UTAH GEOLOGICAL SURVEY

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Utah's Industrial Mineral Landscape,

with a Great Salt Lake Update

Andrew Rupke
Utah Geological Survey
SME, February 15, 2023

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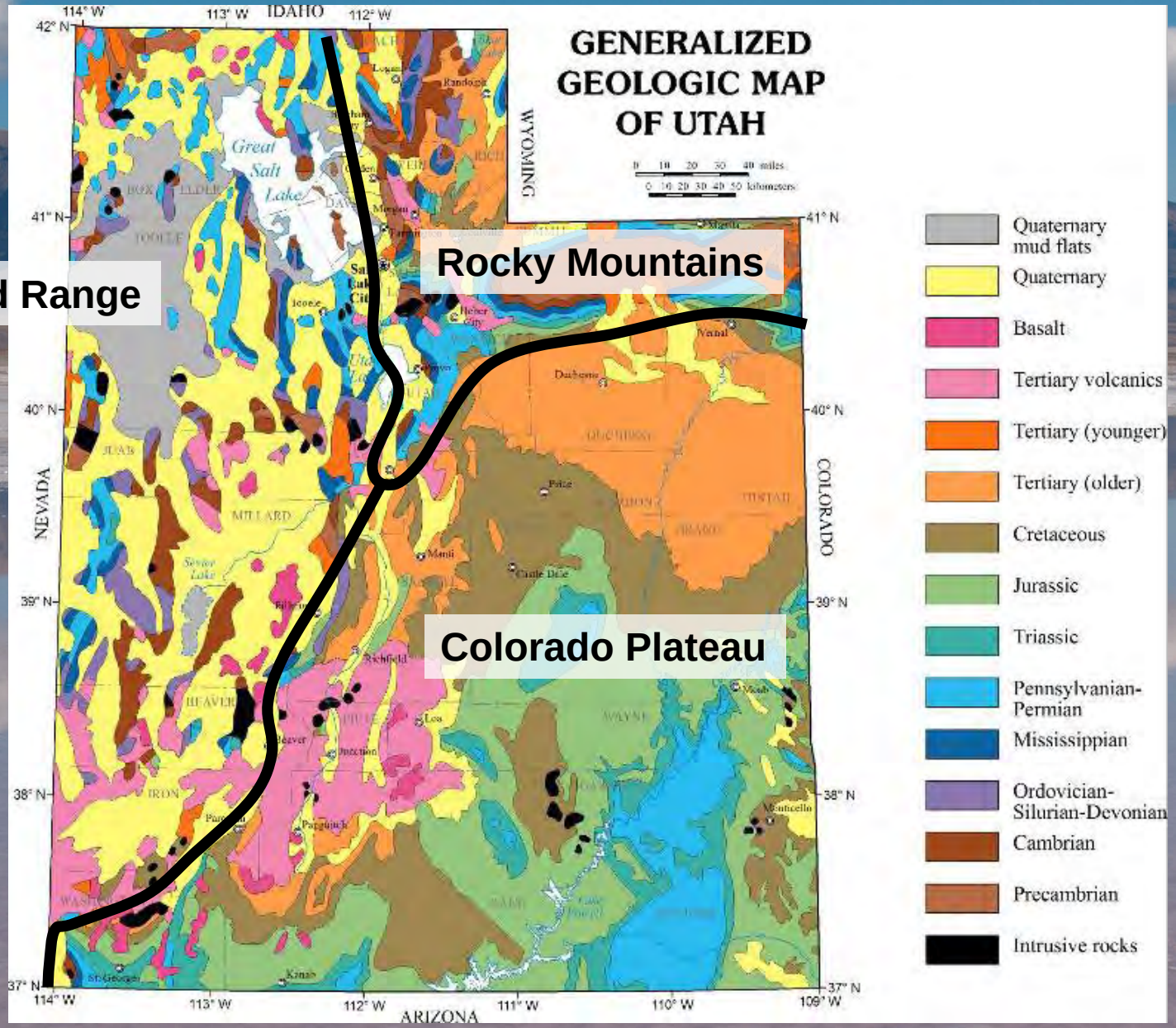

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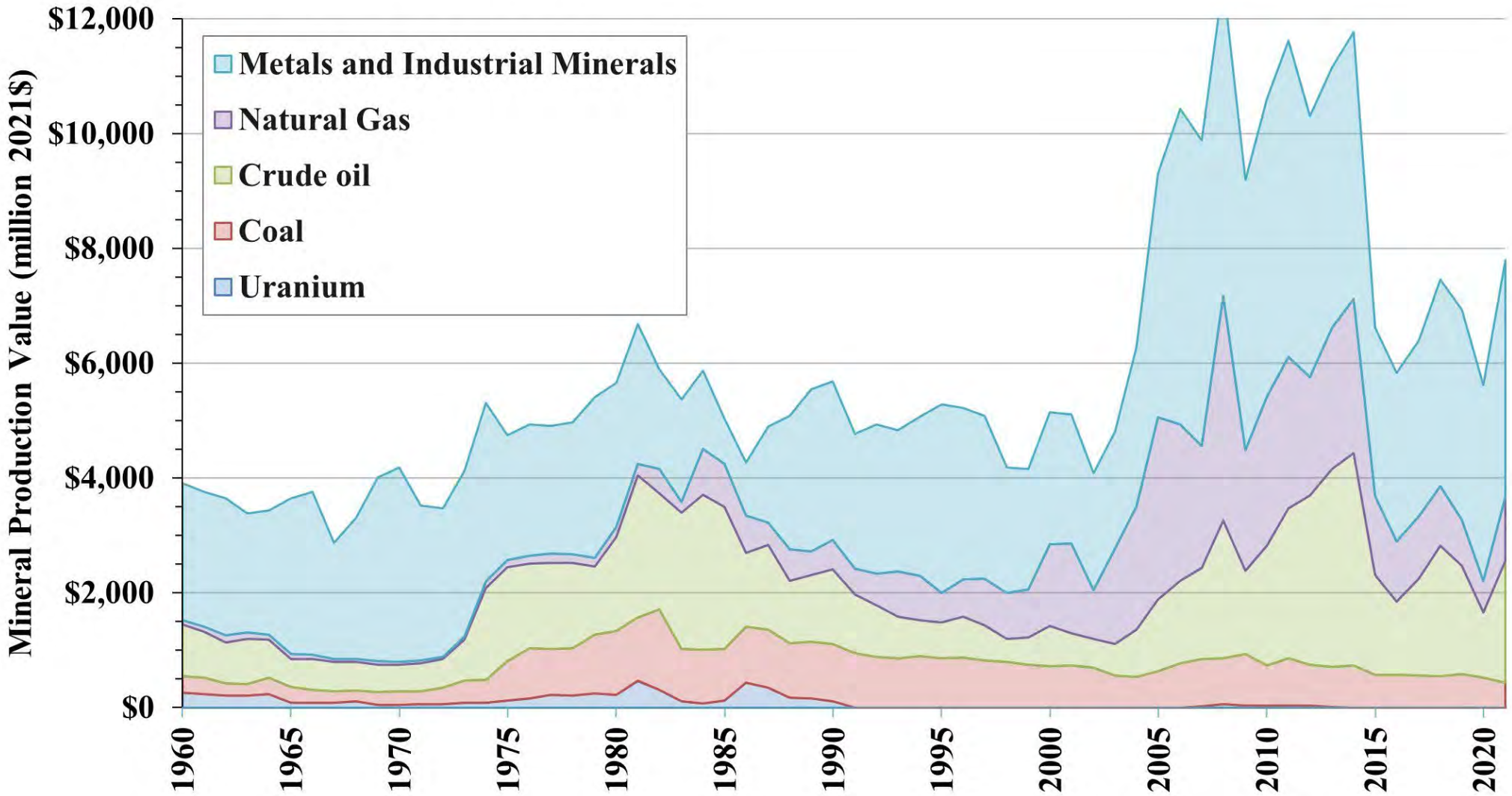
Utah Production Value



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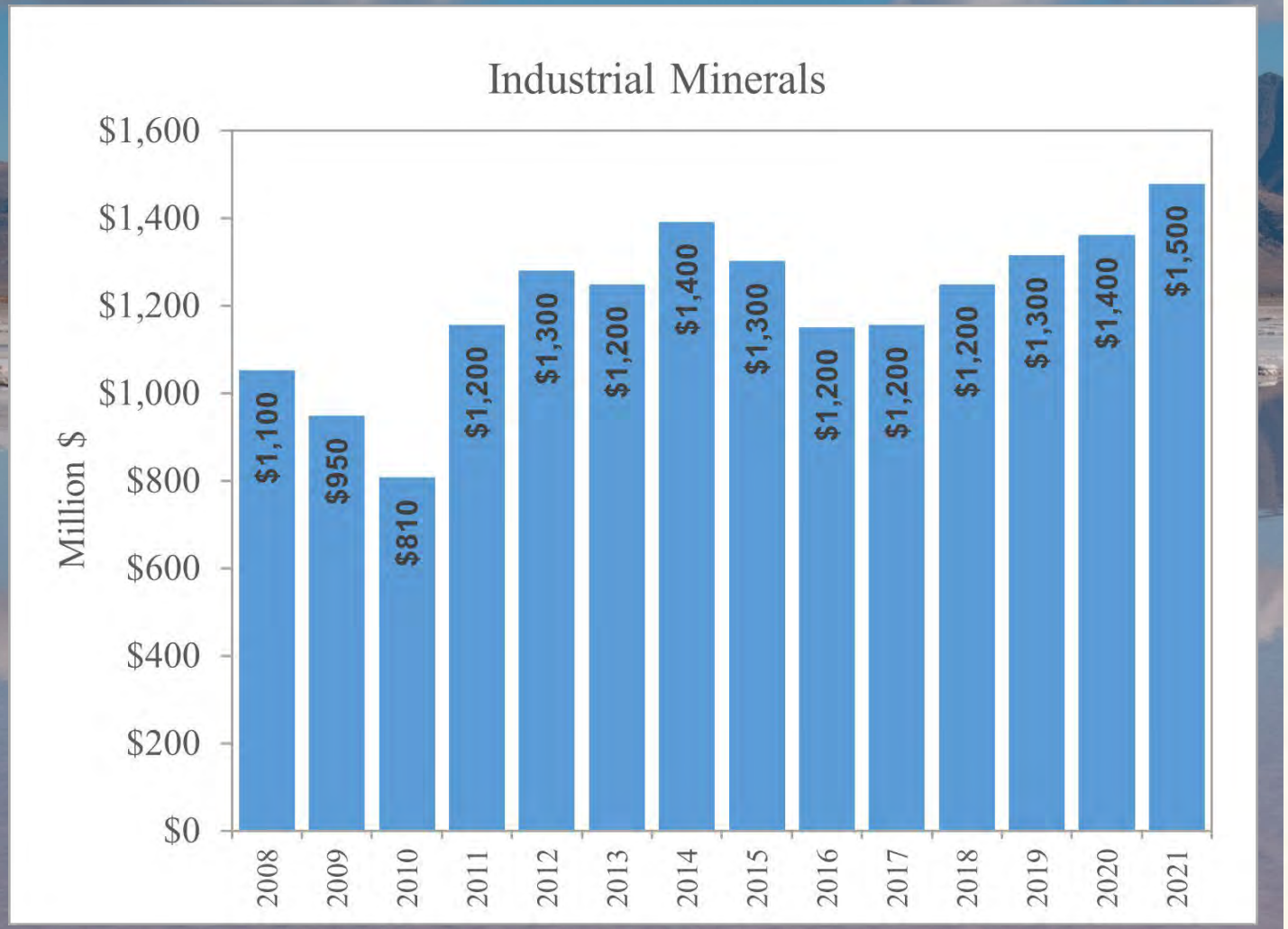

IM = ~1/3 of Utah's mining production value
Remaining value from metals and coal

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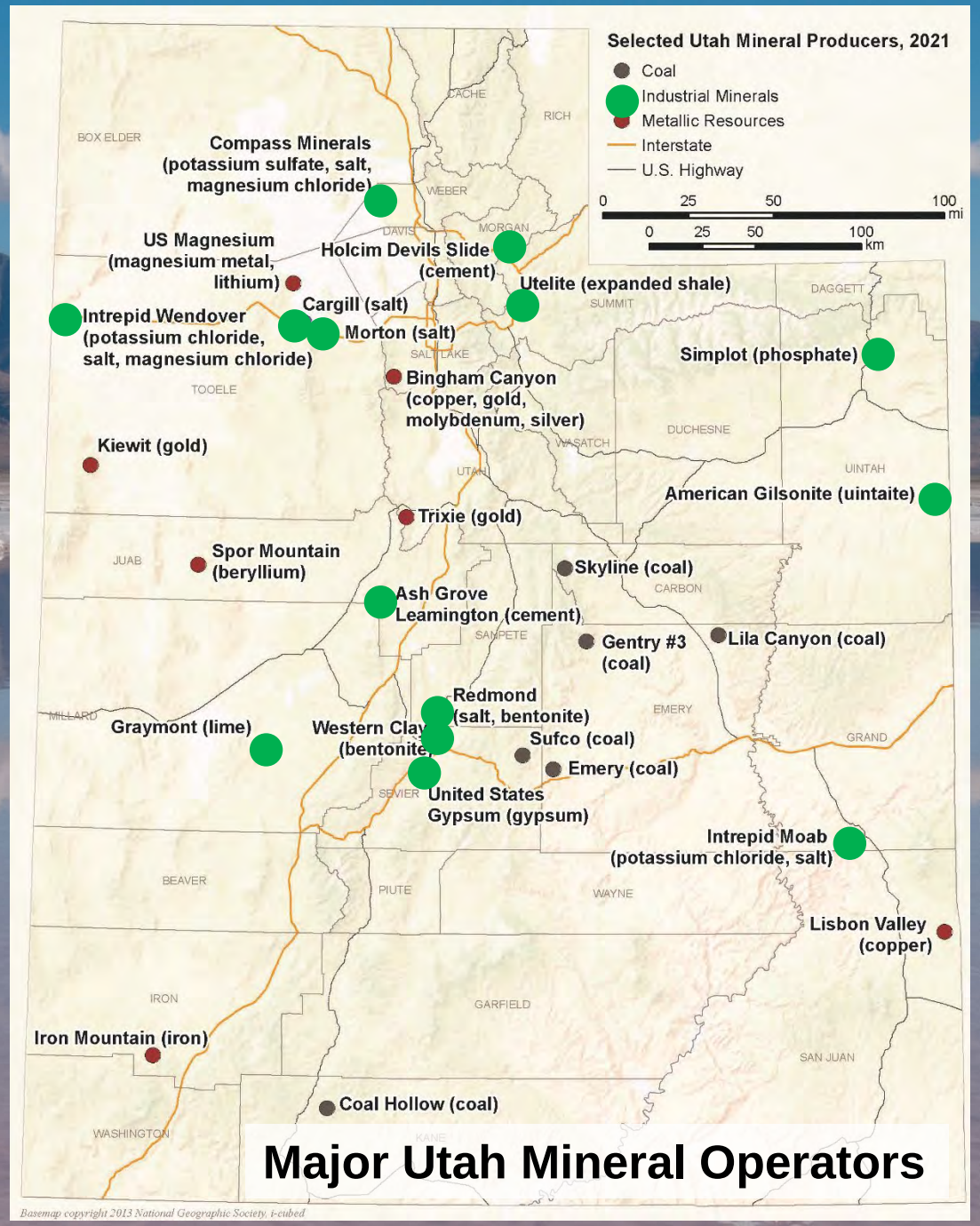

Major Utah Mineral Operators

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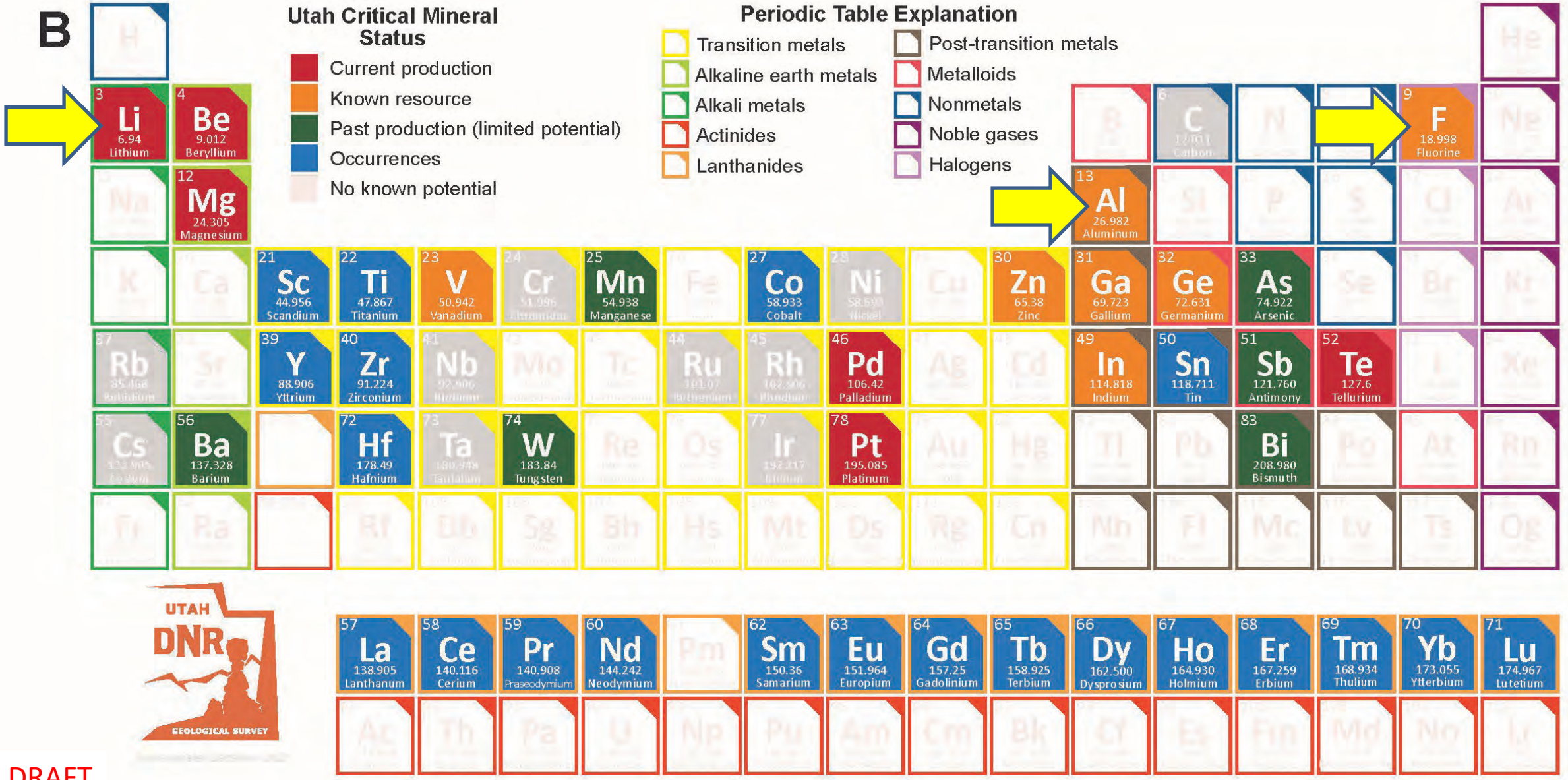
Critical Minerals of Utah



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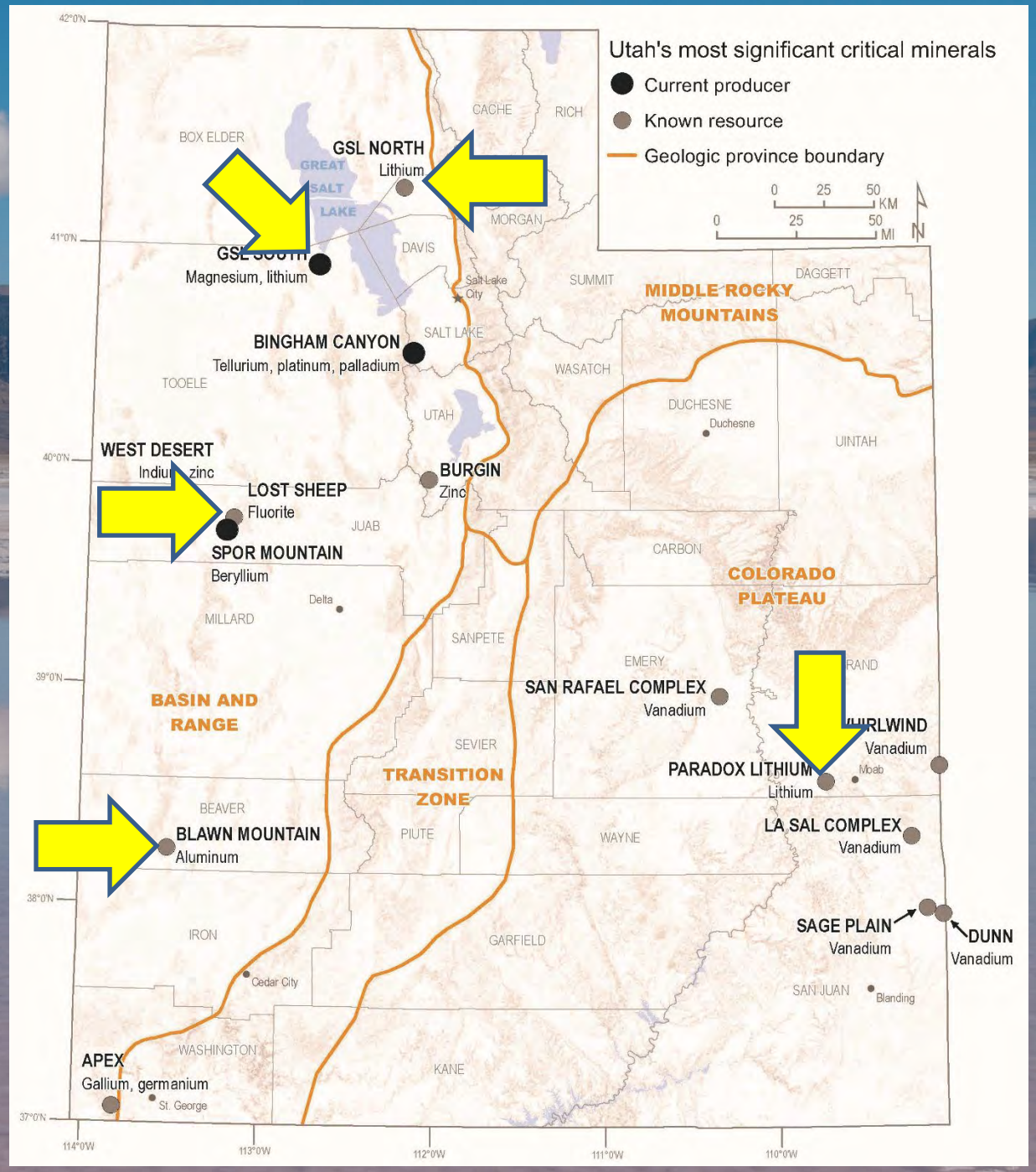
Critical Mineral Producers And Known Resources



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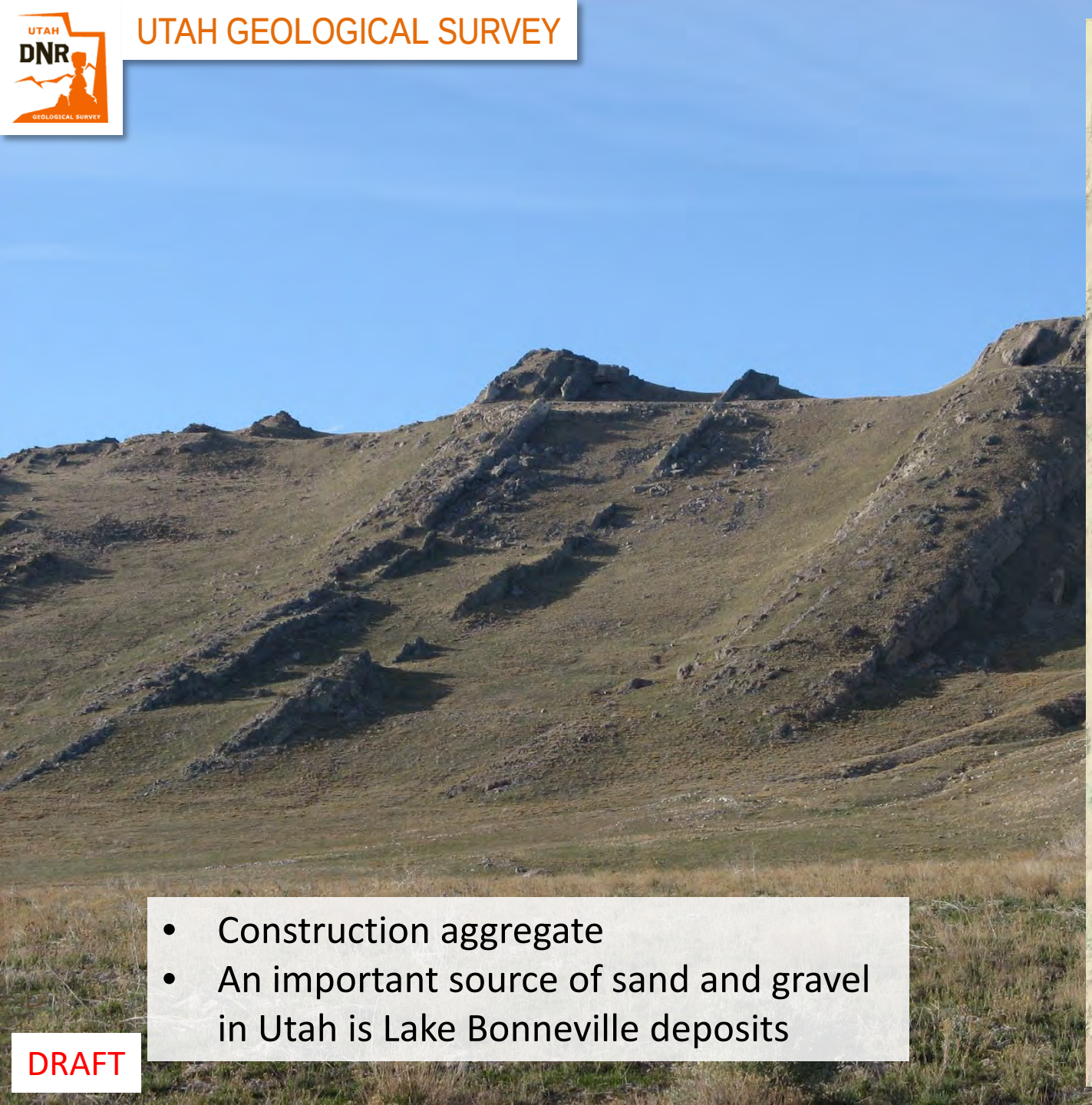

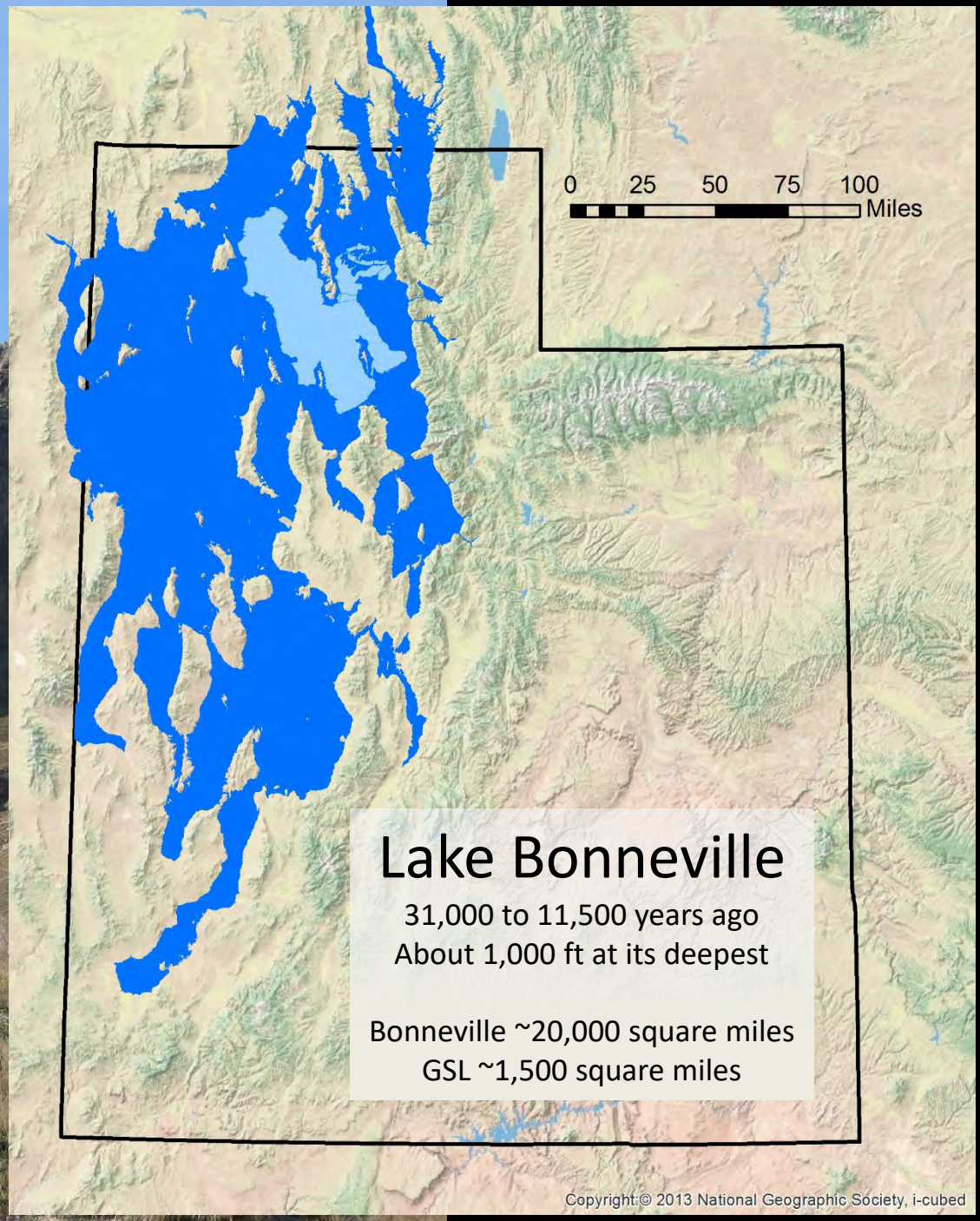

- Construction aggregate
- An important source of sand and gravel in Utah is Lake Bonneville deposits

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Sand and Gravel

- Sand and gravel quarries are coincident with:
  - development (cities, roads, etc.)
  - Lake Bonneville deposits
- Lake Bonneville deposits provide quality, clean sand and gravel
- Take note of shorelines

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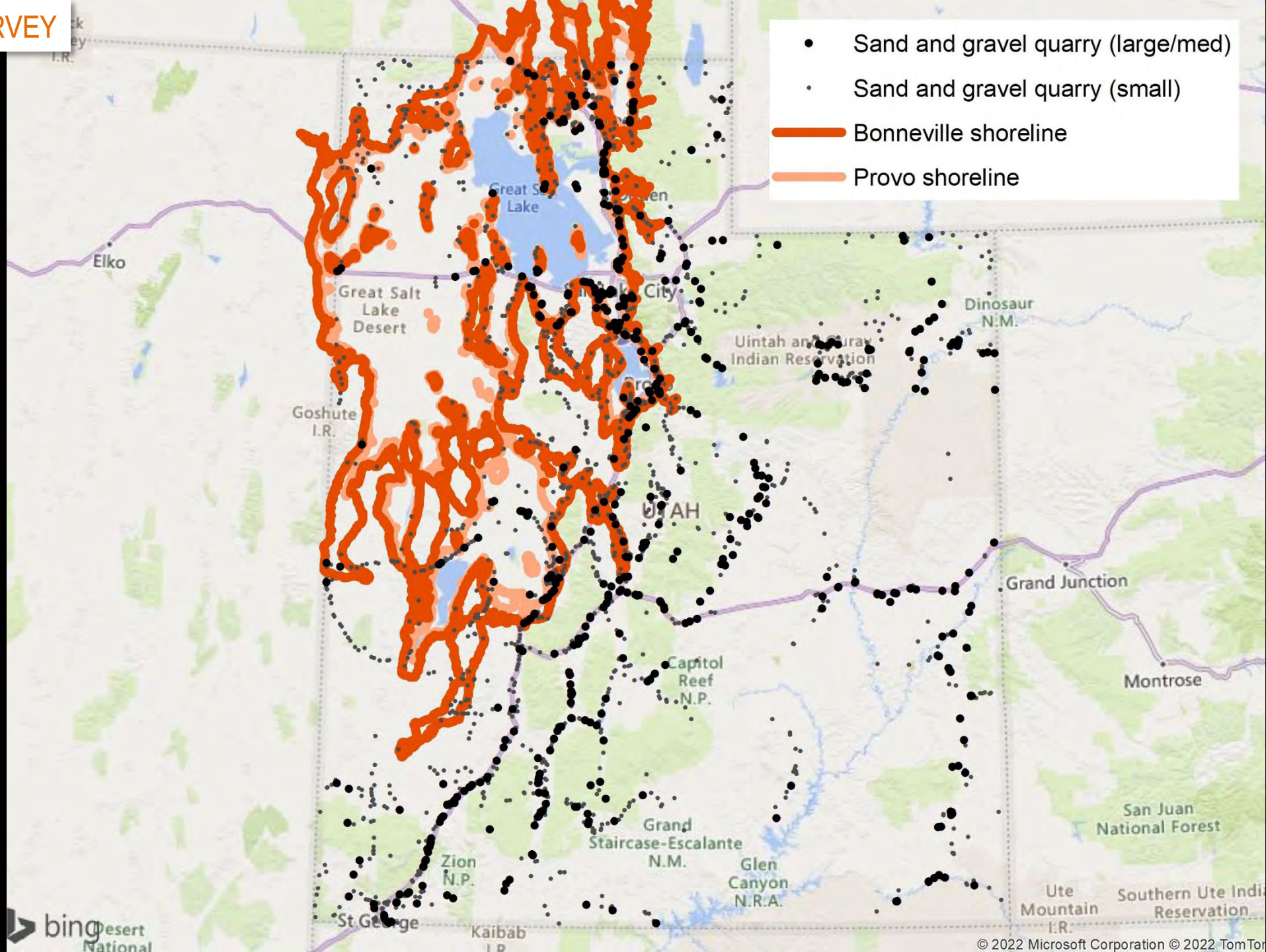
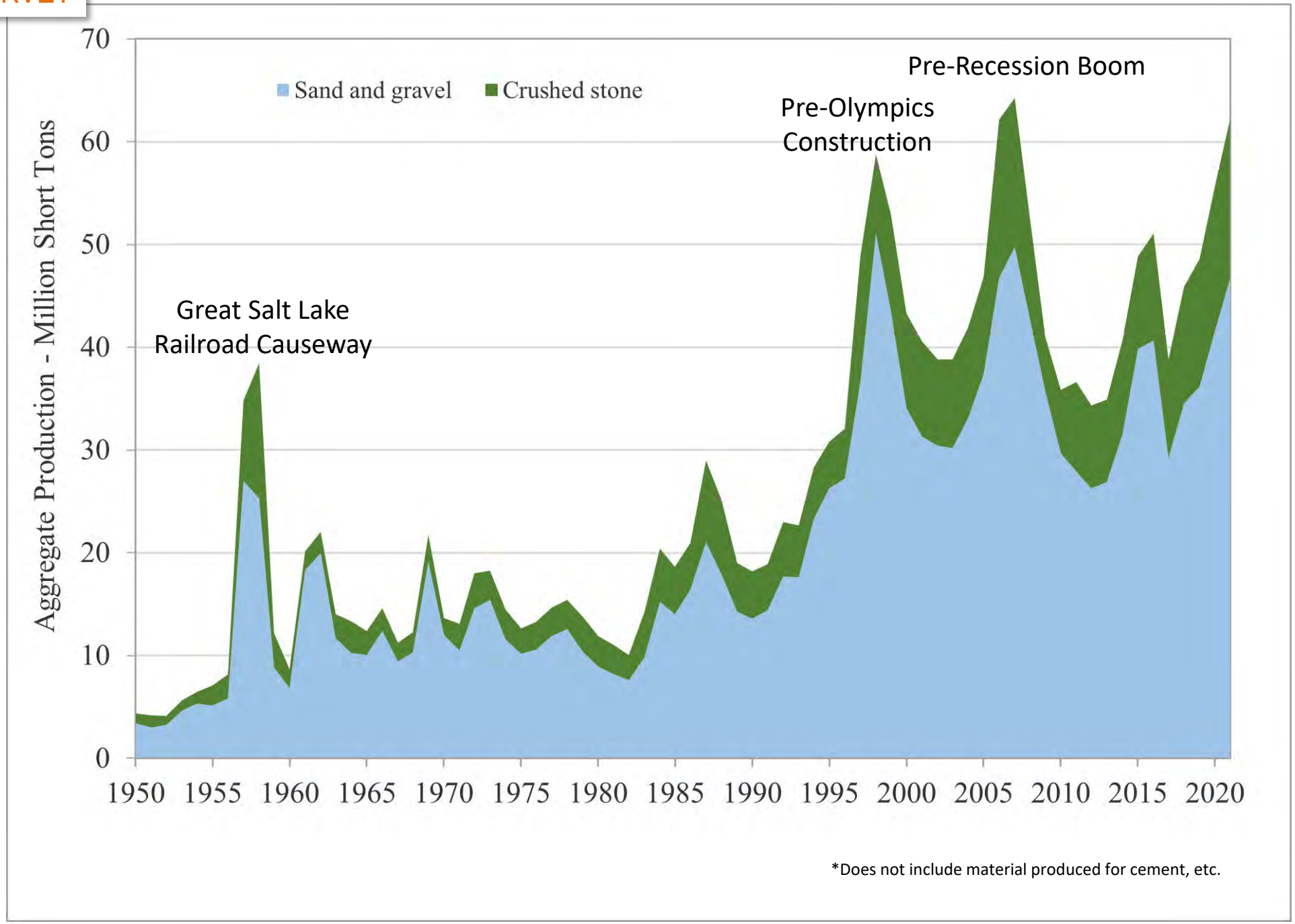


Aggregate Production (Sand and Gravel and Crushed Stone)

- Sand and gravel is sourced from lacustrine, river terrace, alluvial fan, and other deposits (**location dependent**)
- Crushed stone is sourced primarily from Paleozoic carbonates and quartzites



*Does not include material produced for cement, etc.

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Ballast

- Martin Marietta quarry produces a few hundred thousand tons of ballast per year
- Horn Silver Andesite (Oligocene?), quartz latite porphyry?
- Petrographic analysis by operator suggests the material is a quart-hornblende monzonite porphyry
- Durable volcanic rock resistant to freeze/thaw

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Martin Marietta ballast mine near Milford

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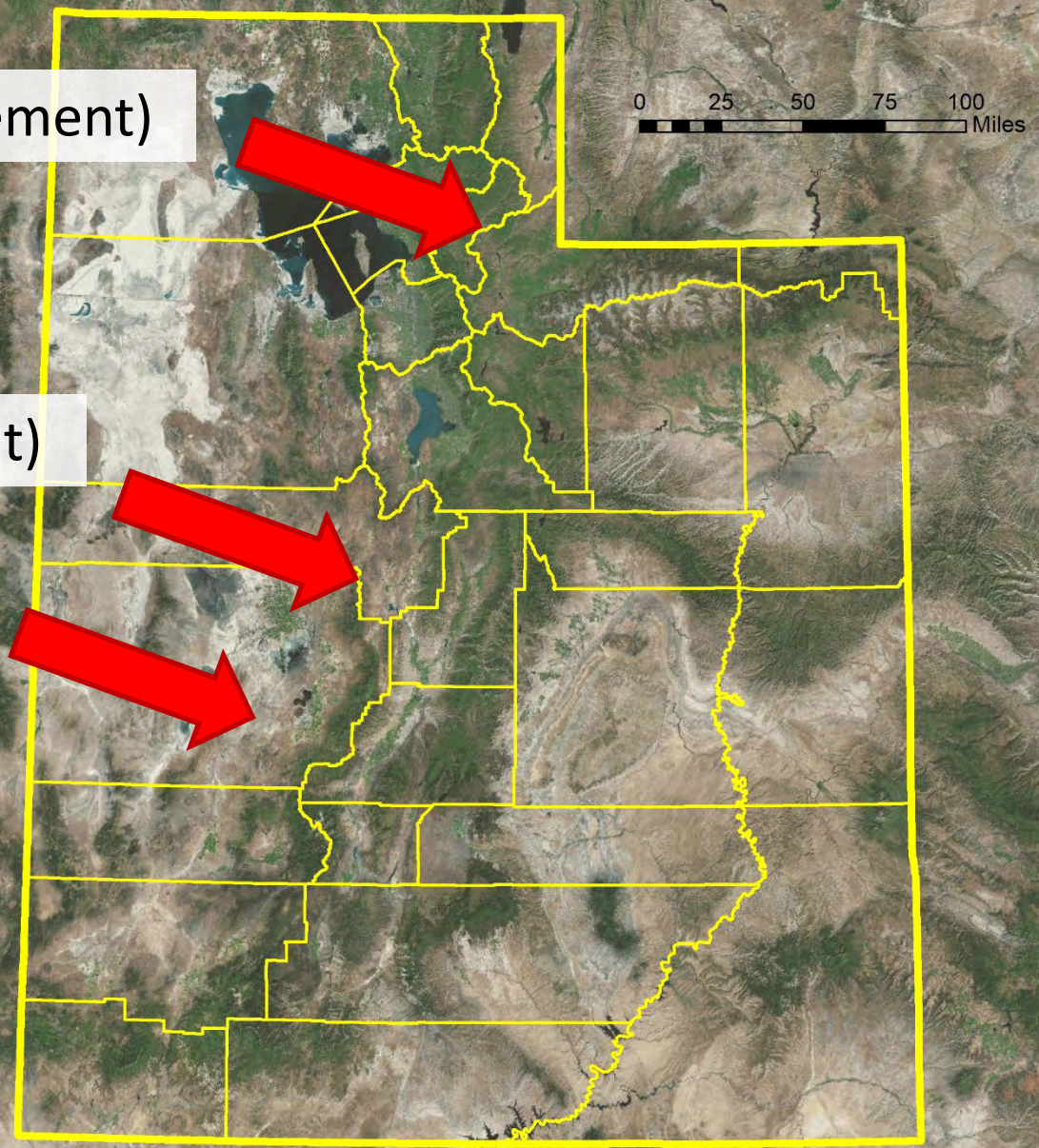
LafargeHolcim at Devil's Slide (cement)

Ash Grove near Leamington (cement)

Graymont near Delta (lime, dolomitic lime)



Cement and Lime Production in Utah

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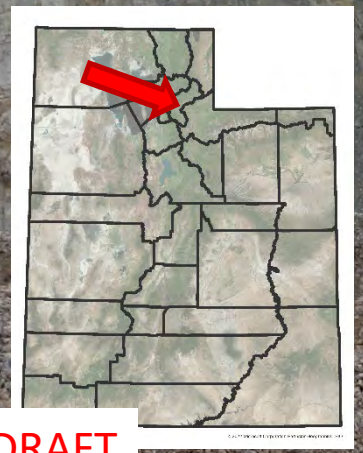
LafargeHolcim – Devil's Slide Plant

- Cement is produced from the argillaceous limestone of the Jurassic Twin Creek Formation
- The Twin Creek is a "cement rock"
- The Devil's Slide plant also uses kaolinite from Koosharem and silica from Jurassic Nugget Sandstone
- Capacity is about 800,000 tons per year



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LafargeHolcim – Devil's Slide Plant

- The Jurassic Twin Creek Formation consists of several members

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Koosharem Kaolinite Mine

Altered Osiris Tuff (lower Miocene to upper Oligocene)

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Ash Grove – Leamington Plant

- Cement is produced from several Cambrian units mined near the plant, including Dome and Swasey Limestones, Whirlwind Shale, Tintic Quartzite
- Other raw materials come from the Mississippian Long Trail Shale Mbr of Great Blue Limestone, Penn-Perm Quartzites, Arapien Shale
- Capacity is about 1 million tons per year

Ash Grove – Leamington Quarry

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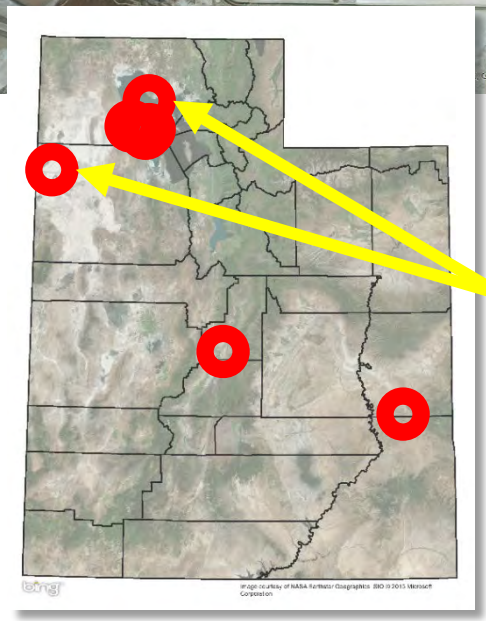
Graymont – Cricket Mountains

- Lime and dolomitic lime are produced from Cambrian geologic units mined near the plant, including the Dome Limestone and “Limestone of the Cricket Mountains”

Salt



$MgCl_2$

- 3.3 million tons produced in 2021
- Compass Minerals, Cargill Salt Co., Morton International, US Magnesium, LLC, Redmond Minerals, Intrepid Potash, Willow Creek
- 78% from GSL (in 2021)

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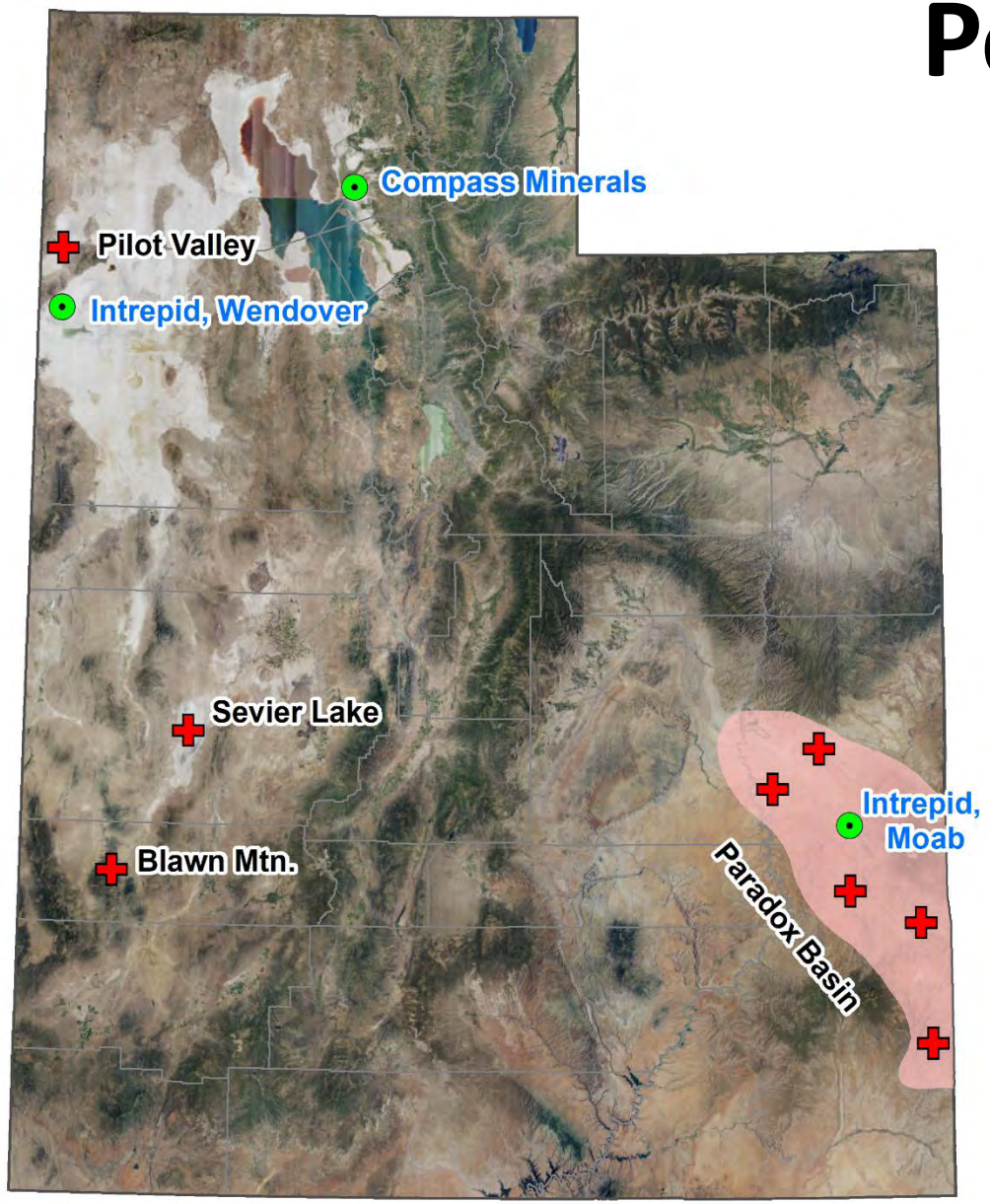
Potash

- Utah Potash Capacity ~520,000 tons
- Utah produces both KCl and K_2SO_4
- Combined 2021 production is 440,000 tons
- Estimated value: $230 million
- Intrepid Potash produces KCl ($353/ton, 2021)
- Compass Minerals produces K_2SO_4 ($618/ton, 2021)



Geological Settings with Potash resources in Utah:

1. Surface Brines (Great Salt Lake)
2. Subsurface Brines (West Desert, Sevier Lake)
3. Bedded Evaporites (Paradox Basin)
4. Alunite (Blawn Mtn.)

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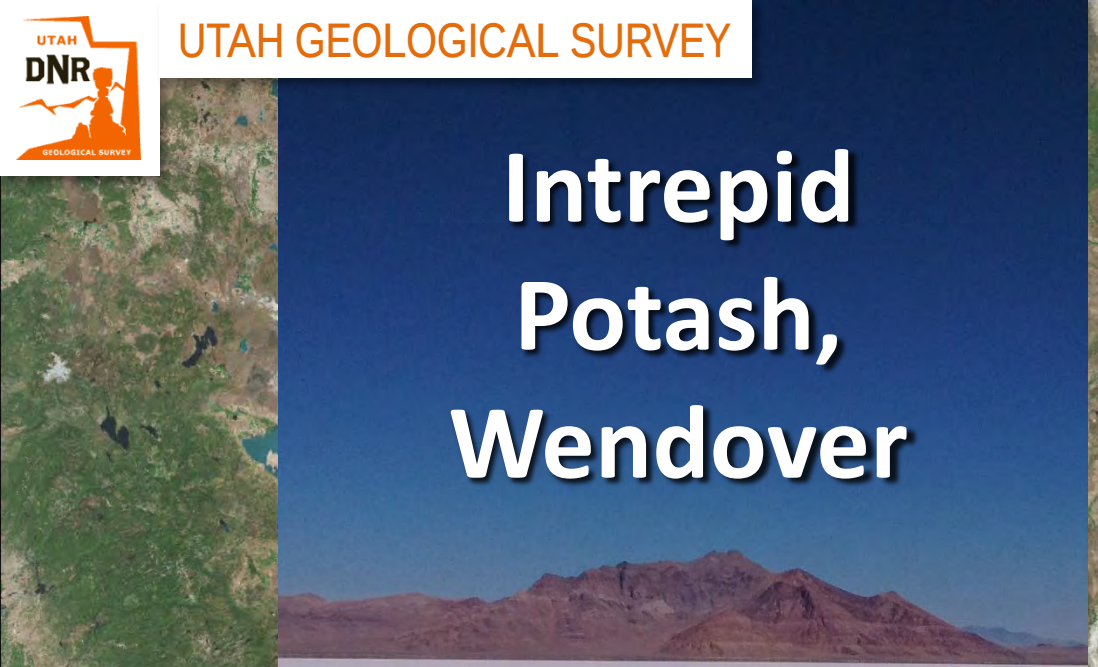
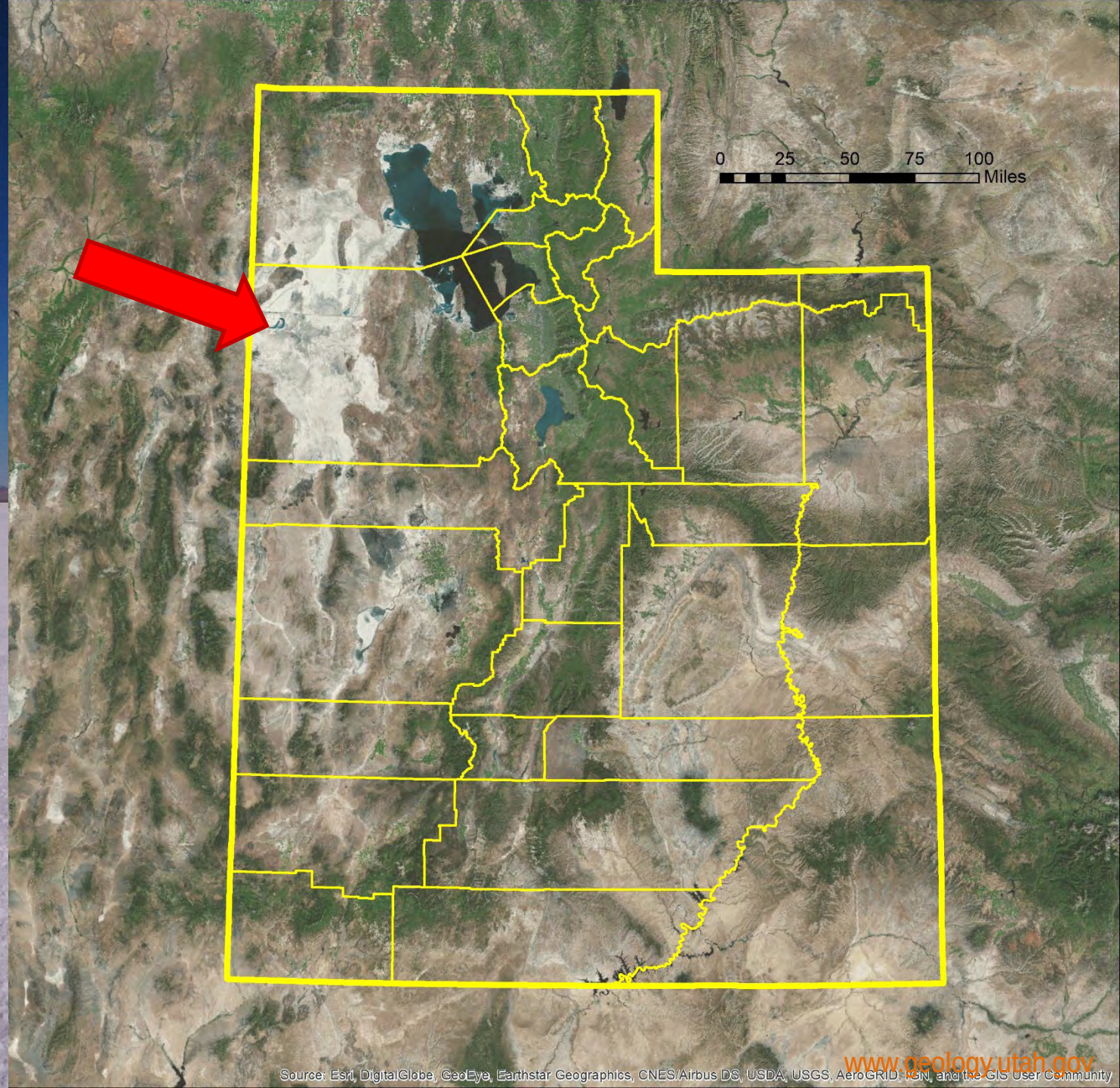
Intrepid Potash, Wendover



Produces KCl from shallow and deep brines at the Bonneville Salt Flats



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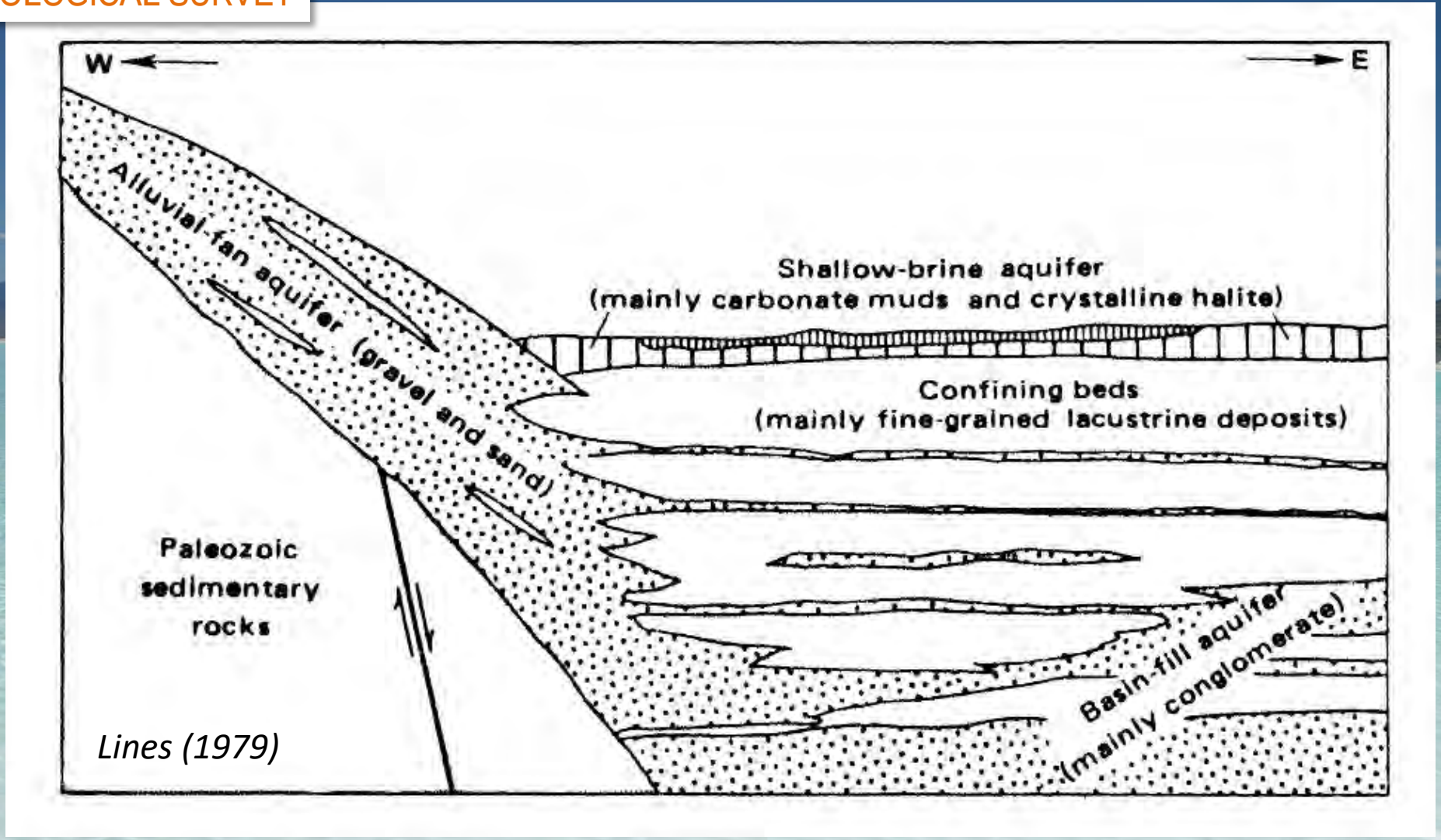

Intrepid Potash, Inc., Wendover

Capacity: 100,000 tons per year of KCl; also produces MgCl2 and NaCl

: Subsurface brines **(shallow and deep)**

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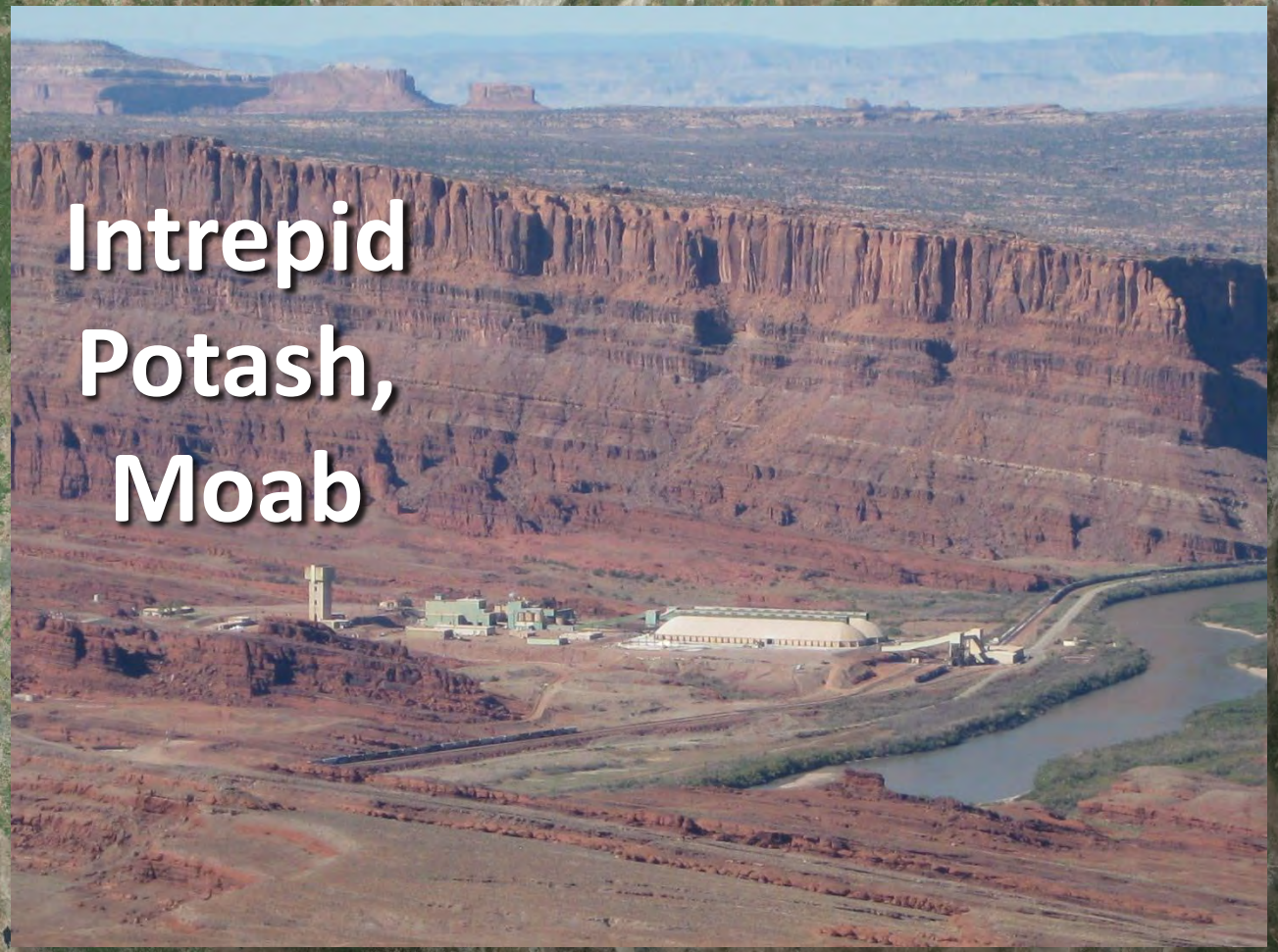
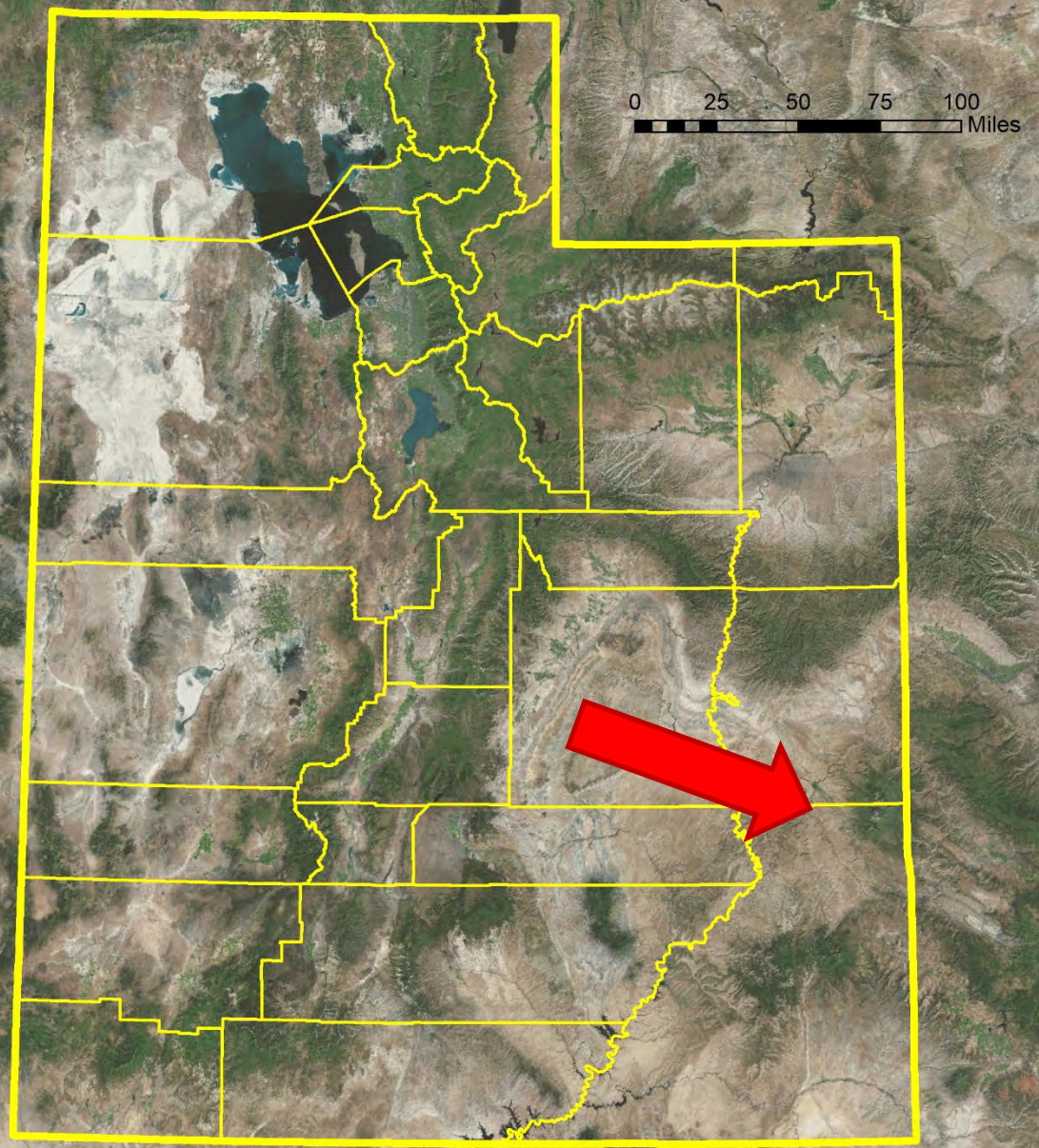


Intrepid Potash, Moab



Produces potash from deep, subsurface evaporites (sylvinite)

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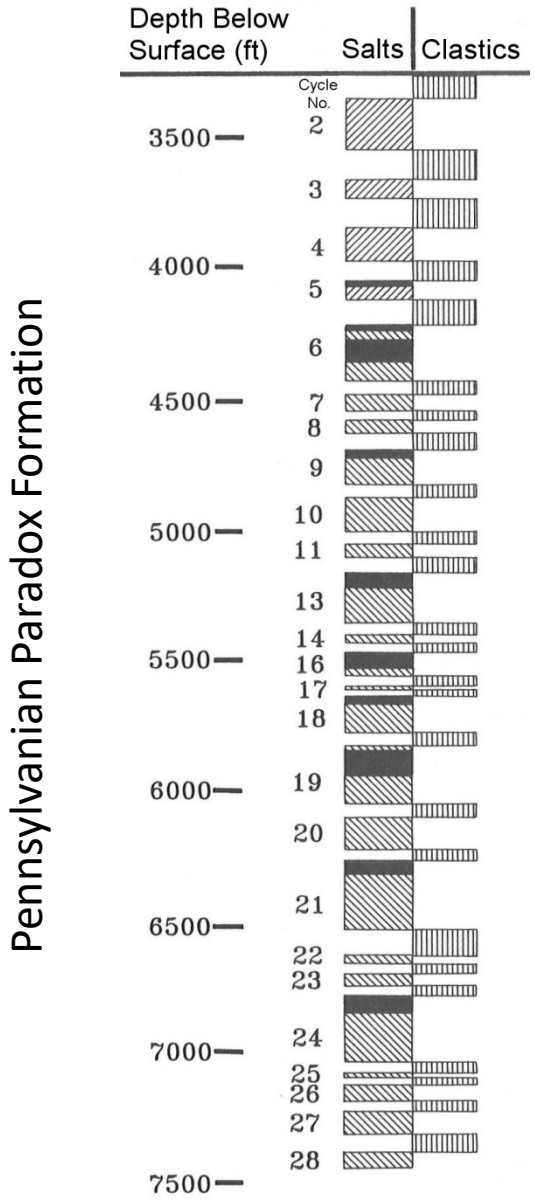
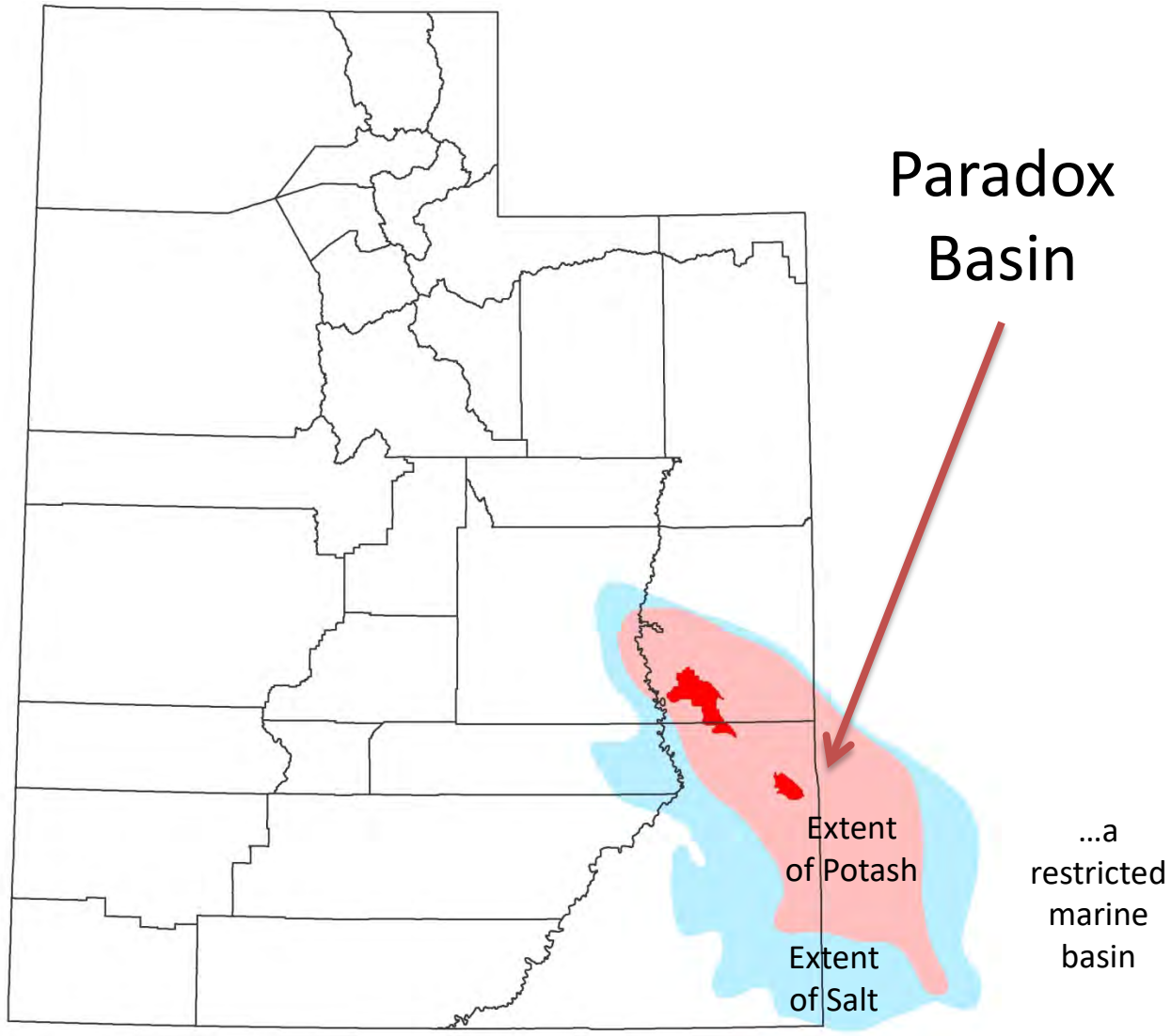
Evaporites of Penn. Paradox Fm.





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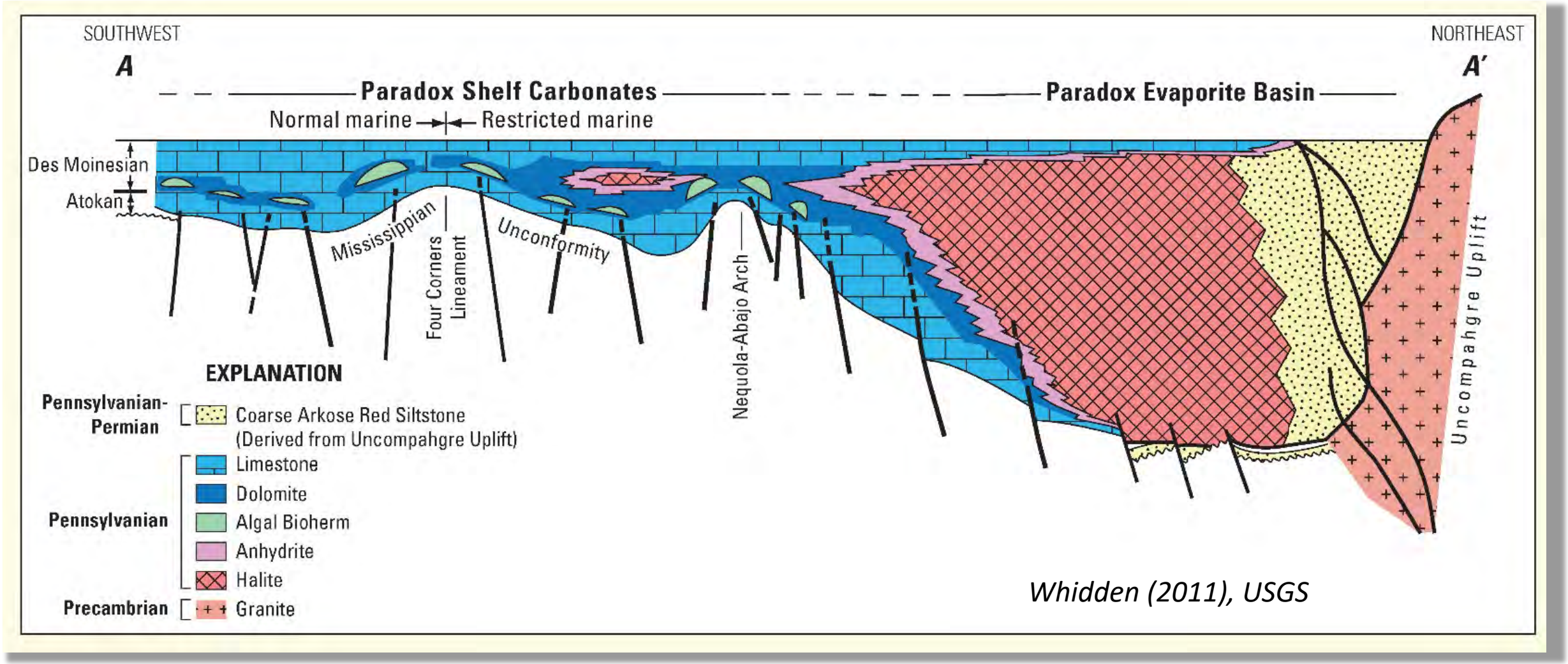
Modified from Morgan and others (1991)



Whidden (2011), USGS

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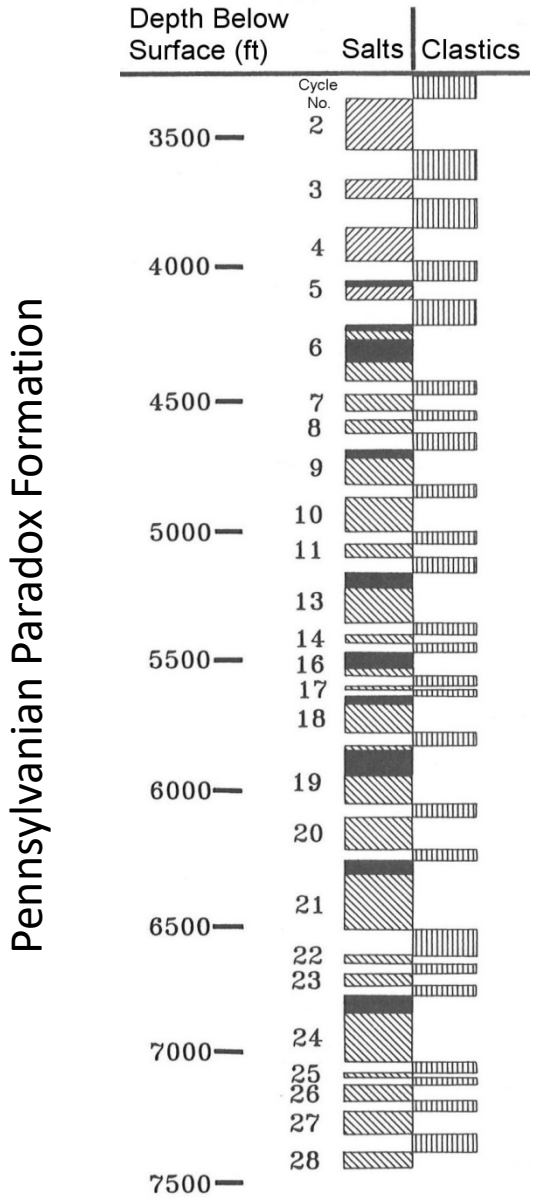
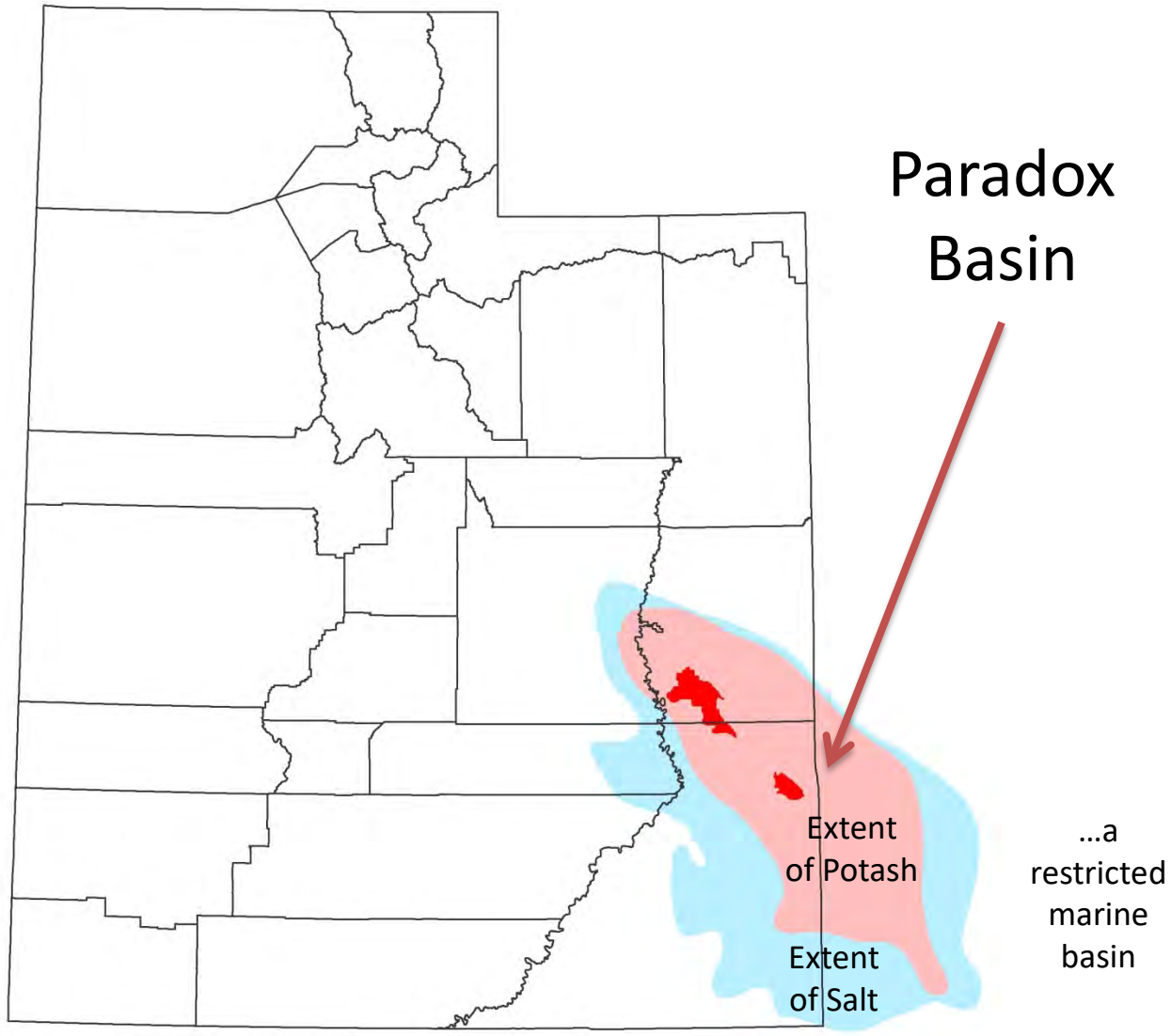
Evaporites of Penn. Paradox Fm.





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Modified from Morgan and others (1991)

Intrepid Potash, Moab

- Capacity: 110,000 tons per year of KCl
- Ore zones average around 6 to 8 ft thick

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Cane Creek Anticline
Intrepid Potash

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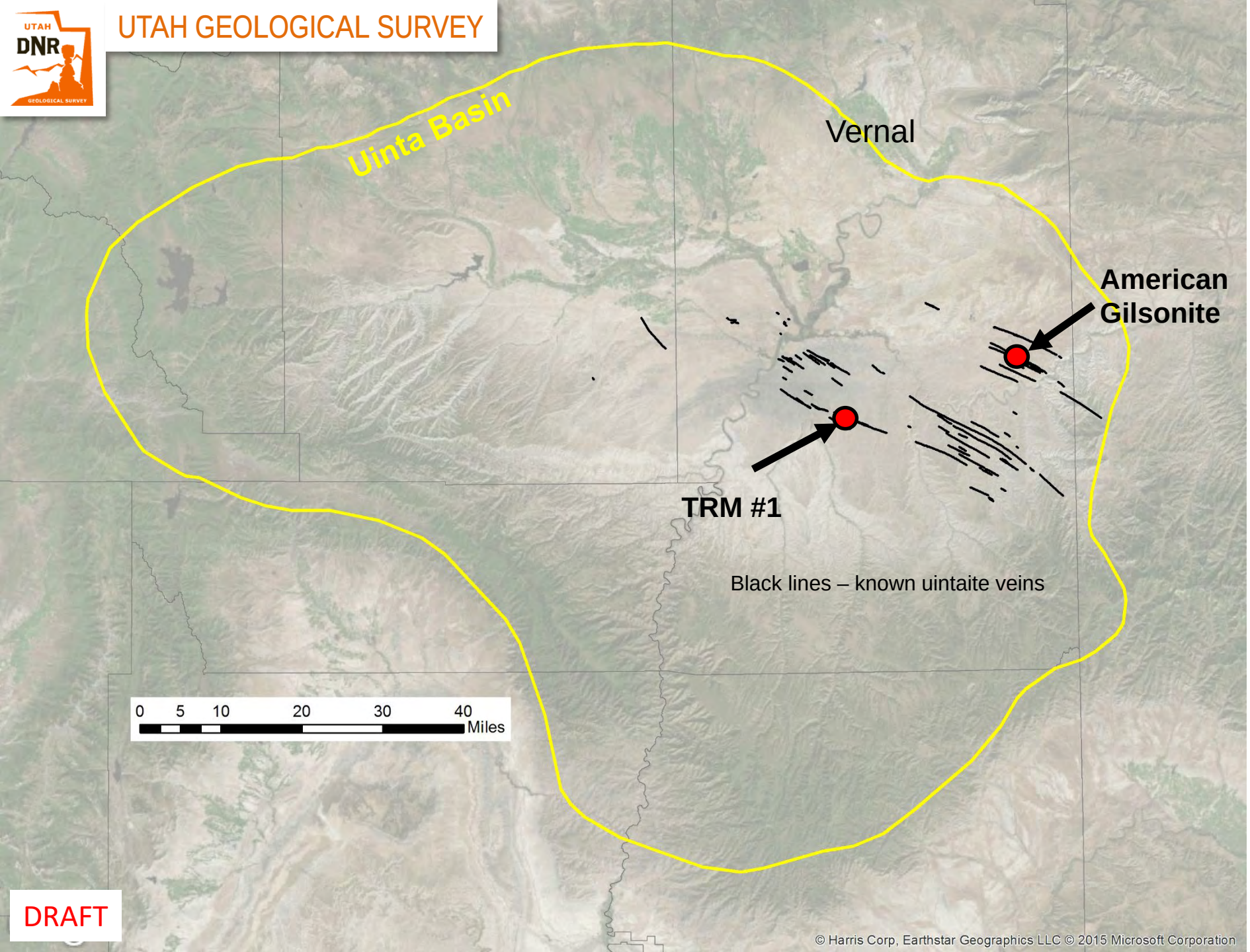
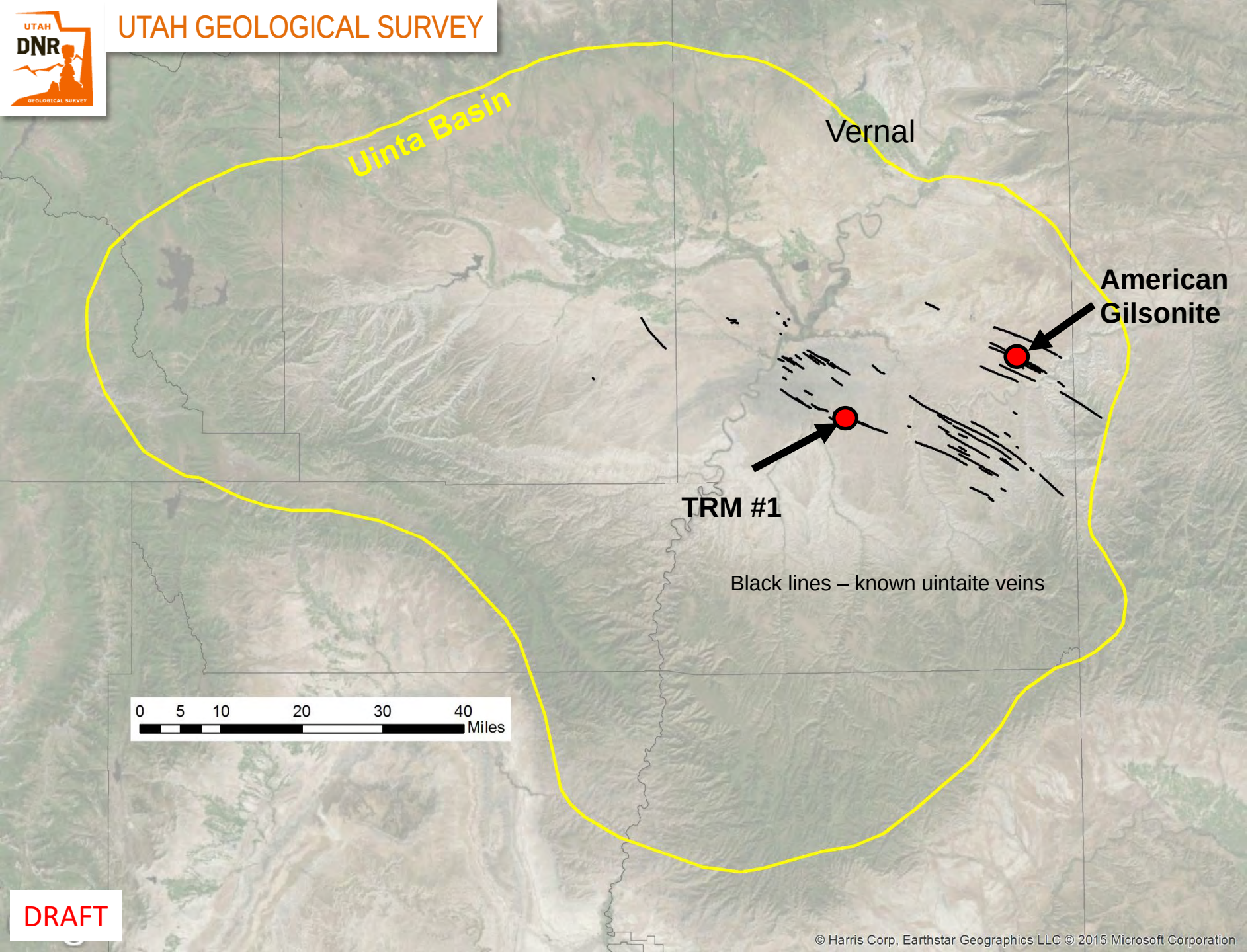


Uintaite (Gilsonite®)

- Uintaite is a solid black hydrocarbon that occurs in vertical veins in the Uinta Basin within Eocene geologic units
- Veins are laterally extensive (up to several miles)
- Uintaite thought to only occur in the Uinta Basin
- Gilsonite is a common name for uintaite that is trademarked by the company American Gilsonite

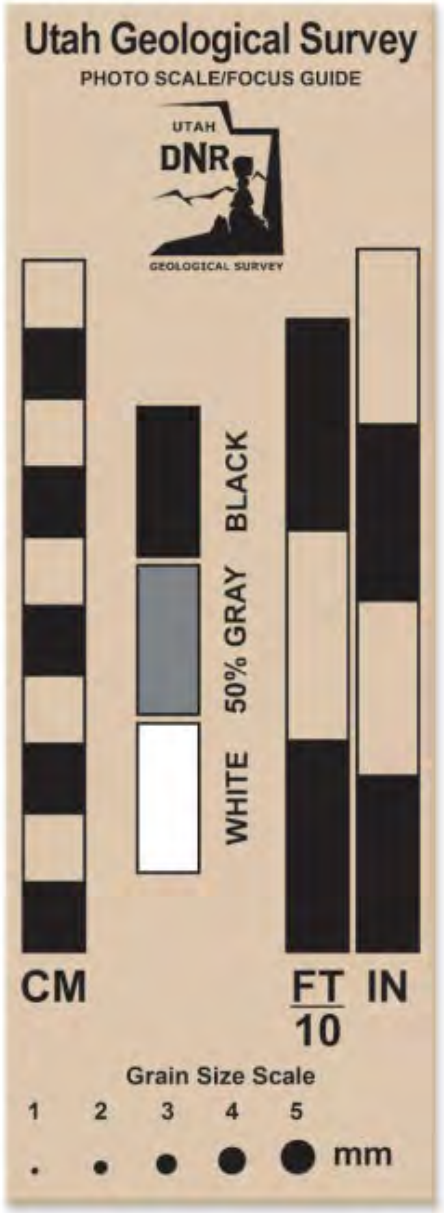


Uintaite (Gilsonite®)

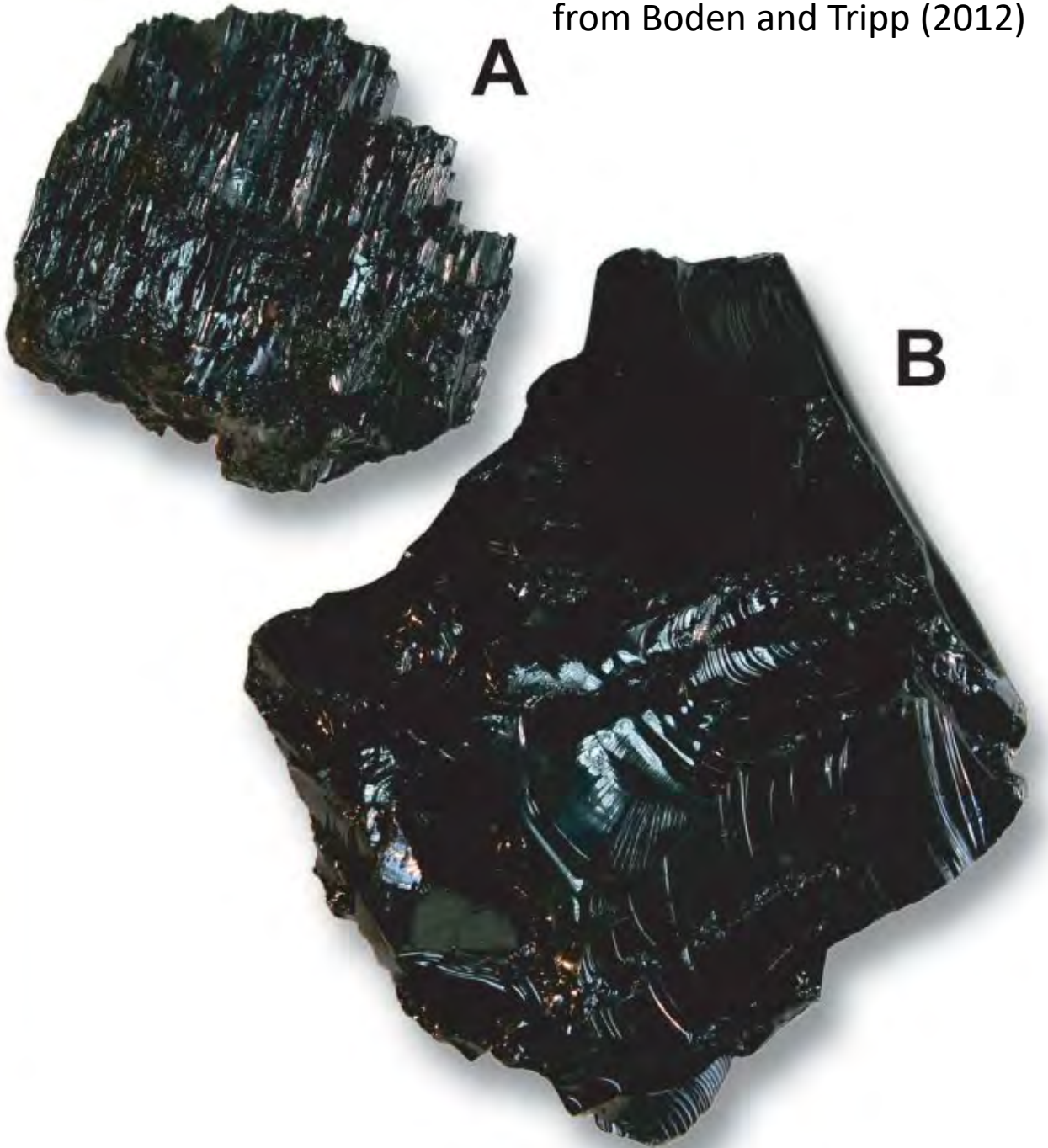
- American Gilsonite is primary producer of uintaite
- Production has been variable, but maximum annual production in last decade or so has been around 80,000 st
- Table Rock Minerals LLC recently opened a uintaite mine (TRM #1) with a capacity of 10,000 st per year
- Coatings, ink, asphalt and drilling additive

Uintaite (Gilsonite®)

- Uintaite has many uses
- Asphalt binder modifier, which improves the bonding in asphalt making it more durable and longer lasting; can also reduce the overall volume of asphalt needed for a project
- Also incorporated into pavement sealers for improved performance



from Boden and Tripp (2012)



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Expanded Shale/Light Weight Aggregate

- Utelite mines and calcines the Cretaceous Frontier Formation to produce expanded shale
- Used as a chip seal aggregate (extends life of chipseal, cheaper to transport, cost effective)
- Can be used for “internal curing” which improves the durability of concrete (reduces cracking); effective for transportation applications such as bridges

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Utelite plant

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Utelite quarry

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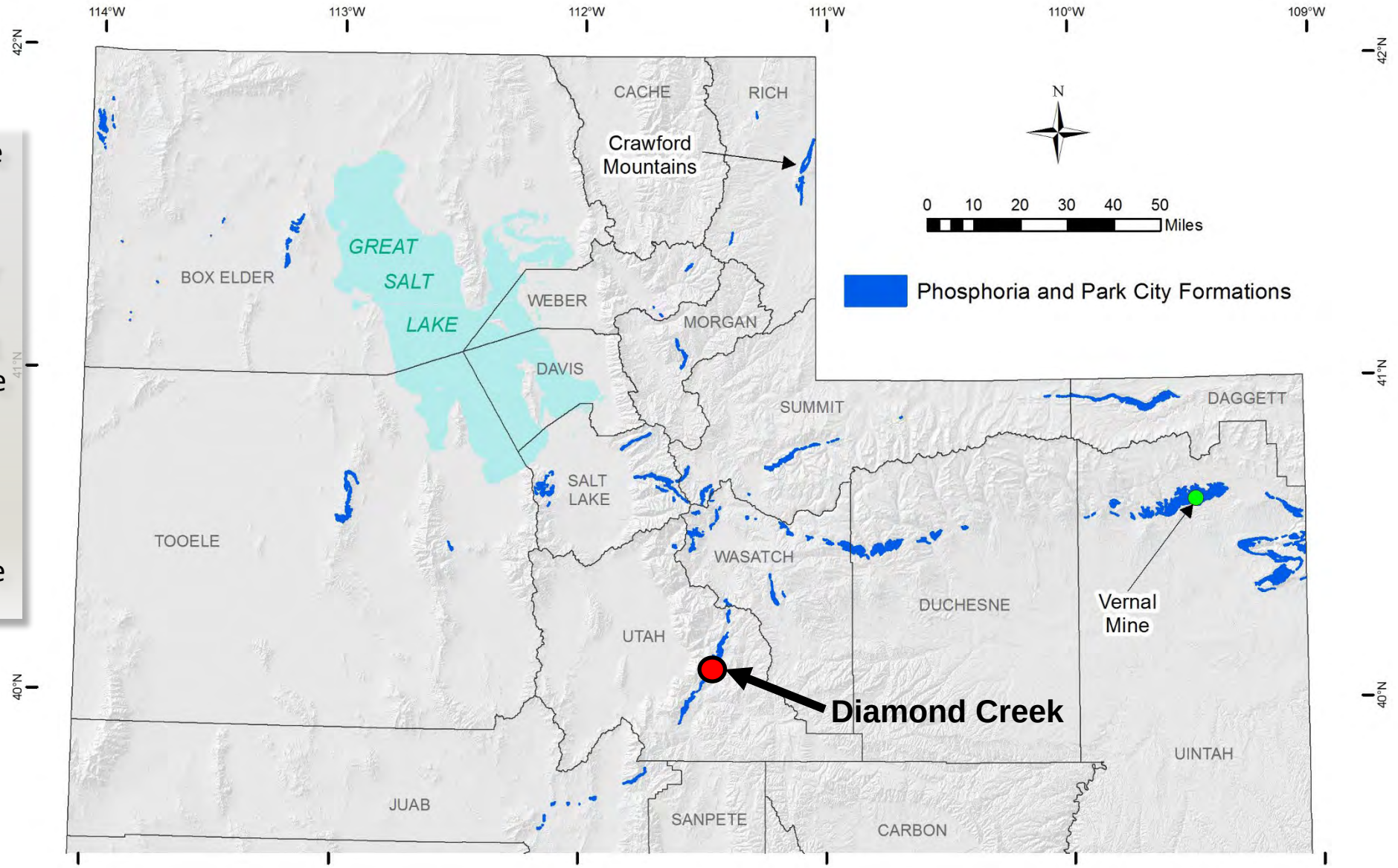
Phosphate

- Phosphate rock is found in the Permian Meade Peak Formation
- Simplot is the major producer in Utah
- 3.8 million tons of ore in 2021
- 1.4 million tons of concentrate in 2021
- Keras Resources is advancing a project at Diamond Creek and has produced small amounts of organic phosphate



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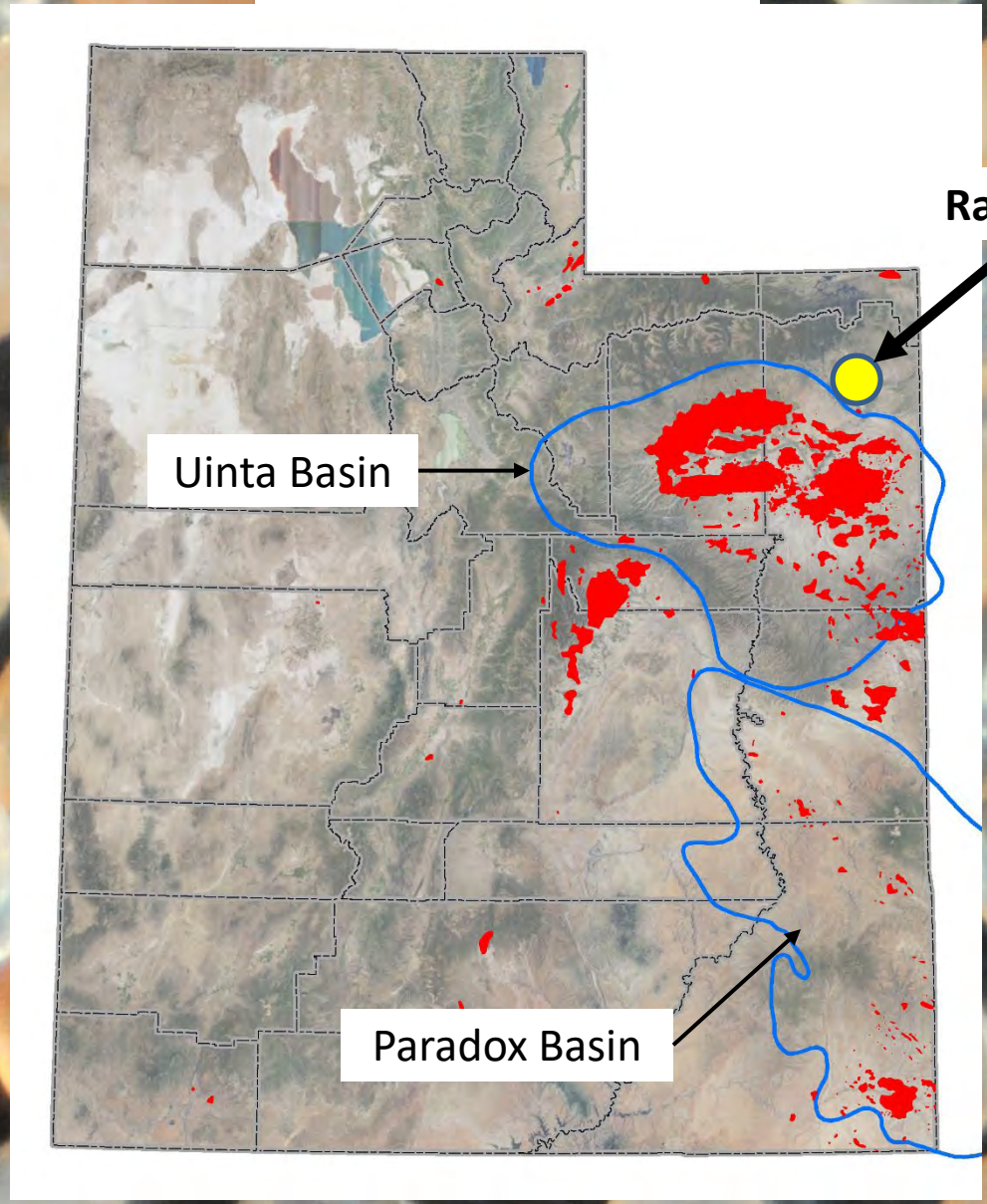
Frac Sand

Frac Sand Exploration

- Sourced from unconsolidated sand and friable sandstone deposits
- More frac sand is being used
- Specifications have shifted (relaxed?)
- Ramsey Hill – currently supplies Uinta Basin, began producing in 2019



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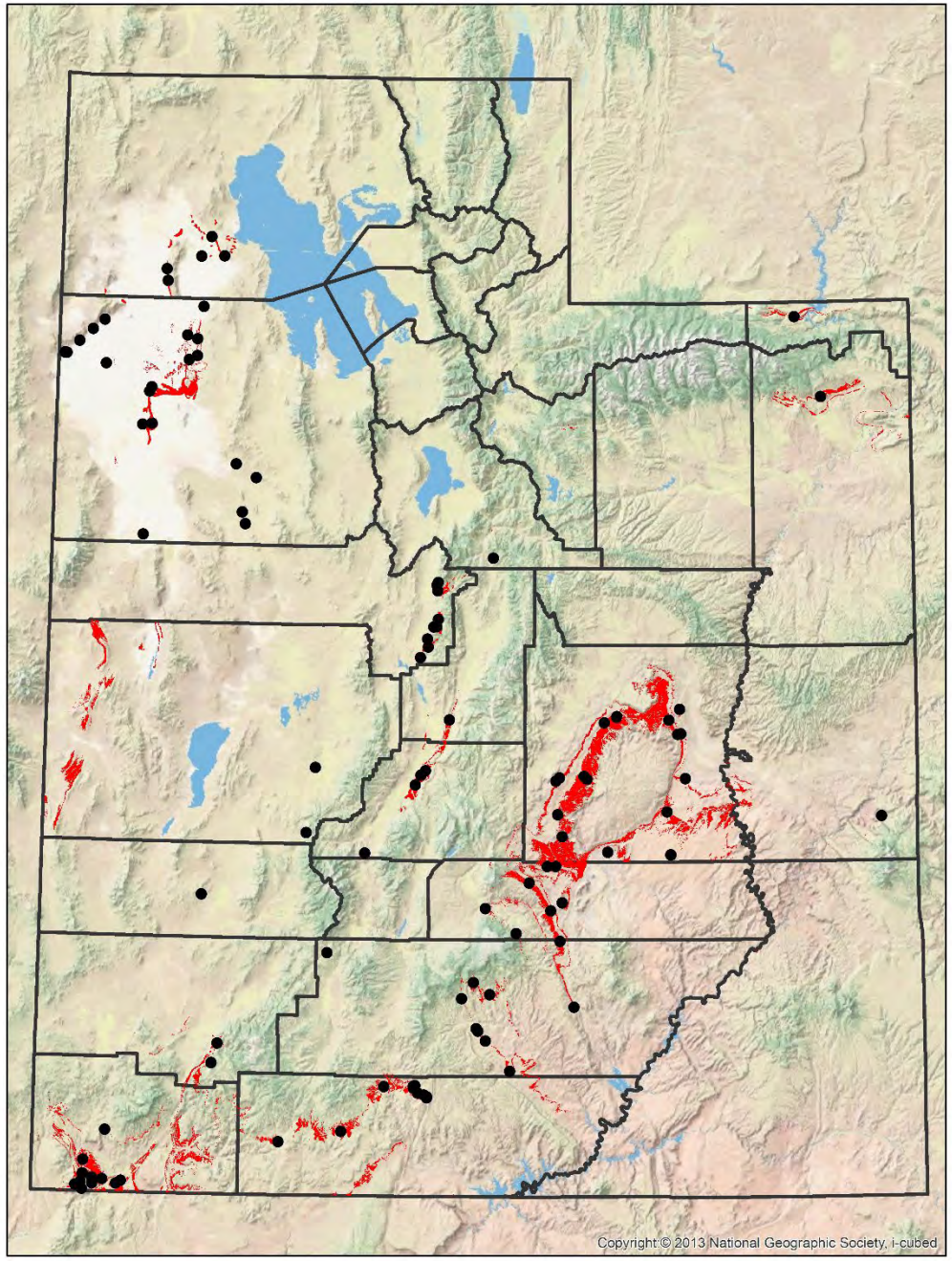
Gypsum

- Utah has large resources of gypsum
- Four operators produced around 770,000 tons of gypsum in 2021
- Progressive Contracting, Diamond K Gypsum, United States Gypsum, Sunroc
- Cement additive, agricultural additive, wallboard production
- Most production is from Jurassic units, but some production is from Permian units; potential also exists in Triassic units



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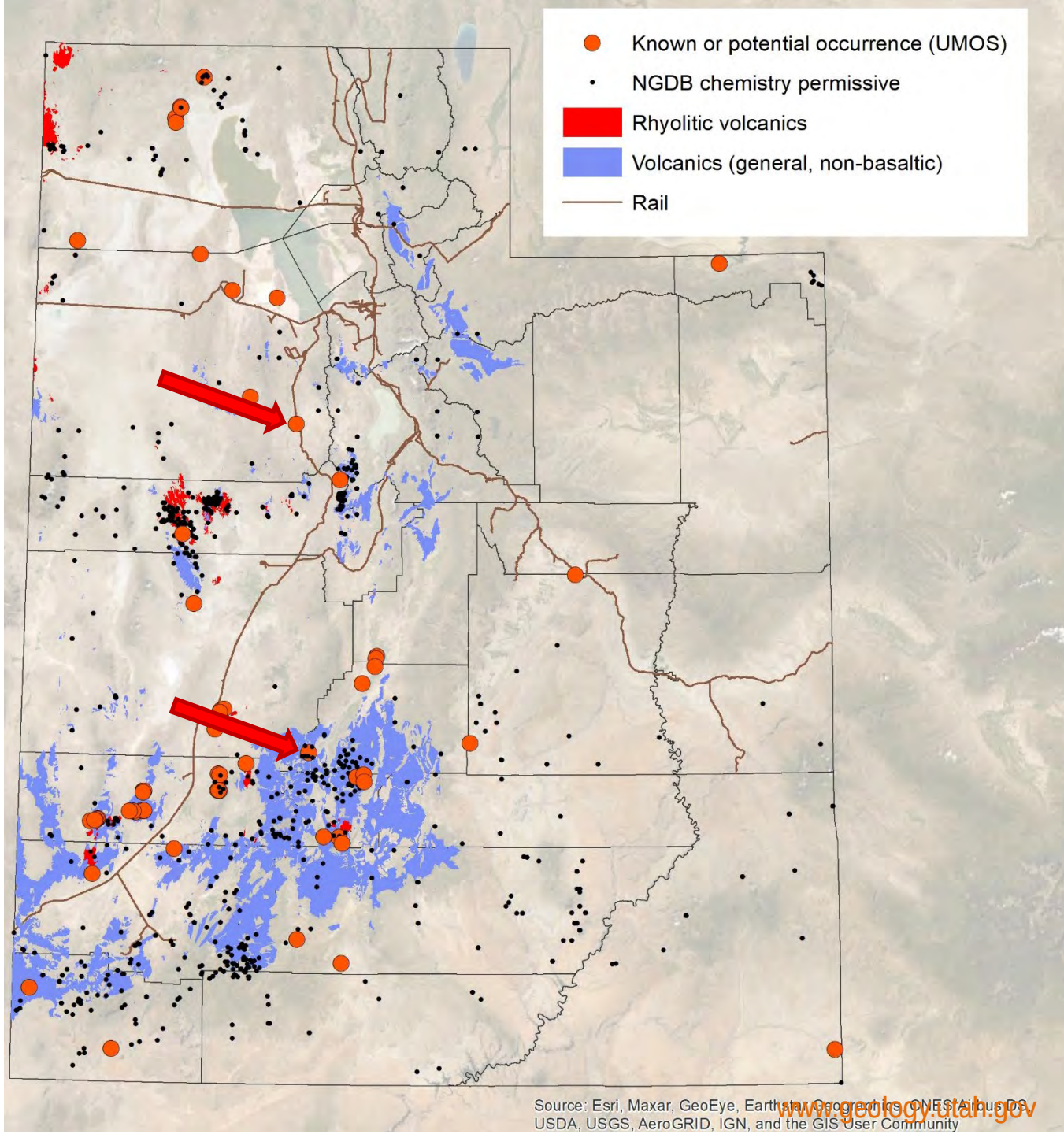
Pozzolan

- Used to extend and enhance cement
- Use of pozzolan can reduce cost and greenhouse gas emissions
- Interest in pozzolan in Utah has picked up over the past few years
- Types of geologic materials used as pozzolan:
  - Volcanic ash (tephras, tuffs, etc.)
  - Diatomaceous deposits
  - Zeolitized volcanic rocks
  - Clay deposits



Pozzolan

- Geofortis is developing a volcanic tephra (ash) from the Miocene Salt Lake Formation, tephras tend to have a large component of glassy particles, which is desirable for pozzolans
- Located in Rush Valley, south of Tooele
- Have proven up a large resource and have begun producing

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lithium
3
Li
6.941

- *BATTERIES!*
- Import reliance
- Annual demand is expected to increase ~500% by 2050 *(Simandl et al. 2021)*
- Global production in 2021 – 530,000 tons LCE *(Jaskula, 2022)*
- Numerous claims staked in Utah in the last several years

Brief definition of critical mineral: A critical mineral is a mineral that is important to the (U.S.) economy or for national defense and that is susceptible to supply disruption.

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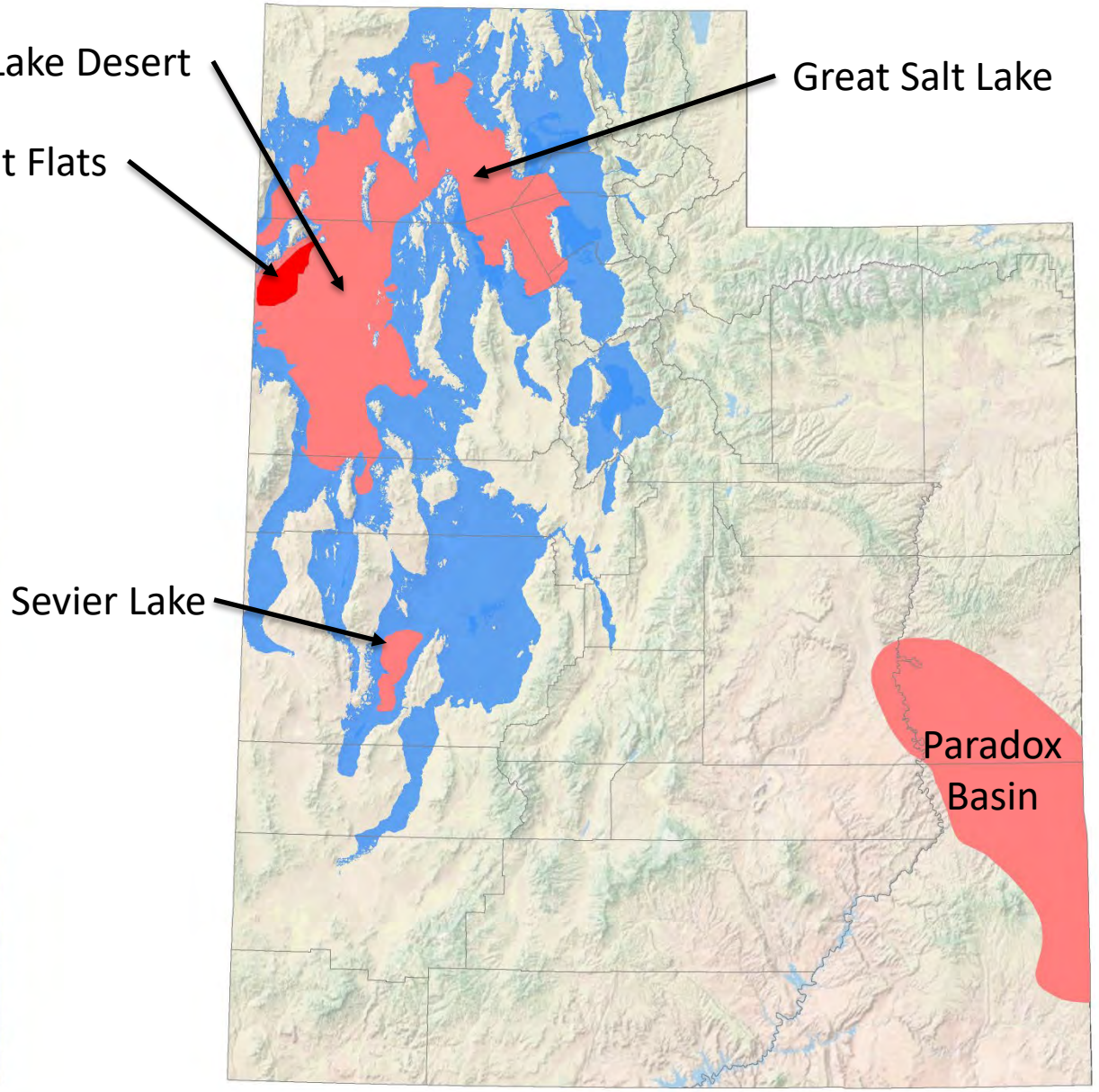
Potential and Known Lithium Brine Resources

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Blue – Bonneville Basin

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UTAH GEOLOGICAL SURVEY

Potential and Known Lithium Brine Resources

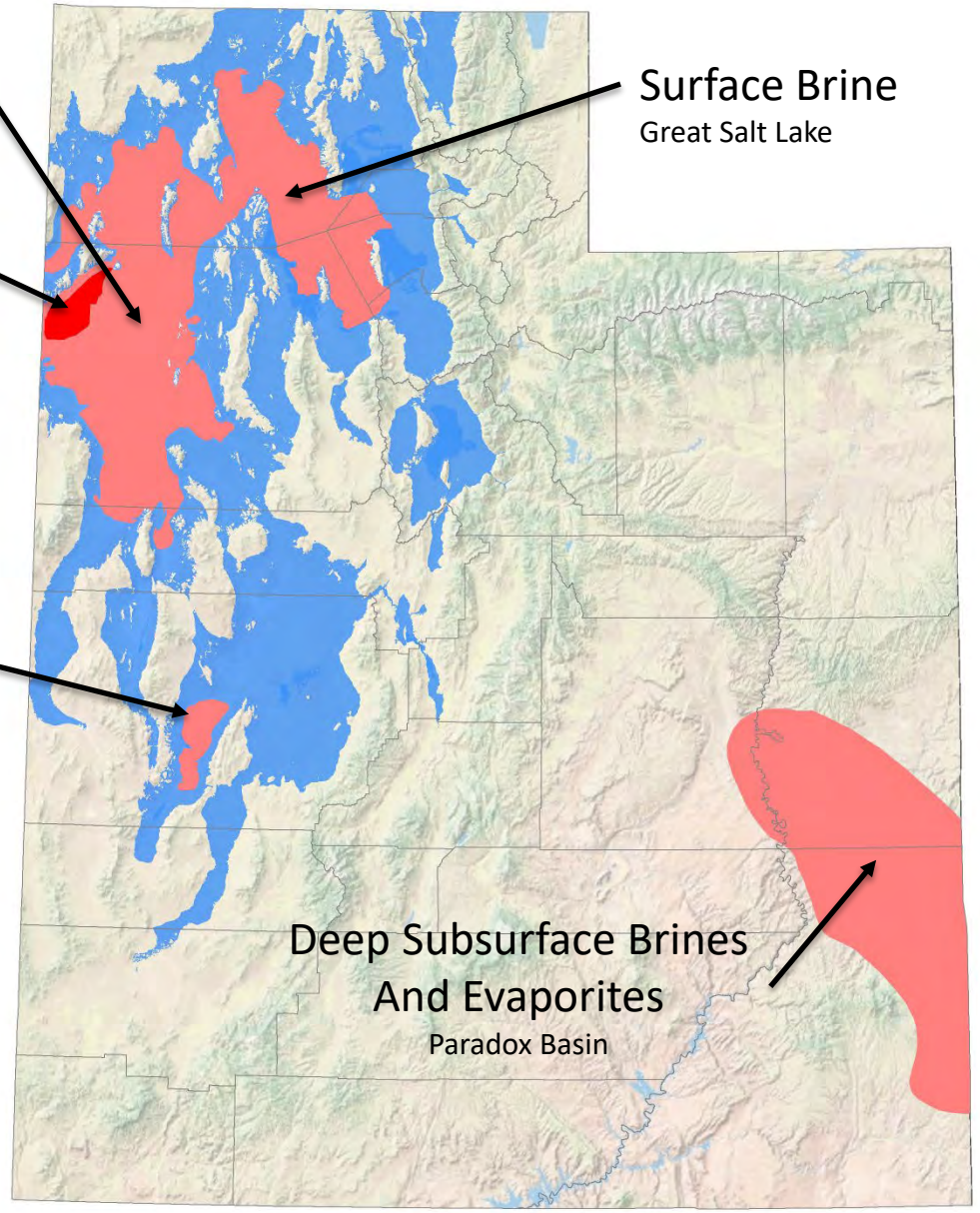
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Shallow Subsurface Brine
Great Salt Lake Desert
Bonneville Salt Flats

Surface Brine
Great Salt Lake

Shallow Subsurface Brine
Sevier Lake

Deep Subsurface Brines And Evaporites
Paradox Basin



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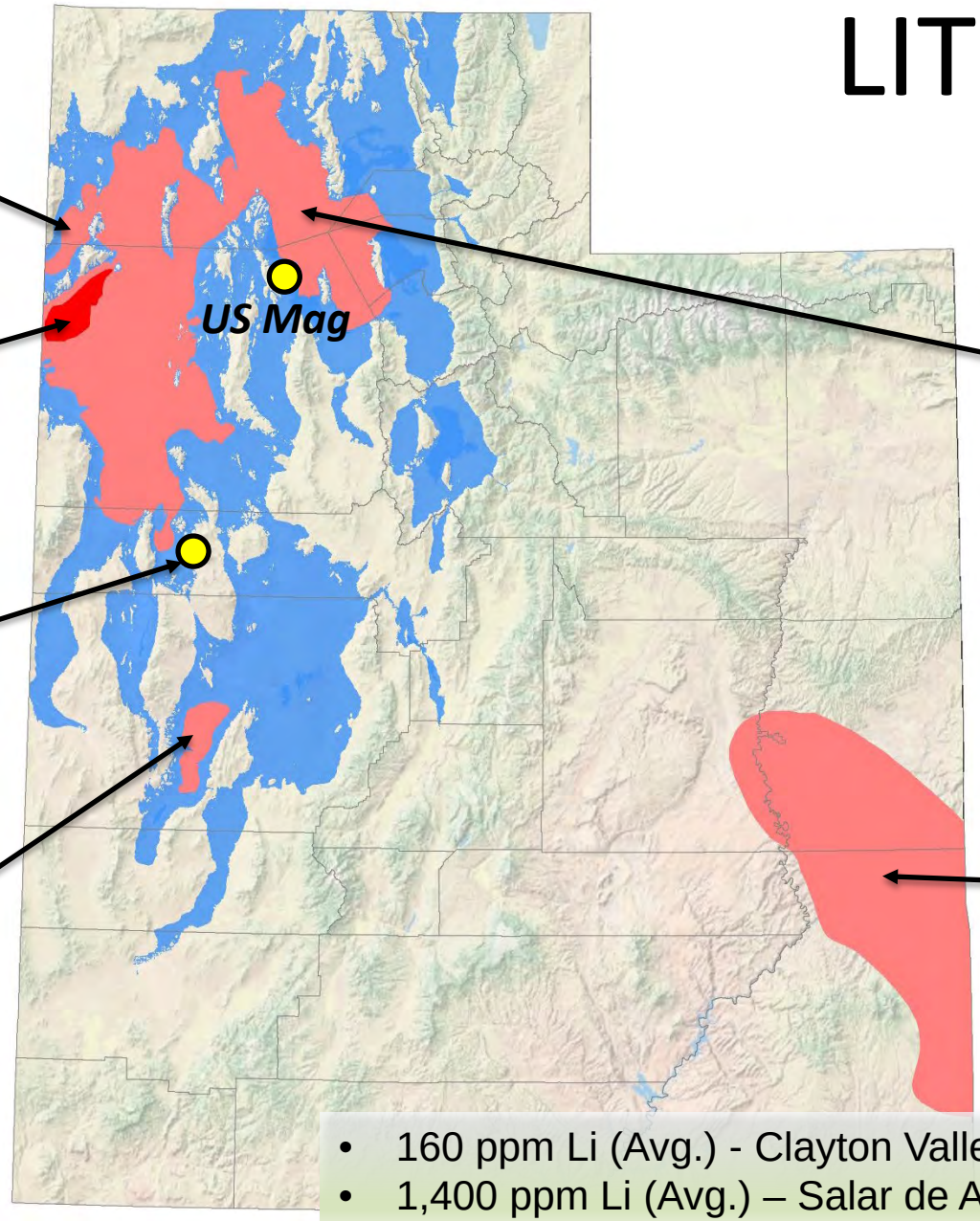
LITHIUM

Pilot Valley
Up to 100 ppm

Bonneville Salt Flats
Up to 140 ppm

Spor Mountain
(highly-evolved volcanics)

Sevier Lake
Up to 40 ppm



Great Salt Lake
Up to 80 ppm

Paradox Basin
Up to 250 (or 500?) ppm

- 160 ppm Li (Avg.) - Clayton Valley, NV *(Munk et al., 2016)*
- 1,400 ppm Li (Avg.) – Salar de Atacama, Chile *(Munk et al., 2016)*

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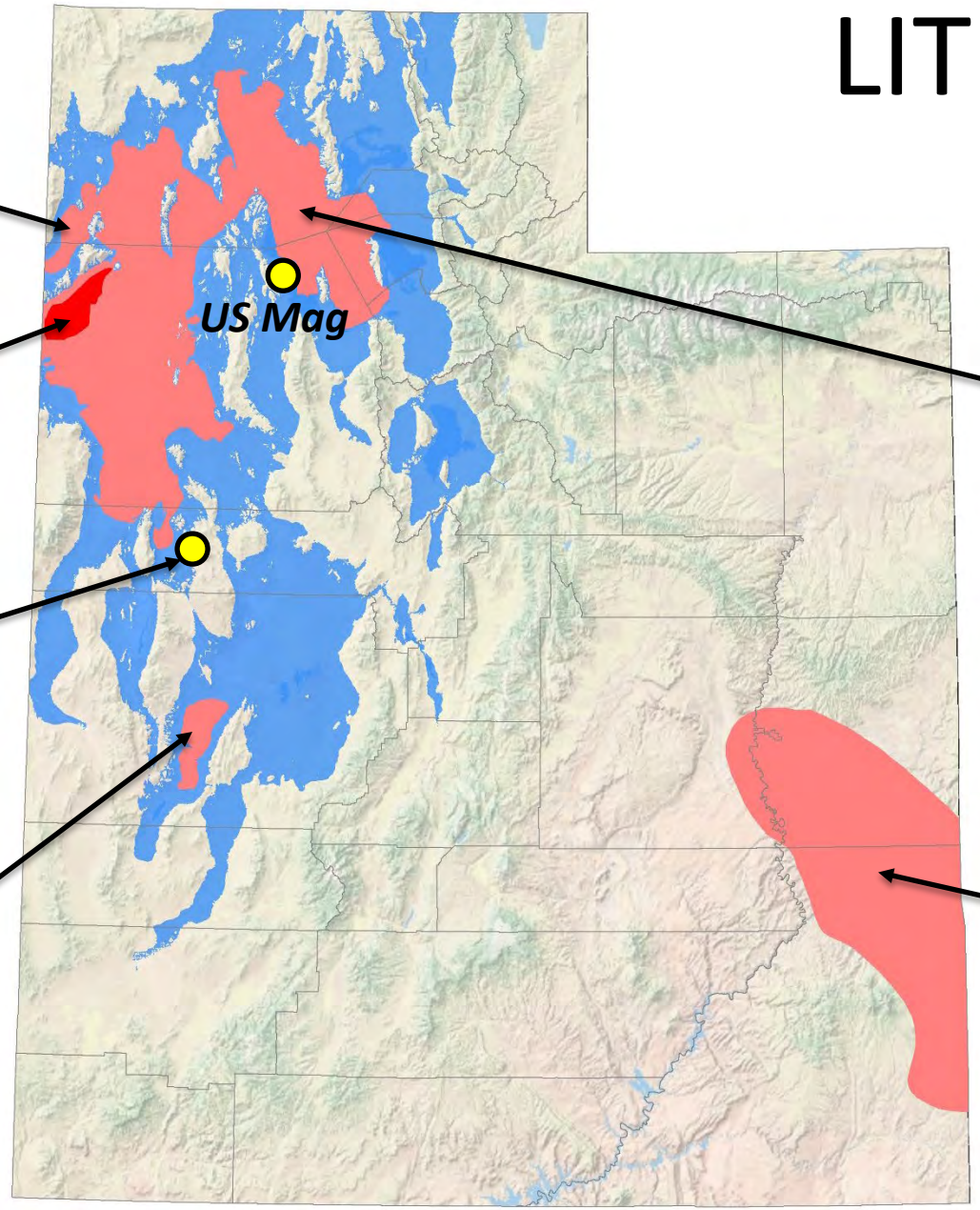
LITHIUM

Pilot Valley
Up to 100 ppm
Mg:Li, 40:1

Bonneville Salt Flats
Up to 140 ppm
Mg:Li, 60:1

Spor Mountain
(highly-evolved volcanics)

Sevier Lake
Up to 40 ppm
Mg:Li, 130:1



Great Salt Lake
Up to 80 ppm
Mg:Li, 250:1

Paradox Basin
Up to 250 (or 500?) ppm
Mg:Li, 130:1

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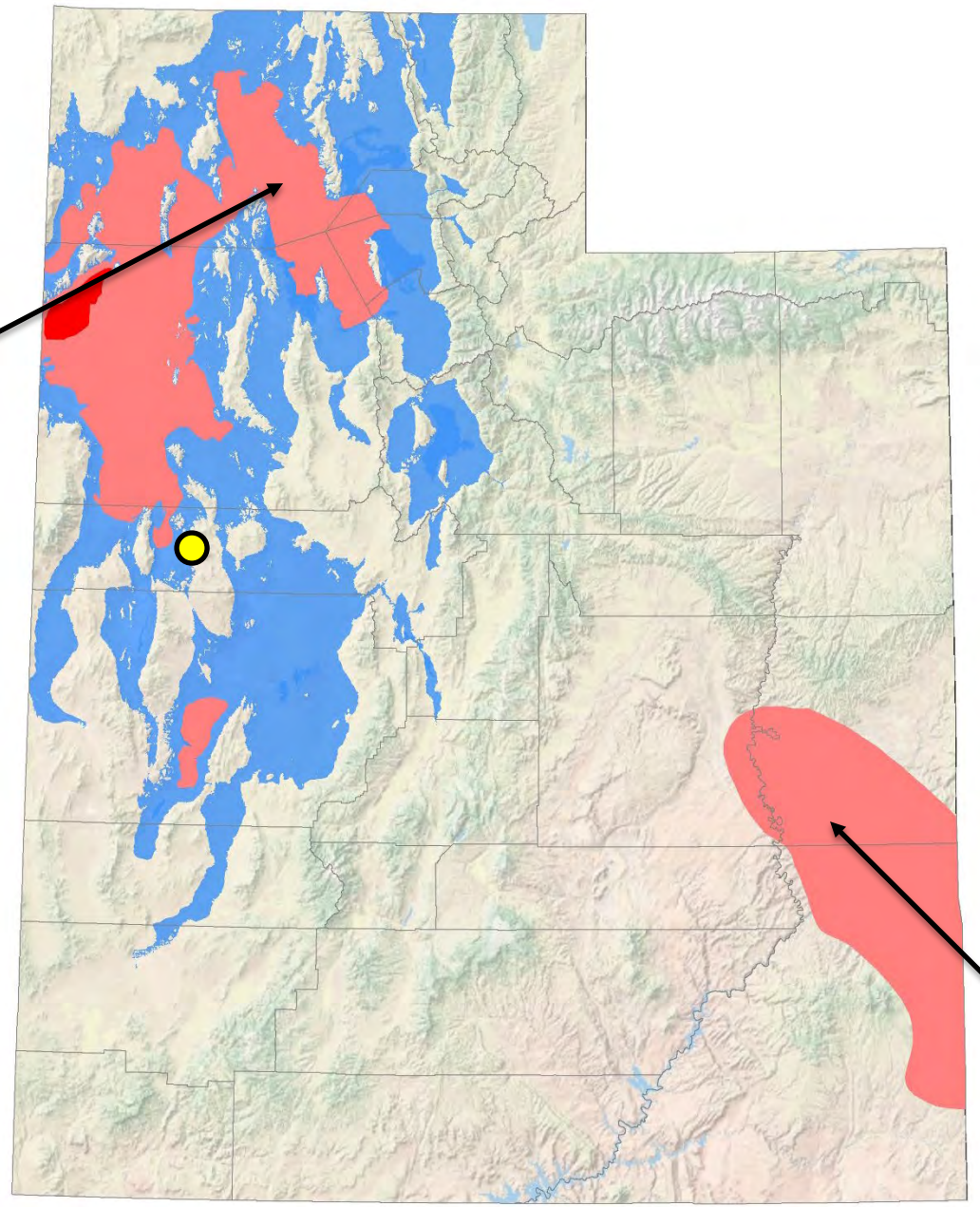
LITHIUM RESOURCES

Great Salt Lake
In-place, indicated resource of 2.6 million tons LCE (Compass Minerals) (entire lake), resource is shared



Paradox Basin
Indicated and inferred, recoverable resource of 1.1 million tons LCE (Anson Resources in small part of Paradox Basin)

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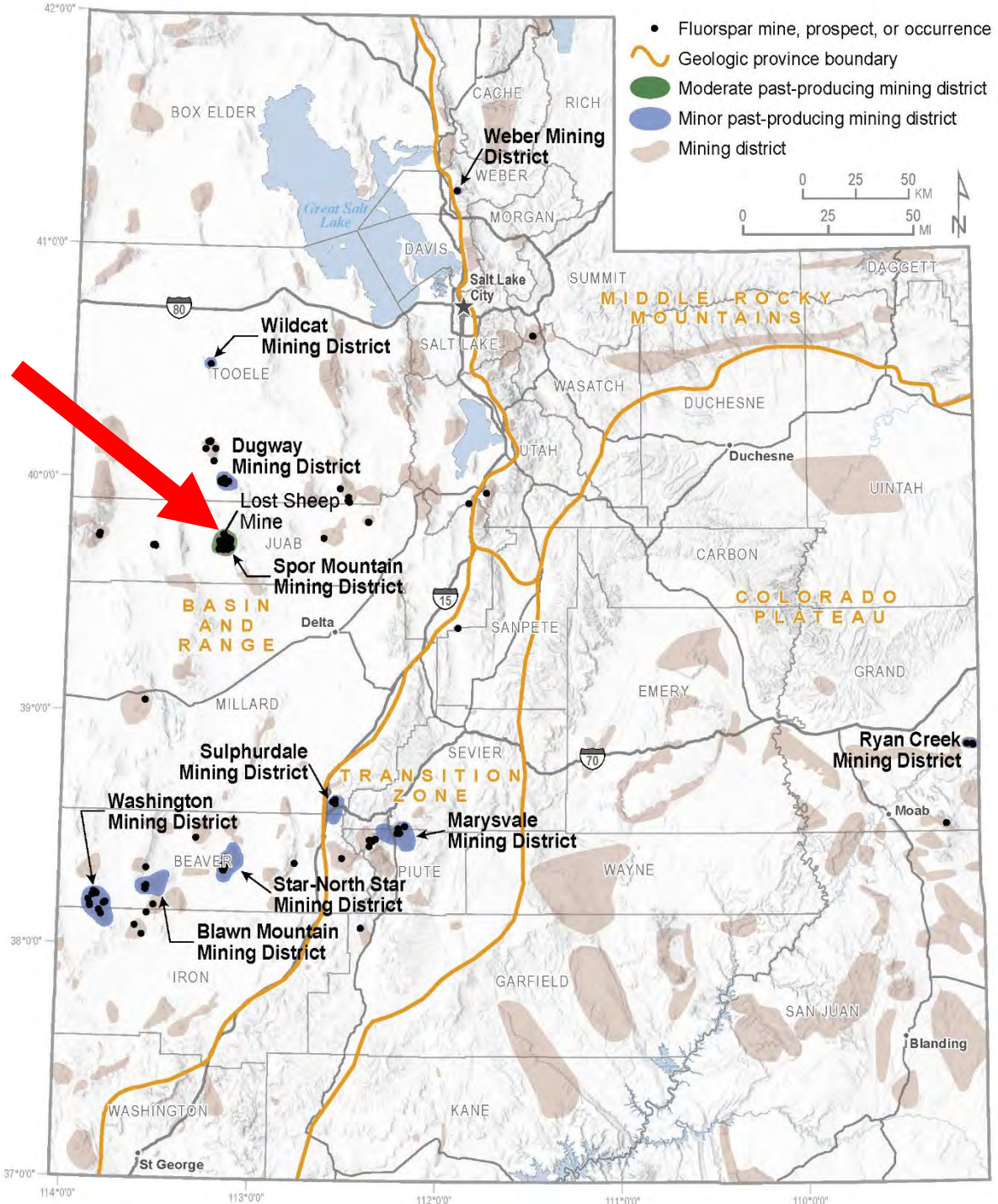
Fluorspar

- Used in steel, cement, and aluminum production, etc.; U.S. is 100% import reliant (as of 2020)
- Ares Strategic Mining is re-opening the Lost Sheep mine in the Spor Mountain district of Juab County
- When production starts it will be the only fluorspar mine in the country



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UTAH GEOLOGICAL SURVEY

Great Salt Lake – An Update

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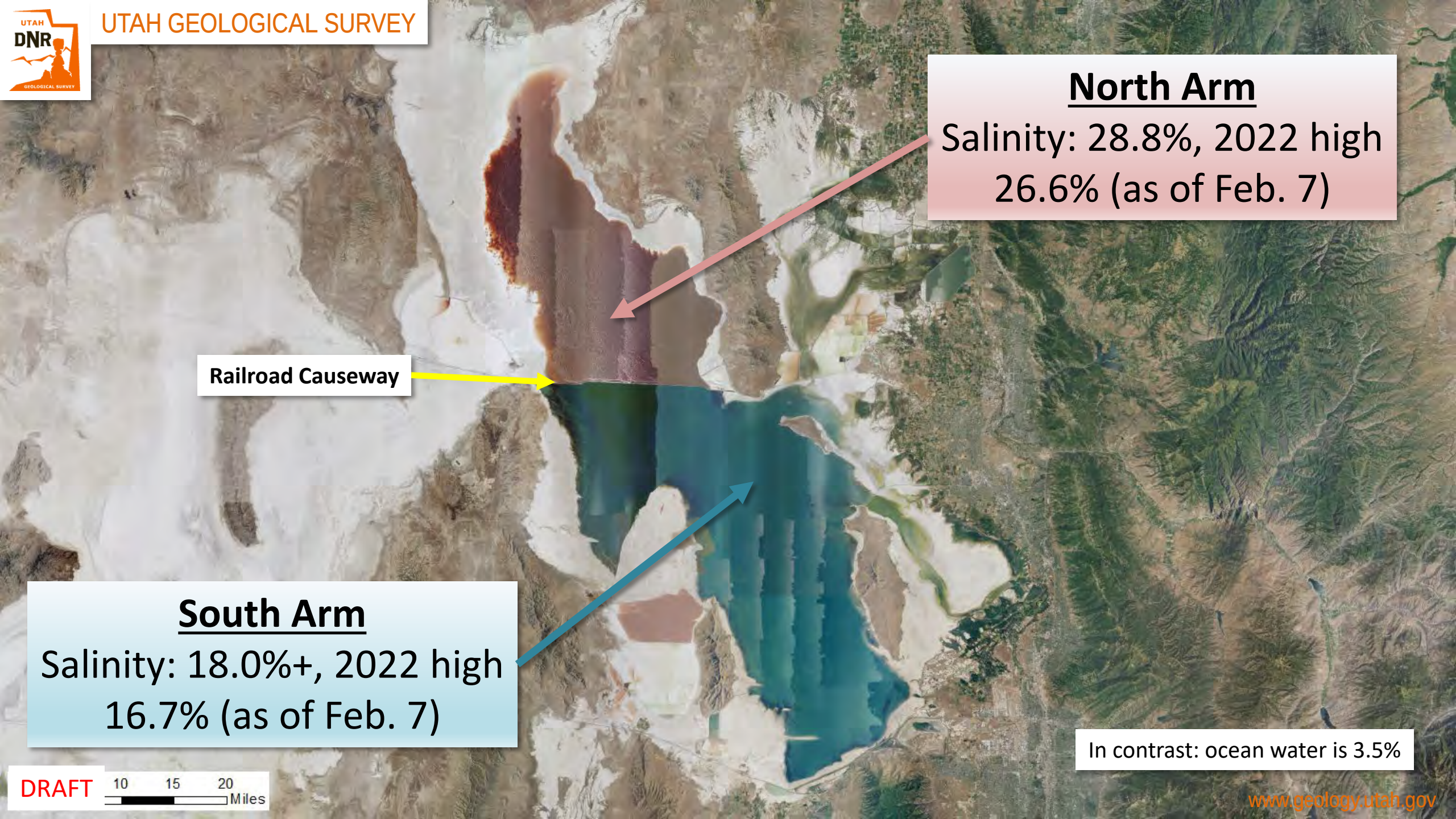
UTAH GEOLOGICAL SURVEY
North Arm
Salinity: 28.8%, 2022 high
26.6% (as of Feb. 7)
Railroad Causeway
South Arm
Salinity: 18.0%+, 2022 high
16.7% (as of Feb. 7)
In contrast: ocean water is 3.5%
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10 15 20 Miles
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UTAH GEOLOGICAL SURVEY
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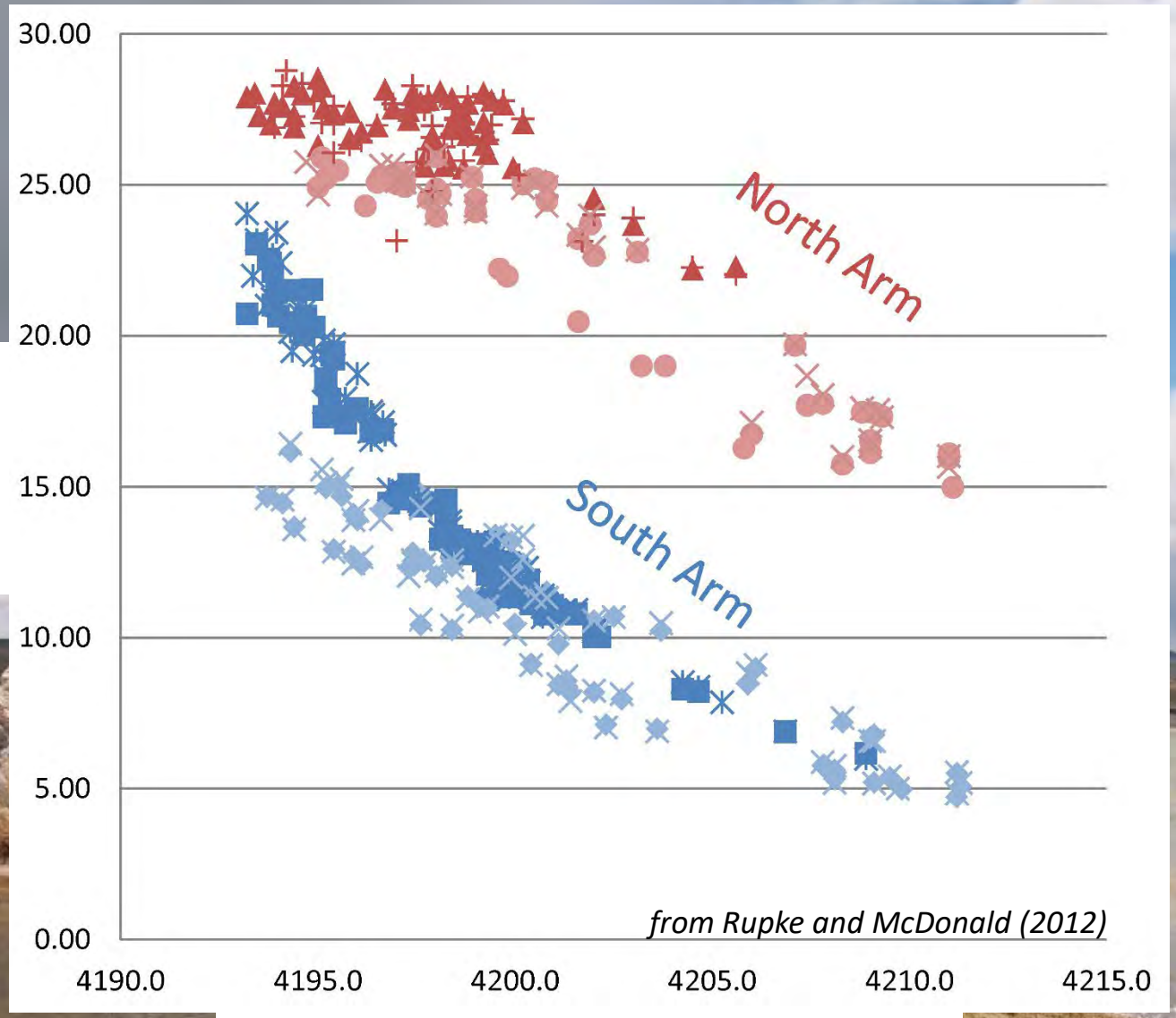
Salinity v. Lake Elevation



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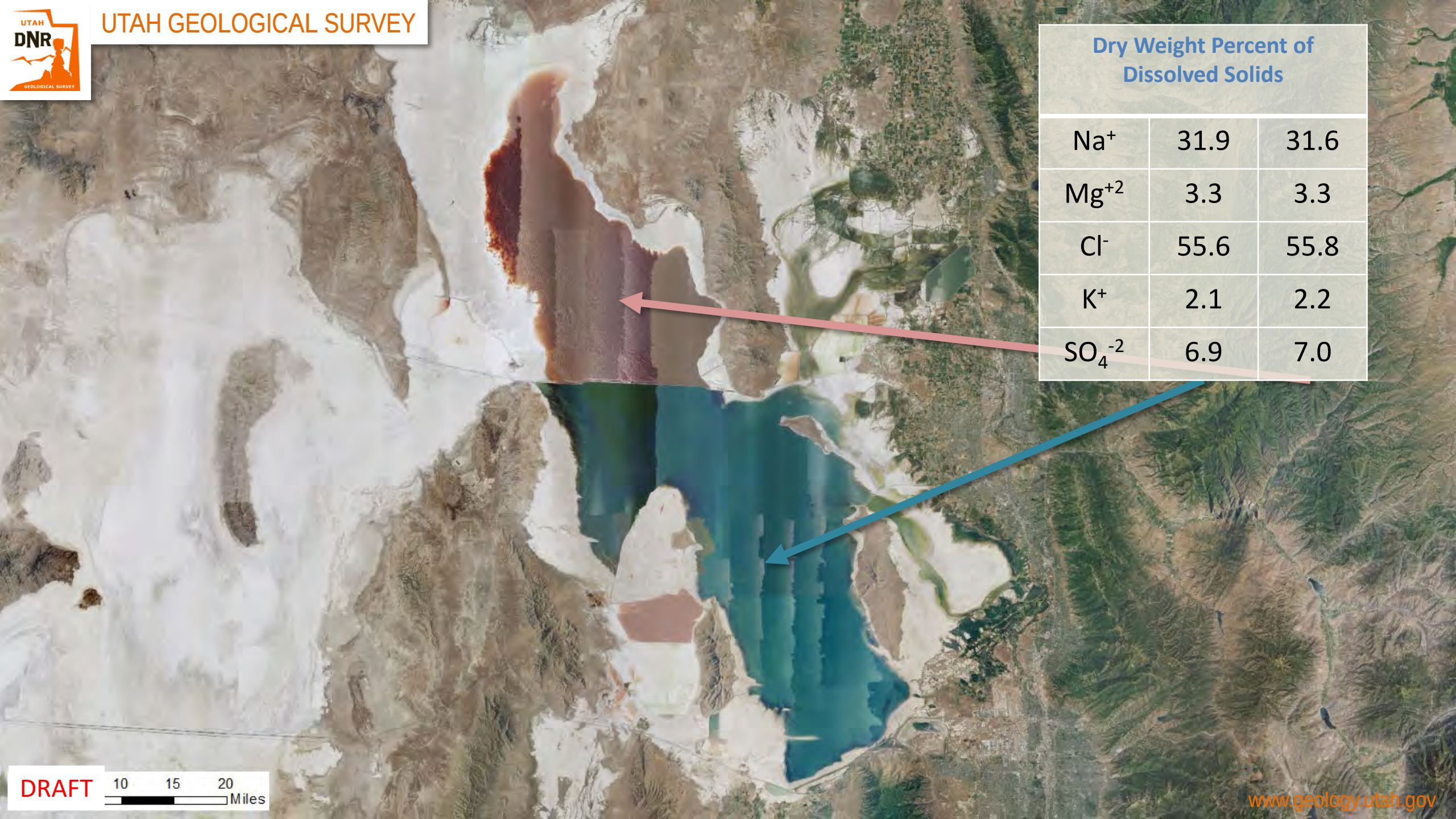
UTAH GEOLOGICAL SURVEY



Dry Weight Percent of Dissolved Solids		
Na^{+}	31.9	31.6
Mg^{+2}	3.3	3.3
Cl^{-}	55.6	55.8
K^{+}	2.1	2.2
SO_4^{-2}	6.9	7.0

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10 15 20 Miles

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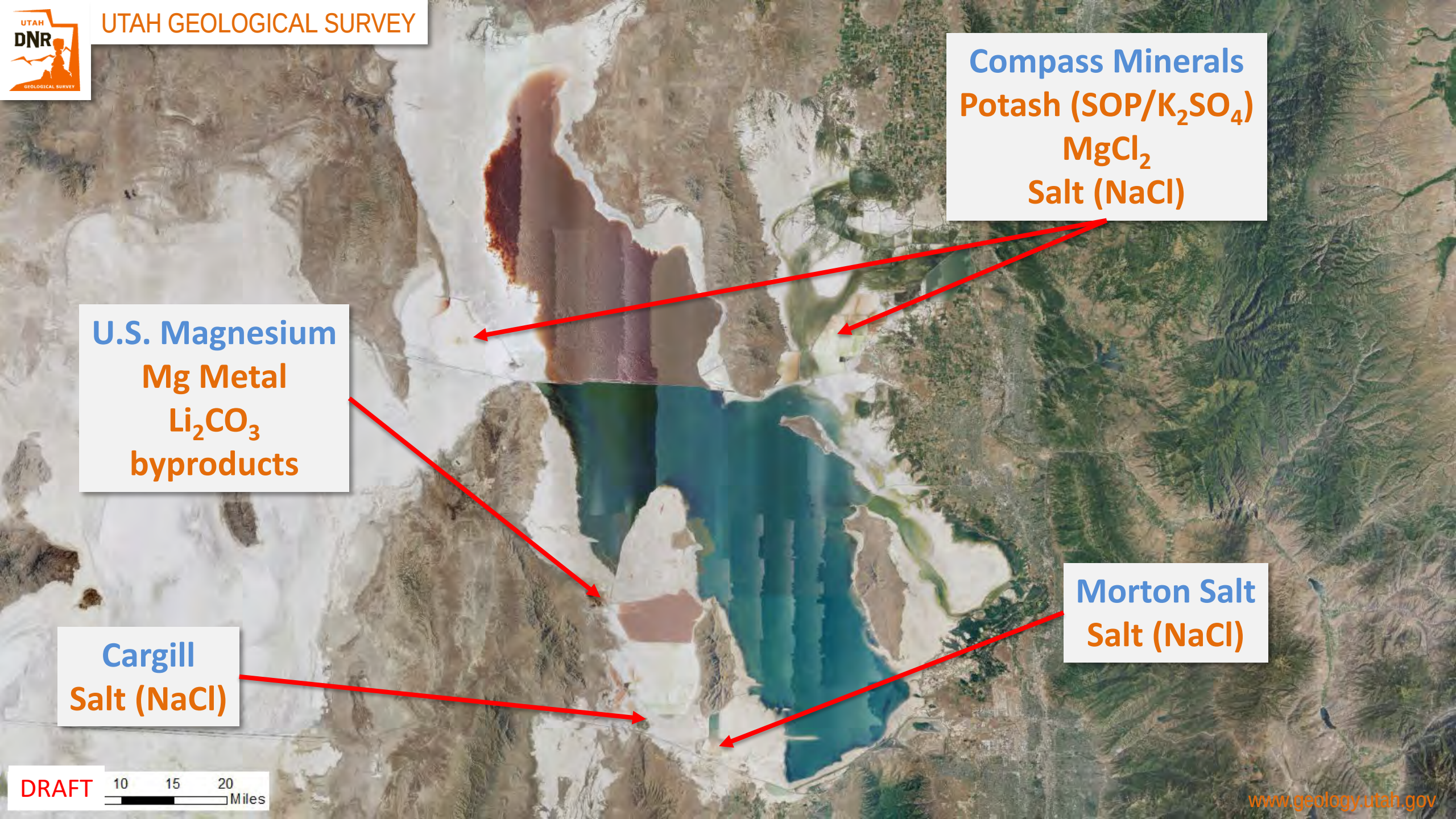
UTAH GEOLOGICAL SURVEY
Compass Minerals
Potash (SOP/K_2SO_4)
$MgCl_2$
Salt (NaCl)
U.S. Magnesium
Mg Metal
Li_2CO_3
byproducts
Morton Salt
Salt (NaCl)
Cargill
Salt (NaCl)
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10 15 20
Miles
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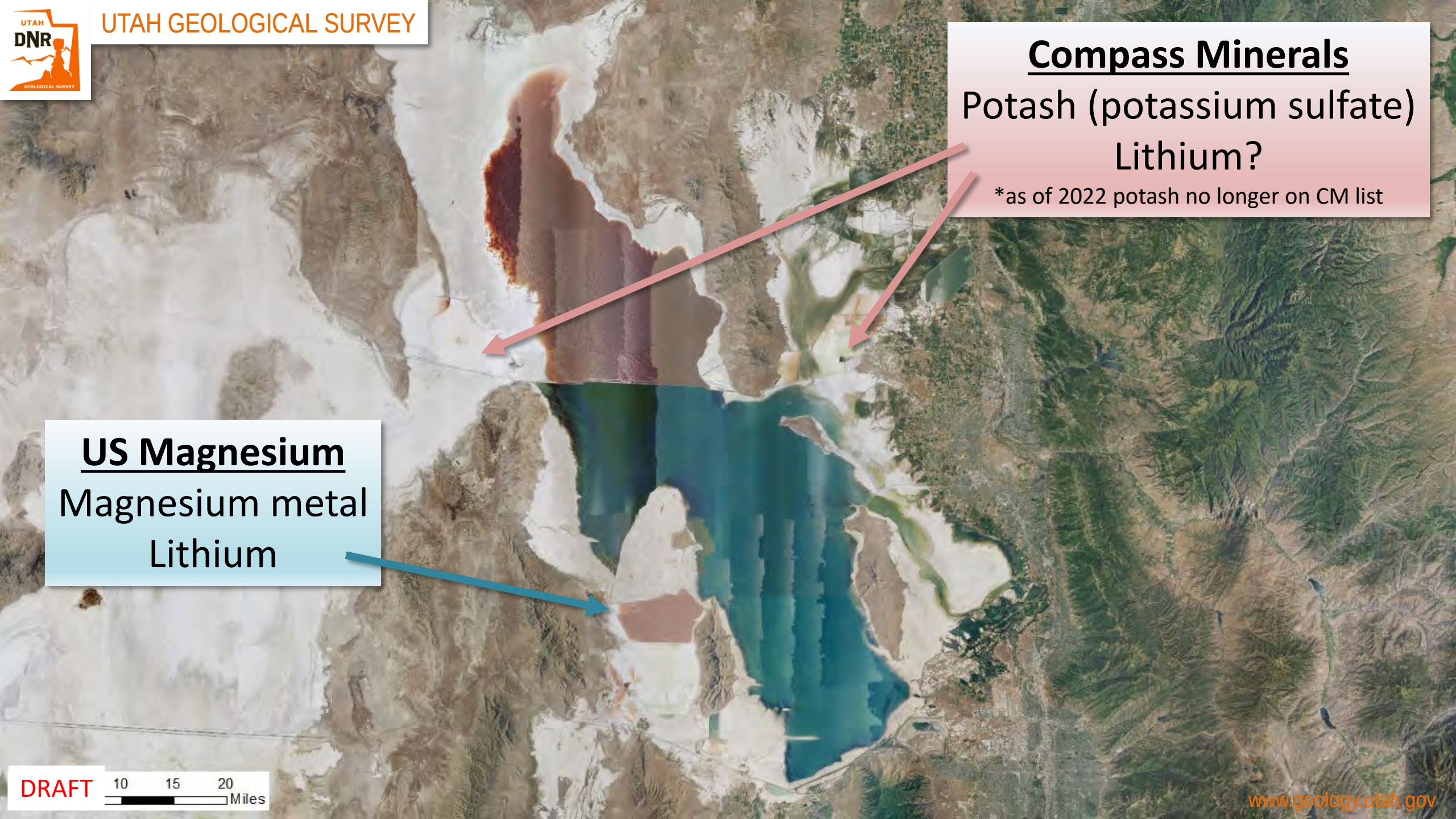
UTAH GEOLOGICAL SURVEY
Compass Minerals
Potash (potassium sulfate)
Lithium?
*as of 2022 potash no longer on CM list
US Magnesium
Magnesium metal
Lithium
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10
15
20
Miles
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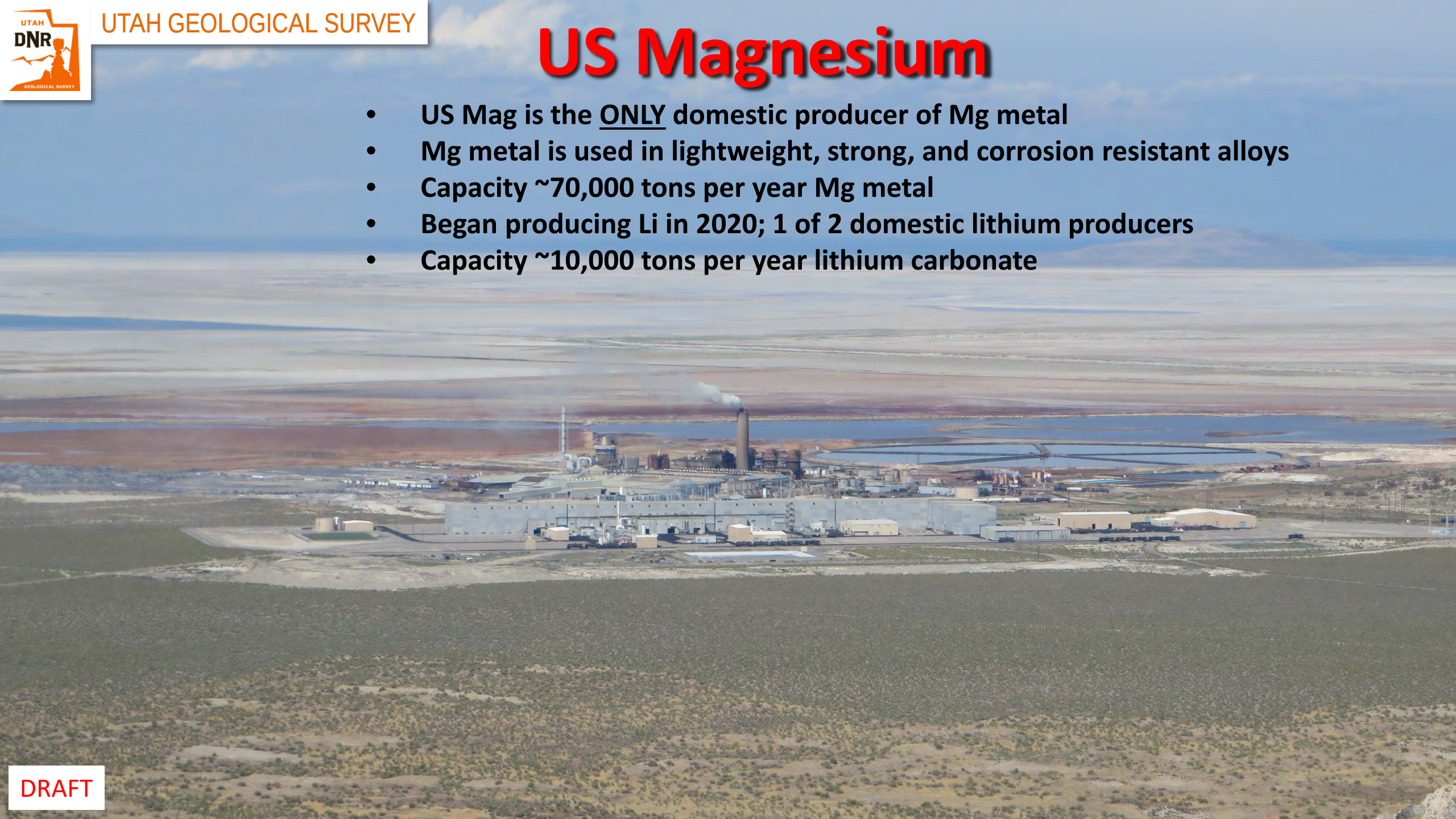
UTAH GEOLOGICAL SURVEY

US Magnesium

- US Mag is the ONLY domestic producer of Mg metal
- Mg metal is used in lightweight, strong, and corrosion resistant alloys
- Capacity ~70,000 tons per year Mg metal
- Began producing Li in 2020; 1 of 2 domestic lithium producers
- Capacity ~10,000 tons per year lithium carbonate



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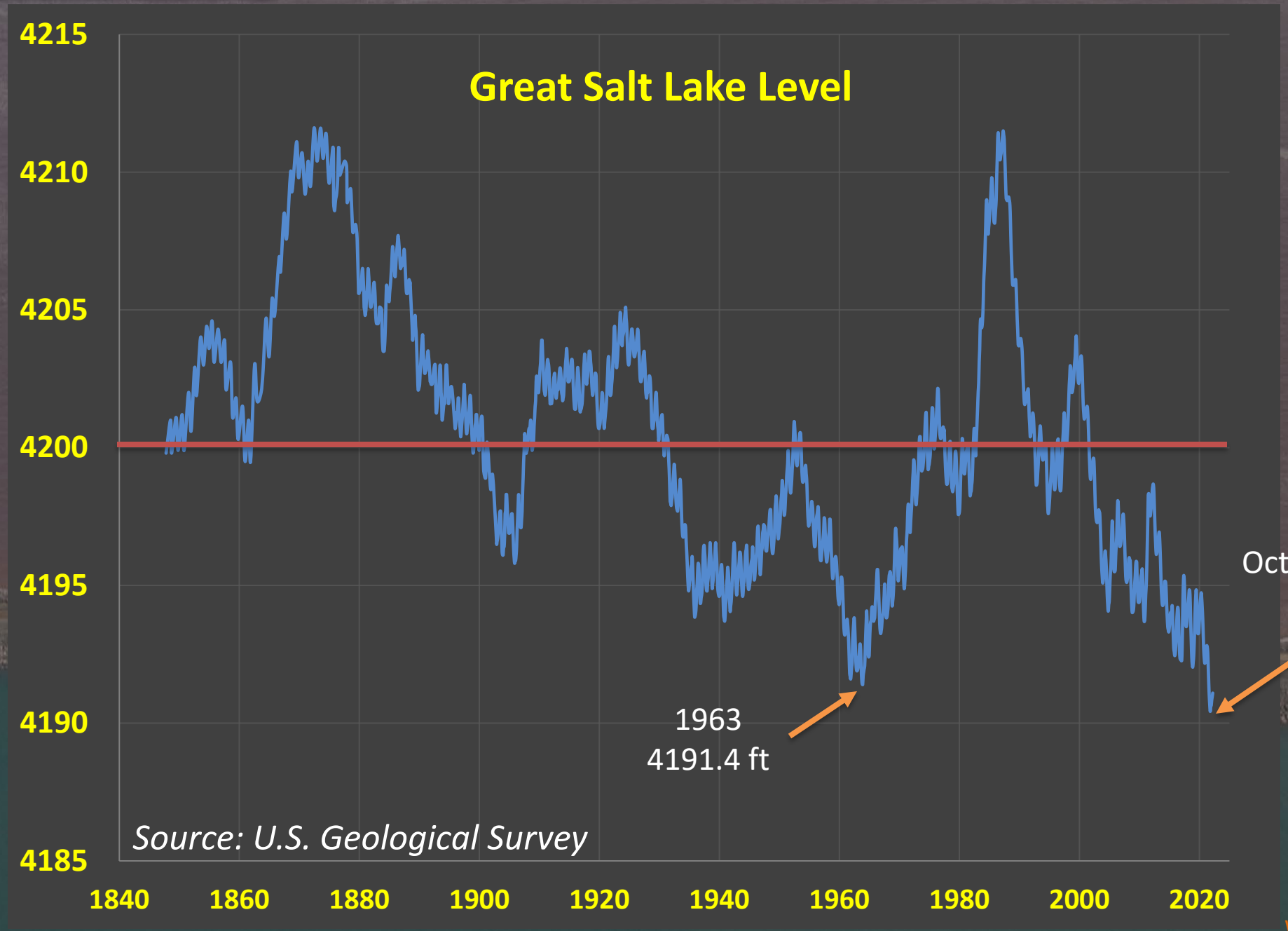
Compass Minerals

- Potash's primary use is in fertilizer
- New CM list in 2022 removed potash; released right *before* war in Ukraine
- Utah is one of only 2 potash producing states
- Compass is the **ONLY domestic** producer of potassium sulfate (K_2SO_4)
- Capacity of 320,000 tons per year of potassium sulfate
- Intends to start Li production in 2025

UTAH GEOLOGICAL SURVEY



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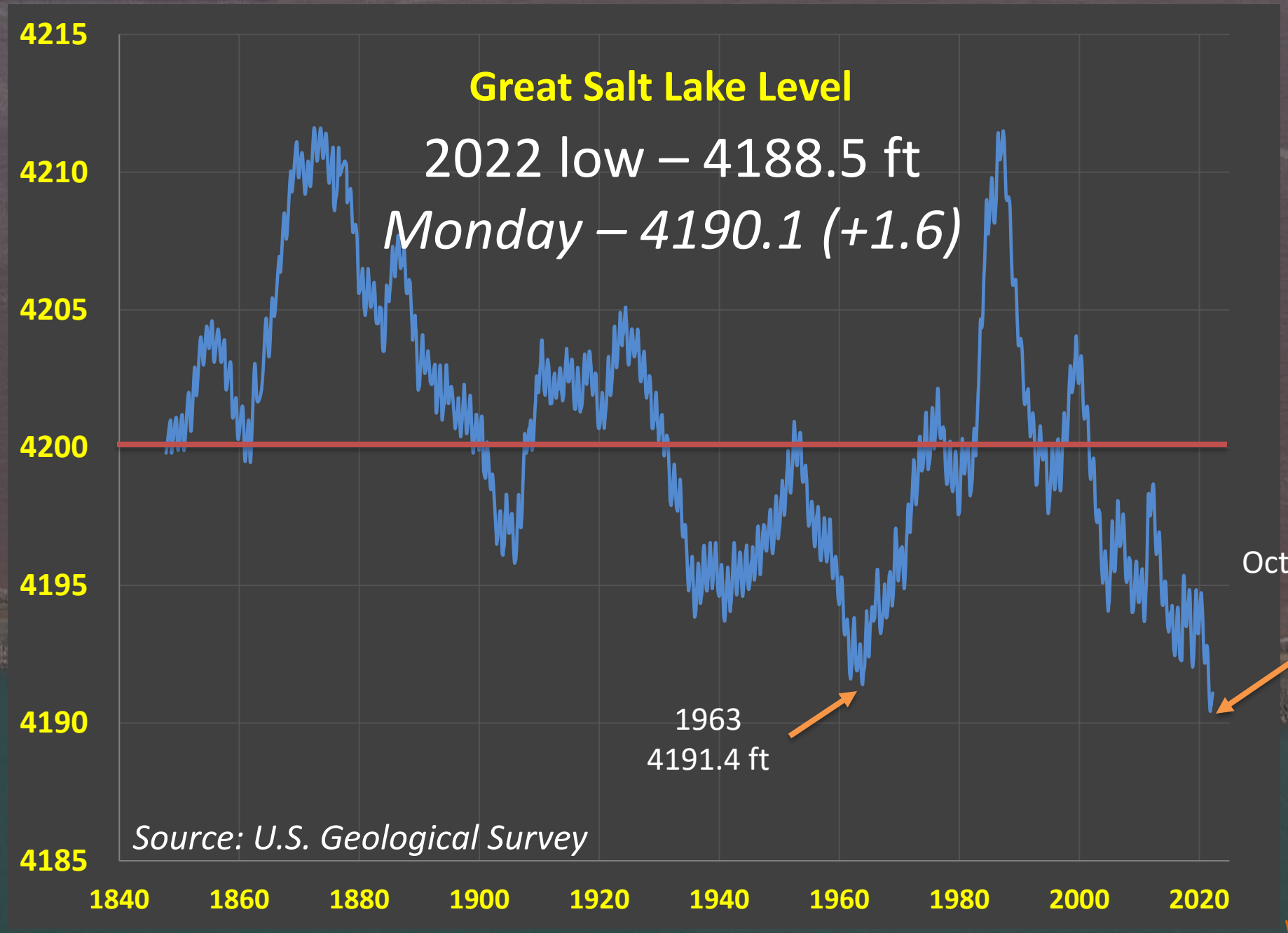
UTAH GEOLOGICAL SURVEY



Consumptive use has dropped lake level by 11 feet *(Wurtsbaugh et al., 2016)*

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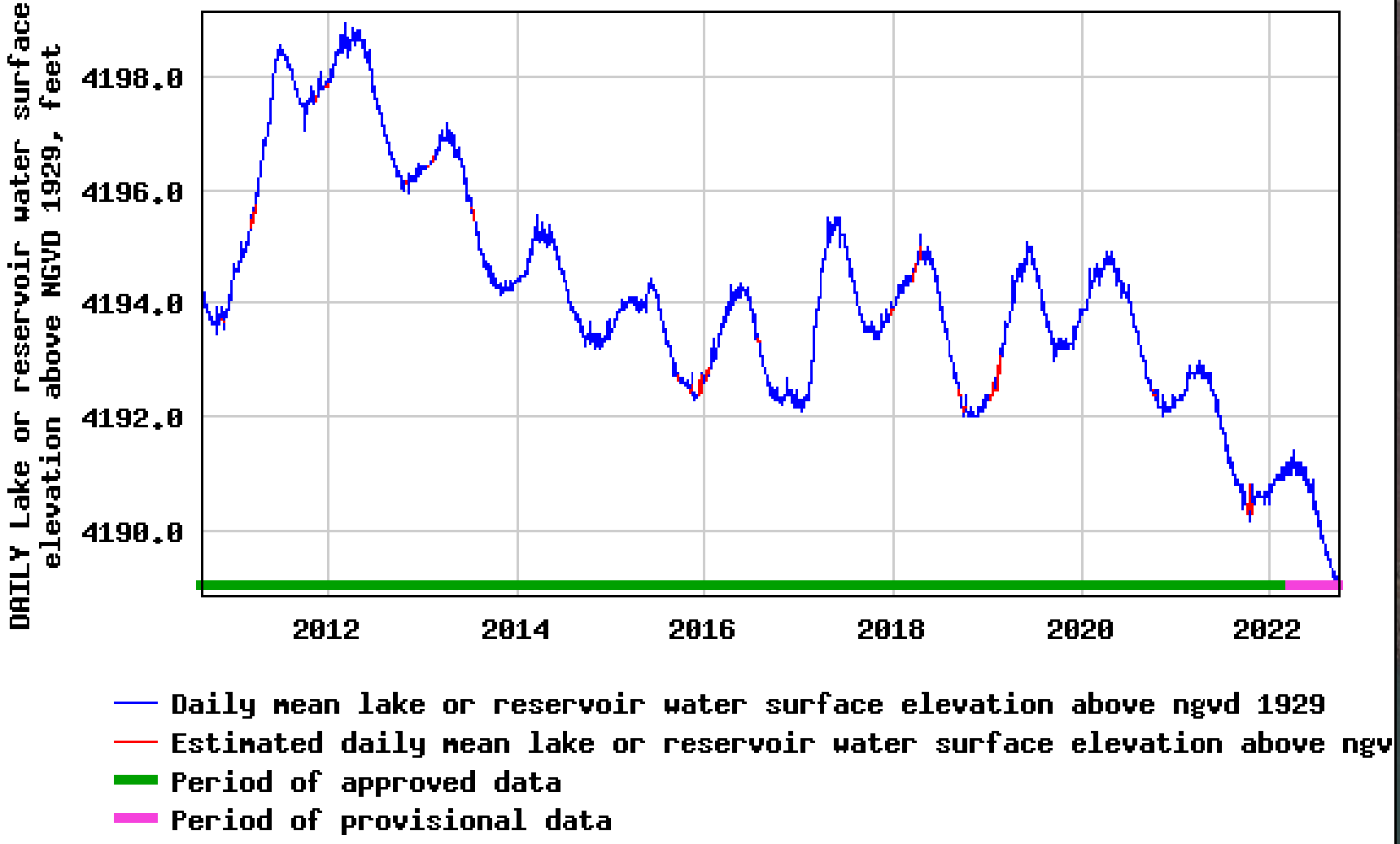
USGS

USGS 10010000 GREAT SALT LAKE AT SALTAIR BOAT HARBOR, UT



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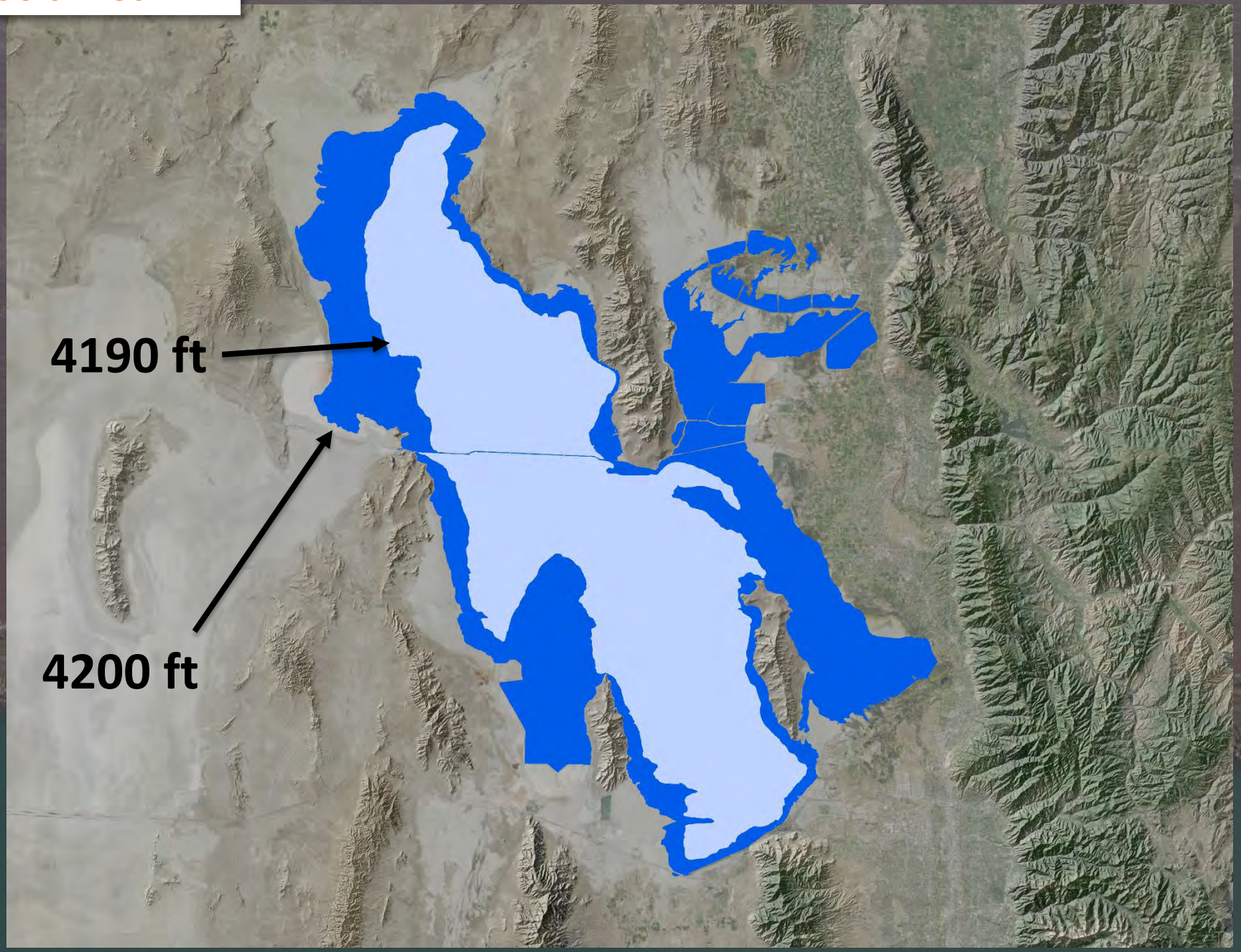

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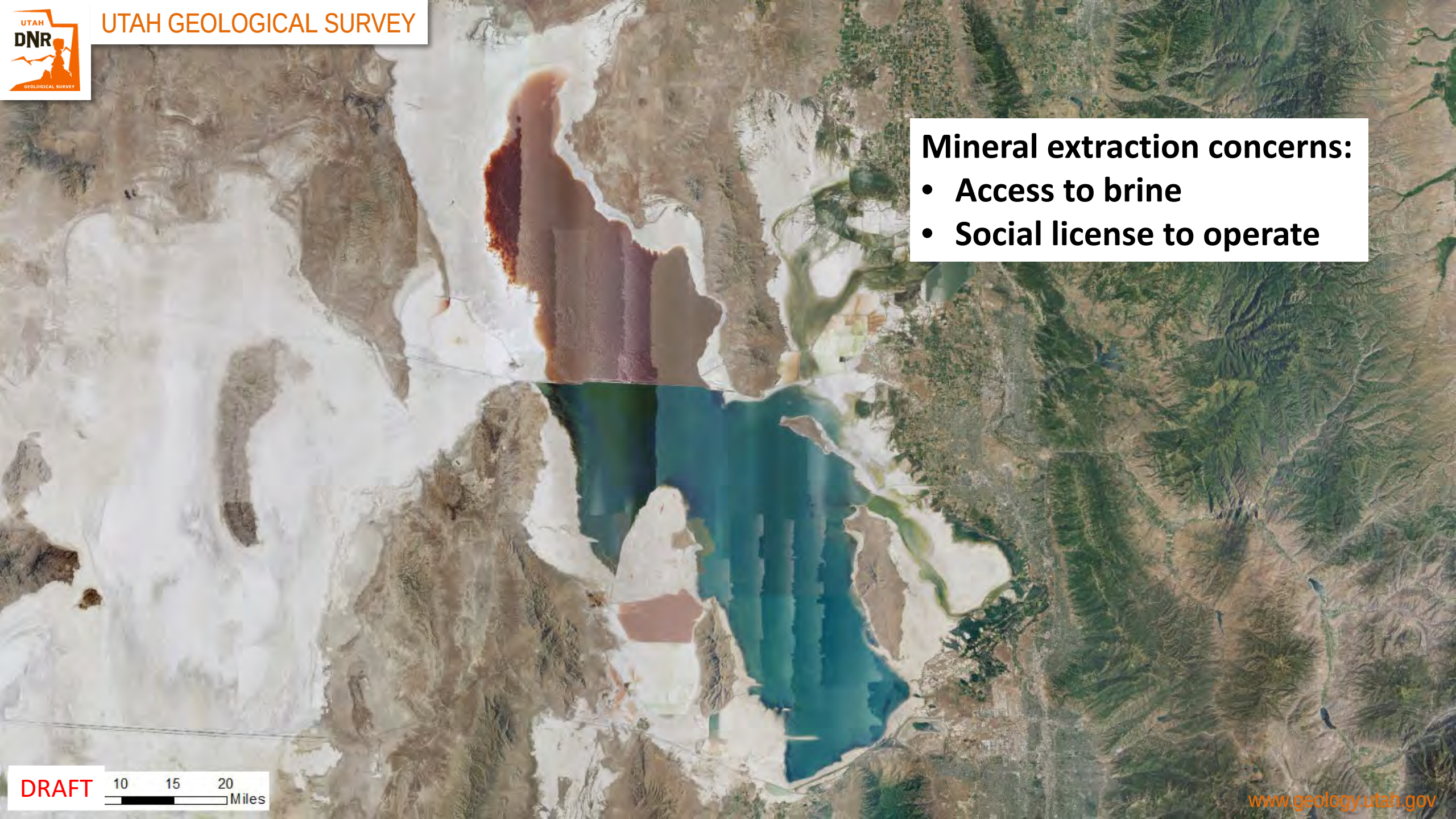
Great Salt Lake *IS* important:

- Important, dynamic ecosystem
  - MAJOR migratory bird flyway and shorebird breeding habitat
    - 10,000,000 birds visit GSL annually
  - Brine shrimp, brine flies (salinity levels are too high…)
  - Microbialites (microbialites are being exposed and dessicated…)
- Economy
  - Mineral industry
  - Brine shrimp (40% of world's brine shrimp eggs for aquaculture)
  - Recreation
- Climatic effects
  - Local precipitation (lake enhances moisture content of storm systems)
  - Lake responsible for 5 to 10% of snowfall along Wasatch Range
- Air quality
  - Exposed lakebed is a source of particulate matter



Mineral extraction concerns:

- **Access to brine**
- **Social license to operate**

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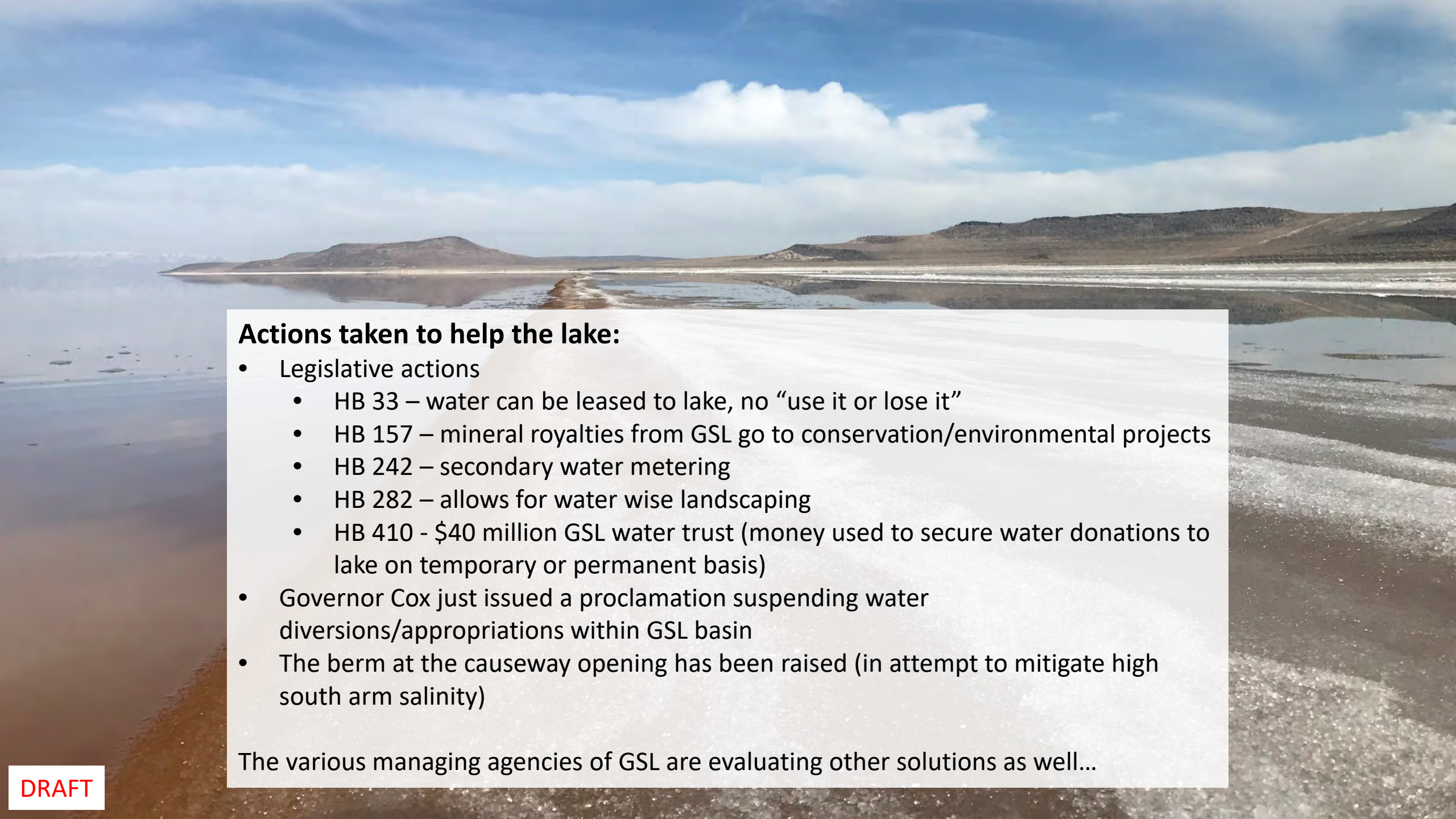
10 15 20 Miles



Actions taken to help the lake:

- Legislative actions
  - HB 33 – water can be leased to lake, no “use it or lose it”
  - HB 157 – mineral royalties from GSL go to conservation/environmental projects
  - HB 242 – secondary water metering
  - HB 282 – allows for water wise landscaping
  - HB 410 - $40 million GSL water trust (money used to secure water donations to lake on temporary or permanent basis)
- Governor Cox just issued a proclamation suspending water diversions/appropriations within GSL basin
- The berm at the causeway opening has been raised (in attempt to mitigate high south arm salinity)

The various managing agencies of GSL are evaluating other solutions as well…

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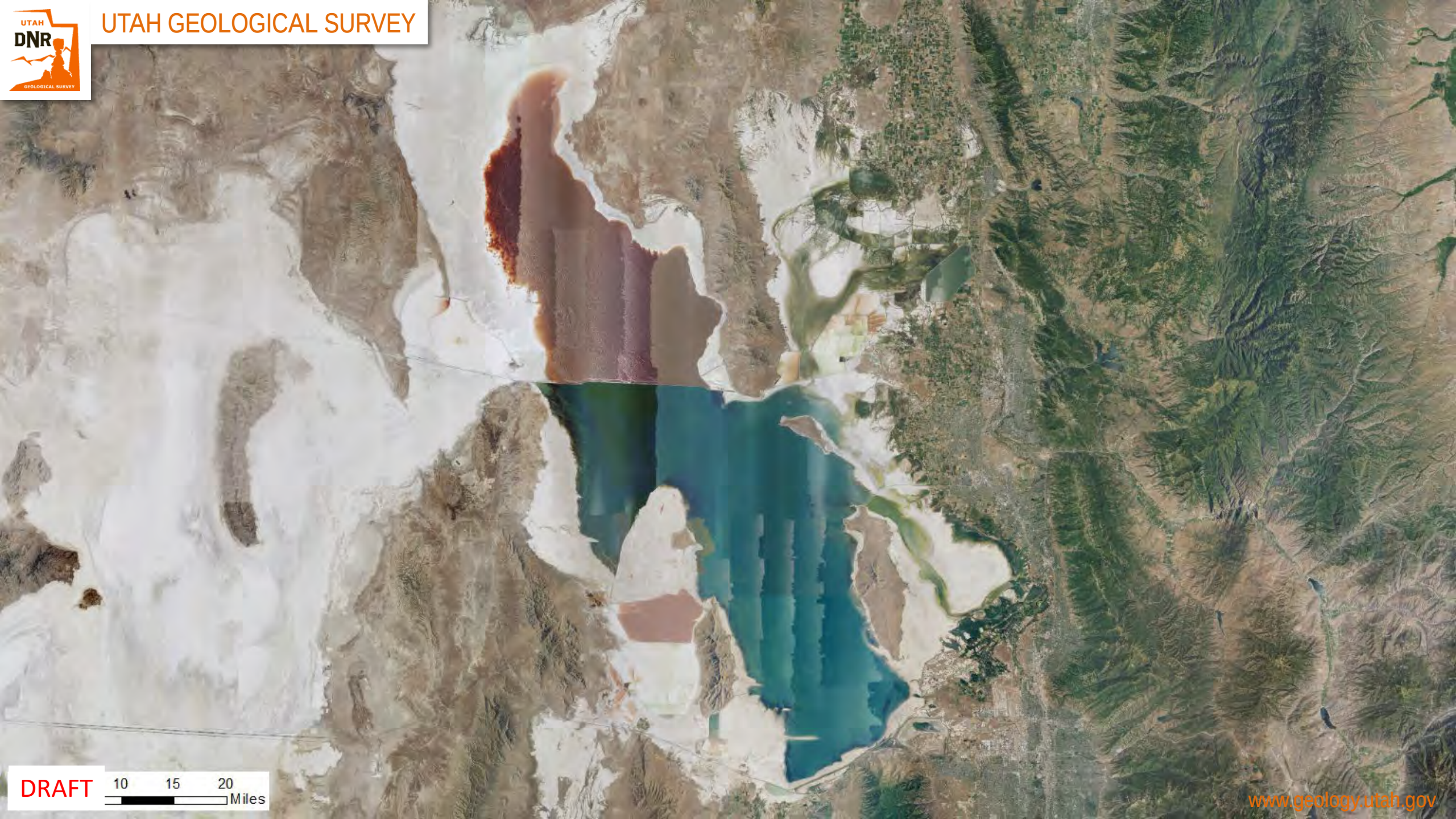
UTAH GEOLOGICAL SURVEY
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UTAH GEOLOGICAL SURVEY

UTAH MINING 2019

UTAH MINING 2020

UTAH MINING 2021

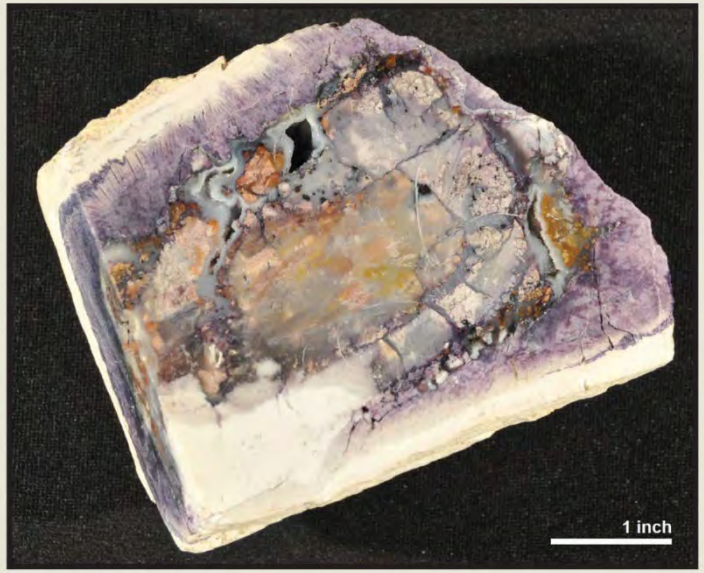
Metals, Industrial Minerals, Uranium, Coal, and Unconventional Fuels

by Stephanie E. Mills, Andrew Rupke, Michael D. Vanden Berg, and Taylor Boden

CIRCULAR 134
UTAH GEOLOGICAL SURVEY
UTAH DEPARTMENT OF NATURAL RESOURCES
2022

CRITICAL MINERALS OF UTAH

by Stephanie E. Mills and Andrew Rupke



CIRCULAR 129
UTAH GEOLOGICAL SURVEY
UTAH DEPARTMENT OF NATURAL RESOURCES
2020

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Download at geology.Utah.gov

Contact:
Andrew Rupke (industrial minerals), andrewrupke@utah.gov, 801-537-3366
Stephanie Mills (metals), smills@utah.gov, 801-537-3308

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