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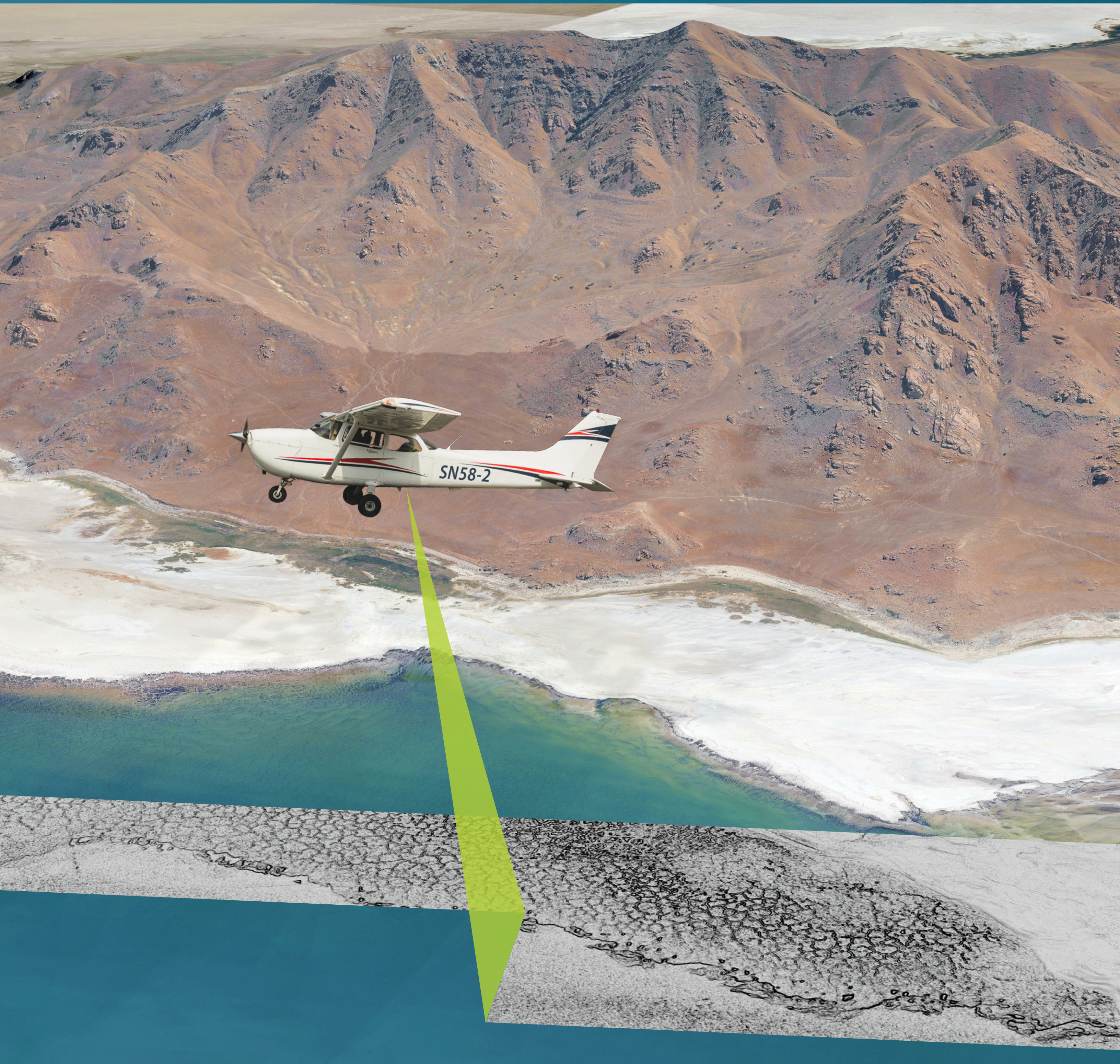

How Green Lasers are Illuminating the Underwater Secrets of Great Salt Lake

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Cover | An artist's rendition of how lidar is deployed to reveal underwater features of Great Salt Lake. Aerial image from Google Earth.

Survey Notes is published three times yearly by the Utah Geological Survey, 1594 W. North Temple, Suite 3110, Salt Lake City, Utah 84116; (801) 537-3300. The UGS provides timely scientific information about Utah's geologic environment, resources, and hazards. The UGS is a division of the Department of Natural Resources. Single copies of *Survey Notes* are distributed free of charge within the United States and reproduction is encouraged with recognition of source. Copies are available at https://geology.utah.gov/map-pub/survey-notes/. ISSN 1061-7930 Printed on recycled paper

DIRECTOR'S PERSPECTIVE

by L. Darlene Batatian

The Utah Geological Survey (UGS) provides timely scientific data about geologic and natural resource assessments throughout the state of Utah. During the 2026 legislative session, we showcased our work to the Natural Resources, Agriculture and Environment Committee and highlighted our statewide footprint with a map of current studies that will help inform and support resource decision-making in communities across the state. We also presented case studies that highlight the return on investment that the UGS provides with our state dollars, and presented the UGS as a "go to" resource for timely scientific data for legislators and their communities. Almost immediately, we were solicited for information on, and included in, several bills that will result in future work on groundwater, wetlands, and critical minerals resources. These include SB254, Extracted Natural Resources Amendments (Sen. Millner); HB546, Public Lands Duty of Care Amendments (Rep. Ivory); and HB509, Wetlands Amendments (Rep. Owens).

The UGS also received approval as part of HB125, DNR Modifications (Rep. Shipp), to update our enabling statute (79-3-202) that adds language formally authorizing the UGS to perform groundwater and surface water resource studies, as well as wetlands resource characterizations and assessments. Although we have performed this work for decades on behalf of the state, groundwater, surface water, and wetlands resource studies were not articulated in our statute. As part of this statute update, the UGS Board was given an additional position to represent groundwater and water resources, and the minerals member role was expanded to include energy and geothermal expertise.

Water resources, Great Salt Lake, mineral resources, geothermal, and geologic hazards continue to be driving issues for the state, and the UGS provides data to support their characterization, exploration, potential for development and informed management. This issue of *Survey Notes* highlights a few of our recent studies, including a first-of-its-kind airborne lidar bathymetric mapping of the floor of Great Salt Lake as well as a study on Utah's pozzolan resources, which can partially replace cement in concrete (a mix of aggregate and cement), providing durable properties and reducing cement production's carbon footprint. Also, the UGS is launching new web-based data products that feature statewide assessments of carbon storage potential, and a geothermal and geophysical data catalogue. This issue also includes information about Utah's unique and interesting geology, including the historic Silver Reef mining district and how Utah's geology has been featured as a backdrop for movies. I invite you to explore and learn more about Utah's geology and resources at geology.utah.gov.

How Green Lasers are Illuminating the Underwater Secrets of Great Salt Lake

by Emily Kleber and Michael Vanden Berg

Great Salt Lake (GSL) has a unique natural ecosystem, from birds to brine shrimp, and wetlands to open water. The lake also hosts a bustling extractive minerals industry and provides numerous recreational opportunities. Recently, the lake has reached historic lows, posing threats to the delicate ecosystem, industries, and surrounding communities. Understanding the impacts of changing lake levels requires accurate modeling of lakebed exposure and changing water volumes. This detailed understanding of the shape of the lakebed (or bathymetry) is invaluable to researchers studying its ecology, hydrology, and natural resources.

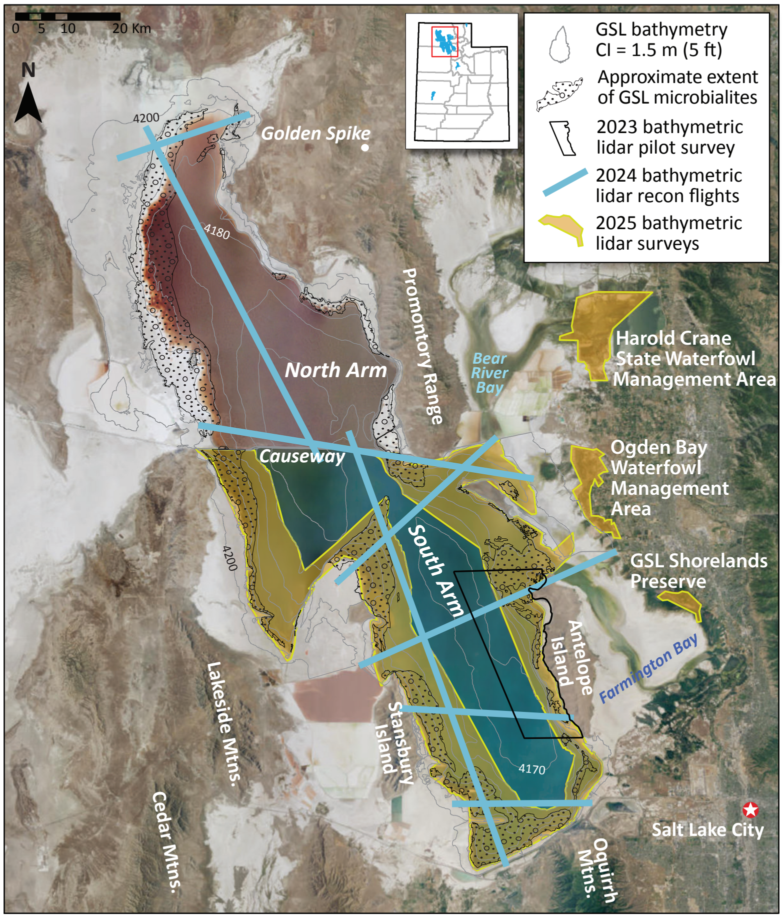
GSL is shaped more like a pan than a bowl. Given the low gradients (or slopes) of the lake bottom, one foot of lake elevation change can move shorelines by miles. Existing bathymetric data for the lake was collected in the late 1990s with sound-based sonar equipment towed behind a boat. Though high tech at the time, this method had several limitations that reduced accuracy, especially for natural features in the shallow waters. But what if you could use lasers instead of sonar?

Enter lidar, "light detection and ranging," or in other words, shooting lasers at the Earth. Terrestrial, or land-based, lidar uses an aircraft-mounted sensor with a near-infrared laser (1064 nanometers [nm] wavelength). As the aircraft flies in a lawnmowing-like pattern, the sensor sends millions of light pulses towards the ground where they bounce off dry land before returning to the aircraft, generating a high-resolution representation of Earth's surface. In contrast, bathymetric lidar systems use a visible green laser pulse (532 nm wavelength) to pierce the water's surface, pass through the water column, bounce off the floor of a water body, and reflect back to the sensor. This reflected data is then processed to create a "point cloud" of tens of millions of elevation points depicting the shape of the lake bottom, shoreline, and playa, both above and below the water.

Collecting and processing bathymetric lidar data has unique technical and logistical challenges and can be impacted by factors including:

Water clarity - GSL is notorious for having murky water, and water clarity impacts how deep the laser pulses can reach. Data acquisition during windows of water clarity is best (e.g., in early summer).

Water depth - The deepest part of the lake is about 25–28 feet deep, depending on lake level elevation. It is difficult for the laser to penetrate to these depths especially if the water clarity is poor due to suspended sediment and/or biological activity.



Bathymetric lidar data coverage of GSL.

Weather - Good data collection requires a window of clear weather, mostly calm water, and specific sunlight angles. However, mirror-glass water often results in most light being reflected off the surface rather than penetrating to the lake bottom.

Lakebed substrate - The laser pulses do not reflect well off soft substrates (e.g., mud) and dark materials that can absorb the laser pulse.

Large area - The lake is very large, nearly 1,700 mi^2, making data acquisition expensive and difficult to manage. Also, processing massive amounts of data (i.e., petabytes!) can be challenging.

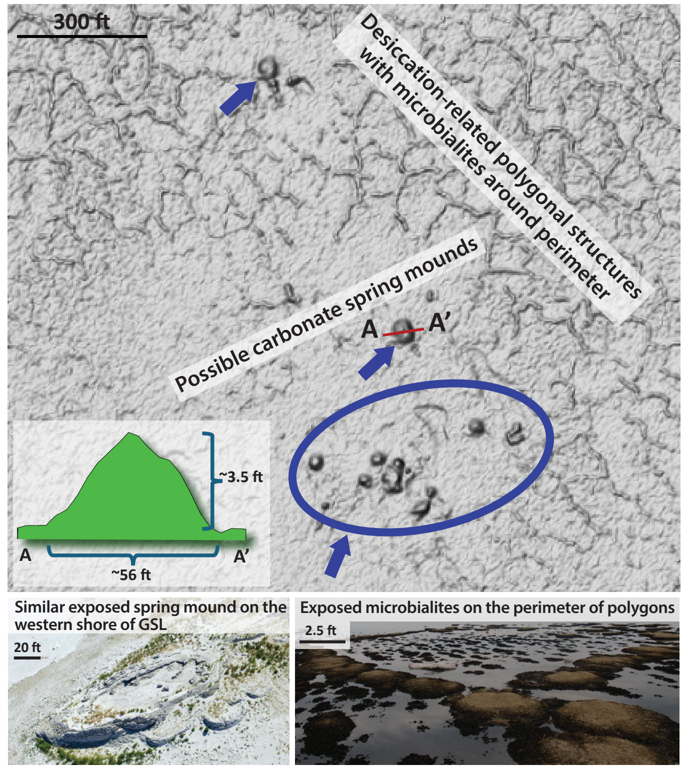
Since 2022, the Utah Geological Survey (UGS) has been leading an innovative effort to assess how well bathymetric lidar data collection could work at GSL, particularly in the south arm. Bathymetric lidar is a technology that has been around for decades but mostly used in marine, freshwater lakes, and river environments. To our knowledge, UGS's efforts are the first time a high-elevation saline lake has been scanned using this technology. In partnership with the Utah Division of Forestry, Fire and State Lands, the UGS commissioned industry-leading specialists Aero-Graphics Inc. (a local Utah-based geospatial company) and Dewberry Inc.

(a large international company with unique expertise in bathymetric lidar data collection) to collect bathymetric lidar data around the lake.

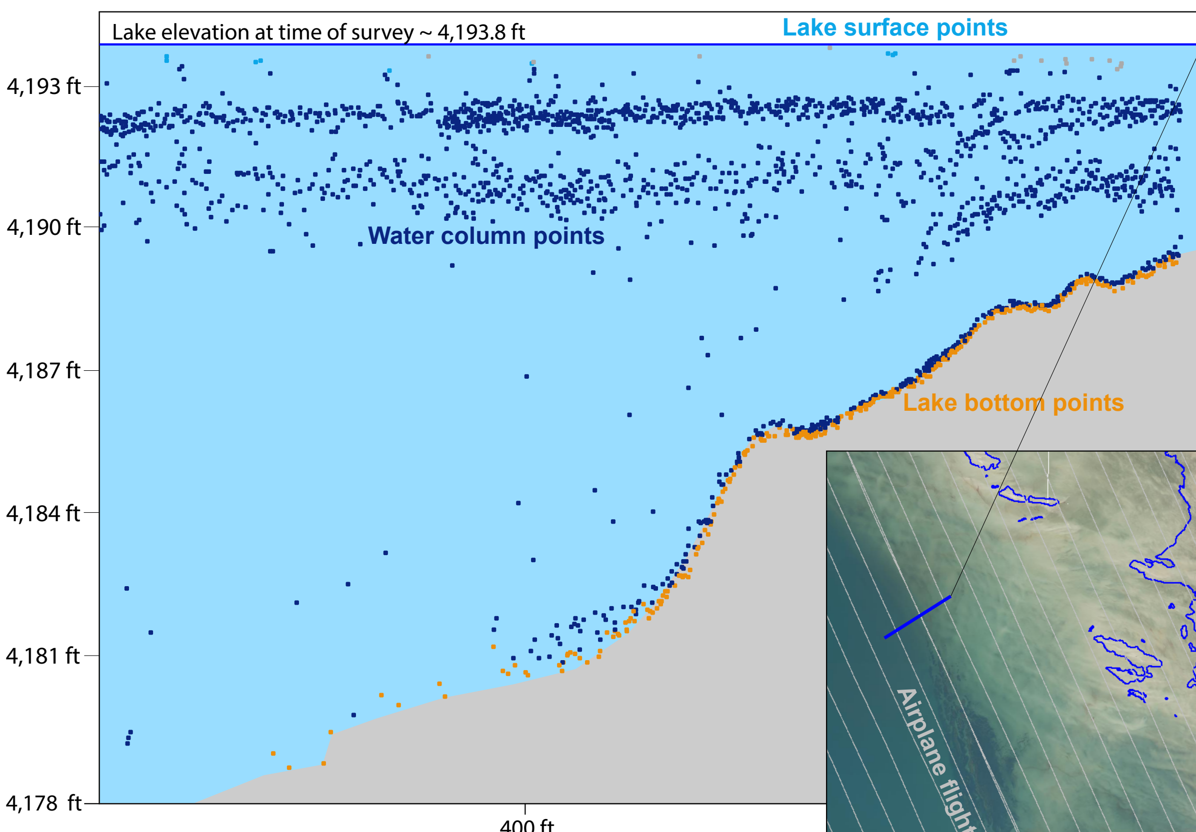
We started the project with a test area to develop best practices with this technology in a unique environment like GSL. The pilot study began in spring 2023 with a 50-square-mile area on the west side of Antelope Island, using an industry standard bathymetric lidar sensor (this data was collected by NV5 Geospatial). Overall, this survey obtained bottom returns over only 28% of the total area surveyed. In the deeper lake areas to the west (greater than 9 feet in water depth) bottom returns were not reliably detected. However, where data was recovered in the shallow shelf environment (depths less than 9 feet), the survey showed unprecedented high-resolution topographic detail, highlighting structures including microbialite reefs and possibly newly discovered spring-related carbonate mounds.

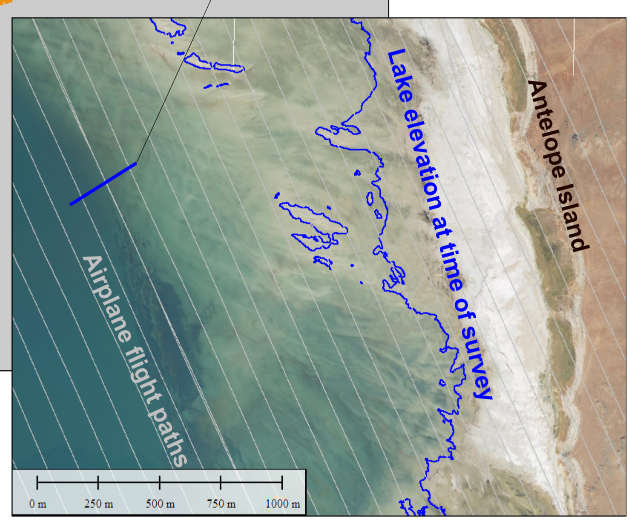
In fall of 2024, more reconnaissance data was collected along single flight paths using a much more powerful sensor. This sensor achieved bottom returns in water depths of up to 15 feet in the south arm but was only able to return data from depths less than 1.5 feet in the murkier north arm. Overall, the pilot study and lake transects provided important parameters for optimal data collection that maximized data quality and helped establish a budget for future surveys.

Taking advantage of the annual clear water window in spring 2025, Aero-Graphics and Dewberry started whole-sale data collection over nearly 400 square miles of the south arm, focusing on the important

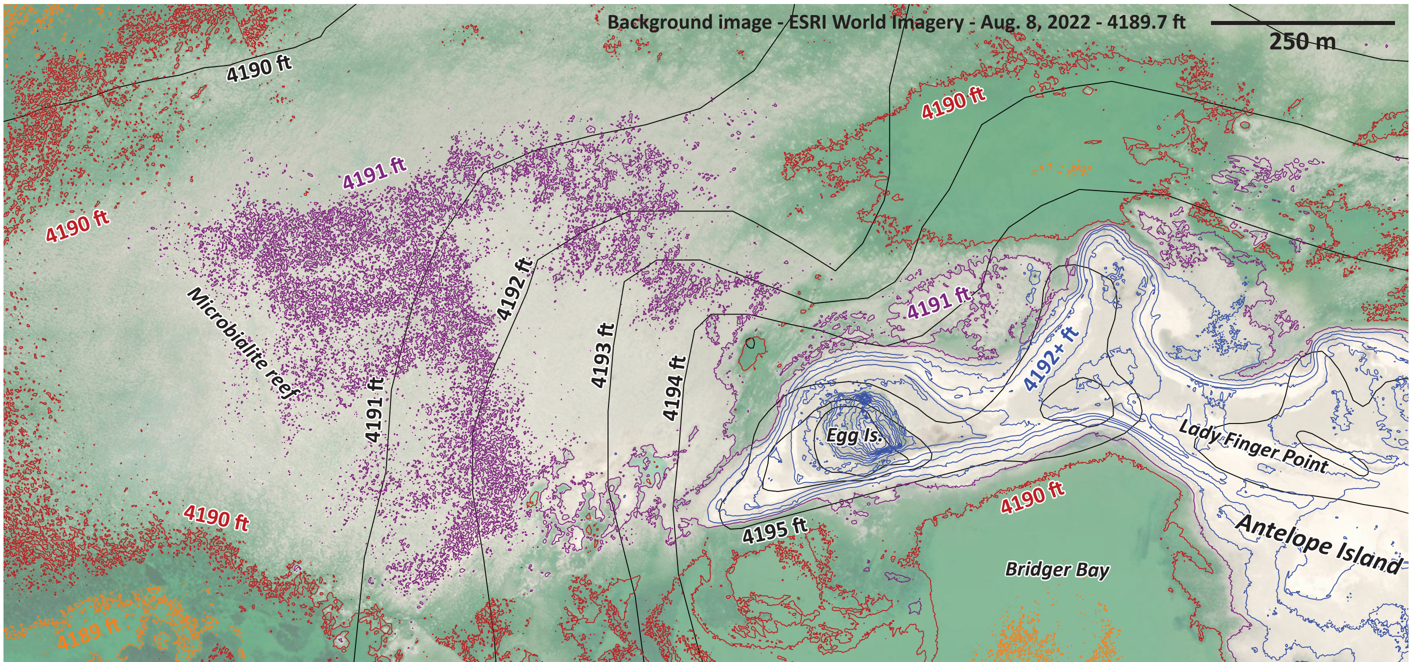


High-resolution bathymetric lidar data from an area about 2 miles west of northern Antelope Island. Several unique features are highlighted including large-scale desiccation-related polygons with microbialite domes growing along the perimeters, as well as newly discovered large-scale mounds interpreted to possibly be related to groundwater springs.





Elevation profile showing spread of bathymetric points from the lidar survey. Green laser pulses from the airplane-mounted sensor need to pass through the water surface and water column before potentially hitting and reflecting off the lake bottom. The number of lake bottom points (orange) decreases with depth.



The new bathymetric lidar data can be used to create more accurate, higher-resolution lakebed elevation contours in the nearshore environment (multi-colored lines) compared to currently published data (black lines). In fact, the resolution is so high that the contours (in purple - 4191 feet) trace around individual microbialite domes that have 0.5 to 1.0 feet of relief.

shallow shelf area around the perimeter of the lake. The project team also collected data over three wetland areas east of the lake. Due to the poor data quality from our test flights over the north arm, further data collection in this area was deemed wasteful. The massive amount of data collected across the lake is currently being processed and full data delivery is scheduled for summer 2026. However, the pilot data is currently available, and we have already received some sneak peaks of the amazing new data.

Early analysis of some of the new bathymetry data is already providing key insights to researchers at the UGS. We found that this new data can be used to much more accurately model lake water elevation, lakebed exposure, and changing water volumes. In addition, the high-resolution data in the shallow water areas will significantly improve our understanding of the spatial distribution of GSL's unique microbialite reefs, and the impacts of low lakes levels and exposure on these important structures, which are recognized as the base of the lake's food web and ecosystem (see *Survey Notes*, v. 54, no. 1).

Bathymetric lidar data can provide a glimpse into the secret hidden world of GSL. The challenges of data collection are immense, and although the technology does not work well in all areas of the lake, the data that is being returned will provide a level of detail about the lakebed never seen before. The UGS is excited to complete this study and share this new data with everyone that studies GSL and its changing environment.

ABOUT THE AUTHORS

Emily Kleber is a project geologist with the Geologic Mapping Program at the Utah Geological Survey. Prior to working with the UGS, Emily worked as a geologist and soil scientist with the Bureau of Land Management, and as a lidar data manager for OpenTopography. She joined the Geologic Hazards Program at the UGS in 2016 and focused on fault- and earthquake-related research before moving to the mapping program in 2023.

Michael Vanden Berg is the UGS Energy & Minerals Program Manager, leading a diverse team of geoscientists that research Utah's energy and mineral resources. His main area of research focuses on the petroleum-bearing lacustrine Green River Formation in the Uinta Basin. He is also involved in research on the modern Great Salt Lake, including its extensive microbialites, as an analogue for ancient lacustrine deposits.

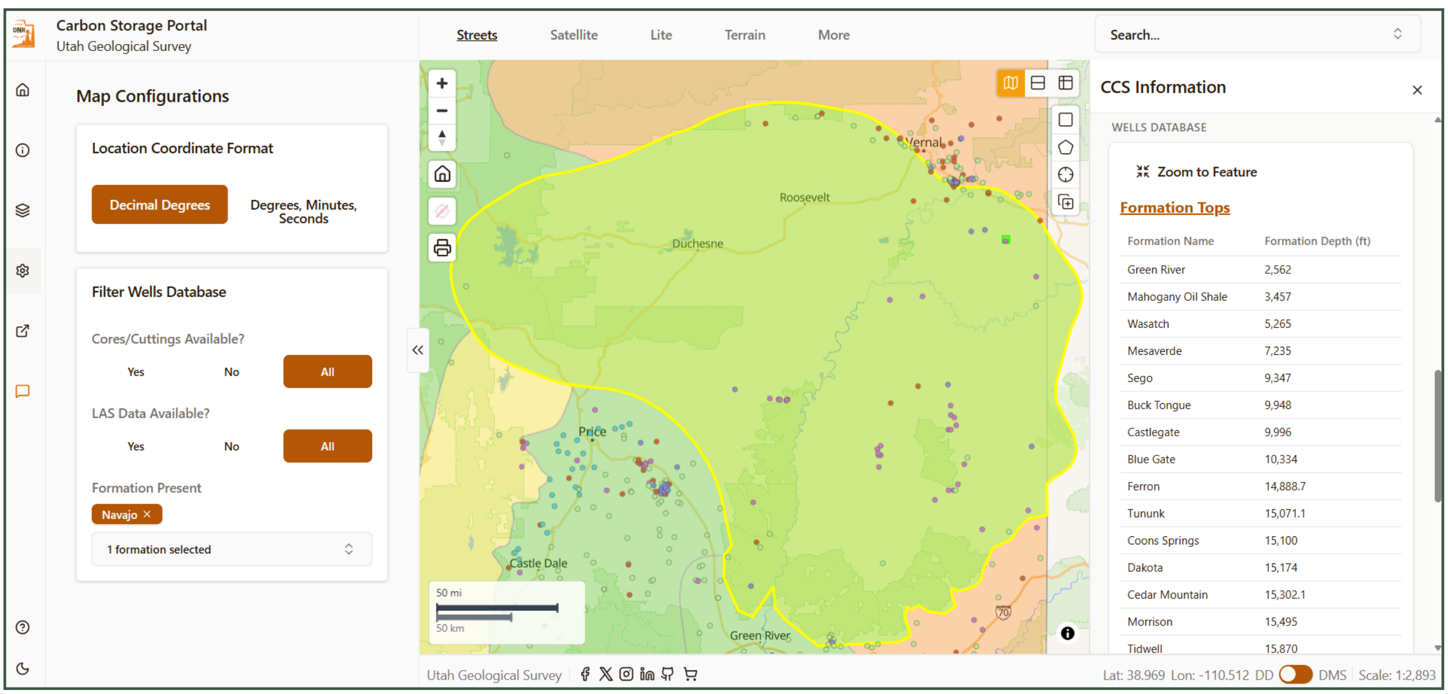
New Energy & Minerals Interactive Web Applications

by Gabriela St. Pierre and Christian Hardwick

The western U.S. holds vast untapped energy and mineral potential. The availability of high-quality, centralized data is fundamental to reducing ("de-risking") the financial and technical obstacles that industry currently faces regarding energy and minerals development. Development of these resources could be greatly enhanced by the consolidation of geological, geophysical, and geochemical datasets currently scattered across various state agencies, private companies, and universities in inconsistent formats. Integrating and standardizing formats of diverse geologic datasets ensures that different computer systems and applications can securely and accurately exchange data with minimal intervention. This interoperability enables seamless data integration and mapping, and facilitates understanding the complex geological controls on energy and mineral systems that can be regional in scope, in some cases spanning state boundaries.

The Utah Geological Survey (UGS) has invested in upgrading our data infrastructure to accelerate energy and mineral development across Utah by addressing this critical barrier of fragmented and inaccessible data. Taking advantage of technological advancements, many UGS web applications, like the ones highlighted in this article, have been upgraded to load faster, accommodate more data, integrate batch downloading, and implement new custom tools. These upgrades increase the accessibility of geologic datasets, enabling UGS staff and external users to spend more time exploring energy and mineral resources. Check out the full library of UGS interactive maps and web applications at https://geology.utah.gov/map-pub/maps/interactive-maps/.

The Carbon Storage Portal (https://maps.geology.utah.gov/carbonstorage) is a tool for the public, scientists, and industry professionals that integrates over 20 years of carbon storage studies, which can inform a wide range of subsurface exploration and research. The application provides access to geologic and spatial data and technical evaluations to support site selection, prospective subsurface storage assessments, and project planning. The interactive visualization is intended to assist stakeholders in evaluating geologic carbon storage options and make informed decisions based on current information. The application includes tools for complex search functions and filtering of subsurface data, allowing the user to display geophysical log information, available cores and cuttings from the Utah Core Research Center, and a new dataset of reservoir characteristics (e.g., porosity, permeability, and salinity). For example, users can search the statewide wells database by unique identifiers, filter by cores/cuttings availability, and select specific geologic formations. Additional supporting layers include geological information such as surface geology and the location of faults, infrastructure information such as pipelines and transmission lines, and sensitive land use areas that might be "off limits" for carbon storage.



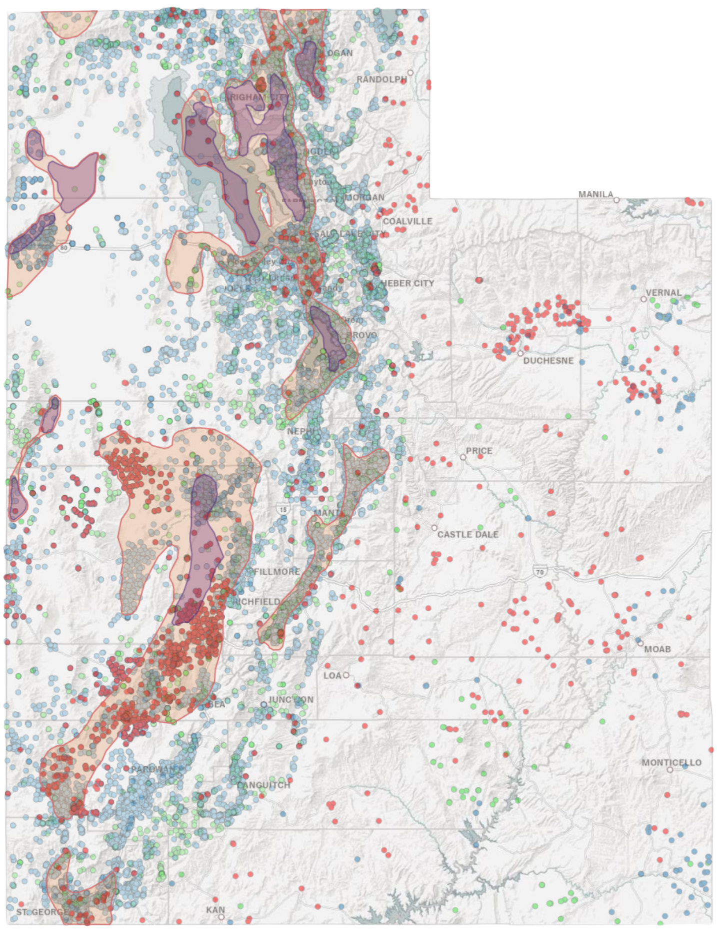
Screenshot of the Carbon Storage Portal web application showing key data layers filtered by wells that have the Nugget/Navajo Sandstone, digital log files, and core/cuttings availability over the Uinta Basin. The web app has filtering options on the left, and highlights descriptions of selected data layers on the right, including depths of formations from a single well.

The Carbon Storage Portal, funded by the Department of Energy in 2024, includes new assessments of the geologic carbon storage potential across the state of Utah. These new studies were completed at the statewide level, as well as smaller geologic regions (e.g., San Rafael Swell, Uinta Basin), and include injection cost estimates per ton of CO_2 and potential CO_2 storage resource estimates. Within the application, these regional and statewide studies highlight essential subsurface data available for wide-ranging exploration, providing a useful digital resource for those interested in exploring Utah's subsurface landscape.

The Geothermal and Geophysical Data Portal web application serves as a comprehensive digital resource for the public, scientists, and industry professionals exploring Utah's geothermal and geophysical datasets. By providing centralized access to a wide array of spatial data and technical resources, this interactive web application supports informed decision-making, facilitates resource characterization and development, and facilitates both current and future research initiatives. Funding for this project, which aggregates subsurface exploration data to evaluate new geothermal potential, was provided via the state of Utah's "Operation Gigawatt" initiative.

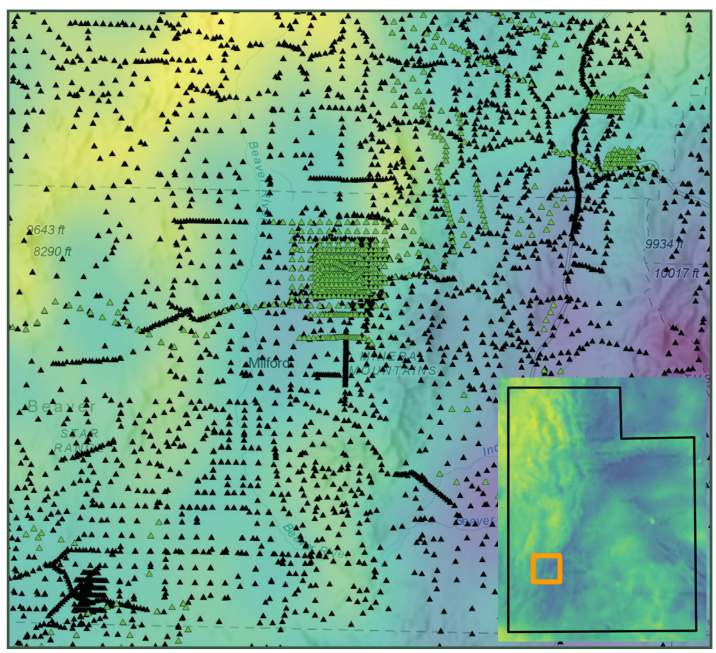
The data is organized into several key thematic categories, beginning with extensive geophysical measurements curated by the UGS. Users can access modern and legacy gravity station data, including complete Bouguer gravity anomalies that highlight subsurface density variations. Furthermore, the web application provides specialized electromagnetic data, such as transient electromagnetics and magnetotelluric data, which measure electrical conductivity at various depths to infer subsurface structures. These datasets are essential for identifying the structural architecture required to host viable geothermal systems.

In addition to raw geophysics, the application highlights specific geothermal indicators and resource areas across the state. This includes data on existing geothermal uses ranging from power plants to aquaculture and detailed inventories of geothermal wells and springs. The application also maps critical indicators like heat flow and identifies deep sedimentary basins where thick sediment acts as an "insulating blanket" over elevated subsurface temperatures. By combining these factors with geological information, such as Quaternary-age fault locations and land ownership data, the application outlines potential resource areas with a high probability for successful geothermal development. In providing these applications, the UGS is creating readily accessible information to expand Utah's energy portfolio.



Screenshot of the Geothermal and Geophysical Data Portal showing an example of spatial coverage of data in Utah.

To visit the Geothermal and Geophysics Data Portal scan the QR code or go to https://maps.geology.utah.gov/geophysics.



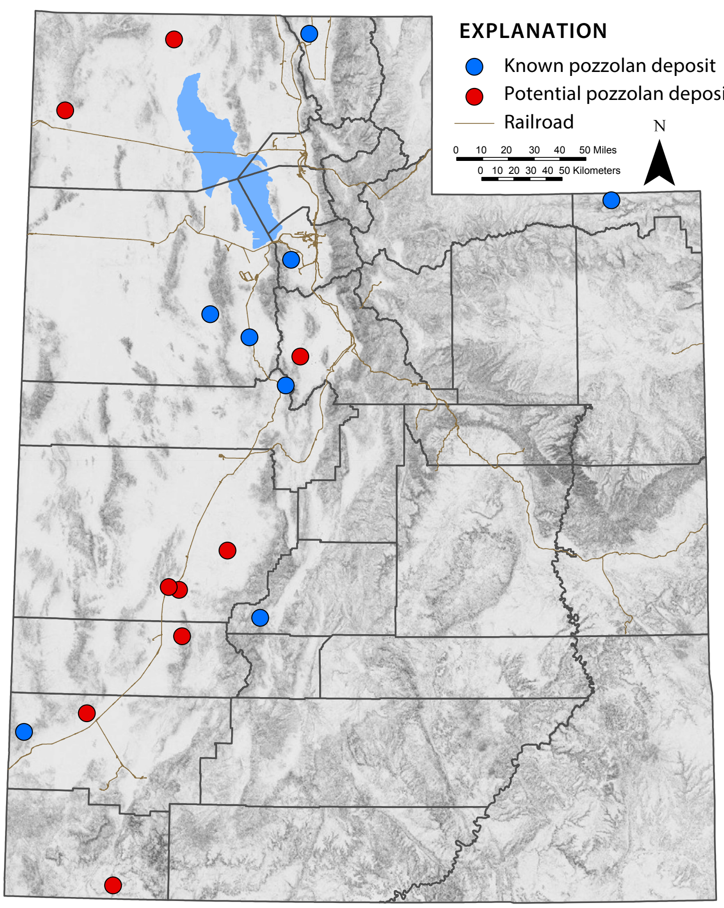
Statewide gravity anomaly data overlain by modern and legacy gravity stations in central Utah from the Geophysical and Geothermal Data Portal.

Pozzolan – Ancient Technology, Future Resource

by Andrew Rupke and Taylor Boden

Concrete is everywhere. It holds our buildings up and is in many of our roads and the sidewalk you strolled down this morning. Two main ingredients make up concrete: aggregate (composed of sand and gravel) and cement, the glue that holds it all together. Aggregate is relatively cheap to mine and produce. But the production of cement is an expensive and energy intensive process in which a variety of rocks and minerals containing calcium, aluminum, silica, and iron are heated up to high temperatures (+1400°C [+2550°F]) in a kiln to combine those elements into compounds that are reactive when water is added. This process also generates significant carbon emissions from fuel combustion used to heat the kiln, as well as the direct release of carbon dioxide from limestone, the source of calcium oxide in cement. Because cement is so widely used, its production is estimated to account for around 8% of global carbon dioxide emissions. Given these facts, are there ways to reduce the cost, energy use, and emissions related to cement production? Yes, and one way to make reductions is by using pozzolan, a siliceous or siliceous/aluminous material. The use of pozzolan dates back thousands of years and was widely used in the Roman Empire. The word pozzolan comes from the town of Pozzuoli, Italy, where volcanic tuffs and tephras were mined for use in Roman concrete. The Romans' use of pozzolanic materials is why their concrete has endured through the millennia (e.g., the Colosseum in Rome).

The Colosseum, which utilized pozzolanic materials in its concrete, still stands today, nearly 2,000 years after construction.



Potential and known pozzolan deposit locations.

Pozzolans are materials that can be added to partially replace the cement in concrete. The chemical and physical properties of pozzolans cause them to be reactive and behave in a "cementitious" way when combined with a concrete mixture. Pozzolans can be both natural and man-made and ideally, they require only limited processing, such as crushing, grinding, and drying. Beyond replacing a portion of the cement, pozzolans often improve the quality of a concrete by making it stronger and more durable. A commonly used man-made pozzolan is fly ash, a byproduct of coal-fired power plants. However, the closing of many coal-fired power plants across the nation has reduced the amount of available fly ash, leading cement producers to look for natural pozzolans.

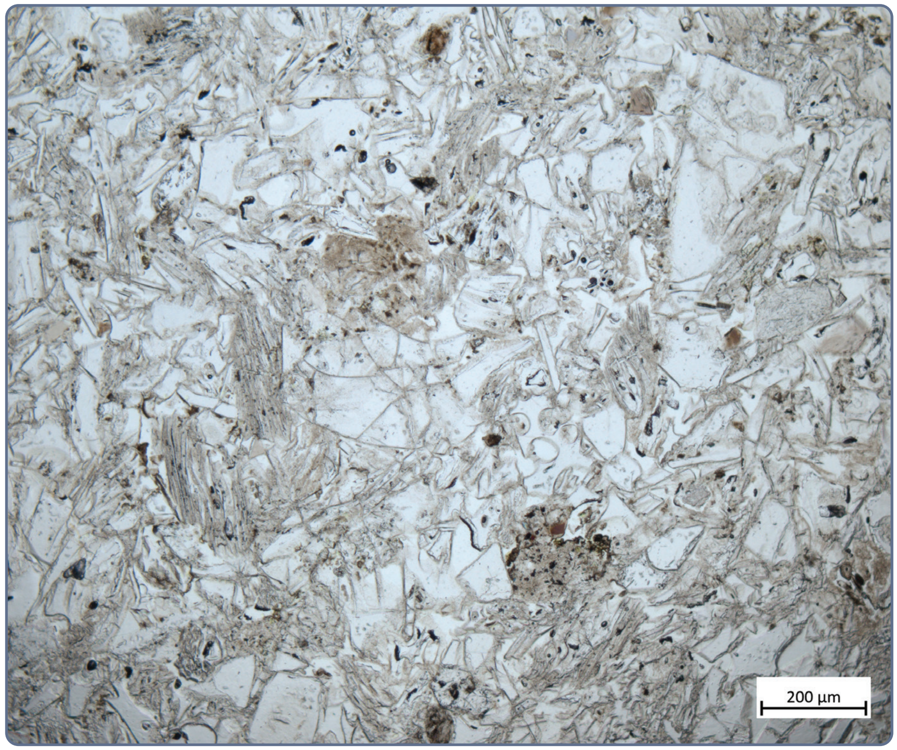
As their name implies, natural pozzolans are sourced from naturally occurring geologic materials such as certain volcanic rocks, specialized clay, and diatomaceous earth deposits. To be "pozzolanic," these deposits generally need to contain high amounts of silica or silicate minerals, and to be reactive, they also need to be amorphous or contain zeolite minerals. Amorphous materials in rocks, such as volcanic glass or diatoms, do not have a regular crystal structure. Zeolite minerals commonly form in altered volcanic deposits and are naturally reactive. Utah hosts all these deposit types.

In response to increased interest in natural pozzolans, the Utah Trust Lands Administration supported the Utah Geological Survey in a study to identify known pozzolan deposits in the state and investigate potential for undiscovered deposits

The data and information from this study can be a starting point for companies interested in locating more pozzolan resources in Utah.

on their lands. For the study we collaborated with Dr. Marie Jackson from the University of Utah, who has studied Roman concrete. The exploratory part of the study focused on identifying volcanic deposits containing the right chemistry (enough silica, aluminum, and iron) and the presence of reactive materials such as volcanic glass or zeolite minerals. Volcanic deposits were the focus because they tend to require less processing than clay deposits, and, in general, Utah's diatomaceous earth deposits are not extensive. We prioritized studying potential deposits that were near transportation (rail and major highways) to minimize shipping costs should a deposit be developed.

Several known pozzolan sources are scattered across the state and include volcanic, clay, and diatomite deposits. One of these deposits, a glass-rich volcanic tephra in Rush Valley, is actively being mined by Ash Grove, a cement company operating in central Utah. Another example of a known deposit consists of volcanic ash beds on the west side of the Salt Lake Valley that were evaluated in the 1970s and found to be suitable for pozzolan. In our search for potential new deposits, we collected and analyzed more than 70 rock samples across the state and identified several areas that may deserve additional evaluation. The data and information from this study can be a starting point for companies interested in locating more pozzolan resources in Utah.



This photomicrograph is of a tephra, a weakly consolidated volcanic deposit, in northwest Box Elder County. Most of the grains in the image are glassy ash-size shards. Glass can be reactive and might give the deposit "pozzolanic" properties.

Find out more:

Read the study! (https://doi.org/10.34191/RI-292)

The Natural Pozzolan Association (www.pozzolan.org)

A study by Dr. Jackson et al. on Roman construction materials: (https://doi.org/10.1073/pnas.1417456111)

Teacher's Corner

2026 UGA TEACHER OF THE YEAR

Mr. Adam Blundell of Farmington High School is the 2026 Utah Geological Association's (UGA) Utah Earth Science Teacher of the Year Award winner! This award recognizes his outstanding efforts in educating youth on important earth science topics. In his Introduction to Oceanography class, Mr. Blundell provides a hands-on learning experience, utilizing regular demonstrations and live experiments that integrate chemistry, biology, geology, and oceanography. His students describe him as an inspiring, top-notch educator, making him a very deserving recipient of this recognition. Congratulations Mr. Blundell!

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Silver Reef,
Washington County, Utah

by Mark Milligan

Located about 20 miles north of St. George, Silver Reef is a historic mining district and ghost town reborn as a residential neighborhood. It is one of the few places in the world where silver was mined from sandstone. Silver is most commonly emplaced by hot, mineral-rich fluids directly within or adjacent to igneous intrusions (magma which cools beneath the surface), and is usually found with other metal ores, especially lead, zinc, or copper. High-grade silver ore was first discovered at Silver Reef in 1866. However, the concept of silver hosted in an unaltered sandstone was unbelievable, so it took 10 years before a silver rush began.

At Silver Reef, silver ore, along with associated copper, uranium, and vanadium, is found in unaltered beds of the Springdale Sandstone Member of the Kayenta Formation. Over 90% of the silver mined in the district was in the form of silver chloride (AgCl, also known as horn silver or chlorargyrite). Horn silver is colorless or grayish white while underground but turns grayish brown in sunlight, making it difficult to see in rocks. The ore is only obvious where it also contains colorful copper or uranium minerals. Trace amounts of silver occur in the Springdale Sandstone across southwestern Utah but is only concentrated enough to be economically mined at Silver Reef.

The origin of the silver and other metals hosted in the Springdale Sandstone has been debated since their discovery. The consensus is that they were likely leached by groundwater flowing through volcanic ash beds in the underlying Chinle Formation, transported upward, then redeposited in the overlying porous beds of the Springdale Sandstone. These beds are part of the larger Virgin anticline, an upward folded structure. This geometry helped to concentrate and trap the mineral-rich fluids in the sandstone. The presence of organic material in the Springdale Sandstone, and likely mixing with near-surface fresher water, modified the rising groundwater's chemistry, causing the metals to precipitate.

Silver Reef ghost town has been reborn as a residential community. Here a wall of the former Lubbock home stands in contrast with a new home behind it. White Reef (Springdale Sandstone) and the overlying Kayenta Formation and Navajo Sandstone are in the background. View to the northwest.

The silver minerals at Silver Reef are nearly invisible but they can occur with colorful copper and uranium minerals. Top samples–blue azurite and green malachite replacing plant fragments. Bottom sample–blue azurite "dots" on sandstone. U.S. quarter for scale.

The Silver Reef mining district produced ore from four distinct "reefs" composed of the Springdale Sandstone—Buckeye, Butte, White, and East. "Reef" in this context describes a rocky ridge that formed a barrier to wagon travel, although the term can also refer to a distinct metalliferous mineral deposit, which is also apt for these four of the area's six named reefs. Buckeye Reef was the richest, yielding 70% of the district's production.

The boom days of Silver Reef only lasted through 1888, when falling silver prices, depleted reserves, and labor disputes conspired to effectively halt major mining operations, although some minor lessee operations continued through 1909. By this time, the district had produced over 219 tons (7 million ounces) of silver worth roughly $500 million at current prices ($70 per ounce as of spring 2026). Sporadic mining from 1949 to 1968 produced an additional 5 tons of silver, 10 ounces of gold, 34 tons of copper, and at least 1.25 tons of uranium oxide.

Areas to Explore

Visits to Silver Reef are best started at the Silver Reef Museum (https://silverreef.org/), located in the historic Wells Fargo and Company Express Building built in 1877. The museum has informative history, mining, and geology displays, as well as knowledgeable docents and two interpretive walking trails through the historical townsite. From the museum, take a dirt road heading in any direction from southeast to west, and you will find something to investigate and explore.

Another option is to visit East Reef and the former small town and mill site of Babylon, located about 4 miles south of the museum, on the east side of I-15. Access is via 900 North Road, located north of the town of Leeds. This dirt road is rough in places and can be impassable when wet. Highlights to see in this area include a young basalt flow, mine workings and ruins, dinosaur tracks, petroglyphs, great bedrock exposures, a small arch, and the Virgin River.

The Silver Reef Museum is the place to start a visit to Silver Reef. The Museum is housed in the historic (1877) Wells Fargo and Company Express Building, on the corner of Wells Fargo and Silver Reef Roads.

View to the northwest from the Silver Reef Museum. From bottom to top, the cliff bands behind the stone structures consist of the Springville Sandstone Member of the Kayenta Formation (White Reef), Kayenta Formation, and Navajo Sandstone. Photo courtesy of the Utah Division of Oil, Gas and Mining.

Reclamation Without Erasing History

During your visit, you may notice many closed mine entrances. Following their legal mandate to protect the public and environment by sealing off mine openings and cleaning up mine waste, the Utah Division of Oil, Gas and Mining's Abandoned Mines Reclamation Program closed 465 Silver Reef mines in 1996 and 1997, and another 184 mine openings at East Reef in 2000. Although abandoned mine reclamation efforts typically strive to return sites to a natural state, the goal at Silver Reef was to preserve mining history while minimizing visual impacts of reclamation efforts. Most mines were backfilled, but the fill was left below the surrounding surface level to keep the appearance of the opening. The appearance of associated mine dumps (piles of waste rock from mine excavations) was also preserved. Furthermore, much of this work was often done by hand to minimize tracks and other disturbances from heavy equipment.

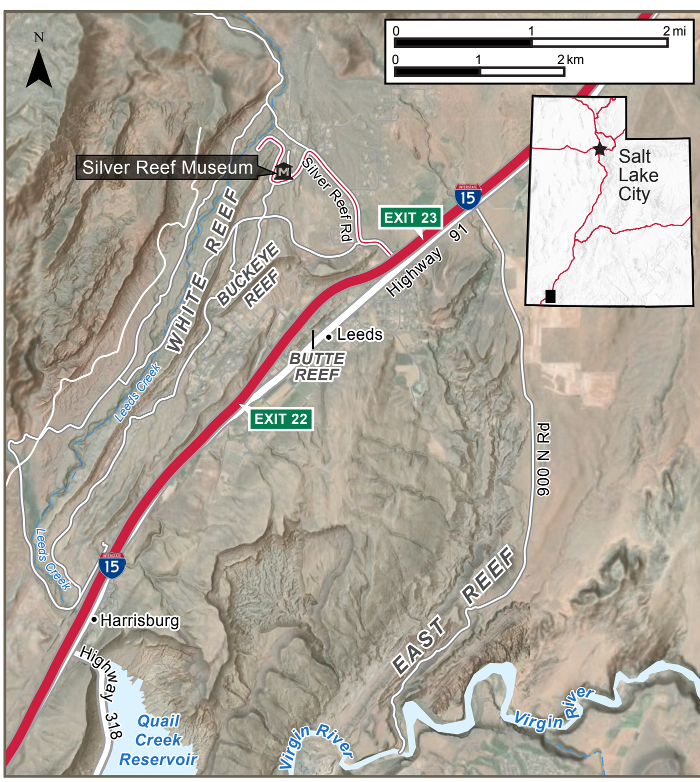
Silver Reef's mine openings provide roosts for multiple bat species and house one of Utah's largest Townsend's big-eared bat maternity colonies, where bats birth and raise their young. To protect them, many mine openings were covered by steel gates and grates that allow bats continued access.

Stay Out and Stay Alive

Although the Silver Reef area has been reclaimed, it is still an old mining district with many associated hazards. Stay away from abandoned mines. They are inherently unstable, dangerous, and illegal to enter.

More Information:

If this brief article piqued your interest, more information can be found in *Silver Reef Mining District* by Robert F. Biek and Chris Rohrer, 2019, and *Geology, Mining History, and Reclamation of the Silver Reef Mining District, Washington County, Utah* by R.F. Biek and J.C. Rohrer, 2006.



How to Get There

Silver Reef is located roughly 10 miles north of St. George on the west side of I-80. All visits should start at the Silver Reef Museum. To get to the museum:

- From the north, take I-15 exit 23 for Utah State Route 228 south to Leeds. Turn right at the offramp stop sign and follow the signs to the museum, which is just over a mile on Silver Reef Road.
- From the south, take I-15 exit 22 for Utah State Route 228 north to Leeds. Turn left at the offramp stop sign. After 1.5 miles turn left and follow the signs to the museum, which is nearly 1.5 miles on Silver Reef Road.

Coordinates: 37.253015, -113.366890

When exploring the area, follow all posted signage and be mindful of road conditions. The road to the museum is paved, but many area roads require high-clearance or four-wheel drive. Take only pictures and leave no trace.

Note there is extensive private property in the area, and heed "no trespassing" signs. Visitors have the responsibility to be aware of land ownership, regardless of signage. Please leave all mining and related relics as you found them.

What Movies Feature Utah Geology? Part 2

by Mackenzie Cope

Utah is well-established as a premier location to film television programs and movies and, in 2024, celebrated a landmark 100 years of moviemaking. The success of Utah's rich film history is intricately tied to the state's geologically diverse landscapes. Utah's unique settings make for natural and wholly believable backdrops that support any number of stories.

This second article (see the first in *Survey Notes*, v. 54, no. 1) continues the tour of filming locations in Utah and the fantastic geology behind these scenes. Whether these movies and television shows are already in your favorites list or new to you, I invite you to take some of the geologic information into your next viewing.

Coral Pink Sand Dunes

The Kanab area has some of the richest film history in Utah due to the variety of geologic settings that include sheer red rock cliffs, brown- and purple-striped slopes, and vast sand dunes. The popular westerns *MacKenna's Gold* (1969) and *The Outlaw Josey Wales* (1976) starring Gregory Peck and Clint Eastwood, respectively, showcase the full range of the region's iconic landscapes.

An often-overlooked filming location near Kanab is Coral Pink Sand Dunes State Park, which has represented the Arabian Desert, desolate Wild West wastelands, and alien landscapes. The sand dunes are estimated to be 10,000 to 15,000 years old and are composed of sand eroded from nearby cliffs of the Jurassic-age Navajo Sandstone. A phenomenon called the Venturi effect causes wind traveling southeast to speed up as it is funneled through a narrow wind gap south of Block Mesas. Past this constriction, the wind slows down again, and the sand drops and settles into growing piles. The sand continues to migrate from wind gusts and forms the many dunes present at Coral Pink Sand Dunes.

In 1942, Universal Pictures, with the prompting of Utah state officials, identified the Coral Pink Sand Dunes as the ideal place to film *Arabian Nights* (1943), although the studio thought it was too remote. With the support of Utah's governor, the city of Kanab made a formal appeal to the Utah Legislature to fund an access road from the highway to the filming location. The area was designated as a state park 20 years later and that road is still used by visitors today.

Some films that feature Coral Pink Sand Dunes State Park:

- *Arabian Nights* (1943, not rated)
- *A Time For Killing* (1967, not rated)
- *One Little Indian* (1973, G)
- *Westworld*, Season 2 (2018, TV-MA)

A still from the television show Westworld, *filmed at the Coral Pink Sand Dunes State Park. Source: "Westworld" Season 2 (2018) / HBO.*

Great Salt Lake and Antelope Island

Great Salt Lake has striking contrasts of blue and pink saline waters, white beaches, and mountainous islands. The current lake formed around 13,000 years ago, as a remanent of Pleistocene-age Lake Bonneville. Because Great Salt Lake has no outlet, salt minerals accumulate as the water evaporates, making the lake salty. The unusually salty lake drew crowds to The Great Saltair, a beach resort built in 1893 on the lake's southern shore. The Great Saltair burned down in 1925, but its replacement, Saltair II, was the filming location of the cult horror film *Carnival of Souls* (1962), which has regained popularity in recent times.

Great Salt Lake also has 17 named islands, although the number of islands fluctuates with the lake level. Antelope Island, the largest, has rocks that date to the late-Precambrian era (greater than ~540 million years old). These rocks were uplifted into mountains during the Sevier orogeny, a tectonic event that occurred roughly between 170 and 40 million years ago. Beginning around 13 million years ago, the area was subjected to Basin and Range extension along normal faults, which created the Wasatch Range, Salt Lake Valley, and the basin that holds Great Salt Lake. Antelope Island, with its eroded sloping peaks, wide-open fields, and bison herd, was an ideal representation of the Oregon Trail according to James Cruze, the director of one of the first film productions in Utah, *The Covered Wagon* (1923). The filming location on the island, called "Camera Flats," is popular with visitors to Antelope Island State Park.

Some films that feature Great Salt Lake and Antelope Island:

- *Carnival of Souls* (1962, PG)
- *Plan 10 from Outer Space* (1995, unrated)
- *Buffalo Dreams* (2005, G)

A still from the silent movie The Covered Wagon, *showing the native bison herd during the hunting scene. The sloping mountains of Antelope Island can be seen in the background. Source: "The Covered Wagon" (1923) / Paramount Pictures.*

Bryce Canyon and Cedar Breaks

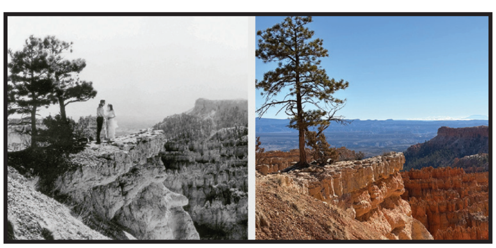
The Cedar City area, Cedar Breaks National Monument, and Bryce Canyon National Park have served as backdrops for cinema since 1924 when Fox Film Corporation filmed *The Deadwood Coach* (1924) at locations throughout southern Utah. This movie, which is a lost silent film (only a few photographs have survived), highlighted southern Utah geology and helped bring in other iconic films.

In 1927, two filming companies, working on *Ramona* (1928) and *The Shepherd of the Hills* (1928), even had a standoff at Cedar Breaks' Inspiration Point, each asserting their claim of being there first to film. Around the same time, some of the first films shot at Bryce Canyon include *Forlorn River* (1926) and *Nevada* (1927), adaptations of books by the legendary author Zane Grey. The director, John Waters, filmed at least three Zane Grey movie adaptations at Bryce Canyon by the time the area was designated as a national park in 1928.

The unique landscape of Cedar Breaks and Bryce Canyon is due to the Eocene-age Claron Formation, which is composed of pink-white-colored limestone that was deposited in shallow lakes, ponds, and marshes. It is not just the colors of the rock that amazes visitors and movie-lovers, but also the erosional "hoodoo" landforms. Hoodoos are created when vertical fractures in the rock collect water and experience freeze-thaw cycles. As the ice expands, blocks of rock are fractured and eroded, creating elaborate hoodoos. The feeling of seeing them for the first time is well-captured in Utah films. Directors have often introduced these landscapes to the audience during a major reveal in the plot or an arrival to a new awe-inspiring location.

Some films that feature Cedar Breaks and Bryce Canyon:

- *Can't Help Singing* (1944, approved rating)
- *Thunderhead: Son of Flicka* (1945, no rating)
- *Snowfire* (1957, no rating)
- *Bonneville* (2006, PG)



A still from the lost silent film, The Deadwood Coach, *filmed at Bryce Canyon National Park and the same location from 2026 near the Sunset Point overlook. Source: "The Deadwood Coach" (1924) / Fox Film Corporation.*

Mount Timpanogos

The long history of films in Utah has created many personal connections with Utah's iconic landscapes. The late Robert Redford, a legendary actor and life-long advocate for protecting public lands, was drawn to the Wasatch Range when he starred in and helped shape *Jeremiah Johnson* (1972). The movie was filmed primarily in Provo Canyon, Uinta-Wasatch-Cache National Forest, and at Mount Timpanogos, named after the local Timpanogos tribe, whose few descendants reside on the Uintah and Ouray Reservation. The mountain is a layer-cake assemblage of Paleozoic-age formations of limestone and sandstone, capped by the Bear Canyon Formation of the Oquirrh Group. The formation was deposited in a shallow marine environment during the Pennsylvanian Period (~300 million years ago) and uplifted during the Laramide orogeny (70–34 million years ago). The massive gray cliffs, often snow-covered as seen in *Jeremiah Johnson*, highlight the remote wilderness associated with the mountain men and Native American peoples.

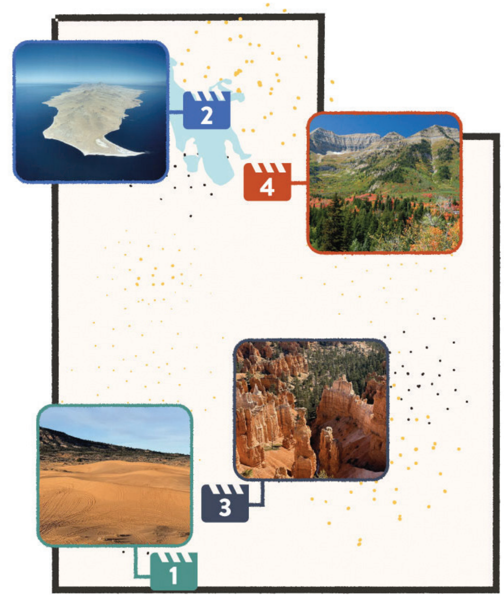
I found my own personal connection to Utah's movie history and landscapes from the disaster thriller movie *Airport 1975* (1974), in which my grandfather, on a chance encounter, was offered a small role. In the film, there are many aerial views of Mount Timpanogos because much of the film takes place on an airborne Boeing 747. The mountains are not only used as an imposing backdrop, but also as an active plot point where the 5,270-foot-tall (and 11,752 feet above sea level) Mount Timpanogos is a barrier the flight crew must avoid colliding with throughout the movie.

Some films that feature Mount Timpanogos:

- *Jeremiah Johnson* (1972, PG)
- *Airport 1975* (1974, PG)
- *Walking Thunder* (1995, rating)

A still from Airport 1975 *with the Boeing 747 in the air with the Wasatch Range in the background. Source: "Airport 1975" (1974) / Universal Pictures.*

My grandfather's experience being in a movie is not unique. There is a vast collection of generational stories of Utahns who were recruited by, and participated in, Utah's movie industry as extras, set builders, and hosts for cast and crew. The unique enthusiasm and giving spirit of Utahns, along with Utah's diverse natural landscapes and geology, have helped the filming legacy in Utah thrive.



Four popular filming locations in Utah: (1) Coral Pink Sand Dunes State Park, (2) Antelope Island and Great Salt Lake, (3) Bryce Canyon National Park, and (4) Mount Timpanogos.

Thank you to the Utah Film Commission for their ongoing collaboration with the Utah Geological Survey, assistance with fact-checking and revisions for this article, and providing imagery. The primary sources of film history presented in this article are *When Hollywood Came to Utah*, Centennial Edition by James V. D'Arc and *Cinema Southwest* by John A. Murray.

For more information about the locations highlighted in this article and Utah's film history, check out these resources:

- Utah Film Commission: film.utah.gov
- Filmed in Utah Itineraries: visitutah.com/things-to-do/film-tourism
- Little Hollywood Museum in Kanab, Utah: littlehollywoodmuseum.org
- Moab Museum of Film and Western Heritage: moabmuseum.org
- The Natural Resources Map & Bookstore utahmapstore.com

Explore the Utah Film Trail!

Utah. America's Film Set.® has been a destination for filmmaking for over 100 years, its diverse landscapes playing a starring role in some of Hollywood's most iconic productions. Now the Utah Film Trail invites film enthusiasts to experience these iconic landscapes firsthand. Featuring a series of physical markers around the state, the trail guides travelers off the beaten path to discover the real-world locations featured in some of their favorite films and television shows. Start your set-jetting journey at utahfilmtrail.com.

• SURVEY NEWS •

THE UGS HAS BEEN SELECTED FOR THE 2026 BHP XPLOR ACCELERATOR PROGRAM

This partnership, announced in February 2026, marks the first time a geological survey has joined the BHP Xplor accelerator program. Through this selection, the UGS will receive $500,000 in funding and technical support to advance mineral research in western Utah. Our team will integrate new regional datasets from the U.S. Geological Survey's Earth MRI program to conduct a modern assessment of the area's mineral potential. These efforts are being led by senior geologist **Dr. Stephanie Mills** and project geologist **James McVey**. We are incredibly proud of their work and look forward to supporting them as they conduct this critical research. Learn more at: geology.utah.gov/utah-geological-survey-selected-for-bhp-xplor-program/.

INTRODUCING THE UTAH GEOTHERMAL NETWORK (UGeN)

UGeN is a collaborative community built to connect people, projects, and ideas across Utah's growing geothermal landscape. This non-competitive group is for researchers, professionals, students, community stakeholders, and those simply interested in Utah's geothermal resources to share insights, spark partnerships, and turn underground potential into real-world impact. Membership is free and offers access to periodic newsletters, meetings, and events focused on advancing geothermal energy development in Utah. Join today at: https://geology.utah.gov/energy-minerals/geothermal/utah-geothermal-network/.

UGeN
Utah Geothermal Network

2026 LEGISLATIVE SESSION HIGHLIGHTS AND EVENTS

The 2026 session was extremely busy for the state with a record 1,000+ bills introduced. Major legislative themes included groundwater, wetlands, critical minerals, and the state management of federal lands. The UGS was an active participant throughout the session supporting bills with public comment and working with legislators to craft studies enabling the Survey to expand research. A significant success this year was House Bill 509, Wetlands Study Amendments, sponsored by Representative Derrick Owens. This bill directs the UGS to conduct a five-year comparative study on wetlands health, tracking the impacts of federal regulatory shifts and outdoor recreation in Davis, Weber, Utah, and Salt Lake Counties. The UGS wetlands team is grateful for this directive and the associated funding, and we look forward to beginning this important work.

On January 31st the UGS participated in Maps on the Hill at the Utah State Capitol to present our various web applications and current mapping projects. This event showcases the diversity of mapping resources in Utah and demonstrates how mapping technology can support decision-makers. Then on February 6th the Natural Resources Map & Bookstore helped the Division of Outdoor Recreation and other local organizations celebrate the depth, uniqueness, and innovation of the outdoor recreation industry by attending Outdoor Recreation Day on the Hill at the Utah State Capitol. The event was well attended and gave UGS employees the opportunity to personally interact with multiple lawmakers and their staff.

EMPLOYEE NEWS

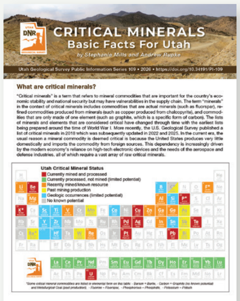
The UGS is excited to welcome **Nguyen Seymour** as our new financial manager. She replaces **Russell Filmore**, who accepted a position with the Utah Division of Water Resources. Nguyen joins the UGS following an impressive 13 year private-sector career, during which she managed finances and led non-profit organizations. She earned a B.S. in business management from Brigham Young University and an MBA from Washington State University. Please join us in welcoming Nguyen to the team. Congratulations to Emily Jainarain who was promoted to Project Geologist, Trevor Schlossnagle and Kathryn Ladig who were promoted to Senior Geologist, and to Paul Inkenbrandt and Eugene Szymanski who were promoted to Senior Scientist. Their hard work and dedication are truly commendable!

IN MEMORIAM

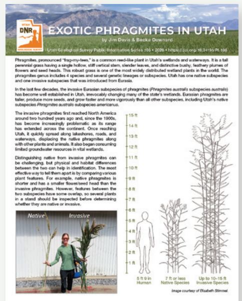
Myron Gene Best passed away on March 13, 2026, at the age of 90. As a distinguished research and academic geologist at Brigham Young University, Myron authored numerous academic papers on regional volcanic tuffs, as well as authored or co-authored over 20 geologic maps for the UGS and numerous maps for the USGS. His collaborative fieldwork and research in the Nevada and Utah deserts led to the discovery of the Indian Peak caldera. In 1997, BYU established the "Myron G. Best Teaching Award" in honor of his dedication to education, and in 2009 he received the Lehi Hintze Award for his outstanding contributions to Utah geology.

NEW PUBLICATIONS

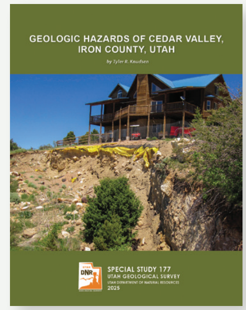
Available at the Natural Resources Map & Bookstore—**utahmapstore.com** and for download at **geology.utah.gov**.



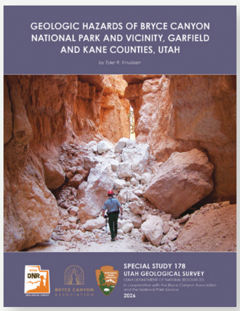
Critical Minerals–Basic Facts for Utah, by Stephanie Mills and Andrew Rupke, 4 p., **PI-109**, https://doi.org/10.34191/PI-109



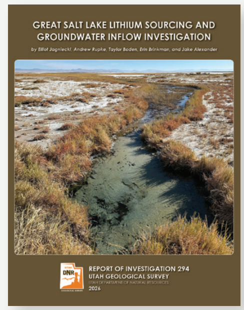
Exotic Phragmites in Utah, by Jim Davis and Becka Downard, 4 p., **PI-08**, https://doi.org/10.34191/PI-108



Geologic Hazards of Cedar Valley, Iron County, Utah, by Tyler R. Knudsen, 2 p., scale 1:24,000, **SS-177**, https://doi.org/10.34191/SS-177



Geologic Hazards of Bryce Canyon National Park and Vicinity, Garfield and Kane Counties, Utah, by Tyler R. Knudsen, 45 p., 15 plates, scale 1:24,000, **SS-178**, https://doi.org/10.34191/SS-178



Great Salt Lake Lithium Sourcing and Groundwater Inflow Investigation, by Elliot Jagniecki, Andrew Rupke, Taylor Boden, Erin Brinkman, and Jake Alexander, 16 p., 1 appendix, 2 plates, **RI-294**, https://doi.org/10.34191/RI-294

Wetland Mapping and Loss in Utah Valley, by Peter Goodwin, Grant Mauk, Rebecca Molinari, and Elisabeth Stimmel, 36 p., 2 appendices, **OFR-776**, https://doi.org/10.34191/OFR-776

Frac Sand Potential on Selected SITLA Lands in Utah, by Andrew Rupke and Taylor Boden, 32 p., 2 appendices, 1 plate, **OFR-777**, https://doi.org/10.34191/OFR-777

Whole-Rock Geochemical Data for the Central West, Central East, Enterprise, Hebron, and Maple Ridge Quadrangles, Utah, by Utah Geological Survey and H. Richard Blank, 1 p., **DS-5**, http://doi.org/10.34191/DS-5

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Update to the Utah Quaternary Fault Database, by Adam I Hiscock, 6 p, **DS-7**, https://doi.org/10.34191/DS-7

RECENT OUTSIDE PUBLICATIONS by UGS Authors

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Bedrock Offset Across the Wasatch Fault in Salt Lake City, Utah, From Teleseismic Converted Phases and Its Geologic Implications, by H.J. Kim, J.C. Pechmann, F.-C. Lin, **A.P. McKean**, and **C.L. Hardwick**: Seismological Research Letters, https://doi.org/10.1785/0220250236

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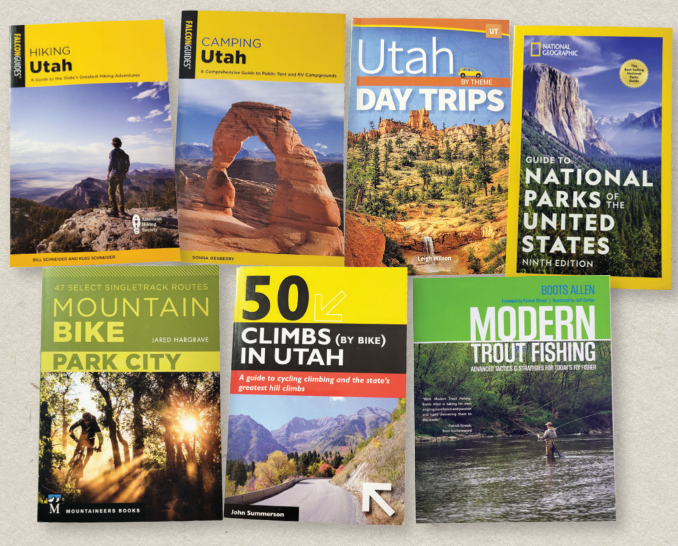

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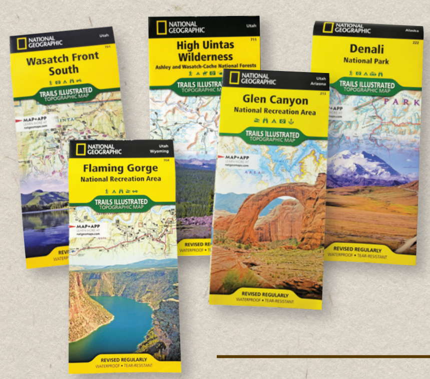

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