA*

Hydrometallurgical processing invariably involves heterogeneous systems where solids, liquids, and gases interact at interfaces of the type solid/water, oil/water, and gas/water. Differences in reactant and product concentrations in the interfacial regions compared with the bulk aqueous phases can lead sometimes to unexpected trends in concentration dependence of dissolution and precipitation rates. This presentation focuses on the following experimental observations: (1) During electrodeposition of iron from aqueous ferrous sulfate solution, addition of ammonium sulfate is found to enhance iron deposition rate, (2) during dissolution of copper in acidic hydrogen peroxide solution, the dissolution rate of copper decreases at high hydrogen peroxide concentrations, and (3) during anodic dissolution of tungsten in basic solution, introduction of tungstate ions (WO<sub>4</sub><sup>2-</sup>) results in enhanced tungsten dissolution. These observations are rationalized with the aid of experimental data derived from surface pH measurements.

**4:29 PM**

## **Challenges and Opportunities of Mineral Processing Techniques in Recycling of Spent Lithium-Ion Batteries**

*G. Yang; Environmental Engineering, National Sun Yat-Sen University, Kaohsiung, Taiwan*

The objective of the paper is twofold. Firstly, it attempts to briefly review the literature concerning the recycling of spent lithium-ion batteries (LIBs) mainly using mineral processing operations such as crushing, screening, electrostatic separation, and flotation. Secondly, it aims at identifying limits and challenges might be encountered in using the conventional mineral processing techniques to obtain high grade of values with high recovery from spent LIBs. However,

like said by the world-renowned physicist Richard Feynman, it is believed that “There’s plenty of rooms at the bottom” to further explore opportunities of mineral processing techniques in recycling of spent lithium-ion batteries.

**4:47 PM**

### Updated Look at the Application of Solid Particles in Fuel Cell Technology

*M. Williams; Mechanical and Energy Engineering, SUSTEC, Morgantown, WV*

Particle processing is a key to using solid particles in fuel cell applications. Selectivity with regard to reactivity, impurities, etc. is important feature and the treatment of particle surfaces could greatly impact the performance of direct carbon fuel cells. Solid fuel particles will become increasingly important in the future. Present energy conversion systems for solid fuels are too inefficient. New energy conversion systems for solid fuels with higher energy conversion efficiencies are possible. Fuel cell technology is a key-technology in these new conversion systems. The direct carbon fuel cell (DCFC) operates on carbon particles obtained from a variety of solid fuel feedstocks. The DCFC is the only fuel cell designed to directly oxidize carbon particles in a special anode chamber. The particles are generally graphite structure with high purity. The electrolyte used is the high temperature solid oxide, molten carbonate or hydroxide electrolyte. Since a pure stream of CO<sub>2</sub> is produced the stream can easily be sequestered and disposed.

**19-002**

## WEDNESDAY, FEBRUARY 27

AFTERNOON

**2:00 PM | ROOM 610**

### Health & Safety: National Occupational Research Agenda and the Future of Miners’ Health

**Chairs:** *L. Saperstein, Missouri University of Science and Technology, Nantucket, MA*  
*D. Snyder, NIOSH, Pittsburgh, PA*

**2:00 PM**

**Introduction**

**2:05 PM**

### Coal Workers’ Pneumoconiosis in the United States

*D. Blackley, A. Laney and C. Halldin; National Institute for Occupational Safety and Health, Morgantown, WV*

The prevalence and severity of pneumoconiosis has risen among working, long-tenured coal miners since the 1990s. This is most notable in central Appalachia, where 21% of those with ≥ 25 years’ tenure were recently re-



ported to have radiographic findings of pneumoconiosis. Recent studies have also described marked increases in progressive massive fibrosis, the most severe form of coal workers' pneumoconiosis (CWP) and silicosis. Hopefully, new federal dust standards will reverse these trends. Continued health surveillance is needed to inform individual miners of their health status and to document the impact of the new standards.

**2:25 PM**

## **Monitoring and Sampling Approaches to Assess Underground Coal Mine Dust Exposures: A Review of the Recent Report from the National Academies**

*E. Sarver; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA*

After decades of decline, rates of occupational lung disease among US coal miners began to increase in the late 1990s, especially in central Appalachia. Following a multi-year effort, MSHA issued a new respirable dust rule in 2014 to lower personal exposure limits, change sampling requirements to better capture probable maximum exposures, and mandate use of new continuous monitoring technology to provide near real-time data to miners. The rule went into full effect in 2016. Around that time, many mines were also increasing use of rock dusting products to meet federal safety requirements, which prompted concerns about the influence of rock dusting on total respirable dust concentrations. At the request of Congress, the National Academies of Sciences, Engineering and Medicine formed a committee to assess the efficacy of respirable dust sampling and monitoring strategies in underground coal mines, and the effects of rock dust application on dust measurements. This presentation will review the major findings and recommendations of the committee's report, which was released in mid-2018 and received significant attention in light of a surge in reported cases of severe lung disease.

**2:45 PM**

## **Assessment of the Predicted Heat Strain Model and Measures of Heat Strain in Mining**

*S. Griffin<sup>1</sup>, J. Burgess<sup>2</sup>, M. Momayez<sup>3</sup>, P. Harber<sup>2</sup> and D. Staack<sup>2</sup>; <sup>1</sup>CEP, Assistant Professor, Tucson, AZ; <sup>2</sup>CEP, University of Arizona, Tucson, AZ and <sup>3</sup>Mining Engineering, University of Arizona, Tucson, AZ*

The Predicted Heat Strain (PHS) model (ISO standard 7933) was adopted by mining companies to aid in the evaluation and management of occupational heat exposures. More research is needed into: a) how well the PHS predicts hyperthermia as measured by CBT; b) how fitness, hydration and control of work rate may affect the ability of the PHS model to predict hyperthermia; and c) how best to use the PHS and/or physiological measurements to develop and engineer optimal work conditions and work-rest cycles to protect mine workers from negative health effects. The proposed research will evaluate the effectiveness of software and medical technology to predict and prevent heat stress and strain in miners in a deep underground mine with markedly elevated rock wall temperatures. Proposed specific aims: 1) Validate the PHS model using environmental and job-specific measurements against CBT measured using ingested heat sensor pills; 2) Evaluate physiological measures of heat strain or susceptibility that may augment use of or potentially replace the PHS model; and 3) Work with our industry partner to refine engineering controls and work-rest cycles to prevent excessive heat strain.

**3:05 PM**

## **Non-chargeable Mining Deaths – A Window into Miner Health**

*G. Luxbacher<sup>1</sup>, J. Koge<sup>2</sup> and G. Poplin<sup>2</sup>; <sup>1</sup>OMSHR, NIOSH, Pittsburgh, PA; <sup>2</sup>SMRD, NIOSH, Spokane, WA and <sup>3</sup>OMSHR, NIOSH, Atlanta, GA*

The Mine Safety and Health Administration (MSHA) by law investigates serious accidents and deaths on mine properties to determine their causes. Deaths that are not related to mining activity based on a formal review process are deemed non-chargeable and are not included in the safety statistics for the industry. Non-chargeable deaths include deaths due to natural causes, deaths due to trespassers, homicides, suicides, and deaths related to drug overdose. MSHA has posted the Fatality Review Committee reports for deaths that have occurred since 2007 on their website, with the names of the decedents removed for privacy. During the period of 2007 through 2017, the mining industry had 472 chargeable and 584 non-chargeable fatalities, the majority of which were due to natural causes. This paper reviews that data by sector (metal/nonmetal and coal), broken down between employees/contractors and unrelated parties, and by cause.

**3:25 PM**

## **Sharing Critical Controls**

*B. Ross; Lowell Institute for Mineral Resources, University of Arizona, Tucson, AZ*

The mining industry understands the value of sharing safety learning as shown by the use of safety shares at meetings, collecting of data on incidents and close calls as well the distribution of fatalgrams sent out by MSHA. These are excellent methods of keeping safety to the forefront – but there is one piece that is missing and that is the sharing of the critical controls that companies put in place to prevent or mitigate accidents and injuries. The University of Arizona, through a grant with the National Institute for Occupational Safety and Health, has started to hold a series of workshops to solicit and document critical controls that companies have put in place that can be shared with the mining industry. This presentation will discuss the workshop methods and some of the key critical controls gathered to date.

**19-144**

**3:45 PM**

## **The NIOSH Mining Program's New Strategic Plan**

*L. Steiner; CDC NIOSH, Pittsburgh, PA*

The NIOSH Mining Program has released a new Strategic Plan, outlining our research goals for the fiscal years 2019-2023. This five-year Strategic Plan provides a roadmap for reducing and eliminating illnesses, injuries, and fatalities for the mining workforce. In developing this plan, the Mining Program considered carefully how best to serve our many stakeholders, which include academia; equipment manufacturers; government; mine operators; mining industry trade associations; organized labor; regulatory agencies, research laboratories; and suppliers. In structuring our plan, we have followed a mining subsector approach that includes coal, crushed stone, sand and gravel, metal, and industrial minerals. This approach allows us to better address the specialized health and safety challenges specific to each subsector. The plan is interactive and provides an alternative method for navigating our website. A demonstration of this plan will be presented.





**4:05 PM**

## **Managing Diesel Exhaust Exposure: The Health Case for Change and the Strive to Eliminate Diesel in Underground Mine Design**

*C. Godwin-Abel; BHP, Saskatoon, SK, Canada*

Diesel exhaust exposure is one of the important health risks we manage in our operations. We proactively engage with industry experts and monitor research to ensure we are up to date with the most current information on this issue, and continually evaluate the effectiveness of our controls. Several studies this decade suggest that there is a lung cancer risk from exposure to diesel exhaust over a working life at levels considerably below common regulatory occupational exposure limits. This presentation will discuss the findings of independent analysis performed for BHP by the Institute of Occupational Medicine (IOM) that informed our position to seek to manage diesel exhaust exposure to as low as technically feasible and how BHP Potash in striving to be the newest new Potash mine has taken to the challenge and largely eliminated diesel equipment in its underground mine design.

**4:25 PM**

## **An Update to the NIOSH Miner Health Program**

*G. Poplin<sup>1</sup>, T. Ruff<sup>1</sup> and J. Kogel<sup>2</sup>; <sup>1</sup>Spokane Mining Research Division, CDC/NIOSH, Spokane, WA and <sup>2</sup>OMSHR, CDC/NIOSH, Atlanta, GA*

As recognized in the 1970 OSH Act, the methods required to understand occupational health are often necessarily different from methods common to occupational safety. The Miner Health Program is a recent, long-term initiative led by the NIOSH Spokane Mining Research Division (SMRD) that aims to establish a systematic, collaborative and proactive approach for improving our understanding of the health status and disease burden in the mine worker population. The objectives for this presentation will be to introduce the components comprising the Miner Health Program, communicate future planning efforts, and elicit key stakeholders involvement in the process.

## WEDNESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 106

### Impacts of SME PhD Grants on Education and Research in Minerals Industry

**Chairs:** *J. Rostami, Colorado School of Mines, Golden, CO*  
*T. Novak, University of Kentucky, Lexington, KY*

2:00 PM  
Introduction

2:05 PM  
Uncertainty in Mine Planning

*C. Roos; Mining Engineering, Montana Tech, Butte, MT*

Uncertainty exists in nearly every aspect of mine planning, however few mining engineers and managers have been able to embrace that uncertainty and plan accordingly. This research focuses on methods that can be incorporated to bridge the gap between conventional mine planning and stochastic optimization techniques with a focus on geologic uncertainty. Emphasis is placed on visualization techniques that can aid in both the engineer's understanding of the uncertainty in the geologic estimates and their ability to communicate the effects of that uncertainty to management.

2:25 PM  
Musing of a First Year PhD Candidate:  
Stakes, Status, and Goals

*R. Weyher; Mining Engineering, University of Utah, Salt Lake City, UT*

In light of the fact that 95% of PhDs in mining engineering pursue corporate careers in lieu of staying in academia, the stakes for the sustainability of our schools, and our industry, could not be higher. As a recipient of the 2018 Robert S. Shoemaker PhD Fellowship Grant, it is my distinct pleasure to report to SME and the SME Foundation on my plans for obtaining a doctorate in mining engineering, gaining teaching experience, bolstering my research and publication record, and pursuing academic and professional service activities. These aspects of graduate studies are critical for competitively pursuing a tenure track career in academia, which is my intent. As a first year PhD candidate, I will be presenting on the degree requirements at the University of Utah, my proposed timeline and course of study, and my expected dissertation topic, which broadly concerns rock mechanics and mining induced seismicity.

**2:45 PM**

## **PhD Fellowship Update: Review of Digital Enablement Initiatives for Mining Operations**

*A. Young; Student Member, Porto Alegre, Rio Grande do Sul, Brazil*

While mines are increasingly data driven, the mining industry is generally playing catchup with the broader industrial sector in terms of understanding fundamental data science principles. My research direction seeks to develop mining-specific data science tools for the industry. To this end, I have begun a careful literature review of mining's latest data enablement initiatives, and I spent the summer as an intern data analyst for Barrick. I will continue to work with them part-time through the school year. My PhD courses have thus far included: data science and visualization, data management, mathematical modeling, transportation optimization, drones (UAVs), and accounting. I am striving to improve my teaching skills as a Teaching Assistant for the Mine Ventilation course and I am involved with the Utah Student Robotics (USR) and SME clubs. My goals for the coming year are to create a research proposal for my PhD dissertation, continue to improve my teaching philosophy through TA opportunities, perform well in my courses, help grow the new Mining Analytics lab, and organize outreach events for public mining education with the USR and the Utah Mining Association (UMA).

**3:05 PM**

## **Alexander Douglas WAAIME PHD Fellowship Recipient**

*A. Douglas; Mining, Missouri University of Science and Technology, Rolla, MO*

Vehicle vibrations caused by poor haul road conditions create multiple negative effects for mines, including slower cycle times, increased maintenance, and operator injury. Roadways deteriorate overtime and graders are dispatched to correct the adverse conditions, often as a reactive approach, with already bad areas of road receiving attention. With 5 years of work experience with SafeMine and Hexagon Mining collecting vibration and GPS data, I saw a need for increased utilization of the data on hand to mines. The first area of research for my PhD involved developing a degradation factor for roads using vibration and GPS data with the aim of improving grader efficiency. I plan to continue research analyzing data in new ways to advance the industry.

**3:25 PM**

## **PhD Fellowship Program Academic and Research Progress Update**

*H. Lammers; Mining Engineering, Colorado School of Mines, Denver, CO*

Requirements for a Ph.D. in mining engineering at the Colorado School of Mines include successful completion of course and research credit hours, a comprehensive exam, and thesis defense. I completed the course credit hour requirement during the 2017-2018 academic year, my first year as a Ph.D. student. I am currently preparing for the comprehensive exam and proposal defense, both scheduled for the 2018-2019 academic year. My third year in the Ph.D. program, 2019-2020 academic year, will include completion of the research credit hour requirement and thesis defense. I will present a brief degree progress update, including outcomes of major milestones, and summarize teaching and research activities to date. My defined research topic is in development, with my research proposal defense scheduled for the 2018-2019 academic year. My ongoing research efforts include a review of geotechnical, geochemical and climate criteria for tailings facility design, operation, and closure.

**3:45 PM**

## **Rock Mechanics and Sonic Properties Utilized for Custom Blasthole Design**

*P. Padgett, K. Perry and P. Worsey; Mining Eng, Missouri Sci and Tech,  
New Harmony, IN*

Rock mechanic and sonic velocity properties of rock strata in a surface coal mine were measured, along with drill rate of penetration (ROP) and then used for blast hole design. All parameters of the shot design were held constant, except the explosive density. A test shot was designed whereby the density of the explosive (ANFO/ Emulsion) was adjusted to match the strata layers based on rock mechanic, sonic velocity, and production drill systems ROP output properties. Pit length was approximately 2,400 ft long and 150 ft wide. Two strips were monitored: a.) strip 1 which was loaded normally, and b.) strip 2 that was custom loaded. Both strip 1 (normal loading) and strip 2 (custom loaded) had four bench shots: S1, S2, S3, and S4 and T1, T2, T3, and T4 each, respectively. Velocity of Detonation (Vod), preand post-flight UAV surveys and fragmentation was measured. Sonic velocity of the strata was measured in exploration drillholes and measured in one blast hole in strip 1 (normal loaded) and strip 2 (test shots). Initial results show some improvement in fragmentation from custom loading, however further investigation is in progress.

**4:05 PM**

## **Utilization of the SME PhD Fellowship Grant for Dissertation Completion**

*R. LaDouceur; Metallurgy, Montana Tech, Butte, MT*

The SME PhD Grant allowed for a unique position through the completion of my dissertation, not only financially but also professionally. Grant writing is difficult and to have the experience, first with getting close in 2015 and being successful in 2016, has been beneficial as I enter my Post-Doctoral research. I have taken full advantage of the networking opportunities and professional experiences the program has opened up for the Grant Fellows, such as Freeport-McMoRan's AIM Fellowship Program. The AIM Program allowed me to use my dissertation research and apply it directly to the needs of industry. Additionally, I already have a course designed to meet the identifiable needs of future mineral processing engineers based on that experience.

TECHNICAL PROGRAM: WEDNESDAY

**WEDNESDAY, FEBRUARY 27**

*AFTERNOON*

**2:00 PM | ROOM 110**

## **Industrial Minerals & Aggregates: Health and Safety in Industrial Mineral and Aggregate Operations**

*Co-sponsored session by  
IM&A and H&S Divisions*

**Chairs:** *P. Roghanchi, New Mexico Institute of Mining  
and Technology, Socorro, NM  
S. Amini, Virginia Tech, Morgantown, WV*

**2:00 PM**

### **Introduction**

**2:05 PM**

### **A Fogging DPM Scrubber for a Personal Work Zone**

*J. Tabor<sup>1</sup>, E. Sarver<sup>1</sup> and J. Saylor<sup>2</sup>; <sup>1</sup>Virginia Tech, Blacksburg, VA and  
<sup>2</sup>Clemson University, Clemson, SC*

Diesel Particulate Matter (DPM) represents an occupational health risk for many underground miners. Particularly in large-opening mines, sufficient ventilation to mitigate high DPM concentrations can be challenging. Prior laboratory research has shown that micron-scale fog droplets might be used to effectively remove DPM from an air stream. In the current work, we are investigating a field-application: a fogging scrubber that could be used to provide a clean air stream to a personal work zone. Here, we present the basic scrubber design and preliminary testing results.

**2:25 PM**

### **A Sensitivity Analysis of Various Heat Sources in Underground Mines**

*M. Teixeira<sup>2</sup>, J. Parrish<sup>2</sup>, K. Kocsis<sup>2</sup> and P. Roghanchi<sup>1</sup>; <sup>1</sup>Mineral Engineering,  
New Mexico Institute of Mining and Technology, Socorro, NM and <sup>2</sup>University  
of Nevada Reno, Reno, NV*

There are two strategies when it comes to managing the heat on underground mines either by providing a ventilation/cooling system or by reducing the contribution of the heat sources. The latter could be achieved, for instance, by reducing the fleet size or other types of machinery. Therefore, the former strategy is likely to be the most economical decision considering that any reduction in equipment would reduce production impacting financially in a contrary manner. Understanding heat sources in underground mines are instrumental in worker thermal comfort and, as a product of increased comfort, higher productivity, and lower risk. In rationalizing what sources generate the most considerable amount of heat underground efforts can be made to increase cooling to those areas allowing higher work efficiency. This paper aims to look at the various heat sources and their contributions to the overall heat load of an underground mine. In this paper, the effect of heat ex-

posure on health, safety, and productivity of mine workers are summarized. A sensitivity analyses study aiming to offer the best cooling strategies are recommended based on the sources of heat in underground environments.

## 2:45 PM

### Assessment and Modeling of Heat-Related Accidents in the US Surface and Underground Operations

*E. Talebi<sup>1</sup>, P. Roghanchi<sup>1</sup> and E. Tarshiz<sup>2</sup>; <sup>1</sup>Mineral Engineering, New Mexico Institute of Mining and Technology, Socorro, NM and <sup>2</sup>National University, San Diego, CA*

Current studies on the consequences of excessive heat exposure in the working environments are mainly focused on evaluation, mitigation techniques, and recommendations concerning heat stress. However, less attention is given to the heat strain in the mining industry. The reaction of mine workers to excessive heat stress is different from person to person. Therefore, heat stress itself cannot be adequately controlled without considering the risks embedded in the individual differences. This study attempts to assess the heat-related accident data in surface and underground mines in the US encountering the individual factors. In this study, miner's experience, age, accident time, accident location, the severity of the accident, and days away from work were analyzed. The data indicate that most heat-related accidents have happened in mill operation and surface mines. However, the heat-related accidents in underground mine should not be neglected. Recommendations were developed based on the mine types, environmental and personal factors, and type of the accidents. The results of the analysis show that the personal factors have significant effects on the rate and severity of accidents.

## 3:05 PM

### Evaluation of After Blast Re-Entry Time Based on Gas Monitoring of Return Air

*D. Bahrami, L. Yuan, J. Rowland, L. Zhou and R. Thomas; CDC NIOSH, Pittsburgh, PA*

Blasting is the main method of production in many non-coal underground mining operations and produces multiple toxic gases as a result. The Mine Safety and Health Administration (MSHA) requires mine operators to measure the level of toxic gases in mines as frequently as necessary to ensure they are below regulatory safety limits. The current practice uses portable gas monitors to check the concentrations of toxic gases after a fixed post-blast time. This paper studies the application of a gas monitoring system in the return entry of a limestone mine to determine a safe re-entry time. The National Institute for Occupational Safety and Health (NIOSH) conducted such a monitoring program in a limestone mine from September 2016 through May 2018. NIOSH/PMRD (Pittsburgh Mining Research Division) is endeavoring to develop workplace solutions to improve detection of and reduce the risk of hazardous conditions. This study showed that the use of gas monitoring in the return air can be a useful tool at the mine operator's disposal to detect and reduce the risk of hazardous conditions and also to reliably estimate the re-entry time.

19-049



**3:25 PM**

## **Improving Accuracy of Helmet-CAM Dust Measurements with the Establishment of Correction Factors for Industrial Mineral Dusts**

*J. Patts, D. Tuchman, E. Rubinstein, E. Cauda and A. Cecala; CDC NIOSH, Pittsburgh, PA*

NIOSH's "Helmet-CAM" exposure assessment system employs real-time dust monitors and mobile video cameras to identify respirable dust exposures. Real-time dust monitors that utilize light scattering are subject to accuracy errors based upon a number of factors. Three types of personal dust monitors were tested in an aerosol chamber comparing the instruments to a recognized standard instrument under controlled conditions. Correction factors ranged between 0.76 and 2.06 across all dusts tested and between 0.8 and 1.5 on the calibration dust and this provides a starting point to obtain more accurate respirable dust concentrations in the future.

**3:45 PM**

## **Investigation of Volatile Organic Carbon Interference in the NIOSH 5040 Standard Method for Measuring DPM**

*P. Guse<sup>1</sup>, E. Sarver<sup>1</sup> and E. Cauda<sup>2</sup>; <sup>1</sup>Virginia Tech, Blacksburg, VA and <sup>2</sup>NIOSH, Pittsburgh, PA*

Exposure to diesel particulate matter (DPM) is an occupational health hazard for many miners. In underground metal/nonmetal mines, personal DPM exposures are regulated. Compliance is determined by monitoring the mass concentration of total carbon (TC), which has two primary components: elemental (EC) and organic carbon (OC). EC and OC are measured using the NIOSH 5040 Standard Method, which employs thermal-optical analysis on filter samples. While the 5040 method intends to only measure the particulate OC, volatile OC is also present in DPM samples and can cause interference with the particulate OC measurement. This issue has been addressed by use of a secondary filter (volatile) beneath the primary sample filter (particulate+volatile), such that particulate OC can be determined by difference. However, a review of several historical datasets sets indicates that approach may not always work. This research seeks to identify sources of volatile OC in affected samples, and to develop a better approach for limiting volatile OC interference in DPM sample analysis. Here, we present recent results, including from work to determine particulate OC directly from an improved thermal analysis.

**19-054**

**4:05 PM**

## **Quantification of the Effects of Carbon on Filter Media in SKC DPM Cassettes on Measurements of Diesel Particulate Matter in Underground Mines**

*J. Noll, E. Cauda, T. Barone and S. Vanderslice; NIOSH, Pittsburgh, Pa, United States Minor Outlying Islands*

Elevated carbon on the media of the SKC DPM cassettes can cause the limit of quantification (LOQ) for diesel particulate matter (DPM) compliance samples in underground mines to be higher. In this study, blank SKC cassettes from different batches were analyzed to quantify the amount of total carbon (TC) on the media and to determine the LOQ associated with these samplers. It was found that the carbon on the media was 5 times higher than other samplers resulting in a LOQ of 68  $\mu\text{g}/\text{m}^3$  TC 8 hr TWA for SKC cassettes. The LOQ may be improved through sample preparation techniques.

**19-039**

**4:25 PM**

## Use of Continuous Dpm Monitoring Data for Engineering in Underground Mines

*F. Wright and E. Sarver; Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA*

In many underground mines, diesel particulate matter (DPM) is a primary occupational health hazard. DPM concentrations can be affected by equipment operating conditions, production cycles, and ventilation. While personal exposure monitoring is commonly done in metal/non-metal mines to demonstrate regulatory compliance, area monitoring can also be valuable for engineering analyses and applications – especially where real-time, continuous data can be collected. Here, we present several field studies from an underground stone mine. One looks at the effects of a modified production schedule to reduce DPM accumulation in working areas, and another illustrates the utility of DPM monitoring data for controlling a ventilation-on-demand system.

## WEDNESDAY, FEBRUARY 27

AFTERNOON

**2:00 PM | ROOM 112**

## Industrial Minerals & Aggregates: Physical Separations in Industrial Minerals Processing

**Chairs:** *S. Saurabh, Millcreek Engineering Company, South Jordan, UT*  
*R. Jain, Outotec USA Inc., Savage, MD*

**2:00 PM**

### Introduction

**2:05 PM**

## FSI Industrial MultiG Technology and High Energy Screening Equipment

*R. Hutchcraft; Mining, SME Member, Sullivan, IN*

Fluid Systems has been working for several years to create a machine that increases capacity, increases separation efficiencies and can make much finer cut points compared to a conventional machine. The MultiG line of equipment can do just that. The MultiG machines have a special technology installed underneath each working screen panel. The technology works on the principle of resonance. The “exciter” installed underneath each working panel uses the vibrator motors frequency to convert the single frequency oscillation into a multi frequency motion. Traditional vibrating sieves use single frequency systems with low amplitude and a low range of frequency to vibrate the machine frame and the screening mesh. MultiG uses a multi





frequency system with a high amplitude and this delivers an infinite range of multi vibrational frequencies directly in to the mesh, avoiding energy waste by avoiding the frame. The mesh vibrates with high G forces and this breaks agglomerates, stops mesh blinding and maximizes capacity. The MultiG, with the use of a variable frequency drive (vfd) can generate three times the energy or more over a conventional machine and use less power and less noise.

**2:25 PM**

## **Magnetic Separation as Applied to Lithium Mining & Processing**

*J. Marin and X. Jiang; Sales, Eriez Manufacturing Co., Erie, PA*

Magnetic separation is an indispensable tool in mineral processing. Mining activities are conducive to generate a substantial amount of tramp metal that damages conveyor belts and crushers. Furthermore, the wear and tear of process equipment can also generate a substantial amount of metallic contamination. Lithium processing falls under a process where magnetic separation becomes a necessary tool to generate a saleable lithium carbonate or chloride product. Lithium is extracted from mineral rock such as spodumene or from a brine solution which is obtained from a "salar". The type of metallic contamination found at a plant varies in shape, size and weight from the beginning of the process to the end. The objective of this discussion is to focus on the magnetic separators commercially available that can effectively remove contamination that is specifically generated during the actual process of lithium mineral. We seek to establish a clear guideline for the process engineer to select the most suitable magnetic separator for the specific problem of ferrous and weakly magnetic materials in a dry or wet processing plant.

**2:45 PM**

## **Dry Beneficiation of Industrial Minerals Using a Tribo-Electric Belt Separator**

*K. Flynn, A. Gupta and F. Hrach; ST Equipment & Technology, Needham, MA*

ST Equipment & Technology, LLC (STET) has developed a processing system based on tribo-electrostatic belt separation that provides the mineral processing industry a means to beneficiate fine materials with an entirely dry technology. In contrast to other electrostatic separation processes that are typically limited to particles greater than 75  $\mu\text{m}$  in size, the STET tribo-electric belt separator is ideally suited for separation of very fine ( $<1 \mu\text{m}$ ) to moderately coarse (500  $\mu\text{m}$ ) particles, with very high throughput. The STET tribo-electric belt separator technology has been used to process a wide range of industrial minerals and other dry granular powders. Successful separations include barite/quartz, talc/magnesite, carbonates/ silicates and iron ore (hematite)/quartz. Separation results are presented for selected calcium carbonate and talc sources, in addition to commercial processing results for barite.

**3:05 PM**

## **Control of Declassified Particles in Classification and Their Impact on the Business**

*D. Switzer and E. Cepeda; Weir Minerals, Madison, WI*

High efficiency hydrocyclones are a necessity in the mining and mineral processing industry. Weir Minerals has enhanced the high efficiency hydrocyclone design with their new classification technology, known as Cavex 2. This design

improves the control of classification of particles by decreasing the larger particles discharged through the underflow. By improving the control of your particle classification, you improve the bottom line and minimize loss at your plant. In this paper, Weir Minerals will discuss the benefits of the new design, the economic impact on grinding circuits and customer success stories.

**3:25 PM**

### **Selection of Vibrating Screens for Mineral Separation Based on Process, Design and Implementation Criteria**

*M. Woodie; Conn-Weld Industries, Princeton, WV*

The topic of vibrating screen selection will be discussed in this paper. Topics such as applicaiton reveiw to choose the proper style of vibrating screen, parameters that determine the proper size of vibrating screen, engineering design information that governors proper screen design, review of topics that govern proper isolation from structural steel and other topics that dictate proper screen selection for appicaitons. Process and Application information reveiw to choose the style of screen and how material size and type influences proper type of screen selection (multi-slope, incline, horizontal, linear incline or dewatering.) Parameters will be reveiwed that help size the screen for the applicaiton. The total amount of surface area to size a screen is critical to the overall success of a screen(s) installation. Once proper style of screen is determined there is an engineering process that is required to design the screen to operate correctly in the environment it will be used. Finite Element Analysis, Dynamic Modeling, Field Vibration Analysis and other engineering tools will be reviewed to best implement a successful vibrating screen installation.

**19-023**

**3:45 PM**

### **Dense Medium Separation**

*I. Bornman; Technology Department, Technology Manager, Kempton Park, Gauteng, South Africa*

Dense Medium Separation (DMS) is an extractive process to beneficiate minerals. Reeves & Platt (1988) describe it as one of the most complex unit processes in mineral processing today, particularly if cyclones are used. Physical separation of the valuable mineral from waste is possible if the density differential is large enough. DMS is well established in the diamond, coal and iron ore industries. DMS is used for pre-concentration of other minerals like nickel, copper and cobalt. DMS is also used to upgrade the valuable material to meet market specifications. It is the most efficient gravity concentrating process available to process engineers. The physical separation in the process occurs where the heavy particles sink through the dense liquid and the light particles float. The paper sets out to describe the DMS process using cyclones. The paper also addresses cyclone design parameters, medium characteristics, the partition curve, maintenance issues and factors influencing the physical separation process. Of these main factors, one of particular interest is the vortex finder length. The paper ends off with practical operational tips for a DMS operation.

**19-107**

**WEDNESDAY, FEBRUARY 27**

*AFTERNOON*

**2:00 PM | ROOM 603**

## **International IV: Sustainable Artisanal and Small Scale Mining in Latin America**

*Chairs: M. Gavrilovic, GR Engineering Services, Denver, CO*

**2:00 PM**

### **Introduction**

**2:05 PM**

### **From United Nations to Boyacá: Corporate Social Responsibility in Colombia Small Coal Mines**

*D. Lezcano and J. Kretschmann; TH Georg Agricola University, Bochum, Germany*

Is it possible for small coal mines to apply the concepts of the United Nations Global Compact, the world's largest corporate sustainability initiative? In Colombia, the department of Boyacá produces the 4.36 % coal production by small and medium-sized mining operations. Up to 50 % of the operations are characterized by artisanal mining techniques such as pick and shovel. The other half of the operations in the region is conducted by semi-machined techniques with tools such as pneumatic hammers and compressors. Families or miners' associations own those mines and carry out the mining business absent of international standards. Nevertheless, globalization and the entry of new economic dynamics are pressuring these mining operations to improve in environmental, social, productive and economic dimensions. The present research is the first approach of the Boyacá artisanal coal mining industry to apply the concept of Corporate Social Responsibility into the framework of the United Nations Global Compact. Key Words: Corporate Social Responsibility, United Nations, United Nations Global Compact, Coal, Small Coal Mines.

**2:25 PM**

### **Experiences and Future Challenges of the Artisanal and Small Scale Mining in Colombia**

*I. Casasbuenas Cabezas<sup>2</sup>, N. Smith<sup>2</sup> and O. Restrepo Baena<sup>1</sup>; Medellin, Antioquia, Colombia and <sup>2</sup>Mining Engineering, Colorado School of Mines, Golden, CO*

This article identifies the current status of the research on artisanal and small-scale mining (ASM) in Colombia. The main goal is to present a review of the literature in order to create a baseline that can be used in future research. ASM in Colombia is an economic activity engaged in by different groups of people, such as individuals, families, and associations. There are many problems in the ASM sector, and most of them are related to economic, social, legal, and environmental challenges. In the past several years, the Colombian government has attempted to address some of these problems by creating different development-focused projects. The Universidad

Nacional de Colombia in Medellin has also led some projects in collaboration with the Energy and Mining Planning Unit and the Ministry of Energy and Mining. These projects include improving the working conditions in the ASM sector and increasing the percentage of ore recuperation. While the current research shows that there have been some positive results, it also demonstrates that the Colombian government needs to continue investing in and supporting research on ASM.

**2:45 PM**

## **An International Mining Health and Safety Student Experience: A Comparison Between the United States and Colombia**

*J. Monsalve<sup>1</sup>, Z. Scopa<sup>1</sup>, L. Farinholt<sup>1</sup>, h. Unander-Scharin<sup>1</sup>, M. Marquez<sup>1</sup>, J. Monsalve<sup>2</sup> and N. Ripepi<sup>1</sup>; <sup>1</sup>Mining and Minerals Department, Virginia Tech, Blacksburg, VA and <sup>2</sup>Minerals and materials, Universidad Nacional de Colombia, Medellin, Antioquia, Colombia*

Colombia is not a major producer of minerals, but the mining industry has played an important role in its economy. Among the main problems encountered in the Colombian mining industry surround informal and artisanal mining, community rejection, weak legal framework and high accident and fatality rates. In 2017, 136 mining fatalities occurred in Colombia and 28 in the United States (US). The fatality rate in Colombia has been increasing at 5% per year over the last 10 years while decreasing in the United States at 12% per year. A collaboration between Virginia Tech and the Universidad Nacional de Colombia have allowed for undergraduate researchers from Virginia Tech to develop a project to compare health and safety regulations and processes in the US to those in Colombia. This has allowed for a technology exchange to bring advances to small-scale mining operations in Colombia. The students have visited mines in the US and researched health and safety regulations in both countries. The program included a visit to mining operations in Colombia in order to work with Mining Engineers on best practice procedures that could be transferred to Colombia to increase safety for miners.

**3:05 PM**

## **An Approach to Sustainable Development Goals and Small-Scale Mining in Colombia**

*K. Ocampo Torres and M. Bustamante; IM CIMEX, Universidad Nacional de Colombia, Medellin, Antioquia, Colombia*

The last 2011 Colombian mining census shows that 72% of mines are small-scale mining; moreover, most of them are not “formal mines”. Thus, implying that they do not accomplish the minimal government requirements to perform mining operations. Furthermore, it shows its significant socio-economic impact within communities where it takes place. Additionally, extractive industries are by far not well received by communities. People against the operations state that mining does not generate sustainable development for the country. However, studies by United Nations Development Programme, Columbia Center on Sustainable Investment, British Columbia University, among other institutions shows linkages between mining and Sustainable Development Goals (SDG) and strategies to achieve those goals from the industry. This research suggests a methodology to identify and quantify the impact that small-scale mining has in such communities. It involves the selection and implementation of SDG Indicators in mining regions, according to their specific conditions. Aiming to design strategies to leverage sustainable development from the extractive activity.

**3:25 PM**

## **Traditional and Small Scale Mining in Marmato, a Case Study of Mercury-Free Processing in Colombia**

*M. Salgado Cabeza<sup>1</sup>, E. Holley<sup>2</sup> and O. Restrepo Baena<sup>1</sup>; <sup>1</sup>Universidad Nacional de Colombia, Medellín, Antioquia, Colombia and <sup>2</sup>Mining Engineering, Colorado School of Mines, Golden, CO*

Traditional and small scale mining in Colombia accounts for approximately 80% of gold production in the country. The government has recently outlawed the use of mercury in mineral processing but has provided little guidance for alternative technologies. This presentation offers potential lessons from the historic mining district of Marmato in the Department of Caldas, where small scale miners have significant experience with relatively sophisticated mercury-free processing technologies. Small scale mining at Marmato exploits epithermal veins by underground methods. Cooperatives and small companies operate mills and cyanidation plants to process the gold-silver ore. Case study mill flow sheets are presented, and the implications for recovery and environmental impacts are discussed.

**3:45 PM**

## **Mining in the Coffee Lands: Lessons of Coexistence in Andes, Colombia**

*O. Restrepo Baena<sup>1</sup>, A. Delgado-Jimenez<sup>1</sup>, N. Smith<sup>2</sup>, E. Holley<sup>2</sup> and J. Lucena<sup>2</sup>; <sup>1</sup>Materials and Minerals, Universidad Nacional de Colombia, Medellín, Antioquia, Colombia and <sup>2</sup>Colorado School of Mines, Golden, CO*

The municipality of Andes is located in the southwest region of the department of Antioquia in Colombia. Its main economic activities are related to agriculture, where coffee has been the dominant commodity in the last four decades. Artisanal and small-scale gold mining (ASGM) has occurred in Andes for more than 150 years and is still both culturally and economically significant in some areas of the municipality. This presentation provides some reflections on the coexistence of mining and coffee in Andes based on the analysis of two fundamental factors: coffee activity and mining communities and their practices. Additionally, we propose some opportunities for strengthening ASGM as a livelihood, based on socio-technical innovations that support cleaner, safer and more sustainable activities. This study is the result of fieldwork conducted in 2018 within the framework of the multidisciplinary, multinational NSF PIRE project Sustainable Communities & Gold Supply Chains: Integrating Responsible Engineering & Local Knowledge.

**4:05 PM**

## **Sustainability and Mining in the Regional Scale As a Process of Transformation – Some Approaches from Three Cases in Colombia**

*O. Restrepo Baena and A. Delgado-Jimenez; Materials and Minerals, Universidad Nacional de Colombia, Medellín, Antioquia, Colombia*

One of the growing challenges for the mining industry is to demonstrate the benefits that it can provide to different stakeholders and their contribution to the sustainability; however, its achievement is consolidated as a process in which variables of the social, economic and environmental context need to be understood and oriented strategically from the early stages of a mining project. The work presents a conceptual model developed from the first and second law of thermodynamics, from which it is possible to understand the relationships and transformations existing between the capitals intervened in

the development of a mining project, as a result of the flows and stocks that consolidates the sustainability at the regional scale. The process of transformation is restricted by the conditions of feasibility that make possible its development, which become the main drivers of sustainability and promote the transformations in the system. The model is applied to three particular cases in Colombia, from which the opportunities and failures presented in them help to conclude some potentials to improve the contributions of mining projects to sustainability at the regional scale.

## WEDNESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 501

### Mining & Exploration: Geosciences: Geology of Gold Deposits

*Chair: B. Clarkson, SRK Consulting (U.S.), Inc., Reno, NV*

2:00 PM

Introduction

2:05 PM

### Corvus Gold's New Gold Discoveries in the Beatty Area, Southwest Nevada

*C. Brechtel; Corvus Gold Nevada Inc., Highlands Ranch, CO*

Corvus Gold, a Canadian junior exploration and development Company, has been exploring for gold deposits in the Beatty area of southwestern Nevada for the past 7 years. The Company has defined four, surface outcropping, gold deposits with a combined resource potential of over 3 million ounces of contained gold and over 9 million ounces of contained silver. Three of Corvus Gold's new discoveries are on the North Bullfrog property about 12 kilometres north of the town of Beatty, Nevada (Sierra Blanca/Yellow-Jacket, Jolly Jane & Mayflower). The fourth deposit, called Mother Lode, is about 8 kilometres east of Beatty. This region of Nevada had sustained gold production from mid-1980 through the 1990's with Barrick Gold's, historic Bullfrog Mine being the largest producer (~2.6Mozs of gold production from 1989-1999). These four deposits cover a time span of 3 million years and represent all three major gold events in the greater Bullfrog District with each event hosting 2-3 million ounces (past production & current resource), culminating in a District endowment of over 7 million ounces of gold.



**2:25 PM**

## **Geology of the Dark Star Gold Deposit: Carlin-style Mineralization, the Railroad-Pinion District, Carlin Trend, Nevada**

*M. Newton, D. Harris, D. Ernst, R. Edie, M. Harp, M. Jackson, S. Koehler and M. Laffoon; Gold Standard Ventures, Elko, NV*

The Dark Star gold deposit, is located on the Carlin Trend, within Gold Standard Ventures Railroad-Pinion project. Dark Star gold mineralization is hosted in Pennsylvanian-Permian bioclastic debris flow conglomerate, part of a shallow marine shelf sequence. These host rocks are considered atypical to the older Carlin shelfslope carbonate assemblage. At North Dark Star, mineralization is associated with a NNE-trending syncline and the north-striking, east-dipping Ridgeline fault, with mineralization offset by crossing WNW structures. Mineralization at Main Dark Star is stratigraphically controlled within the west-dipping debris flow conglomerate. The oxidized Dark Star deposit is potentially minable via a shallow open pit.

**2:45 PM**

## **Oligocene, Transitional Mesothermal-Epithermal Gold Deposits of the Fondaway Canyon District, Nevada**

*J. Margolis; Canarc Resource Corp, Reno, NV*

The Fondaway Canyon district in northwestern Nevada contains gold-arsenopyrite-stibnite mineralization hosted in Mesozoic shale along a 3.7-km long, eastwest shear-zone system (SZS) reaching 1 km in width. Mineralized mafic dikes dated at 25 Ma broadly coincide with the SZS. Shear-zone mineralization consists of replacement-style, gold-arsenopyrite-silica-carbonate adjacent to and within highly ductily-deformed, locally diffuse faults and fractures. Late-stage quartz veins, locally containing stibnite, fill these structures but contain low gold contents. The resulting shear-stockwork vein zones locally form broad, moderately-dipping corridors reaching widths of 100-150 m. A left-stepping releasing bend developed late within the SZS. The strongest mineralization in the district is localized at the structurally-complex corners of the rhombic dilation zone, where late, northeast-striking, extensional, linkage faults hosting brittle epithermal quartz veins intersect the east-west SZS structures. The project contains a 2016, non-43-101 compliant resource of 1.06 million ounces of gold grading 6.31 grams per tonne.

**3:05 PM**

## **Cenozoic Tectonic Evolution of the Great Basin and Relation to Ore Deposits**

*M. Newton; Tectonex, LLC, Winnemucca, NV*

The Great Basin developed in Cenozoic time as a large sinistral pull-apart zone with the hinge zone region centered on the Ruby Mountains metamorphic core complex and Grant Range detachment fault system. The Great Basin was created by oblique extension in a WNW-ESE direction, orthogonal to normal faults that trended dominantly NNE-SSW (N-S). The dominant sense of shear producing the Great Basin was sinistral along NE-trending strike-slip and oblique faults. Subsidiary NW-trending dextral strike-slip and oblique fault systems were locally dominant and important for gold mineralization in the Carlin and Cortez trends. The interaction of the three main Tertiary fault systems – NE-SW sinistral strike-slip and oblique faults, NW-SE dextral strike-slip and oblique faults and N-S normal faults – localized magmatic and hydrothermal fluid movement in crustal-scale structural zones and in-

fluenced district-scale and deposit-scale geometries of gold deposits. The world-class gold deposits of the Carlin, Cortez and Getchell trends are in Eocene structural corridors that formed in a dominantly sinistral pull-apart zone that developed on the northwest side of the Great Basin hinge zone.

**3:25 PM**

### **Geologic Overview of the Cripple Creek and Victor Gold Mine; Cripple Creek, Colorado**

*S. Siebenaler; Mine Technical Services, Newmont Mining Company, Cascade, CO*

The Cripple Creek and Victor gold mine is a world-class gold deposit that has produced over 20 million ounces of gold historically through underground methods and 5 million ounces during modern surface operations using heap leach and mill processing. The geology of the deposit centers in Pre-Cambrian igneous rocks, cut by a Tertiary breccia diatreme pipe structure, which is cut by a complex range of volcanic intrusives. Gold deposition occurred late in the diatreme emplacement, and is associated with moderate, generally sub-economic silver, and elevated levels of tellurium. Mineralization is occasionally associated with sulfides, moderately occurs as free gold, and commonly occurs as gold-silver tellurides which have also produced some museum quality telluride mineral specimens.

**3:45 PM**

### **La Cienega Gold Project, Sonora, Mexico**

*G. Ferdock; Consultant, Virginia City, NV*

The La Cienega Project is in the “Golden Triangle” of northwest Sonora, Mexico. Gold mining has been documented to be nearly continuous in the district since the eighteenth century and the indigenous people are said to have collected placer gold prior to European contact. The primary gold source is attributed to eroded portions of mesothermal quartz veins common in the Paleo-proterozoic (~1.7 Ga) orthogneiss host. Gold is hosted within fine grained base metal sulfides and pyrite mineralization, as well as selvages and nuggets of native metal. Gold values in the veins average less than 1 ppm, with local ore shoots containing values to 112 ppm. Estimated historical production is between 500,000 and 1 million ounces, based on surface and underground disturbance.

**4:05 PM**

### **Gold Targeting Within the Battle Mountain District**

*S. Briscoe; Newmont, Elko, NV*

With the improvement of 3D modeling software and computer hardware, larger and more detailed geological models can now be built. Utilizing existing data, a new district scale 3D computer model and subsequent geologic interpretation of Battle Mountain has been constructed with the intent of discovering new mineral deposits. By integrating detailed geologic mapping, remote sensing, as well as 2D and 3D geophysical products, a new level of realism in 3D geological models has been achieved. By improving our understanding of the geometry of today's geology, we can better work towards understanding the geologic processes active during the time of gold deposition. Armed with this, we can better predict the area of formation of gold deposits and target exploration efforts more efficiently.



**WEDNESDAY, FEBRUARY 27**

*AFTERNOON*

**2:00 PM | ROOM 502**

## **Mining & Exploration: Geosciences: Resource Geology & Geostatistics**

***Chairs:** A. Jewbali, Newmont Mining Corporation,  
Greenwood Village, CO  
M. Moore, Maptek, Lakewood, CO*

**2:00 PM**

### **Introduction**

**2:05 PM**

### **Extracting Value from Simulation Models: Feasibility Grade Control**

*M. Rossi; GeoSystems International, Boca Raton, FL*

This paper discusses the use of CS models to provide mill feed grade profiles for different time periods. The conventional approach of classifying block estimates as ore or waste generally does not adequately represent dilution, lost ore and the anticipated grade control data, including variability of mill feed from the pit and possible stockpiles. The detailed simulation of grade control practices can be done, but at the Preor Feasibility stage of the project may be impractical, since drawing dig limits on multiple benches is tedious and time consuming. Using the Feasibility Grade Control (FGC) method as developed by the Centre for Computational Geostatistics (CCG, University of Alberta-Edmonton), the CS models can be processed quickly to establish dilution and lost ore, and predict daily or short-term feed to the mill. The simulated nodes can be aggregated into selective mining units with adequate representation of likely geometries to be recovered from the pit, to mimic anticipated selectivity. An example from a polymetallic deposit is shown, where the main commodities of interest are copper (Cu), uranium oxide (U<sub>3</sub>O<sub>8</sub>), gold (Au), and silver (Ag).

**19-004**

**2:25 PM**

### **Re-opening of the La Coipa Mine, a Geometallurgical Approach**

*E. Esper<sup>2</sup> and D. Cameron<sup>1</sup>; <sup>1</sup>Cameron Resource Consulting, LLC, Harrison, ID and <sup>2</sup>Kinross Minera Chile, Copiapo, Chile*

La Coipa is one of the world's classic high-sulfidation epithermal districts, hosting ten known Ag-Au deposits, several of which were continuously exploited from 1989 – 2013 when mining was temporarily suspended. A feasibility study is underway to evaluate a re-start of the operation, mining the newly discovered Pompeya deposit and others. The largest district orebodies occur in gently plunging mantiform bodies of vuggy or massive silica alteration hosted by volcanoclastic rocks. Lesser, but significant tonnages of ore occur in advanced or intermediate argillic alteration. Control of physical, metallurgical and geochemical ore characteristics is key to operational success at La Coipa. Filtration rates and metallurgical recoveries are highly variable within, or between orebodies. These parameters must be accurately estimated to define ore limits, determine blending options and optimize the operation. The feasibility study is supported by geometallurgical block

models that incorporate estimates of pay metals, deleterious elements and process variables. Each estimate is constrained by modelled domains that are based on lithology, alteration, redox, fault and geochemical models.

**2:45 PM**

### **Modeling Blast Movement and Dig Line Design for Grade Control**

*E. Isaaks; Earth Sciences, Isaaks & Co., Emerald Hills, CA*

Current industry practices for designing post blast dig lines are underdeveloped, suboptimal and yield excessive ore loss and dilution. The “best” current practice consists of designing pre-blast dig lines which are subsequently modified without blast or block grades to “fit” the post blast muck pile using moot two dimensional techniques. The result is excessive dilution and ore loss. This paper presents the conditional simulation of blast movement which generates a 3-dimensional post blast block model with block grades. This step is followed by the design of optimum post blast dig lines based on block grades and constrained by a minimum mining width. A case study is presented which illustrates the modeling of blast movement by conditional simulation and the design of optimum post blast dig lines.

**3:05 PM**

### **Implementation of Revenue Based Ore Control Modeling at Cripple Creek and Victor Gold Mine**

*S. Siebenaler, M. Lytle and D. Greene; Mine Technical Services, Newmont Mining Company, Cascade, CO*

The Cripple Creek and Victor (CCV) gold mine is located ~2 hours SW of Denver and has ~25 million ounces of historic production. The geology of the mine is a breccia pipe diatreme intrusion with gold deposition occurring late in the emplacement and is associated with generally North by Northwest trending vertical ore trends. In 2018, in conjunction with continuous improvement initiatives and utilizing new metallurgical recovery studies, CCV migrated the ore control (OC) and Short term Ore Control (STOC) block models from ore binning based on strict cutoff grade criteria to revenue influenced ore characterization. These changes were done in alignment with changes to the resource model, long range, and metal planning. This presentation will cover rational and methodology to migrate the OC and STOC models and discuss the impacts and lessons learned from making the transition to revenue based operational ore routing.

**3:25 PM**

### **A New Rapid Brine Release Extraction Method in Support of Lithium Brine Resource Estimation**

*T. Yao<sup>1</sup>, M. Milczarek<sup>1</sup>, F. Reide<sup>2</sup>, D. Weber<sup>3</sup> and M. Brooker<sup>4</sup>; <sup>1</sup>GeoSystems Analysis Inc, Tucson, AZ; <sup>2</sup>FloSolutions, Santiago, Chile; <sup>3</sup>Montgomery and Associates, Denver, CO and <sup>4</sup>Hydrominex Geoscience, Greenwich, NSW, Australia*

Lithium brine mining via groundwater extraction accounts for the majority of the world's lithium production. Lithium concentrations can be highly variable across a lithium deposit and host aquifers typically consist of highly heterogenous layered sediments. Whereas aquifer pumping tests can provide data on large-scale aquifer properties, results typically cannot resolve explicit estimates of lithium grade and specific yield. Consequently, brine

mineral resource estimation requires supporting data from both field and laboratory testing programs to estimate the lithium concentrations associated with various lithologies. Laboratory methods to determine brine release range from moisture retention characteristic and centrifugal tests to simple suction methods to establish drainage. We have developed a new rapid brine release test based on a modified standard method to determine specific yield characteristics of core samples collected during exploration drilling. To date this method has been used to determine specific yield characteristics on hundreds of samples from several different brine deposits in North and South America. Case studies will be presented.

**3:45 PM**

## **Local Capping in Resource Estimation**

*R. Cooper; Newmont Mining, Colorado Springs, CO*

The depths of stationarity are rarely satisfied in estimation domains. The concept of a single capping value when using ordinary kriging for estimation is generally a compromise. While it may well work satisfactorily for the global domain there are usually local areas where it is less than ideal. One approach to this problem is to do local capping based on the data close to individual blocks or the data used to estimate individual blocks so that the capping changes on a block by block basis. An approach to achieving this is examined from a practitioner's standpoint and the results discussed.

**4:05 PM**

## **New SEC Rules for Disclosure of Exploration Results, Mineral Resources and Mineral Reserves: What You Need to Know**

*K. Awuah-Offei; Mining & Nuclear Engineering, Missouri University of Science & Technology, Rolla, MO*

The Securities and Exchange Commission (SEC) has adopted new rules on how mining firms registered in U. S. markets are to disclose exploration results, mineral resources and mineral reserves. These rules are intended to better align U. S. rules with the CRIRSCO guidelines that are in force globally. This presentation discusses the major changes introduced by the new rules and their impact on how mining professionals and firms estimate and disclose exploration results, resource and reserves. The paper reviews the major differences between the rules and the SEC's Industry Guide 7 as well as differences between the rules and other CRIRSCO-based rules. The presentation highlights the role of qualified persons in the proposed rules.

## WEDNESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 503

### Mining & Exploration: Innovations & Technologies: Automation in Mining: The Present and The Future

**Chairs:** *M. Yildirim, Caterpillar Inc, Chandler, AZ*  
*E. Gilliland, Virginia Tech, Blacksburg, VA*

2:00 PM  
Introduction

2:05 PM  
**Agent-Based Optimization for Truck Dispatching in Open-Pit Mines**

*M. Owusu-Tweneboah<sup>1</sup>, V. Temeng<sup>1</sup> and K. Awuah-Offe<sup>2</sup>; <sup>1</sup>Mining Engineering, University of Mines and Technology, Tarkwa, Western Region, Ghana and <sup>2</sup>Mining & Nuclear Engineering Department, Missouri University of Science and Technology, Missouri, MO*

Although, the literature contains many dispatch algorithms none of them was specifically developed for autonomous trucks that are intelligent (i.e. each truck has its own artificial intelligence). Truly intelligent autonomous trucks will require a new generation of dispatch algorithms. This work proposes an agent-based truck dispatch algorithm that conceptualizes trucks as intelligent agents that make autonomous dispatching decisions to maximize their utility. The advantages of this algorithm includes adaptive utility functions that encapsulate all of management's objectives and agent's with broad situational awareness. They are also more suitable for autonomous trucks. We evaluate the new algorithm against simple 1-truck-for-N-shovels dispatch strategies using discrete event simulation. The simulation results show that the new algorithm has significant advantages over 1-truck-for-N-shovels dispatch algorithms. Future work will compare this algorithm's performance against multi-stage dispatch algorithms.

19-044

2:25 PM  
**Preparedness of Ghanaian Mine Stakeholders for Adoption of Autonomous Surface Mining Systems**

*B. Kansake<sup>1</sup>, F. Kaba<sup>3</sup>, N. Dumakor-Dupey<sup>2</sup> and C. Arthur<sup>2</sup>; <sup>1</sup>Mining and Nuclear Engineering Department, Missouri University of Science and Technology, Rolla, MO; <sup>2</sup>Mining Engineering, University of Mines and Technology, Tarkwa, Western Region, Ghana and <sup>3</sup>Mining, Newmont Golden Ridge Limited, Akyem, Eastern Region, Ghana*

Autonomous mining systems have been deployed for improving mine performance. However, there is fear of job losses. Adoption of autonomous systems is envisaged to be resisted by major stakeholders in Ghana due to high illiteracy and unemployment. This paper assesses the preparedness of Ghanaian mining stakeholders for adoption of autonomous systems to

Ghana's surface mining industry. Closed and open-ended questionnaires administered to mine stakeholders. Respondents were generally unwilling to accept autonomous systems into Ghanaian mines due to fear of increased unemployment. We propose setting up of a mining education fund (MEF) for training stakeholders in autonomous mining systems.

19-009

2:45 PM

## The Industrial Internet of Things (IIoT) and Autonomous Vehicles in Underground Mining in the US

*K. Costner<sup>1</sup>, F. Günther<sup>2</sup>, H. Mischo<sup>2</sup> and J. Brune<sup>1</sup>; <sup>1</sup>Mining Engineering, Colorado School of Mines, Tomball, TX and <sup>2</sup>TU Bergakademie Freiberg, Freiberg, Sachsen, Germany*

Underground autonomy has been explored for the past 50 years to improve safety and productivity in mines. Since then, mining equipment has been able to improve productivity while also separating and distancing workers from hazards. While remote operation and automation improves the safety of the mine, more recent trends go towards autonomous, robotic operation of certain mining equipment. Equipment that usually follows a simple pattern of motion, such as haultrucks or track-bound vehicles lend themselves more easily to autonomous operation than equipment that required more complex controls. This presentation looks at the applications for robotic equipment and the role of the Industrial Internet of Things (IIoT) role in autonomy.

19-147

3:05 PM

## Anthropogenic Autonomy: The Human Aspects of Mining Automation

*C. Gilbert; Caterpillar, Tucson, AZ*

Mining technology is at the forefront of any modern-day mining operation. Command for Hauling truck automation combines existing mining technologies into a machine capable of operating on its own, making safe decisions, and maintaining consistent, predictable production goals. With several sites currently operating with autonomous haulage across the globe, Cat Command for Hauling has enabled productivity increases of over 20%, and has moved nearly one billion tonnes autonomously in the past five years. But long before the trucks begin hauling autonomously, the implementation journey involves extensive preparation, training, and change management. People, processes, and technology on a mine site make up a three-legged stool: each one is crucial in successful implementation. Without well-trained people and efficient processes, technology will only exacerbate current operational issues. But if the right processes are in place, the potential benefit through utilization improvements can have significant gains on safety and production on site. Training regimens, personnel requirements, and operator feedback is compiled here to provide insights into the human element of autonomous mining.

**3:25 PM**

## **A Mixed Integer Linear Programming Approach Towards Truck Dispatching Problem in Surface Mines**

*A. Moradi Afrapoli, M. Tabesh, S. Upadhyay and H. Askari-Nasab;  
Department of Civil and Environmental Engineering, University of Alberta,  
Edmonton, AB, Canada*

Truck dispatching tools make decisions on the next destination of trucks in surface mining operations. Several decision making models have been developed and published to make optimal truck dispatching decisions in the past 50 years. However, thus far developed models ignore some important objectives such as meeting path flow rate requirements. In this paper, we introduce a mixed integer linear programming model that dispatches trucks to shovels considering multiple important objectives and limitations. The goal in presenting this model is to develop a truck dispatching model that minimizes cumulative lost time for the entire active material handling fleet, including both shovels and trucks, as well as minimizing fluctuation in required path flow rates while respecting operational constraints such as truck capacity, shovel digging rate, and processing plants feed rate. To test the performance of the developed truck dispatching model, we implemented it in an integrated simulation and optimization model of an iron ore case study. The case-study illustrates and quantifies the improvements in various mining operation KPIs when the new model replaces the benchmark dispatching tool.

**3:45 PM**

## **Automated Technologies, Artificial Intelligence, and Machine Learning in Mining: A Business Case**

*Z. Hyder<sup>1</sup> and K. Siau<sup>2</sup>; <sup>1</sup>Business and Information Technology, Missouri University of Science and Technology, Rolla, MO and <sup>2</sup>Business and Information Technology, Missouri University of Science and Technology, Rolla, MO*

Automated technologies, artificial intelligence, and machine learning are getting global attention as the modern technologies impacting the future technological, economic, social, and communal makeup of our societies, businesses, and industries. These technologies have the potential to bring positive as well as negative changes. In mining, the use of these technologies started with the introduction of semi-automated haulage trucks and has since been progressing to various sectors of mining industry and to many mining operations. In this paper, the authors have analyzed the potential areas of application of these technologies in mining along with their positive and negative impacts on the sector in general and on specific operations in particular. In addition to potential advantages and disadvantages of these technologies, the paper discusses various challenges and hurdles that the implementation of these technologies faces in the mining sector. The paper provides practical examples and case studies of successful and unsuccessful implementation of these technologies and discusses some best practices that can help in overcoming major obstacle when implementing these technologies.

**4:05 PM**

## **Creating the Digital Mine of the Future with Autonomous Systems and Drones**

*D. Ward; Airobotics, Petah Tikva, Israel*

Enabling automation of physical operations that impact core mining processes is the first step towards transitioning to the digital mine of the future. Automated drones are uniquely capable of performing frequent, repeatable aerial data collection and analysis missions, as well as relieving mining professionals from hands-on tasks, which are Dangerous, Dull and Dirty. Fully automated systems enable data collection & analysis methods by accessing hard to reach places and performing high-frequency data collection at a fraction of the time & costs. Dan Ward, Mining Technology Manager at Airobotics, will discuss the era of Digital Data Delivery, and share benefits that automated drone operations entail.

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## **WEDNESDAY, FEBRUARY 27**

*AFTERNOON*

**2:00 PM | ROOM 504**

## **Mining & Exploration: Innovations & Technologies: Technology Innovation and Applications: Gaining Value from Fleet Management Systems**

*Sponsored by: OceanaGold*

**Chairs:** *S. Dessureault, MST Global, Tucson, AZ*  
*K. Boyce, Caterpillar, Tucson, AZ*

**2:00 PM**

### **Introduction**

**2:05 PM**

## **Installing a CMMS for Managing Fixed and Mobile Assets in a Producing Junior Copper Gold Mining and Milling Operations and Measuring the Gains in Operating Productivity, Production Output and Equipment Reliability.**

*S. Britton; Operations, Rambler Metals & Mining, Baie Verte, NL, Canada*

Rambler Metals & Mining, Ltd is a Canadian junior Copper mining and milling company whose principle assets are the Ming Copper Gold mine and the Nugget Pond mill located on the Baie Verte peninsula, Newfoundland, Canada. In early 2018, the company installed a computerized maintenance management system (CMMS) and transitioned from a paper-based, breakdown driven repair strategy to a computerized data driven management system for maintaining its' fleet and assets. The CMMS software is a cloud based, cost

effective, planning tool that improved tracking, scheduling and executing repair work, as well as providing asset analysis and parts inventory management to drive down the ownership cost of using and managing each fixed and mobile asset. As a result, the mining/milling operations have enjoyed improved performance asset performance. For example, the underground haul truck fleet of 7 vehicles has increased its' availability percentage in the first 4 months has improved from the low 70 percent to consistently over 85 percent. This paper will document the decision and implementation steps for installing the CMMS software, plus present and discuss the gains made to date by the operations.

**2:25 PM**

### **How Can Modern Software Improve Strategic Openpit Planning?**

*R. Downer; OpenContour, Salt Lake City, UT*

Mining is an expensive and Managers want to explore or change production scenarios. The focus for efficient open pit mine operations must be to find the best pit geometry and schedule given the forecasted economics and plan inputs. A faster way to manage mine planning is needed. Opencontour software can help mining companies move past that problem by making pit design and scheduling easier. An engineer can quickly import base surface contour and block models to rapidly gain a graphical representation to specify and review. Opencounter also links the designs with schedules. The software is designed to quickly create iterations on the plan and then view and compare physical and financial data. The cloud based software with web browser access means that IT is minimized and mining engineers are given advanced capabilities. The interface is accessible through a standard browser such as Google Chrome. Data doesn't leave your computer, providing for the safety of your information. The integrated speed of design, analysis, and accessibility means that the mine team can rapidly work through multiple prototypes to find the most optimal changes necessary to meet market conditions.

**2:45 PM**

### **Ensuring Your Fleet Management System Lives Up to Its Full Potential**

*A. Da Silva; Customer Value, Modular Mining Systems, Inc., Tucson, AZ*

With today's technologies, mines are capable of operating more efficiently and productively than ever before. However, simply investing in the latest solutions is no guarantee that mines will realize and sustain the persistent results they seek. For technology to deliver maximum value, implementation must be accompanied by a structured program encompassing systems validation, workforce training and skills development, and mindset-management at all levels. This presentation will discuss how deploying industry-leading technologies alongside a comprehensive, value-focused performance assurance program can facilitate an environment of continuous improvement. Within this framework, mines are able to meet their immediate goals while also achieving lasting results over the life of mine. Through examples, we will demonstrate how an investment in performance assurance has helped several mining operations overcome recurring challenges, resolve performance issues, and achieve greater realized value-in-use from their fleet management system.



**3:05 PM**

## **Fleet Management – Advanced Features and Integration**

*S. Kirkman; Caterpillar, Brisbane, QLD, Australia*

While most of the world's larger mines use some form of Fleet Management System, many are using these systems for little more than recording production. However, those who make use of the more advanced features of their Fleet Management System, and can integrate with rest of their operations, stand to achieve the greatest gains. During the session we will discuss the productivity improvements that are available through advanced features such as the management of shift change, fuelling and payload, the use of open assignment to achieve production goals, and dynamic blending functionality. A case study will be provided, illustrating the very significant improvements that can be achieved. Finally, we will discuss a model for the addition of customer specific functionality to a standard Fleet Management product that allows for integration with a mine's other operational systems, without limiting the ability to maintain, support and upgrade the core Fleet Management System.

**3:25 PM**

## **A New KPI to Monitor Fuel Optimization, Mean Time Between Fueling (MTBF)**

*M. Yildirim; Global Mining, Caterpillar Inc, Chandler, AZ*

One of the most common material handling method in surface mining is the truckshovel operation. The cost of truck-shovel operation includes Hauling, Loading, Drill & Blast, Haulage Support, and Other Functions. Haulage cost dominates the total operating cost with a 45-50% contribution. The major contributors of haulage cost are Fueling (18%), Tires (16%), Operator (14%), Owning (22%), Repair & Maintenance (30%). The focus of this work is Fueling Cost. Optimization of the fueling cost can be achieved in two different ways: 1Reducing the fuel consumption rate 2Reducing the time consumption at the fuel station. There are many studies performed for years to reduce the fuel consumption rate by running trucks more efficiently. However, there is no Key Performance Indicator (KPI) formula that shows the effect of fueling time on mine production. Fueling time has direct effect on the operating time as it is one of the major operating delays in mine operations. This paper shows the way to calculate the effect of fuel time on overall mine productivity and the potential gain once optimized. A new KPI name is introduced by this study which is called 'Mean Time Between Fueling'

**3:45 PM**

## **Becoming a Data-Driven Operation: Barrick Goldstrike Underground**

*M. Antunano; Goldstrike Underground, Barrick Nevada, Elko, NV*

The process to become a data-driven operation require the interaction of several elements to make it possible; most importantly a consistent data management policy and culture change. This process is even more challenging in Underground Operations where gathering reliable operational data is difficult not only for the physical constraints but the complexity associated to them. In 2013 Goldstrike Underground started this process, first as a site initiative and later as part of Barrick's Digital Transformation, evolving from using data in a limited fashion to depend on it almost completely enhancing awareness on our processes and triggering actions to improve them. This presentation will asset the challenges faced, lessons learned and outcomes achieved during this process at Goldstrike Underground as well as the opportunities generated by it.

**4:05 PM**

## **Machine Intelligence Systems – Simplifying Production Reporting Through Automation**

*C. Nelms; Mining Division, RDOIC, San Antonio, TX*

Visual display of minesite operations and real time production. Competition among operators regarding who is the most efficient. Playback of a previous day, week or month of a load cycle or machine status in an instant. Automated reporting of load and dump quantities or machine status for production or maintenance review. These are all aspects of the new means by which a mine can operate with a machine intelligence system. The discussion will present a “Day in the Life” of a mine with a simulator showing real time machine status of an active mine site over a 24 hour period.

**4:25 PM**

## **Haul Cycle Truck Productivity Improvement by Enhancing Present Short Interval Control Tools Utilizing Deep Neural Networks**

*C. Viejo, C. Carlson and B. Danic; Teck Resources, Vancouver, BC, Canada*

Haul cycle productivity is a significant factor for any surface mining operation around the world. Impacts to truck productivity are generally related to a combination of road conditions and design, payload variance, driver's experience, weather variation, machine component life and truck model. These variables in combination are not accounted for in fleet management systems present speed projections and dispatching algorithms leading to suboptimal truck-route assignments. In this paper, we propose a wide and deep neural network solution to identify variability in single truck speed, by modelling individual truck, driver and external factors and predicting vehicle productivity from real-time path reconstruction using GPS and sensors information. Targeted productivity gains can be locked in by identifying causes of variances in short intervals, close or near real-time to be addressed by supervisors, training department, maintenance crew, road crew, dispatchers and senior management in mines.

**WEDNESDAY, FEBRUARY 27**

*AFTERNOON*

**2:00 PM | ROOM 505**

## **Mining & Exploration: Management: Economic Development: The Importance of Reimagining Mining Communities**

*Chairs: E. Muteb, Freeport-McMoRan, Morenci, AZ  
T. Hosick, Phoenix, AZ*

**2:00 PM**

**Introduction**

**2:05 PM**

### **Building Economic Resilient Mining Communities – A Roundtable Discussion**

*E. Muteb and T. Hosick; Freeport-McMoRan, Morenci, AZ*

Mining investments and stakeholder interactions have the potential to serve as a positive catalyst in sustainable development for host communities. Collaboration and action between governments, companies, and communities is essential in realizing the full potential of these investments. Encouraging the economic diversification necessary to developing resilient communities that can flourish beyond the life of the mine is a common challenge across many host communities. Initiatives, such as ICMM's Closure Guidance and the United Nations Sustainable Development Goals continue to encourage the private sector to define its role in this space. Using Freeport-McMoRan/Climax Molybdenum's Henderson Operations as a case study, the challenges of economic diversification will be explored through the perspectives of the mining industry, academia, and local governments through a facilitated discussion.

**4:05 PM**

### **Local Returns on Tax Forfeited Lands**

*J. Marinucci; Lands & Minerals, St. Louis County, Hibbing, MN*

In Northeastern Minnesota, the value of the land is measured in many ways. This value is defined by the vast timber and gravel resources, beautiful lakes and landscapes to fish, hike, bike and more. This land is also home to one of the top 5 mining regions in the United States. As the steward of the State of Minnesota's Tax Forfeited properties, St. Louis County is maintaining the ability to develop lands for the best use possible. This is a continuous process that requires strong partnerships to execute a vision of both preservation and growth for the benefit of the Minnesotans.

## WEDNESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 506

### Mining & Exploration: Operations: New and Expanding Mine Operations

*Chairs: J. Anderson, Barrick, Elko, NV*

2:00 PM

#### Introduction

2:05 PM

#### Shaft Sinking Ventilation and Refrigeration Systems with Roadheader

*C. Rawlins; Mining, SME, Oakville, ON, Canada*

Traditional shaft sinking (drilling and blasting) generally allow for the application of ventilation and associated equipment. As a first in deep mining shaft sinking, when mechanised equipment such as a Roadheader is applied, there is an additional demand on the system to counter the heat load from the equipment within the shaft. The application of air only is not adequate to offset the heat loads with such a system and refrigeration with heat exchanger/s are needed. The shaft walls were frozen to contend with the influx of water into the shaft and due to the rock formations in the area. The shafts were frozen from surface to about 700 m below surface. There are two ventilation systems applied for the shaft sinking system, i.e. a winter ventilation system and a summer ventilation system. The ventilation systems operate with a force and an exhaust fan system and depending on the season, either the heater of the heat exchanger system is applied. The shaft sinking system is scheduled in phases, i.e. shaft sinking and temporary lining, then the SBR is raised (removed) to surface where after the Galloway is lowered into the shaft to do the permanent lining from shaft bottom to surface.

2:25 PM

#### Stockpile Facility Analysis Using Dynamic Simulation

*B. Syers<sup>2</sup> and M. Franklin<sup>1</sup>; <sup>1</sup>MOSIMTEC, LLC, Herndon, VA and <sup>2</sup>Twin Metals Minnesota, St Paul, MN*

MOSIMTEC LLC (MOSIMTEC) built a simulator for Twin Metals Minnesota LLC (TMM) to help solve questions surrounding the company's stockpile design. MOSIMTEC and TMM have previously worked together to develop simulation models of specific underground actions for use in supporting engineering studies, including stope production and material handling. This new simulation focuses on stockpile facility sizing for TMM's underground mining project prefeasibility study. For mining projects, having a large Coarse Ore Stockpile (COS) is a benefit to the operation and provides flexibility to overcome typical operating issues such as shut downs. The COS also decouples the mine and the mill, allowing each to operate efficiently in their own shift work time. While operators prefer to have a large COS, the TMM project is challenged to reduce project footprint and infrastructure height as much as possible, whilst maintaining target production throughput. Hence, MOSIMTEC created a simulation of the ore flow system from crushers underground to the COS on the surface. The simulation was used in order to help with the design criteria for the stockpile facility, including the underground conveyor capacity.

**2:45 PM**

## **A Brief Look into New Portal Mine Planning and Execution**

*P. Braden; Underground Engineering, Barrick Gold Corp, Elko, NV*

Many times within the mining industry, mineralized deposits cannot be fully recovered due to constraining circumstances. Though the ore body could be mined effectively by an open pit, environmental and regulatory constraints, paired with many other limitations, may decrease the overall effectiveness of a surface operation. Circumstances such as these may bring the opportunity of a portal mine to the discussion table. Once a portal mine has been selected as the most profitable option for an UG, planning and execution must commence. This presentation will discuss many aspects of the new portal mine within the Arturo Mine located in Northern Nevada, a joint venture partnership between Premier Gold and Barrick Gold Corporation, operated by Barrick Gold Corporation.

**3:05 PM**

## **The Construction of Two Small-Scale Caving Mines at La Encantada Mine**

*A. Sinuhaji; Mining Engineering, First Majestic Silver Corp, Vancouver, BC, Canada*

First Majestic Silver's La Encantada is a producing mine, with a capacity of 3,000 tpd. The mine has been in production since 60 years ago. The previous owners of the mine have employed post pillar cut and fill, with rock backfill material containing higher grades than the current mining cut-off grade. The La Encantada team is currently constructing two small-scale caving mines, San Javier Breccia and La Prieta mines, to exploit the high grade material that is left as pillar, as well as the economical backfill material. Sublevel and incline caving methods are currently being investigated for the two potential mining zones above, respectively. In order to meet the objective above, the mining levels of the new caving mines have to be developed in the rock pillar between the old mining levels. The poor rock quality of the development area, combined with lack of geological and geotechnical information and different survey systems used throughout the mine life, has made the construction process becomes quite challenging. The paper discusses the studies and steps carried out to ensure the safe construction of the mines and to bring them into production within the approved budget and schedule.

**19-121**

**3:25 PM**

## **Underground at Kennecott: The Past, Present, and Future**

*W. Robertson; Underground Project Development, Rio Tinto, Salt Lake City, UT*

The Drainage Gallery Ore (DGO) deposit, Rio Tinto's underground production mining beneath the Kennecott pit, has the potential to be much more than a highgrade boost to the mill feed. It is part of a larger strategic opportunity to add value to existing operations and powering a perceptual shift change of acceptable mining methods at a surface controlled operation. Utilizing 30+ years of underground history, the DGO operation is setting the stage for large scale underground operations ensuring collaborating with open pit operations to maximize the potential of the Kennecott property.

### 3:45 PM

#### Expansion of the Cuajone Mine, Southern Peru Copper

*J. Salazar Muñoz; Mining, Mining Engineering, Lima, Lima, Peru*

Expansion of Cuajone Mine and Concentrator Plant to 125 KTPD (Kilo Metric Tons per Day of Processing) is required to offset the copper grades decrease beginning in 2022, so fine copper production can improve to 202,000 MT per year. The change in copper grade is 0.64% in current years. Starting 2022, it will be 0.49%. Cuajone reserves are 1.8 Billion MT, meaning there is enough ore to suggest alternatives to increase production contributing to value and sustainability to Southern Peru. The proposed alternative of expansion has positive economic and financial indicators over a period of 15 years of evaluation. After assessing several expansion alternatives the 125 KTPD alternative has the best results.

### 4:25 PM

#### Rehabilitation of Resolution Copper's No. 9 Shaft

*M. Watt<sup>2</sup> and A. Chaudhary<sup>1</sup>; <sup>1</sup>Resoluion Copper, Rio Tinto Projects, Superior, AZ and <sup>2</sup>RSVUSA Consulting Inc., Gilbert, AZ*

Resolution Copper's No. 9 Shaft was completed in 1972 to a depth of 4,823' and has been out of operation and flooded for more than 20 years resulting in largely unknown conditions. Deepening of the No. 9 Shaft by an additional 2,000' to support Resolution Copper's orebody characterization program and mine development requires the shaft to be rehabilitated with a life span of 50 years. This paper describes an exciting project under development in Arizona including aspects of engineering design, the challenges, and solutions of the work completed to date.

## WEDNESDAY, FEBRUARY 27

AFTERNOON

### 2:00 PM | ROOM 703

#### MPD: Chemical Processing: Secondary Value Recovery

*Chairs: B. Carlson, Gopher Resource, Plymouth, MN  
K. Mills, RPMGlobal, Greenwood Village, CO*

### 2:00 PM

#### Introduction

### 2:05 PM

#### Experimental Methods of Flowsheet Development for Hard Drive Recycling by Preferential Degradation and Physical Separation

*B. Ott, P. Taylor and E. Spiller; Metallurgical and Materials Engineering,  
Colorado School of Mines, Golden, CO*

Neodymium recycling from computer hard drives by the mineral processing practice of liberation and separation is envisioned and evaluated. Magnetic material is liberated from the hard drive, constructed mostly of malleable



metals, by preferential degradation of the brittle magnet material. The process developed is shown to recover greater than ninety-five percent of the magnet material with a product grade of over 80 percent magnet material by mass. The process is designed to co-produce stainless steel, aluminum, nickel alloy, carbon steel, and printed circuit board concentrates as contributors to the recycle value of hard drives. The evaluation of hard drive encased value and processing costs shows the economic viability of the recycling process.

**2:25 PM**

## **Investigation into the Recovery of Rare Earth Elements from Illinois Basin Coarse Refuse by Heap Leaching**

*H. Tang, J. Werner and R. Honaker; Mining Engineering, University of Kentucky, Lexington, KY*

Laboratory heap leaching studies have been conducted on coarse refuse generated from a plant treating Kentucky No. 13 seam coal to assess the ability to economically recover rare earth elements (REEs) and other critical materials. An experimental program performed using heap leach columns evaluated the effects of pH and aeration rate on REE recovery, acid consumption, and leaching kinetics. The leaching process was found to proceed in two distinct stages, i.e., dissolution followed by acid generation. Optimum conditions were identified based on maximization of REE recovery. The results suggested that heap leaching is a promising method for minimizing the cost of REE recovery. Heavy REEs were preferentially leached which resulted in leachates having a REE distribution dominated by yttrium and neodymium.

**2:45 PM**

## **In-Situ Characterization and Pilot Injection Well Leach Testing to Evaluate and Optimize Secondary Recovery of Gold from Old Heaps**

*N. Clayton; Water and Environment, Mine Water Services, WSP USA Inc., Tucson, AZ*

Previously-leached gold ore heaps at two neighboring mines are being assessed for leach reactivation using raffinate injection wells to recover residual gold using innovative in-situ characterization, modeling, pilot testing and real-time monitoring techniques. Phase 1 involved comprehensive characterization of the heaps using sonic core drilling; core chemistry, metallurgy, mineralogy, and leachability lab analysis; advanced geophysical logging for in-situ hydrogeology and mineralogy evaluation; and 3D property and unsaturated flow injection numerical modeling to determine feasibility and best options for secondary gold recovery. Phase 2 consists of targeted injection pilot well leach testing, including intensive 3D monitoring of leach solution movement and chemistry in the subsurface.

**3:05 PM**

## **Recovery of Rare Earth Elements from Pennsylvania Acid Mine Drainage through Staged Precipitation**

*B. Vaziri Hassas and M. Rezaee; Energy and Mineral Engineering, The Pennsylvania State University, University Park, PA*

It has been estimated that the U.S. need for rare earth elements (REEs) can be met through the processing of secondary sources such as coal and coal by-product streams. Coal acid mine drainage (AMD) has been of environmental concern for decades but recently found to be an economical source

of critical elements including REEs. To develop a sustainable treatment of AMD, laboratory experiments were conducted for recovering REEs while encapsulating elements of concern. AMD samples used for this study were originated from abandoned mines or coal refuse piles of Lower Kittanning coal seam in PA. Characterization results revealed that the samples contain high HREE/LREE ratio in the range of 0.7 to 1.35. A total REEs recovery of up to 96% was obtained from the AMD samples through a staged precipitation process. The process parameters were then optimized for maximizing the recovery and grade of REEs, and the results are discussed in this paper.

### 3:25 PM

#### **A Novel Utilization of Blast Furnace Slags (BFS): Preparing High-Temperature Composite Phase Change Materials (C-PCMs)**

*C. Anderson and Y. Zhang; Colorado School of Mines, Golden, CO*

Blast furnace slag (BFS) is the main hazardous solid waste during the iron-making process, which has huge output and low comprehensive utilization rate. In this study, a novel utilization method for BFS to prepare high-temperature composite phase change materials (C-PCMs) was proposed. The porous structure and thermostability of BFS were first characterized. Then, three typical PCMs ( $\text{NaNO}_3$ , Al and  $\text{Na}_2\text{SO}_4$  with different operating temperature) were used to fabricate BFS-based C-PCMs by means of mixed sintering process, among them,  $\text{NaNO}_3$  had excellent chemical compatibility with BFS and the prepared C-PCMs had perfect phase change performance. Furthermore, the  $\text{NaNO}_3$ /BFS PCMs could retain good thermal reliability after 100 thermal cycles, which presented the potential application in the thermal energy storage system. In addition, the morphological structure, thermal reliability and heat transfer property of the  $\text{NaNO}_3$ /BFS C-PCMs were characterized by using SEM, TG-DSC, etc.

### 3:45 PM

#### **Circulation of Sodium Sulfate Solution Produced During NiMH Battery Waste Processing**

*A. Porvali, V. Agarwal and M. Lundström; Chemical and Metallurgical Engineering, Aalto University, Espoo, Finland*

Hydrometallurgical recovery of rare earth elements (REE) from NiMH battery waste can be performed using sulfuric acid leaching followed by selective precipitation as double salt ( $\text{RENa}(\text{SO}_4)_2 \cdot \text{H}_2\text{O}$ ) by adding  $\text{Na}_2\text{SO}_4$  as a precipitating agent. The formed double salts can be treated further with NaOH solution to form REE hydroxides. This study focuses on metamodeling of a simulated flowsheet with design of experiments (DOE). Based on literature survey, a process flowsheet was developed using HSC Sim software. The created flowsheet focuses on circulation of solution containing  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{SO}_4^{2-}$  ions and impurities liberated in the NaOH treatment of double salt precipitate. The effect of seven parameters (P1-P7) on seven responses (R1-R7) were modeled using central composite design (CCD).

19-046



**WEDNESDAY, FEBRUARY 27**

*AFTERNOON*

**2:00 PM | ROOM 707**

## **MPD: Comminution**

*Sponsored by: Moly-Cop*

**Chairs:** *M. Jorgensen, Jorgensen Engineering & Technical Services, Centennial  
O. Arafat, Metcom Technologies, Hamilton, ON, Canada*

**2:00 PM**

### **Introduction**

**2:05 PM**

### **Application of High Pressure Grinding Roll Technology in Silver Heap Leaching**

*T. Howard<sup>1</sup>, B. Carlson<sup>2</sup> and J. Bilant<sup>1</sup>; <sup>1</sup>Coeur Mining, Lovelock, NV and <sup>2</sup>Forte Dynamics, Fort Collins, CO*

High Pressure Grinding Roll (HPGR) technology has been evaluated to replace tertiary cone crushing at Coeur Rochester as an opportunity to improve silver recovery. In 2016 and 2017, an onsite and third-party pilot program was initiated to understand the impact to metallurgical recovery and heap leach performance the crusher would have when generating a crushed product. In 2018, Forte Dynamics evaluated the HPGR laboratory metallurgical data from Coeur Rochester and all third parties to develop field scale leach curves for the new crushing application. The laboratory recovery test work data was consolidated and upscaled to field conditions to simulate expected heap leach performance. Utilizing available metallurgical data, the introduction of HPGR technology has the potential to increase Coeur Rochester's ultimate silver recovery rate by 9%, from 61% to 70%, and shorten the overall timing of silver recoveries from 20 years to just over two years.

**19-040**

**2:25 PM**

### **HPGR: Why Skewing Is a Requirement for Operational Applications**

*S. Hannot, F. van der Meer, H. Knapp and T. Lundquist; Weir Minerals, Venlo, Netherlands*

High pressure grinding rolls (HPGR) are an energy efficient solution for comminution of industrial minerals and metal ores. The basic process involves compression and grinding of a particle bed in the operating gap between two counter-rotating rolls. Maintaining a controlled and evenly distributed operating pressure between the rolls is of high importance. As it is difficult to control feed segregation, the HPGR design should compensate and adapt for the uneven pressure distribution as much as possible. This work discusses one approach to compensate and adapt for the uneven pressure by allowing the rolls to skew relative to each other. The approach is supported by operating data from HPGR installations.

2:45 PM

## HPGR Roller Wear Management System

*M. Perrucci and D. Andreo; Process Industries, Mining, ABB Inc., Littleton, CO*

High Pressure Grinding Roll's (HPGR) rollers start to wear over a period of time, based on factors such as ore characteristics, operating pressure, feed material size and non-uniform feed presentation across the roller width. The rate of wear amongst the two rollers is typically not equal; this leads to differences in the tangential speeds of the rollers, resulting in a less effective grinding process due to the fact that the slip between rollers is not optimal. The higher the differential wear, the faster is the deterioration of the roller diameters and consequently the worse will be the comminution efficiency. In this presentation, a dynamic load share control for the HPGR rollers is presented, which allows the operators to equalize the wear rate and extend the roller life time. Called RollXtend™, this solution includes a load share factor which can be parameterized based on the wear measurement performed manually during maintenance procedure. Experiences from a site installation in South America are presented and compared with typical figures from conventional HPGRs without the dynamic load sharing.

3:05 PM

## Acquiring Plant Data for Grinding Circuit Performance Analysis

*O. Arafat, R. McIvor and K. Bartholomew; Metcom Technologies, Hamilton, ON, Canada*

To properly assess the performance characteristics of a grinding circuit, specific plant information is needed. To obtain a meaningful interpretation of a circuit's performance it is essential that the information is collected and analyzed using consistent and accurate methods. It is only upon successful collection and analysis of this data that specific changes to operating conditions and equipment be recommended with confidence to achieve performance improvements. Information is classified into two general groups. Existing data is information on the process and equipment which remains unchanged from day to day. It includes circuit flow sheets and equipment specifications. Required data is information that is collected through a grinding circuit survey. It includes stream sample characteristics, and instrument readings during the time of the survey. Samples are characterized for % solids, SG, and size distributions. The quality of the data is evaluated before concluding the survey was successful and subsequent circuit performance analysis can begin. An overview of the fundamentals of plant data acquisition using a systematic approach with practical examples will be presented.

3:25 PM

## An Innovative Mill Charge Analysis: MillSense

*E. Sharifi<sup>1</sup> and P. Blanz<sup>2</sup>; <sup>1</sup>Outotec Canada Ltd., Burlington, ON, Canada and <sup>2</sup>Outotec, Espoo, Finland*

Bearing pressure, power draw and other indirect indications of mill's volumetric charge are widely used for grinding mill control systems. Nealy all of these parameters are also influenced by variables other than volumetric charge such as density and temperature. Outotec has recently developed a new system measuring the volumetric charge with a more direct approach. MillSense sensor contains both strain gauges and accelerometers and attaches directly to a liner bolt for accurate charge position and volume measurement. In addition to the charge measurement, MillSense provides other vital inputs related to the mill's operation, such as media trajectory estimates and overall vibration levels. The accompanying advanced mill control system

provides new opportunities for reacting to ore hardness and other ore changes by adjusting the mill's ore feed, rotational speed and water feed. With a reliable system for mill state measurement and advanced control, the whole grinding circuit will achieve higher throughput, increased availability and improved liner life. This paper presents the potential process improvements and economic gains using MillSense technology.

**3:45 PM**

## **New Technologies for Vibratory Grinding of Minerals**

*S. Massman; General Kinematics, Crystal Lake, IL*

Mineral processors around the world are searching for new revenue streams with processes such as micron grinding and mechanochemical grinding. These advanced process techniques open up new opportunities in the comminution of numerous minerals, ores, and aggregates. One of the best ways to achieve consistent results during these processes is with new technologies of vibratory grinding drums. Recent advancements have allowed this style of drum to increase grinding energy transmitted to the material, generating higher throughput in a smaller footprint. In addition, today there are more tools and data available to optimize systems before installation. Learn how current market trends have influenced the R&D of this new product innovation and recent test data outlines how this has been accomplished.

**4:05 PM**

## **Microwave-Enhanced Comminution: Which Rock Types Are Suitable?**

*M. Nicco<sup>2</sup>, E. Holley<sup>2</sup>, p. Hartlieb<sup>1</sup>, R. Kaunda<sup>2</sup> and P. Nelson<sup>2</sup>; <sup>1</sup>Chair of Mining Engineering and Mineral Economics, Montanuniversität Leoben, Leoben, Austria and <sup>2</sup>Mining Engineering, Colorado School of Mines, Golden, CO*

Understanding how the mineralogy influences the efficiency of microwave irradiation could subsequently enhance comminution by facilitating the extraction of valuable minerals before processing the ore. Microwaves have been considered as a potential tool for weakening the rock before comminution, but they do not affect all rock types in the same way. This study aims to understand the mineralogical controls underlying rock mass weakening during microwave irradiation. Previous work showed that moderate irradiation time leads to a consequent reduction in rock strength via the propagation of an intraand intergranular fracture network with preferential mineralogical associations. This study examines the mineralogical associations of microwave-induced fracture networks in order to determine the causative mechanisms and thus the appropriate rock types for the application of this technique. Three types of granitic rocks with varying composition of hydrated minerals were exposed to 3kW microwave irradiation for 60 to 300 seconds. An integrated approach of micro computing tomography, optical and scanning electron microscopy was used to analyze the nature of the induced fractures.

## WEDNESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 705

### MPD: Flotation: Flotation Equipment and Operational Aspects

*Sponsored by: thyssenkrupp*

**Chairs:** *T. Bhambhani, Cytec Industries Inc., Stamford, CT  
R. LaDouceur, Montana Tech, Butte, MT*

2:00 PM  
Introduction

2:05 PM  
**Improving Flotation Circuit Performance  
with a Large Mechanical Flotation Cell**

*T. Mattsson<sup>1</sup>, R. Grau<sup>2</sup> and A. Rinne<sup>2</sup>; <sup>1</sup>Outotec, Canada Ltd, Burlington, ON, Canada and <sup>2</sup>Outotec, Finland, Pori, Pori, Finland*

After start-up of the first 500m<sup>3</sup> TankCell flotation cell in 2014, the over 300m<sup>3</sup> mechanical flotation cells have earned their place in large-scale flotation operations. These 500 to 630m<sup>3</sup> cells, designed for projects with large throughputs, provide savings in project capital and operational expenditure through savings in foot print, energy, and less equipment to install and maintain. Addition to savings in different project phases, these cells have proven to provide operational flexibility and improvements in flotation circuit control. In this paper case studies from 500 and 630 m<sup>3</sup> TankCell installations will be given. In the case studies the metallurgical performance before and after installation of a large TankCell will be compared.

2:25 PM  
**Rougher Flotation Cell Froth Level Control  
to Increase Copper Recovery**

*M. Ferra; REXA, West Bridgewater, MA*

In 2017 a copper mine near Globe, Arizona improved their production rougher cells productivity using Electraulic actuators in the flotation process by enabling excellent tank liquid and froth level process stability. Tank cell slurry volume can change due to feed/discharge fluctuations from neighboring tanks. When traditional pneumatic actuators are used, they have sluggish response times and overshoot due to the inherent physical property of air being compressible. Electraulic actuators have the benefit of hydraulic stiffness to deliver accurate and repeatable (0.1%) dart valve positioning. The results are an increase of the launderer copper concentrate grade by 2-3%.

**2:45 PM**

## **Consideration of the Pulp/Froth Interface in the Compartment Model of Flotation**

*R. LaDouceur<sup>1</sup>, P. Amelunxen<sup>2</sup> and C. Young<sup>1</sup>; <sup>1</sup>Metallurgy, Montana Tech, Butte, MT and <sup>2</sup>Aminpro, Lima, Peru*

Many challenges still exist with the development of precise and accurate predictive models for froth flotation. Most state-of-the-art models are based on the two-compartment model with entrainment; however, these models have difficulty in separating the role of froth zone recovery from collection zone recovery. For this reason, modern, commercially available flotation models are not capable of predicting some important phenomena that occur in industrial mineral flotation plants. In plant scale flotation, recovery of molybdenite is often slower in the presence of more hydrophobic species such as chalcopryrite, which is not typical of a first order kinetic process. Atypical kinetics for molybdenite are due to froth loading as opposed to constant froth phase or pulp/froth interface recovery. Information is needed on the grade of floatables in the collection and froth zones, the froth height, gas holdup in both collection and froth zones and atmospheric pressure acting on the overall system which were determined, and preliminary findings are presented.

**3:03 PM**

## **Effects of Two-Stage Grinding on Flotation of Performance of a Au-Cu Sulphide Ore**

*O. Bica<sup>1</sup>, E. Ozdemir<sup>1</sup>, I. Can<sup>1</sup>, H. Boz<sup>2</sup>, H. Hassoy<sup>3</sup> and Z. Ekmekci<sup>1</sup>; <sup>1</sup>Mining Engineering Department, Hacettepe University, Mining Eng. Dept. Beytepe/Ankara, TURKEY, Ankara, Ankara, Turkey; <sup>2</sup>Lidya Madencilik, Ankara, Turkey and <sup>3</sup>Artmin Madencilik, Ankara, Turkey*

Grain size distribution of the minerals in an ore determines liberation characteristics and requirements for grind size in flotation circuits. In most of Au-Cu sulfide ores, Au is usually distributed in sulfide minerals (e.g. pyrite, chalcopryrite, arsenopyrite, etc.) and non-sulfide minerals. In case of variable grain sizes, one stage grinding may not provide the optimum liberation and effective separation of valueable minerals. In this study, performance of single-stage and two-stage grinding on the flotation performance of a Au-Cu sulfide ore was investigated. The flotation circuit was based on bulk sulfide mineral flotation followed by regrinding and differential copper flotation. Variable Au grades (from 4 g/t to 30 g/t) in flotation feed resulted in fluctuations in the Au grade of the bulk flotation tails, even with similar Au recoveries. Two alternative bulk flotation flowsheets were tested to control and minimize loss of Au in flotation tailing. Mill-Float (MF) and MillFloat-Mill-Float (MF2) mode of operation were tested at different grind sizes. The results showed that MF2 circuit improved the recoveries and reduced loss of Au in flotation tail.

**3:23 PM**

## **Pre-Concentration of Alunite Using Froth Flotation to Improve Recovery and Grade**

*H. Askari Sabzkoohi<sup>2</sup>, F. Dehghani<sup>1</sup>, M. Salarirad<sup>3</sup>, A. Sachan<sup>1</sup> and T. Ghosh<sup>1</sup>; <sup>1</sup>Mining and Geological Engineering, University of Alaska Fairbanks, Fairbanks, AK; <sup>2</sup>Mining Engineering, Islamic Azad university Science and Research Branch, Tehran, Tehran, Iran (the Islamic Republic of) and <sup>3</sup>Mining and Metallurgy Engineering, Amirkabir University of Technology, Tehran, Tehran, Iran (the Islamic Republic of)*

The depletion of bauxite reserves around the world has necessitated the search for viable alternative sources of aluminum. The major non-bauxite

source of aluminum is Alunite. Lixivation is the common industrial practice of extracting aluminum from alunite, however, it invariably leads to significant losses due the formation of Sodium aluminosilicate and Potassium aluminosilicate complexes owing to the presence of quartz as a gangue mineral. Due to the low degrees of freedom of alunite, froth flotation, as a pre-concentration method, is a viable alternative to increase selectivity in downstream processes. In this study, flotation tests were performed by varying several parameters such as collector types and dosages, pH, and percent solids, to maximize recovery and grade characteristics of the product concentrates.

**3:43 PM**

### **Improving Froth Characteristics in FMI Morenci Concentrator Using Customized Frother Blend**

*J. De La Rosa<sup>1</sup>, B. Wilson<sup>1</sup> and E. Blanco<sup>2</sup>; <sup>1</sup>Mineral Processing, Solvay, Tempe, AZ and <sup>2</sup>Freeport-McMoRan Morenci Concentrator, Morenci, AZ*

Optimal flotation circuit performance is an integral part of attaining the highest possible degree of mineral separation. The performance of a flotation circuit is influenced by particle size, water chemistry, equipment, and mineralogy of the ore. Each ore body presents its own set of challenges, requiring a unique chemical scheme to maintain optimum recovery and concentrate grade levels. Creating unique, customized chemistry blends involves a significant amount of planning, lab work, plant trialing, and data analysis. However, with cooperation between metallurgical and operations teams, such a challenge is attainable. A customized frother blend, OREPREP® F-717, was jointly developed by Solvay and Morenci personnel for Freeport-McMoRan's Morenci concentrator in an effort to address opportunities to improve metallurgical performance. This paper addresses the successful development and implementation of OREPREP® F-717 at Morenci and its subsequent performance in the plant. OREPREP® F-717 improved froth mineralization and mobility, thereby improving both coarse and fine particle recovery while avoiding detrimental downstream effects.

**4:03 PM**

### **The Power of Bazin – Production Forecasting with the Bazin Methodology**

*F. Laroche<sup>2</sup>, D. Di Sandro<sup>1</sup> and A. Vien<sup>2</sup>; <sup>1</sup>Member SME, Eagle Farm, QLD, Australia and <sup>2</sup>Unkown, Logan Lake, BC, Canada*

Back in 1994, Claude Bazin presented a novel method for linking size data from milling predictions, to the feed input of flotation models. It was achieved with the revelation of a simple metal/mineral distribution versus size distribution relationship. This allowed optimisation of flotation feed P80 targets through grade and recovery predictions. Apply this further and we can forecast grade and recovery from a varying mine plan via product size distribution predictions. This paper presents a case study where this elegant method has been used, at Highland Valley Copper, to build a very powerful forecaster at their process plant, built from historic operating data. The methodology has been used by this operation to forecast production on a quarterly, annual and life-of-mine basis since the late 1990's. It has been upgraded several times to incorporate new drivers as the complexity of feed stocks has increased over the years.

**19-116**

**4:23 PM**

## **Advantages of the mixedROW™ Flotation from FLSmidth**

*D. Lelinski, D. Stevens and A. Weber; FLSmidth, Midvale, UT*

FLSmidth supplies two types of flotation machines: WEMCO®, a self-aspirated one and the nextSTEP™ a forced-air, externally aerated machine. FLSmidth has delivered more than 54,000 flotation cells worldwide. As both machines operate differently and recover different particles (size, liberation, hydrophobicity) and FLSmidth is the only supplier offering both types of machines, the focus has been to mix-and-match these machines. Initially in the mixedCIRCUIT and then in the mixedROW. A combination of machines in the plant having different functions i.e. rougher, cleaner, etc. is called a mixedCIRCUIT. Historically with WEMCO roughers and nextSTEP cleaners. A combination of forced air and self-aspirated machines in the same row is called mixedROW. FLSmidth has installed and tested a combination of nextSTEP and WEMCO cells in plants on different continents. This began a few years ago with the mixedCIRCUIT and more recently with mixedROW configurations. FLSmidth has even retrofitted brownfield installations to accomplish mixedROW configurations. Advantages of the mixedROW over a single type of flotation machine will be presented once permission to publish the results has been received.

## WEDNESDAY, FEBRUARY 27

AFTERNOON

2:00 PM | ROOM 612

### Research: Current Research Activities and Research Needs in Mining and Minerals Industry- Panel

**Chair:** *J. Rostami, Colorado School of Mines, Golden, CO*

#### Research Committee Panel

*J. Rostami; Mining Engineering, Colorado School of Mines, Golden, CO*

The panel discussion is coordinated by the Research Committee of SME to provide a forum for exchanging ideas and experiences about the research needs and current research activities in the field of mining, exploration, and mineral engineering. The panelists represent high level managers and individual researchers in industry and government. The panelists are involved in planning of future research activities in coal, metal, and industrial minerals both in surface and underground operations, and mineral processing.

#### Panelists Include:

**Srinivas Veeramasuneni**

*Vice President, Chief Innovation Officer, USG Corporation*

**Patrick Taylor**

*Director of Kroll Institute for Extractive Metallurgy,  
Colorado School of Mines*

**Paul Lever**

*CEO, Mining 3, Australia*

**Jez Leeming**

*Global Product Director – Entry Development Systems,  
Komatsu Mining Corp*

**Jessica Kogel**

*Director of NIOSH-Mining*

**Ferri Hassani**

*Webster Chair Professor, Department of Mining and  
Materials Engineering, McGill University*

**Rick Gilbert**

*Vice-President Technology, Freeport-McMoRan*

**Murali Gadde**

*Senior Director, Applied Analytics and Geotechnical Eng*

**Jay Armberger**

*Product Manager, Room & Pillar / Highwall Mining  
Underground Technology Solutions*





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