UTAH GEOLOGICAL SURVEY

SURVEY NOTES

Volume 57, Number 3

September 2025

THE HYDROGEOLOGY AND ECOLOGY OF THE MATHESON WETLANDS PRESERVE: A CONNECTED STORY

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Design | *John Good*
Cover | The Central Pond of the Matheson Wetlands with the Colorado River portal in the background to the south.

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

It is truly the honor of a lifetime to be the new State Geologist and Director of the Utah Geological Survey (UGS). As the 8th Utah State Geologist, I join an esteemed cadre that includes Lee Allison and Rick Allis, who I worked alongside in my past role as Salt Lake County Geologist, and Bill Keach, who I worked under for the past year. I am the second female State Geologist of Utah, following in the pioneering footsteps of Genevieve Atwood, who was also the first female State geologist in the nation.

I step into this role at a pivotal time, as we transition from a survey rich in senior geologists retiring to make way for a much younger generation. It is also a time of precipitous transformation of our Federal government and the UGS has also had to take a hard look at our budget and priorities. To navigate confidently through these challenges, I am grateful for the steady and supportive leadership of Utah Department Natural Resources Executive Director Joel Ferry and Deputy Director Nathan Schwebach, as well as our sister DNR agencies, with whom we work closely to advance the State's most important and strategic priorities of energy, critical minerals, water, and the health of the Great Salt Lake ecosystem.

One of my first priorities is to take our UGS team through a strategic planning effort I've dubbed "Return to Mission." Our leadership team has reviewed our enabling statute, and we are refocusing our funding and staff to our most important mission: Assess, advise, and assist."

The UGS geoscience and technical support teams continue to be led by experienced, knowledgeable program managers who excel in technical sciences, as well as the business management and "people" skills essential to keeping our staff and projects on track. I admire the very high level of scientific expertise and excellence delivered by our Energy & Minerals, Groundwater & Wetlands, Geologic Hazards, and Geologic Mapping professionals, as well as the GIS and Data Management technical services that support these teams. Our Geologic Information and Outreach team provides legislative and public information outreach to our essential stakeholders: industry, legislators, and members of the public. And while our demographically younger cadre of geoscientists are being mentored by some of the best geologists in any state survey in the nation, they are also challenging us to work differently with new tools.

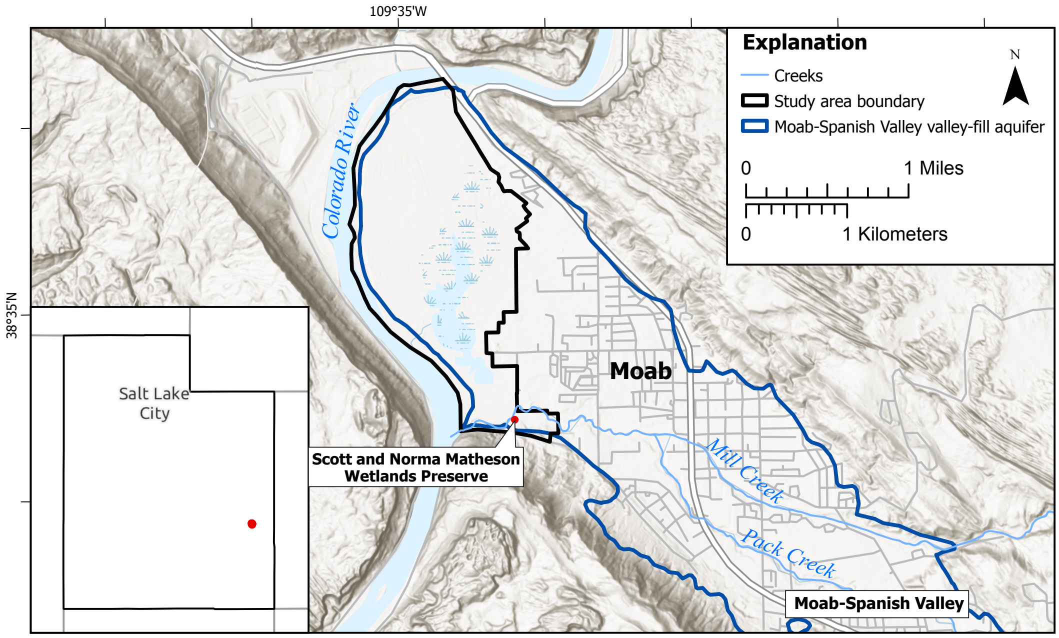
I am pleased to announce Stefan Kirby as our new deputy director. Anyone who has worked with Stefan through his long career at the UGS will recognize his cross-disciplinary geosciences expertise, as well as his natural leadership skills. Stefan's ability to be both visionary and pragmatic will serve the UGS well.

I am fortunate to have enjoyed a long and adventurous geologic career, working in diverse terrains including alpine, permafrost, modern carbonates, and alluvial basins, in Alaska, Guam, and across multiple western and coastal states. As a young woman piloting a Zodiac raft alongshore Alaskan islands, I could not have foreseen where my adventurous geological wanderings would take me. My work has included geologic mapping, environmental soil and groundwater investigations, geologic hazard studies, and land development investigations. I offer my decades of skills and perspectives in service of the UGS: We must rise to the occasion and take our place as the organization that provides "bedrock information" that is instrumental in informing industry and policy decisions for sound resource development and growth for Utah and the nation. It is truly my honor to serve in this role.

THE HYDROGEOLOGY AND ECOLOGY OF THE MATHESON WETLANDS PRESERVE: A CONNECTED STORY

by Kathryn Ladig, Rebecca Molinari, Kayla Smith, and Trevor H. Schlossnagle

The Scott and Norma Matheson Wetlands Preserve ("the Preserve") is an 894-acre wetland adjacent to the Colorado River, bordering the western edge of Moab, Utah. The Preserve provides habitat to more than 200 species of wildlife and is a popular local destination for hiking, birding, and hunting. It is a sensitive environment that could be negatively impacted by upgradient water consumption and possible upwelling of a brine layer that underlies the fresh water of the Moab-Spanish valley-fill aquifer (VFA) within the boundaries of the Preserve. To address these concerns, we investigated how water flows into and through the Preserve, whether vegetation patterns are changing, and if the brine layer location is changing.



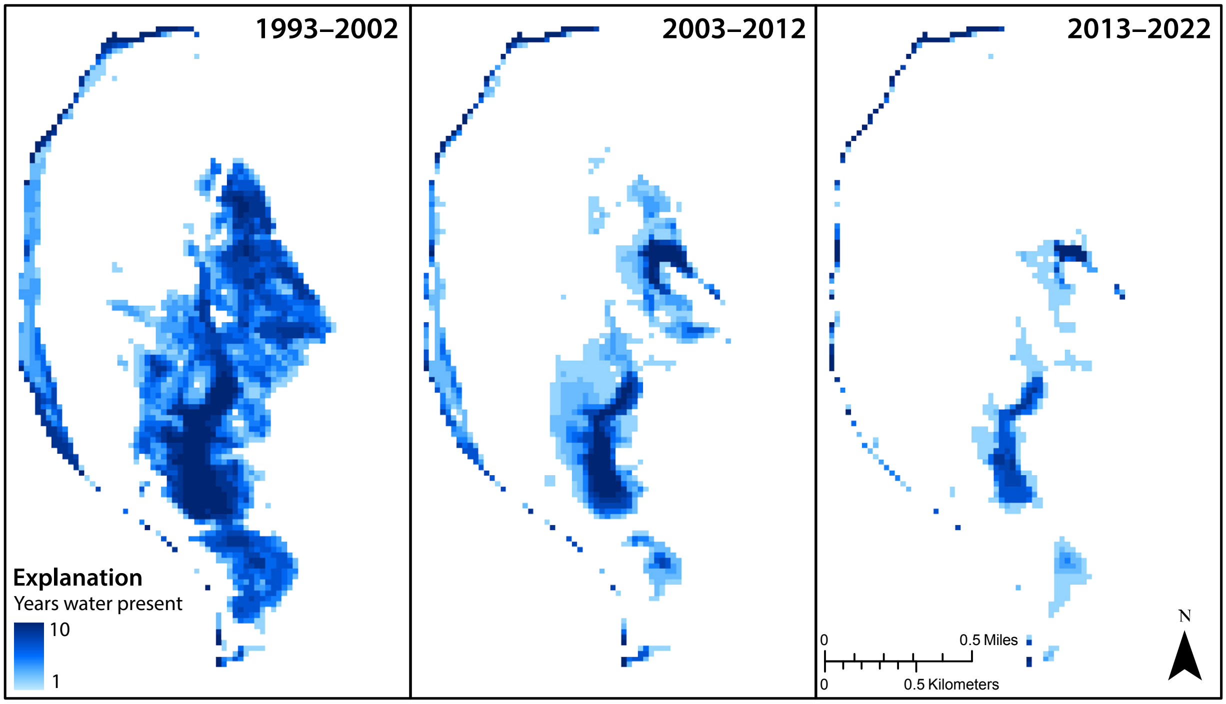
The Moab-Spanish Valley alluvial aquifer, the area where the Glen Canyon Group is absent in the subsurface, and the boundaries of the study area.

To assess how much water flows into and out of the Preserve, we calculated a water budget (the sum of hydrologic contributions and losses) using field measurements, remote sensing, and the U.S. Geological Survey (USGS) Soil-Water Balance Model, version 2. We found that just over 1000 acre-feet of water passes through the Preserve annually. This small volume of water is vulnerable to water diversion and usage upstream (south and east) of the Preserve in Moab-Spanish Valley.

Our study showed that flood events provide crucial water during the start of the growing season. However, these events are short-lived, leaving vegetation reliant on precipitation, groundwater, and springs through much of the growing season.

We used a dye-tracer test to track how water moves from springs on the east side of Highway 191 to the Preserve. We found that spring water is essential to sustain the health of the wetlands on the east margin of the Preserve, particularly as groundwater levels drop throughout the summer. Water rights allow this spring water to be allocated to a dredged pond in the Preserve or used by landowners and the City of Moab, potentially cutting off the surface water supply from the springs to the eastern part of the Preserve.

Remote sensing analyses on datasets collected from 1993 to 2023 show that surface water extent and frequency of inundation have decreased since 1993, leading to changes in vegetation communities. The western Preserve has had an increase in bare ground and annual species, and a decrease in woody vegetation. These changes are driven in part by fire, tamarisk beetle introduction, mechanical tamarisk removal efforts, and invasion by annual plants, but also may be affected by changes in hydrology and salinity. Normalized Difference Vegetation Index (NDVI) levels, a measure of greenness and proxy for vegetation health, have declined and plant communities on the western edge of the marsh have changed over the past 10 years, likely driven by changes in groundwater levels and spring water use. Vegetation changes in the Preserve are shifting from herbaceous vegetation to invasive annuals and problematic perennials, such as reed canary grass and knapweed. Salinity impacts from the underlying shallow brine layer may further decrease vegetation vigor and contribute to the observed trends.



The number of years that surface water was present in each decade according to modeled median May through June surface water extent.

We collected water level measurements from monitoring wells throughout the study area that allowed us to make 22 potentiometric-surface maps, which represent the groundwater surface in the VFA at the time data was collected. These maps indicate that groundwater flows generally from east to west across the Preserve, toward the Colorado River. Lower horizontal hydraulic gradients are common in the spring and higher gradients are common in the fall.

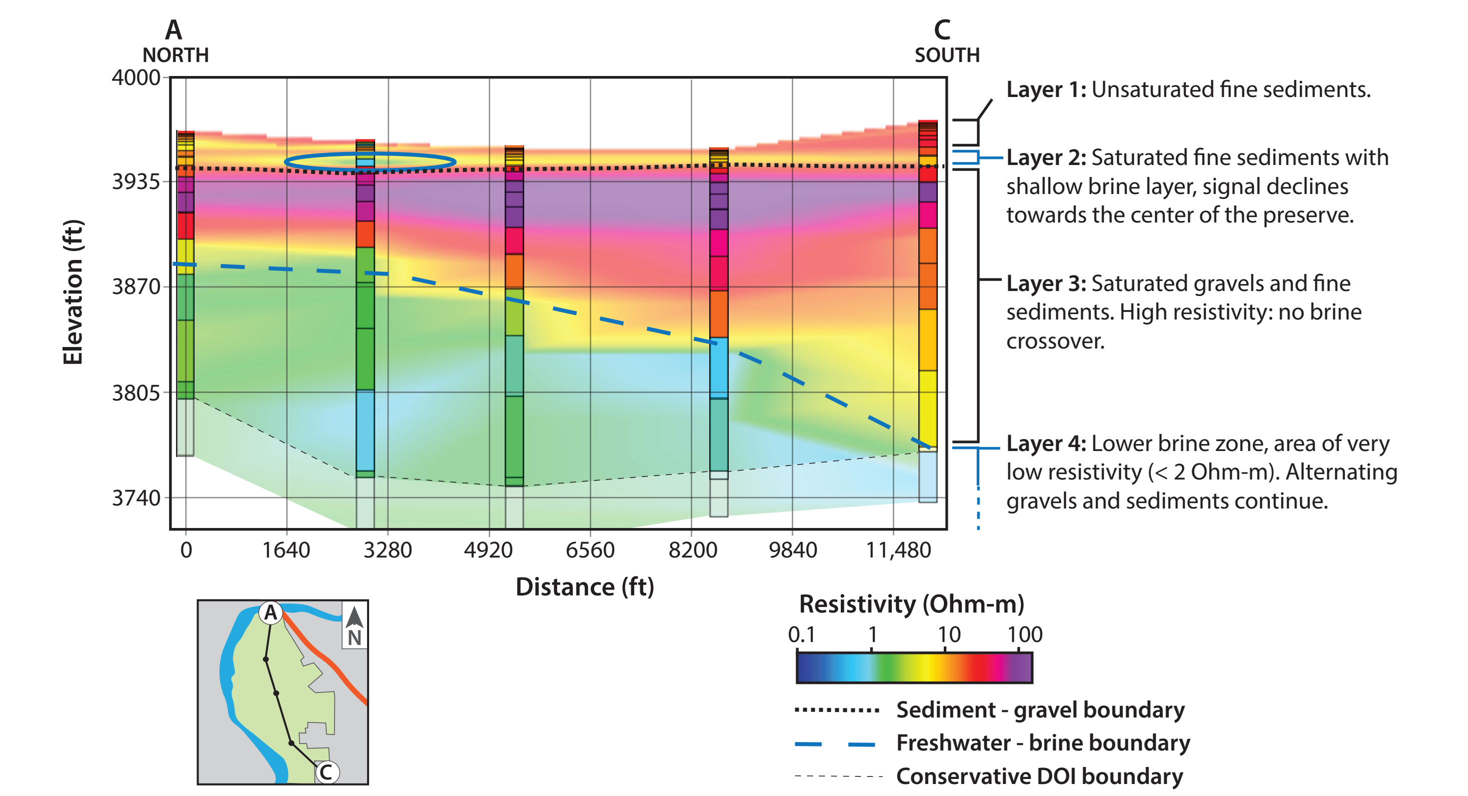
We also constructed potentiometric-surface maps for the brine layer. These maps show decreasing hydraulic head both north and south, originating from a divide near the midpoint of the Preserve. However, the brine may not be flowing and may instead be trapped under the freshwater layer, its location dependent on the elevation of the salt-rich Paradox Formation caprock and overlying freshwater head. We found that VFA groundwater levels move in step with the Colorado River flow (i.e., higher river flow corresponds to higher groundwater levels), except for water levels in wells near the southeast margin of the Preserve, which are highest prior to the peak Colorado River stage, showing the importance of groundwater inflow in these areas.

To constrain the location and origin of the brine, we used transient electromagnetic (TEM) surveys and electromagnetic-induction (EMI) logging, both of which measure electrical conductivity of the subsurface, as well as groundwater chemistry analyses. These methods show that the brine is deepest in the southeast region and shallowest in the northwest region of the Preserve, moving from deep to shallow near the midpoint of the Preserve. Near this midpoint, the potentiometric surface maps show a shallow brine divide, the vertical gradient is upward, and the vegetation community changes. These observations indicate that either the brine is moving upward in this area because of a zone of increased hydraulic conductivity or because the Paradox Formation is closer to the land surface here than it is to the south.

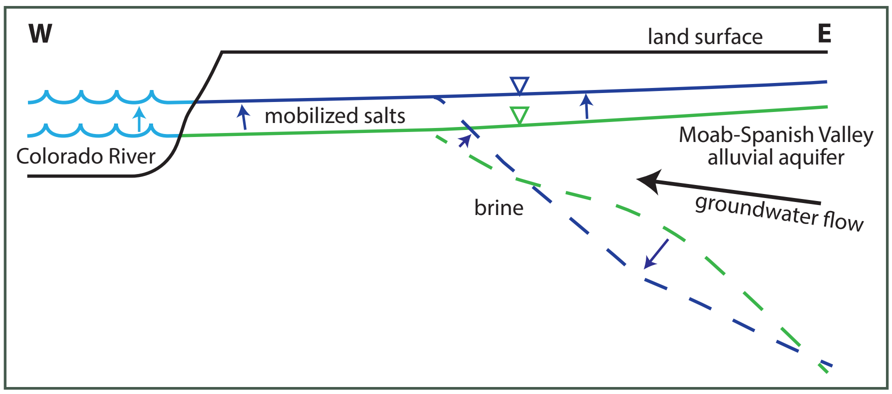
Chemistry analyses indicate that the brine is most chemically similar to water produced from the Paradox Formation where the brine transitions from deep to shallow and where the vertical hydraulic gradient is most strongly upward. The brine is also more chemically similar to the Paradox Formation with increasing depth. In the southern part of the Preserve, data indicate mixing between Paradox Formation waters and VFA fresh water.

We observed, in general, that freshwater head and salinity have a direct relationship in wells close to the river and an indirect relationship in wells farther from the river. We explain the varied response of conductivity to hydraulic head by two dynamics. We infer that sediments near the Colorado River contain interstitial salts that dissolve as groundwater levels rise, causing greater salinity in wells near the river. Salinity decreases as groundwater levels decline and the salts precipitate and are deposited out of solution. Meanwhile, groundwater in the more central part of the Preserve responds like groundwater in an unconfined coastal aquifer that has passive saline-water encroachment. In this case, a decrease in the freshwater pressure head of the unconfined VFA results in the brine water shifting farther underneath the fresh water until it reaches a new equilibrium. Conversely, an increase in freshwater pressure head would shift the brine back toward the river, analogous to the coast in an unconfined coastal aquifer.

The results of our study show that a limited volume of water supports the Preserve's wetland ecosystem. Whether or not the brine rises toward the surface, 30-year trends indicate that reduced water availability has already altered the plant communities that are habitat for species such as migratory birds and the razorback sucker fish, a Utah Species of Greatest Conservation Need. Continued monitoring of the hydrology and ecology of the Preserve will help guide management decisions of this sensitive environment.

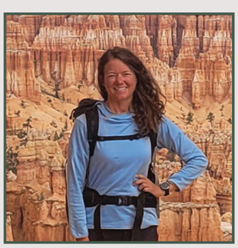


Annotated TEM pseudo 2D cross section from May 2023 describing the location of the brine through the interpreted differences in resistivity.



A cross section depiction of groundwater flow and how it changes during low and high groundwater conditions. The green lines represent conditions during low Colorado River flows and low groundwater levels. The blue lines represent conditions when Colorado River flows and groundwater levels are high. The solid lines are the water table and the dashed lines are the approximate brine surface. The blue arrows indicate the change from low groundwater conditions to high groundwater conditions.

ABOUT THE AUTHORS



Kathryn Ladig is a Project Geologist with the UGS Groundwater & Wetlands Program. Her current projects include studying evapotranspiration through eddy covariance and water-budget analyses.

Kayla Smith is a Project Geologist with the Energy & Minerals program. Kayla works primarily with the geophysics team for subsurface analysis in geothermal and groundwater research.

Rebecca Molinari is a GIS Analyst with the Groundwater & Wetlands Program. Her work focuses on wetland mapping and analyzing spatiotemporal trends of vegetation and surface water across Utah.

Trevor Schlossnagle is a Project Geologist with the Groundwater & Wetlands Program. Trevor's work with UGS has focused on applying geochemistry to groundwater issues, including water budgets, hydrogeologic characterization, and monitoring hydrologic effects of watershed restoration projects.

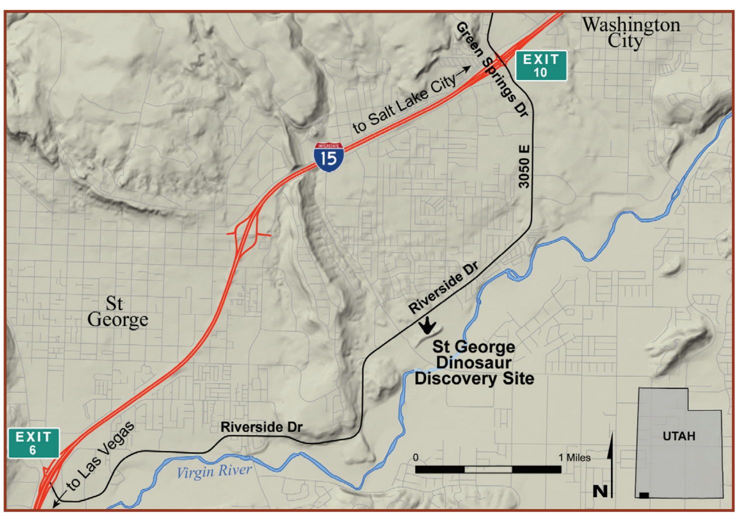
A RACE AGAINST TIME: ST. GEORGE DINOSAUR DISCOVERY SITE UNEARTHS OVER ONE THOUSAND FOSSILS IN HISTORIC SALVAGE EFFORT

by Don DeBlieux

The St. George Dinosaur Discovery Site (SGDS) is a world-class dinosaur tracksite, renowned for its remarkably well-preserved Early Jurassic-age (201–174 Ma) tracks (see *Survey Notes* v. 34, no. 3). Discovered in 2000 beneath a sod farm on the outskirts of St. George, Utah, the site has been carefully preserved in a state-of-the-art museum. As the city has expanded, the site is no longer on the outskirts but is now encompassed by urban development.

In January of 2025, the paleontologists at the SGDS received urgent news that the City of St. George planned to build an electrical substation on land across the street from the museum. Previous work on and near the site had documented numerous fossils in multiple strata of the Early Jurassic-age Moenave Formation. With the land slated for development, they knew a rapid salvage excavation was imperative to preserve the site's scientifically significant fossils. News of this monumental project quickly spread worldwide via newspapers, television, and online media. As long-standing collaborators with the SGDS (for over 20 years), the Utah Geological Survey offered immediate assistance. An astounding 750 individuals responded to the call for volunteers, with over 500 people ultimately dedicating their time and effort to the excavation. The Utah Geological Survey paleontology team spent a week in March 2025 working to collect fossils and help supervise the many volunteers. In addition to the many citizen volunteers, crews from universities and museums from Arkansas, California, Colorado, Idaho, Montana, Texas, and Utah joined the excavation. Many businesses and individuals also contributed thousands of dollars to help buy equipment for the project.

In May, the city revised its plans, relocating the substation to an adjacent parcel, thereby preserving the invaluable fossil-bearing rocks. Thus, after two intense months of daily excavation, the SGDS crew could finally pause for the season, allowing them to begin assessing the collected fossils. Preliminary analysis of the extraordinary discoveries from what has now been aptly dubbed the "Substation quarry" (SQ) suggest a one-of-a-kind collection of fossils.



University of Arkansas Ph.D. candidate Clayton Forster cleans rock debris from the upper fish bed while SGDS lead paleontologist and curator Andrew Milner uses a rock saw to cut around a fish fossil from the lower fish bed. Photo by Don DeBlieux.

Remarkable Finds from the Substation Quarry

Fossils were recovered from five distinct stratigraphic levels within the Whitmore Point Member of the Moenave Formation. Most fossils were concentrated in the lower fish bed (LFB) and the upper fish bed (UFB). Collectively, over 1,000 fossils have been meticulously collected and cataloged from these two prolific units at SQ.

The LFB yielded the most complete and semi-complete fish specimens, including primitive ray-finned fishes such as semionotids and palaeoniscoids, as well as the distinctive lobe-finned coelacanths. Some of these represent previously described species, but the majority likely belong to entirely new taxa. Once excavated, these fish fossils will require painstaking preparation. The sheer volume of fossils collected means there will be years of preparation to be completed by museum staff and volunteers.

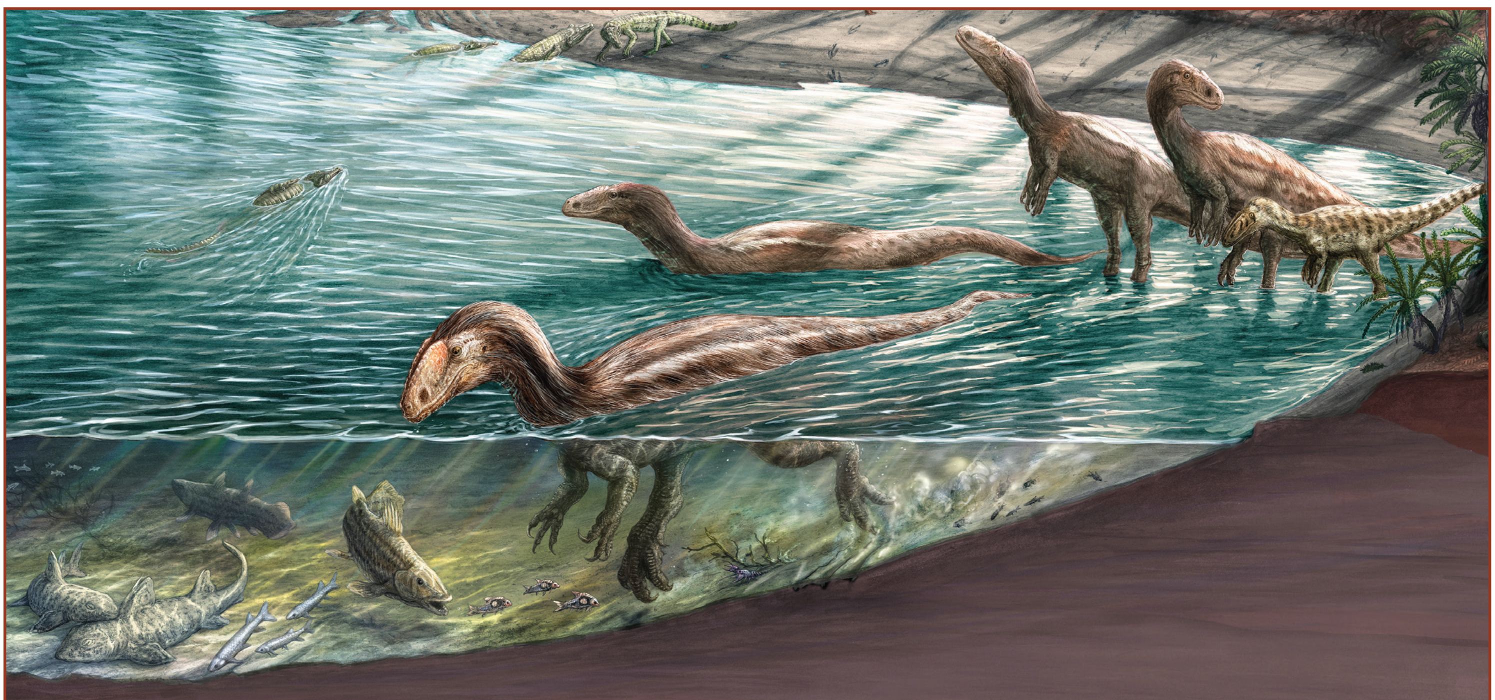
The UFB alone yielded over 700 individual fossils, predominantly consisting of individual skeletal elements. Fish remains found in the UFB primarily consist of disarticulated elements including numerous teeth, fin spines, and scales from hybodont sharks. The UFB also proved to be the primary source of terrestrial vertebrate fossils. Dinosaur remains include two types of teeth from large and small carnivorous theropods. Isolated bones belonging to theropod dinosaurs were also collected from the UFB.

The theropod dinosaurs discovered at the SQ, and in adjacent rock units, almost certainly represent new species. The large theropods appear to be closely related to *Dilophosaurus*, whereas the smaller species are likely coelophysoid theropods. Additional skeletal elements, particularly from the skull, will be necessary to formally describe them as new species.

A well-preserved semionotid fish fossil embedded within a red ironstone concretion from the lower fish bed at the Substation quarry. White line shows the approximate outline of the fish. Photo by Andrew Milner.

A large theropod dinosaur tooth discovered in the upper fish bed of the Substation quarry. Photo by Hunter Carter. Scale bar is in millimeters.

Other notable discoveries at the SQ include a new track horizon featuring the rare footprints of swimming dinosaurs. Invertebrates, their trace fossils, and plant remains were also documented. In summary, the excavation at the SQ was a resounding success, made possible by the generous contributions of time, effort, and resources from numerous individuals and organizations. The thoughtful relocation of the substation ensures this site will remain available for future excavation, transforming a potential loss into a remarkable victory for science and the community. The vast number of fossils collected will provide years of invaluable scientific investigation, greatly enriching our understanding of the Early Jurassic ecosystem of southwestern Utah.



This illustrative mural depicts a reconstruction of the Early Jurassic ecosystem of Lake Whitmore.* Megapnosaurus *dinosaurs wade into the shallow waters, while below the surface, two hybodont sharks rest on the bottom as three semionotid fish swim past. To their right, two coelacanths pursue three small palaeoniscoid fish. Several crocodilomorphs are also visible at the top of the scene. Art by Brian Engh (http://livingrelicproductions.com/).

PALEO NEWS

Utahraptor State Park: Preserving Dinosaur and Human History

by Ben Dlin

Utah's newest state park, Utahraptor State Park, opened May 23, 2025, and offers an illuminating glimpse into the deep past when ancient creatures roamed the land, as well as a poignant reminder of more recent history. Situated about 15 miles northwest of Moab in Grand County, the park spans over 6,500 acres and encompasses the Dalton Wells and Willow Springs area.

A Window into the Age of Dinosaurs

The Dalton Wells Quarry is one of North America's largest dinosaur bone beds. Excavations have uncovered over 5,500 bones representing more than 10 dinosaur species, including the park's namesake, *Utahraptor ostrommaysorum*. This formidable predator, measuring up to 20 feet in length, lived during the Early Cretaceous Period, approximately 125 million years ago. The quarry also yielded fossils of other dinosaurs such as *Gastonia*, a heavily armored herbivore, and *Moabosaurus*, a long-necked plant-eater.

Utahraptor *skeleton.*

The bone-bearing geological layer at Dalton Wells is the Yellow Cat Member of the Cedar Mountain Formation, among the most productive dinosaur fossil-bearing units in the state. The Yellow Cat Member is mostly drab-colored mudstone, siltstone, and sandstone deposited by ancient rivers and floodplains. These sediments were deeply buried, compacted, and cemented into rock before being exposed by uplift and erosion, enabling paleontologists to study the prehistoric environments where dinosaurs once lived and how those environments changed over time.

A cast of the lower jawbone of an Iguanodon *displayed at the visitor center.*

Utah State Paleontologist Dr. James Kirkland emphasized the significance of the Dalton Wells Quarry, describing it as "the most important dinosaur site in the United States" due to its extensive deposits of dinosaur bones. At least 10 species found here have not been identified elsewhere in North America. He further highlighted the site's exceptional diversity and richness, stating, "It's a gold mine of new dinosaurs. There are 30 that are only found here in Moab Valley.... Dalton Wells has more kinds of dinosaurs than Dinosaur National Monument" (https://www.sltrib.com/news/environment/2020/02/11/hunt-may-be-over-next/). Dr. Kirkland believes that there may be more than 100,000 fossils still buried at the Dalton Wells Quarry.

Echoes of Human History

Beyond its paleontological significance, the park is a site of historical importance. In the 1930s, the Dalton Wells area housed a Civilian Conservation Corps (CCC) camp, part of a New Deal program aimed at providing employment through the Great Depression. During World War II, the camp was repurposed as an internment facility for Japanese Americans deemed "troublemakers" by U.S. authorities. New interpretive displays in the Visitors Center highlight this history and provide a striking impression of the impacts of this troubling time in U.S. domestic politics.

A display about the park's history as both an internment camp and Civilian Conservation Core camp.

Utahraptor State Park visitor center.

A birds-eye view of the park and its newly constructed campsites.

Grand Opening and Visitor Center

On May 23, 2025, Utahraptor State Park officially opened its doors to the public. The grand opening ceremony celebrated the culmination of years of planning and development. The park features modern amenities, including a campground with 61 sites, flush restrooms, showers, and trailheads for hiking, mountain biking, and OHV use.

A standout feature of the park is its visitor center, which offers engaging exhibits on both the area's prehistoric and cultural histories. Visitors can explore displays showcasing dinosaur fossils, learn about the geological processes that shaped the landscape, and reflect on the human stories tied to the land. The center serves as an educational hub, fostering a deeper understanding of the region's rich and multifaceted heritage.

Utah Department of Natural Resources Executive Director Joel Ferry speaks at the grand opening of the new state park in May 2025.

One of the most significant changes to the area is the management of grounds and facilities; the Utah Division of State Parks will maintain staff on site to assist visitors, and, importantly, help safeguard paleontological sites. As this has been an area of paleontological study for over 50 years, scientists have had to contend with disturbance, vandalism, theft, and even the use of fossils as fire rings for campfires. Management on site will help ensure that these irreplaceable natural resources are maintained for future generations.

A Legacy Preserved

Utahraptor State Park stands as a testament to the state's commitment to preserving its natural and cultural heritage. It offers a unique opportunity to connect with the distant past of dinosaurs and the more recent history of human resilience and reflection. As visitors explore the park, they are invited to consider the layers of time that have shaped this remarkable landscape.

For more information on visiting Utahraptor State Park, including hours, fees, and trail maps, please visit the official website: https://stateparks.utah.gov/parks/utahraptor/.

Teacher's Corner

High School Summer Internship

This summer, Lillian and Bella, two high school seniors from a local public school, participated in our second annual Internship Program. Under the mentorship of UGS scientists, they gained hands-on experience by performing fieldwork and learning the applications of various technical tools used in our five different programs. This program is a great opportunity to inspire young scientists and prepare them for a career in geological science.

Earth Science Week 2025

Due to staffing issues and shifting priorities at the Utah Geological Survey, our on-site activities for Earth Science Week 2025 are being postponed. We offer a variety of online earth science activities and teacher resources on our website at geology.utah.gov/teachers/earth-science-week/, and encourage you to explore these valuable materials. Check back for updates about Earth Science Week 2026.

WHAT'S WITH ALL THIS DUST?

Glad You Asked!

by Abby Mangum

After a long winter of inversions and cabin fever, it is normal to crave fresh air. But then suddenly, spring comes, and the air is full of haze again! What is going on? The answer: dust.

What are dust storms?

Utah historically experiences frequent dust storms from March to May, with a secondary peak in the fall. Most of these dust events are a result of cold fronts and occasional thunderstorms in the summer. Basin and Range topography (north-south-oriented valleys and mountains) funnels strong, southwesterly winds produced from these storms, transporting dust north towards the Wasatch Front.

Dust problems

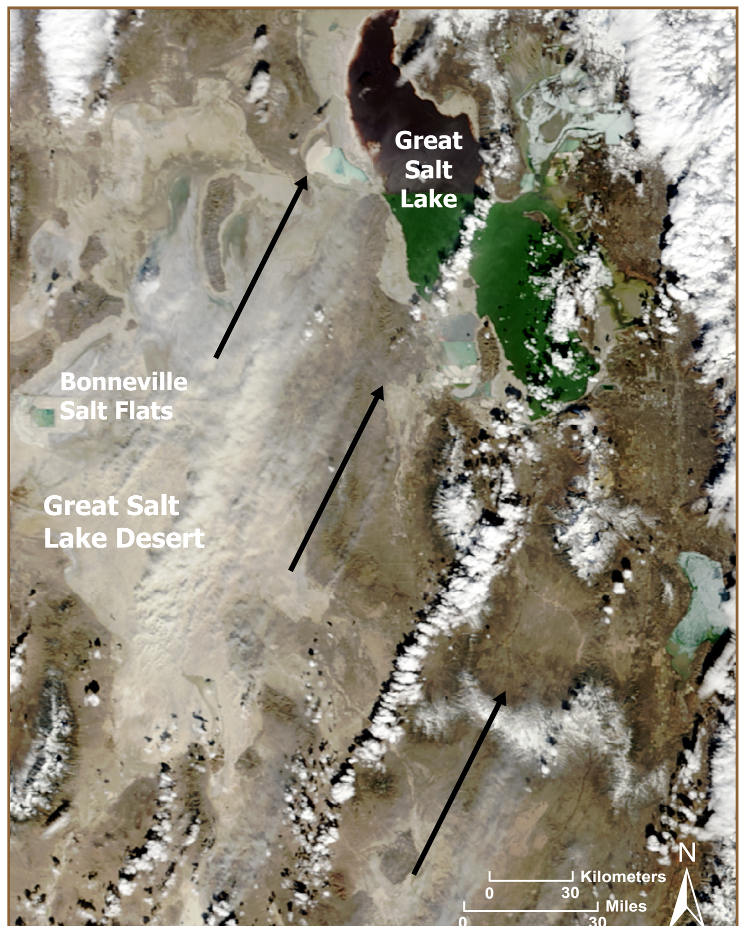
This dust consists of clay and silt-sized sediment (2–50 micrometers in diameter), which are small enough to be easily transported by wind. However, the small size of these particles also means they are easily inhaled, potentially causing health issues such as pneumonia and Valley fever, an illness caused by inhaling airborne spores of a fungus called Coccidioides that lives in the soil of arid regions. Dust also reduces visibility, which can lead to roadway accidents, and can contain various organisms, minerals, and metals that affect air quality and water resources. An additional environmental impact of the dust is that it can cause early onset melting of the mountain snowpack. A dark layer of dust on the snowpack reduces the snow's albedo (reflectivity), causing the snow to absorb more sunlight and melt faster. This early snowmelt can disrupt Utah's water management practices, and the dust can introduce foreign minerals and organisms into the alpine environment.

Dust storm in Milford Flat, Utah, on March 4, 2009. Photo by the U.S. Geological Survey.

Where does dust come from?

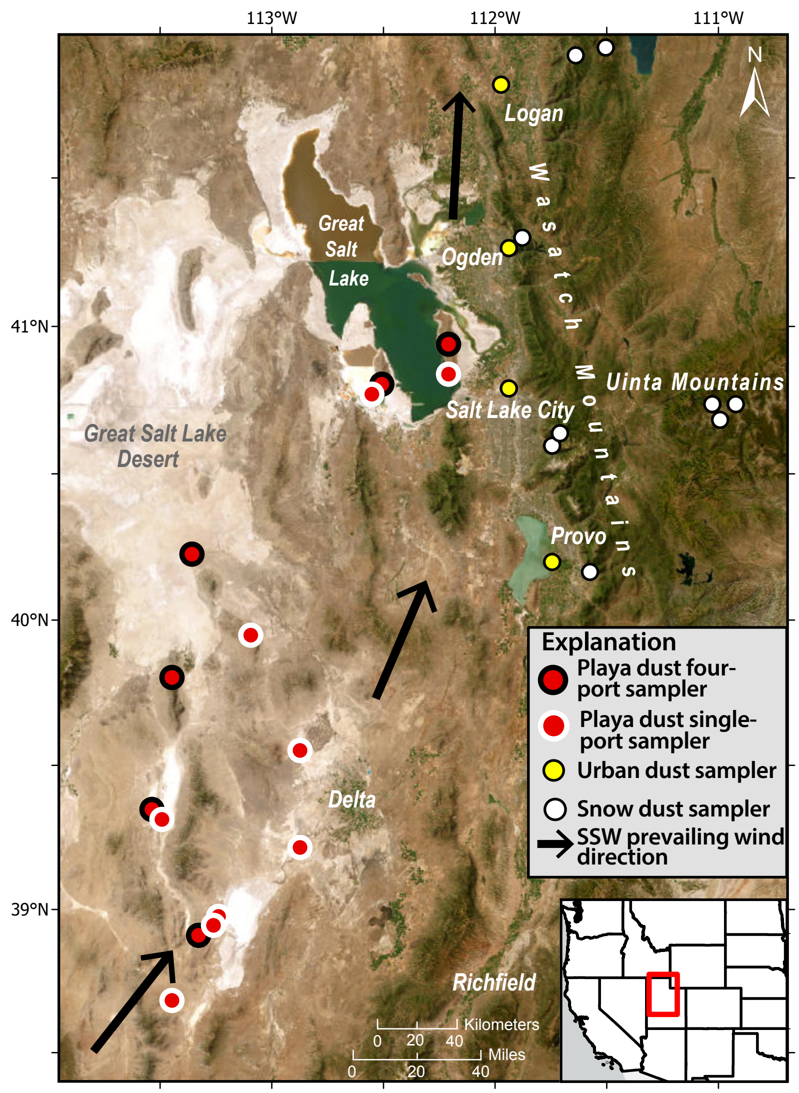
Much of the dust reaching the Wasatch Front comes from dry lakebeds (playas) in western and southwestern Utah. Arid regions such as Sevier Dry Lake, the Bonneville Salt Flats, and other playas in this area are particularly vulnerable to drought-related changes in vegetation, as well as impacts from grazing, mining, urban development, and off-road vehicle travel. A fraction of dust that researchers collected along the Wasatch Front contains man-made aerosols from urban and industrial sources, such as mining and smelting.

Researchers across Utah are working hard to understand dust sources and track their impacts. One way they are doing this is through "fingerprinting": identifying a dust sample's unique



A satellite image of a dust storm sweeping across the Great Salt Lake Desert towards the Wasatch Front. Taken March 4, 2009, by MODIS (Moderate Resolution Imaging Spectroradiometer) on NASA'S Terra satellite. The dust shows up as pale, rippling clouds above the duller tan desert below. The arrows indicate the northeast direction the dust storm is traveling.

traits, like its chemical makeup, microbes, or tiny differences in atoms (called isotopes). Like matching a fingerprint to a suspect, these clues help trace the dust back to its source. For example, scientists might find that the dust on your car in Salt Lake City matches the chemical "fingerprint" of sediment from a dry lakebed hundreds of miles away. Researchers collect dust samples throughout the state, focusing on the west desert, urban areas (via rooftop samplers), and snow in the Uinta Mountains. They then prep these samples in a lab by exposing them to a series of acidic leaching solutions, and then analyze them using an instrument that measures the isotope ratios of elements, like the amount of Strontium-87 to Strontium-86. These ratios are unique to specific regions, and researchers can compare them between sample sites to determine the "source" (dust origin) and "sink" (where dust gets deposited). It is vital to continue monitoring these sources so that future management decisions can be made.



Dust sampling locations in Utah. Playa dust samplers are placed in dry lakebeds. Urban dust collectors are placed on rooftops of buildings. Snow dust samples are collected in the mountain snowpack. These samplers and associated data are courtesy of Greg Carling, researcher and professor at Brigham Young University.

Snow pits like this one dug by researchers from the University of Utah are studied throughout the winter season. The dark lines are previous dust events preserved in the snow layers. Understanding the unique "fingerprint" of the dust layers can help track its origin. Photo by Otto Lang .

What can we do?

Less dust in the air means cleaner lungs, safer roads, and a healthier winter snowpack. You can start making a difference today! Mindful choices, like conserving water, using best practices for agriculture and grazing management, and even staying on designated roads while exploring, can help reduce dust emissions. As we all work together, our efforts can have a significant impact. More research is needed to mitigate this problem, but mindful land and water use can help reduce dust storms in the future.

Further Reading:

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Tony Grove, Cache County, Utah

by Stephanie Carney

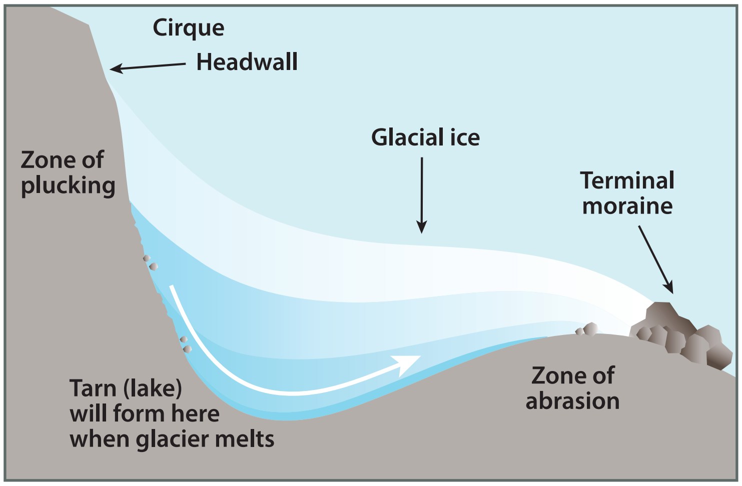
View west-northwest of the Swan Peak Formation (tan and white rocks at base of the cliff) and Fish Haven and Laketown Dolomites.

Tony Grove, located in the Bear River Range in northeastern Utah, is a popular area for recreation, including hiking, camping, and paddle-boarding and kayaking on picturesque Tony Grove Lake. This lake and other nearby lakes, such as White Pine Lake, owe their existence to glaciers that once flowed down the drainages of these high elevation areas during the last glacial cycle. The Last Glacial Maximum in northern Utah occurred between about 18,000 to 24,000 years ago, near the end of the Pleistocene Epoch. Through the growth and advancement of these alpine glaciers, the local rocks were scoured and eroded, leaving behind glacial landforms including cirques, glacial moraines (composed of debris or till eroded by the glacier), and hummocky topography. Cirques are alpine valleys shaped like a lopsided bowl or armchair with a steep headwall and a concave floor. After the glacier melts, the floor of the cirque can fill with water to create a cirque lake or tarn, like Tony Grove Lake. The lake is nestled at the base of the cirque's headwall cliffs and steep slopes, which are composed of Late Ordovician- to Silurian-age (roughly 470 to 420 million years old) Swan Peak Formation, Fish Haven Dolomite, and Laketown Dolomite.

Long before the Bear River Range was subjected to glacial erosion or even existed, the rocks that outcrop at Tony Grove were made from sediments deposited in a tropical marine setting along a passive continental margin, which is a region of minimal tectonic activity much like the present East Coast of the U.S.. Sandstone, siltstone, and shale of the Swan Peak Formation were deposited in a nearshore and intertidal environment, whereas the slightly younger, overlying Fish Haven and Laketown Dolomites were deposited on shallow carbonate platforms like the Bahamas today. After hundreds of millions of years, these sediments, which had been buried and lithified into rock layers, were uplifted and thrust eastward by the Sevier orogeny, a mountain building event during the Late Jurassic through middle Paleogene Periods (~160 to 50 million years ago). Near the end of the orogeny, the Eocene-age Wasatch Formation, a reddish-orange-colored conglomerate and siltstone unit, was deposited on top of the exposed older rocks. Beginning around 17 million years ago, the Bear River Range was uplifted further as Basin and Range extension shaped the valleys and mountain ranges seen today.

Today, the Swan Peak Formation is exposed north and west of Tony Grove Lake and it has eroded into an interesting stair-step pattern up the slope from the lake. The unit hosts many trace fossils that were left by burrowing marine organisms, as well as body fossils including trilobites, brachiopods, and nautiloids, which were among the top predators in the ocean during the Ordovician Period. The sandstone beds host conspicuous horizontal trace fossils; although these fossils resemble seaweed-like structures called "fucoids," they are postulated to indicate offshore burrowing activity of worms and possibly trilobites. Another trace fossil, *Skolithos*, is also present; these vertical to slightly inclined tubes were made by worms when they needed to escape from strong currents.

Just west of the lake, the Fish Haven Dolomite forms a dark-gray cliff between the white and tan Swan Peak below and the light-gray cliffs of the Laketown Dolomite above. It has abundant reef-forming fossils such as tabulate and rugose (horn) corals, crinoids, and stromatoporoid sponges. The overlying Laketown Dolomite is also known to host similar fossils as well as brachiopods and nautiloids.



Schematic diagram of a glacial cirque.

Skolithos *trace fossils within the Swan Peak Formation.*

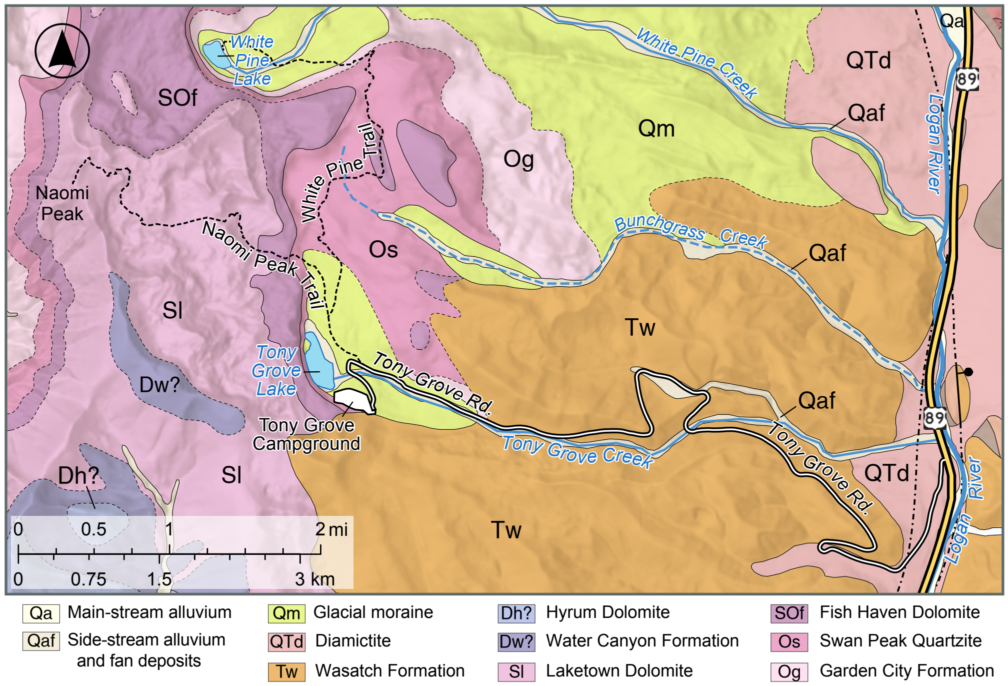
Horizontal burrows on a bedding surface in the Swan Peak Formation.

The dolomite that forms the Fish Haven and Laketown formations is susceptible to weathering (dissolution) from slightly acidic water. Over thousands of years, slightly acidic groundwater has seeped down into the subsurface through faults and fractures, slowly dissolving the dolomite and creating ever widening pathways (see *Survey Notes* v. 52, no. 2). This weathering and erosion from water has resulted in the formation of over 100 known caves and pits in the area. The largest cave, Main Drain, is over 1,200 feet deep. These caves are located high above the present water table, and most have formed in a stair-step pattern with shorter horizontal passages connecting longer vertical drops, typical of alpine cave systems. Cave and pit entrances occur on the surface of the Laketown Dolomite, however, entering these caves and pits is not advisable and only professionals with proper equipment should attempt to do so.

Tony Grove has been a recreational destination since the late 1800s. Upscale residents of Cache Valley were known to make the arduous trip up Logan Canyon and camp near the lake during the hot summer months. The name of the lake is thought to come from the word "tony," a slang term used in the late 1800s and early 1900s to describe the aristocracy or well-to-do. In the 1930s, the lake was augmented with an earthen dam, likely to make it larger and stay reliably filled.

Stromatoporoid sponges.

Nautoloids (about 3 to 4 inches long).

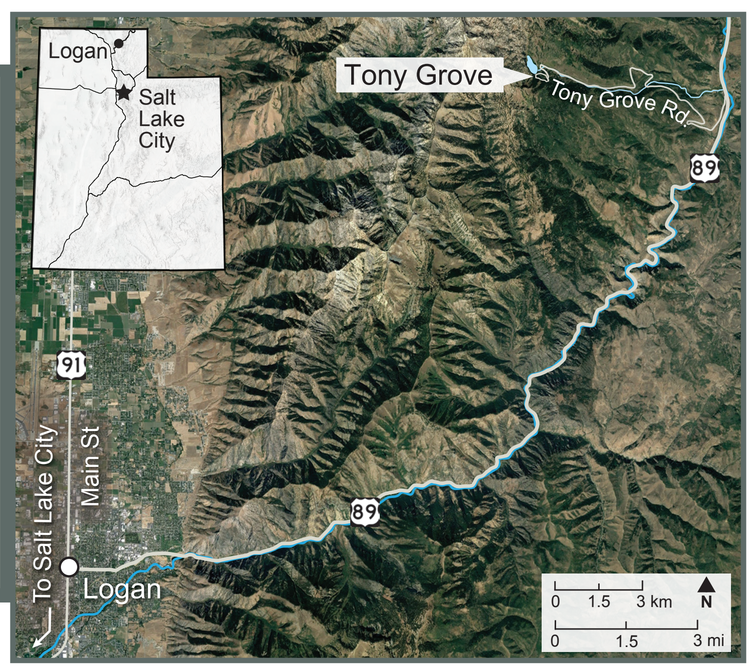


Simplified geologic map of the Tony Grove area. Modified from Dover (1995).

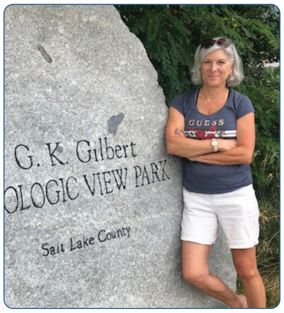
How to Get There

From Main Street in Logan, Utah, head east into Logan Canyon on 400 North/U.S. Route 89 for about 22 miles. Turn left on to Forest Road 141, then take another immediate left onto Forest Road 003. Follow the signs to Tony Grove Lake, which is about 6 miles. Tony Grove Lake is at an elevation of 8,050 feet and its weather (or climate) station records an average of 300 inches of snow in the winter. The road is usually impassible from mid-October to late May, depending on snowfall and temperatures.

Coordinates: 41°53'38.3"N, -111°38'38.3"W



Employee News



Darlene Batatian has been appointed the new State Geologist and Director of the Utah Geological Survey, succeeding Bill Keach, who retired in March. Darlene brings extensive professional experience in geologic field mapping, hazards, groundwater investigations, land development, and public policy. She holds a bachelor's degree in earth sciences from UC Santa Cruz and a M.S. in geology from Idaho State University. Her diverse career includes drilling paleomagnetic cores on Alaskan islands, mineral resource delineation for proposed Wilderness Study Areas, and groundwater monitoring projects at Hill Air Force Base and in the U.S. Territory of Guam. Darlene served as Salt Lake County Geologist from 1998 to 2006, where she addressed the impacts of geologic hazards on proposed developments and played a crucial role in advancing Utah's professional licensure requirements for geologists. As Deputy Director, Darlene demonstrated exceptional leadership and strategic direction for the UGS, and we look forward to her continued leadership.

Stefan Kirby has been promoted from his current role as Geologic Mapping Program Manager to UGS Deputy Director, replacing Darlene Batatian. Stefan is a licensed Professional Geologist, with a diverse background in field geology and interpretive science, and has authored and co-authored numerous journal articles, reports, and geologic maps across Utah. His extensive work also includes a variety of geologic mapping, structural geology, stratigraphy, geothermal projects, isotope geochemistry, basin-scale groundwater studies and water budgets, statistical analysis of basin-scale groundwater chemistry, aquifer testing, and the drilling and completion of various types of groundwater monitoring wells. Stefan received a B.S. in geology from Colorado State University in 1999 and M.S. in geology from Utah State University in 2005 and joined the UGS in 2004. We are confident that Stefan's leadership and expertise will benefit all UGS disciplines in his new role.

Madeline Griem has accepted the position of assistant curator of the Utah Core Research Center (UCRC). Madeline brings a strong academic background to this role, holding a B.S. in history from Emporia State University and an M.S. in museum studies from IUPUI. Prior to joining us, she served as the collections assistant for the Indiana Geological and Water Survey. **Mark Radwin** joined the Groundwater & Wetlands Program as a post-doctoral researcher specializing in satellite imagery analysis with applications for surficial geology, hydrology, and climate. He recently completed his Ph.D. from the University of Utah, and his work will focus on the Bonneville Salt Flats and Great Salt Lake Basin, as well as a wide range of other projects that will benefit from his unique skill set. A warm welcome to Madeline and Mark!

Janae Wallace retired in July after 29 years in the Groundwater & Wetlands Program, starting as a time-limited Geologist and ending as a Senior Scientist. Prior to joining the UGS in 1996 she worked with the U.S. Geological Survey's (USGS) Desert Wind Project, monitoring changes in climate-sensitive areas. She has a B.S. degree from the University of Utah and M.S. degree from Northern Arizona University. Janae's projects involved groundwater quality, especially groundwater quality classifications, nitrate studies, septic-tank density analysis, aquifer storage and recovery projects, detailed descriptions of water-well cuttings, and watershed restorative initiative projects working in concert with sister agencies in the Utah Department of Natural Resources and Utah Department of Environmental Quality. Janae built steadfast and lasting partnerships with local, regional, State, and Federal partners including the U.S. Environmental Protection Agency and the Town of Castle Valley to help planners ensure that their communities have clean drinking water. Janae served on the Board of the USGS's National Groundwater Monitoring network for 10 years. Janae co-authored many reports, four of which won the UGS Crawford Award for most influential geologic publication. Janae has been a great asset to the Survey, and her talent and knowledge will be greatly missed. We wish her well in her retirement.

Geological Society of America Rocky Mountain Section Meeting

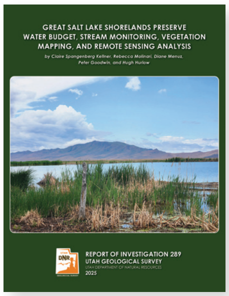
We were proud to participate in the Geological Society of America's Rocky Mountain Section Meeting May 19–20 in Provo, Utah. This event allows geoscientists to share knowledge, encourage professional growth, and discuss the latest research in Earth sciences. Several members of the UGS contributed to the meeting by presenting posters, giving talks, and leading field trips allowing us to highlight Utah's unique geology and show our dedication to advancing geoscience in the region.

Professional License Exams

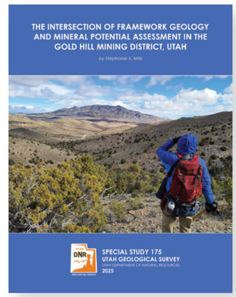
Congratulations to Jim McVey, Kayla Smith, Kate Baustian, and Erin Brinkman on becoming licensed professional geologists by passing the required Fundamentals of Geology and Practice of Geology exams. Other staff well on their way to obtaining licensure are Abby Mangum, Greg Gavin, and Kristi Rasmussen who passed the Practice of Geology exam and Rachel Willmore who passed the Fundamentals of Geology exam. Their hard work and dedication are truly commendable!

New Publications

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

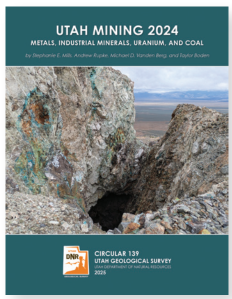


Great Salt Lake Shorelands Preserve Water Budget, Stream Monitoring, Vegetation Mapping, and Remote Sensing Analysis, by Claire Spangenberg Kellner, Rebecca Molinari, Diane Menuz, Peter Goodwin, and Hugh Hurlow, 48 p., 3 appendices, **RI-289**, https://doi.org/10.34191/RI-289

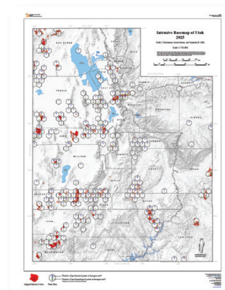


The Intersection of Framework Geology and Mineral Potential Assessment in the Gold Hill Mining District, by Stephanie E. Mills, 54 p., 4 appendices, **SS-175**, https://doi.org/10.34191/SS-175

Copper in Utah, by Stephanie E. Mills, 4 p., **PI-107**, https://doi.org/10.34191/PI-107



Utah mining 2024—Metals, Industrial Minerals, Uranium, and Coal, by Stephanie E. Mills, Andrew Rupke, Michael D. Vanden Berg, and Taylor Boden, 26 p., **C-139**, https://doi.org/10.34191/C-139



Intrusive Basemap of Utah, by Noah J. Christensen, Austin Jensen, and Stephanie E. Mills, 15 p., 1 appendix, 1 plate, **DS-2**, https://doi.org/10.34191/DS-2

Interim Geologic Map of the Francis Quadrangle, Summit and Wasatch Counties, Utah, by Lauren J. Reeher and Abigail E. Conger, 15 p., 2 plates, scale 1:24,000, **OFR-770DM**, https://doi.org/10.34191/OFR-770DM

Interim Geologic Map of the Blanding North Quadrangle, San Juan County, Utah, by Matthew C. Morriss, 12 p., 2 plates, scale 1:24,000, **OFR-771DM**, https://doi.org/10.34191/OFR-771DM

Interim Geologic Map of the Huntsville Quadrangle, Weber and Cache Counties, Utah, by Greg N. McDonald, Adam P. McKean, Zachary W. Anderson, Elizabeth A. Balgord, and W. Adolph Yonkee, 26 p., 2 plates, scale 1:24,000, **OFR-772DM**, https://doi.org/10.34191/OFR-772DM

Interim Geologic Map of the Wildcat Mountain and East Part of the Currie 30' x 60' Quadrangles, Tooele County, Utah: Phase 1, by Donald L. Clark, Charles G. Oviatt, Eric H. Christiansen, Christian L. Hardwick, Kayla D. Smith, and David Page, 28 p., 2 plates, scale 1:62,500, **OFR-773**, https://doi.org/10.34191/OFR-773

Recent Outside Publications by UGS Authors

Seismic Imaging of the Salt Lake Basin Using Joint Inversion of Receiver Functions and Rayleigh Wave Data, by H.J. Kim, F.-C. Lin, J.C. Pechmann, **C.L. Hardwick**, and **A.P. McKean**: Journal of Geophysical Research, Solid Earth, v. 130, issue 13, 16 p., https://doi.org/10.1029/2024JB030927

Emergent, Experimental, and Established Geothermal Resources in Utah's Great Basin, by **E. Szymanski**, **C.L. Hardwick**, **S.M. Kirby**, J.N. Moore, C.G. Jones, and S.F. Simmons, *in* Garcia, P., Nelson, D., Shimabukuro, D., and Wakabayashi, J., editors, From the Late Mesozoic forearc to the Quaternary Great Basin: Geological Society of America Field Guide 73, p. 67–92, https://doi.org/10.1130/2025.0073(01)

Understanding Groundwater Resource Vulnerability at Bryce Canyon National Park, Utah, Using Applied Geophysics at the Rubys Inn Thrust Fault, by **T.H. Schlossnagle**, **K.D. Smith**, and T.C. Gilkerson, *in* Petrie, E.S., Ferrill, D.A., Evans, J.P., and Bradbury, K.K., editors, Fault structure, deformation mechanisms, and why fault zones matter to society: Lithosphere Special Issue 15, https://doi.org/10.2113/2024/lithosphere_2024_149

Significance of Spring Inflow to Great Salt Lake, Utah, by L.E. Bunce, T.K. Lowenstein, **E. Jagniecki**, and D. Collins: Hydrology, v. 12, no. 6, https://doi.org/10.3390/hydrology12060159

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