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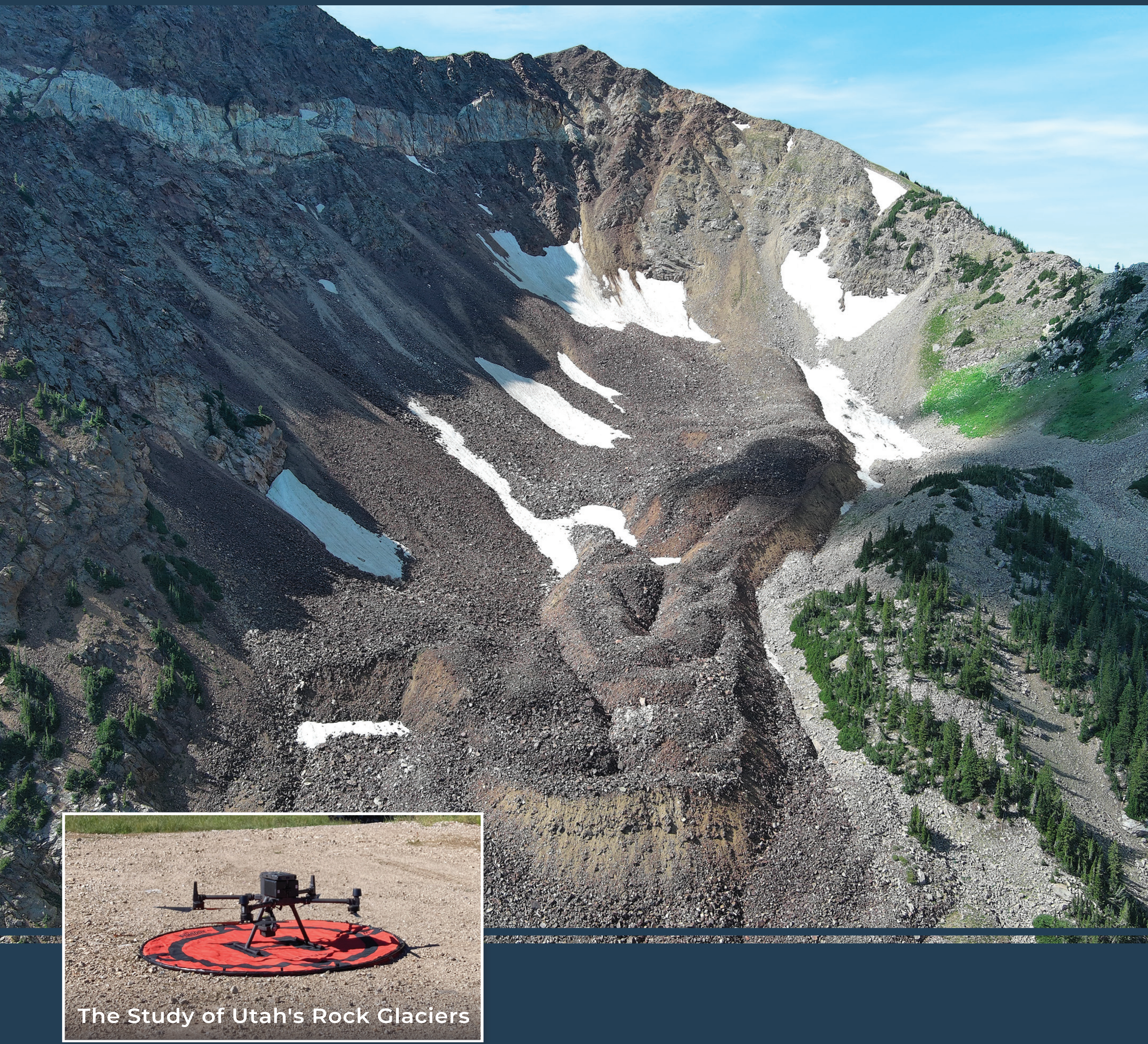

The Study of Utah's Rock Glaciers

Contents

Design | *Jen Miller*
Cover | *The Gad Valley rock glacier at the Snowbird ski resort in Little Cottonwood Canyon, Utah. Inset: Drone survey take-off in Gad Valley.*

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DIRECTOR'S PERSPECTIVE

On the road to heaven (and heat)

Jack Kerouac in his famous book, *On the Road*, wrote "As we crossed the Colorado-Utah border, I saw God in the sky in the form of huge gold sunburning clouds above the desert that seemed to point a finger at me and say, 'Pass here and go on. You're on the road to heaven'."

This past June the UGS had the opportunity to share our version of heaven with 145 geologists from across the country. They were in Park City for the annual meeting of the Association of American State Geologists, which we hosted. In addition to the usual meetings associated with any convention, we took time to visit some great geologic sites in Utah. Trips were to an array of locations within a few hours drive of Park City.

Our pre-meeting field trip was to the Vernal area to see phosphate deposits, Gilsonite®, and oil shale of the Green River Formation. A highlight of the trip was an after-hours dinner at the world-famous Dinosaur National Monument "bone wall" quarry, with a special lecture by State Paleontologist James Kirkland.

During the meeting, we took participants to visit nearby geologic areas. We first took our guests to the hot pots of Midway, Cascade Springs, Sundance Resort, and Bridal Veil Falls along the Wasatch Back. On another trip we visited Snowbird ski resort to view the geology and discuss the mining history. That night we toured the seismic base isolators that protect our state Capitol in the event of a large earthquake, after which former Utah State Geologist Genevieve Atwood gave a speech in the Capitol Rotunda.

The meeting concluded with a visit to learn about the quantity and quality of Ogden Valley's groundwater and its connection to surface water. We finished that day with visits to landslide hazards of the Wasatch Back. The meeting was very successful and the UGS enjoyed showcasing our fantastic geology.

In the last couple of months I have also had the opportunity to visit a number of geothermal sites in Utah along with some of our state legislators. As solar and wind energy production expands in our state, so does the interest in growing geothermal energy production. All three are often considered renewable sources of energy. What distinguishes geothermal from the others is that it is base-load renewable energy and dispatchable, which means it is available 24 hours a day, 7 days a week, 365 days a year. It is quiet and clean, runs at about 80% of installed capacity, and Utah has abundant geothermal resources, mostly untapped. Currently about 73 MW of electricity is produced in Utah from geothermal resources. That is 0.1% of the total undeveloped geothermal resource potential in Utah, which is estimated at 49,400 MW. State leaders and the private sector alike see opportunities to facilitate the shift to greener and more sustainable sources of power. Private companies are actively developing geothermal resources in central Utah as they work towards a goal of 400 MW. And still, that amount is less than 1% of Utah's potential. The opportunity to significantly grow is real.

Tapping geothermal can contribute to maintaining the heaven that Jack saw when he first arrived in Utah. As you visit the geologic wonders in Utah, hopefully it will expand your slice of heaven.

Lastly, a heartfelt thank you to Mike Hylland, Deputy Director who retired in July following a 30 year, stellar career with the UGS. Thanks Mike for your clear and wise perspectives.

Photo: A geothermal well in the wind farm near Milford, Utah.

ROCK GLACIERS

Reminders of a Glacial Past and Dynamic Landforms in a Warming Future

by Matthew Morriss

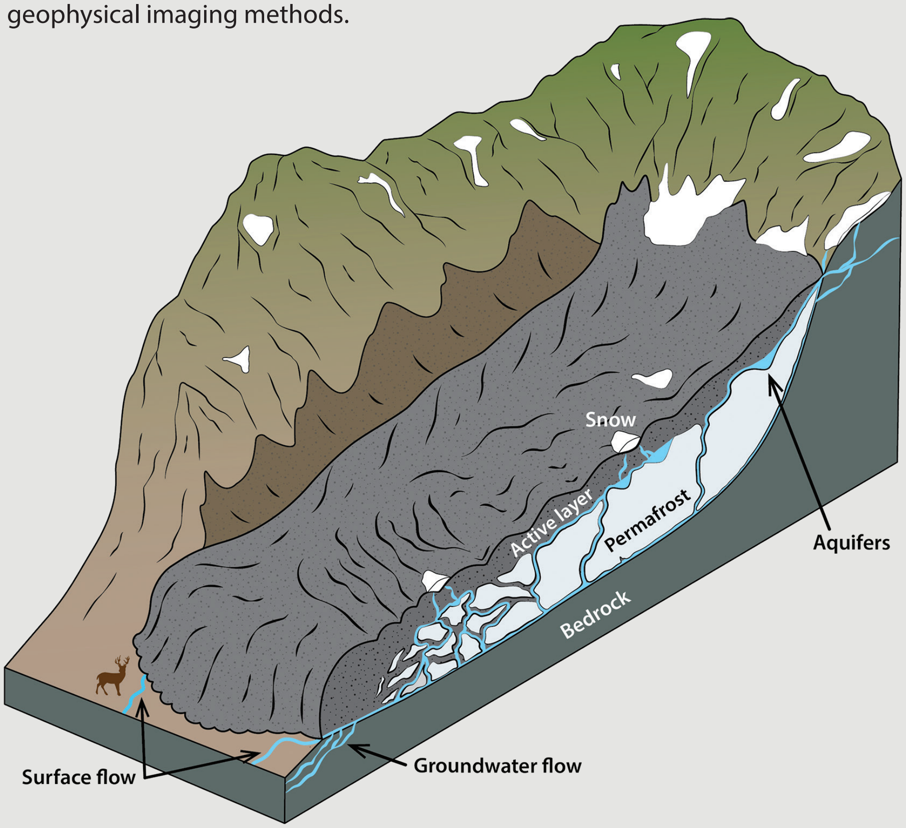
Utah is a state of dramatic landscapes that include red rock canyons of southern Utah, wide open desert valleys of the West Desert, and the high alpine environments of the Wasatch Range and Uinta Mountains. These alpine zones owe their modern form to ice glaciers that occupied this region multiple times over the past 2.5 million years. These glaciers carved and widened valleys, and generally sculpted the region into the landscape seen today in canyons like Little Cottonwood and Big Cottonwood of the Wasatch Range. As geologists, we study these glacial landscapes and the piles of debris they left behind, known as moraines. However, there are still glimmers of active ice glaciers here in Utah seen in landforms known as rock glaciers.

Rock glaciers form in high elevation alpine environments. They can contain large accumulations of ice, insulated from warmer temperatures by a carapace of fallen rock called talus. Talus also hides the true interior structure of the landform. However, with the help of geophysical imaging techniques like ground penetrating radar, geologists can find out how much ice there is and where it is distributed within the rock glacier. Scientists think that rock glaciers formed during the most recent geologic period known as the Holocene (approximately 11,700 years to present) and not from remnants of glacial ice from the last glaciations. Rock glaciers form from the accumulation of snow in steep, shaded, north-facing areas at high elevation that collect and protect a winter's snowpack from melting through the summer. Several colder years with more snow accumulation could yield a permanent snowfield, which through a colder decade or two would transition to ice through its own weight and internal pressure. Then with a drier and warmer spell, that snow becomes buried and insulated by rock and rocky debris.

An oblique aerial photo of the Gad Valley rock glacier at the Snowbird ski resort in Little Cottonwood Canyon, Utah. Note the steep front on the left, indicating the potential for ice cementation of sediments. The rumpled surface texture is known as "ridge and furrow" topography, emblematic of rock glacier movement.

View from above of the Timpanogos rock glacier, showing its ridge and furrow surface texture created by the slow downslope movement of debris covering the internal ice mass.

A repeat of this process over thousands of years leads to the growth of a rock glacier. Rock glaciers are distinctly different from glaciers in that they have few to no crevasses and rarely have visible ice on their surface. Rock glaciers cover relatively small areas compared with their older ice glacier relatives. In the Wasatch Range, rock glaciers have an average area of approximately 74 acres (0.1 mi^2 [0.3 km^2]). Their overall volume remains more enigmatic. Determining volume requires measurements of their thickness which is hard to constrain without methods like ground-penetrating radar, an actual drill core through the rock glacier, or other geophysical imaging methods.



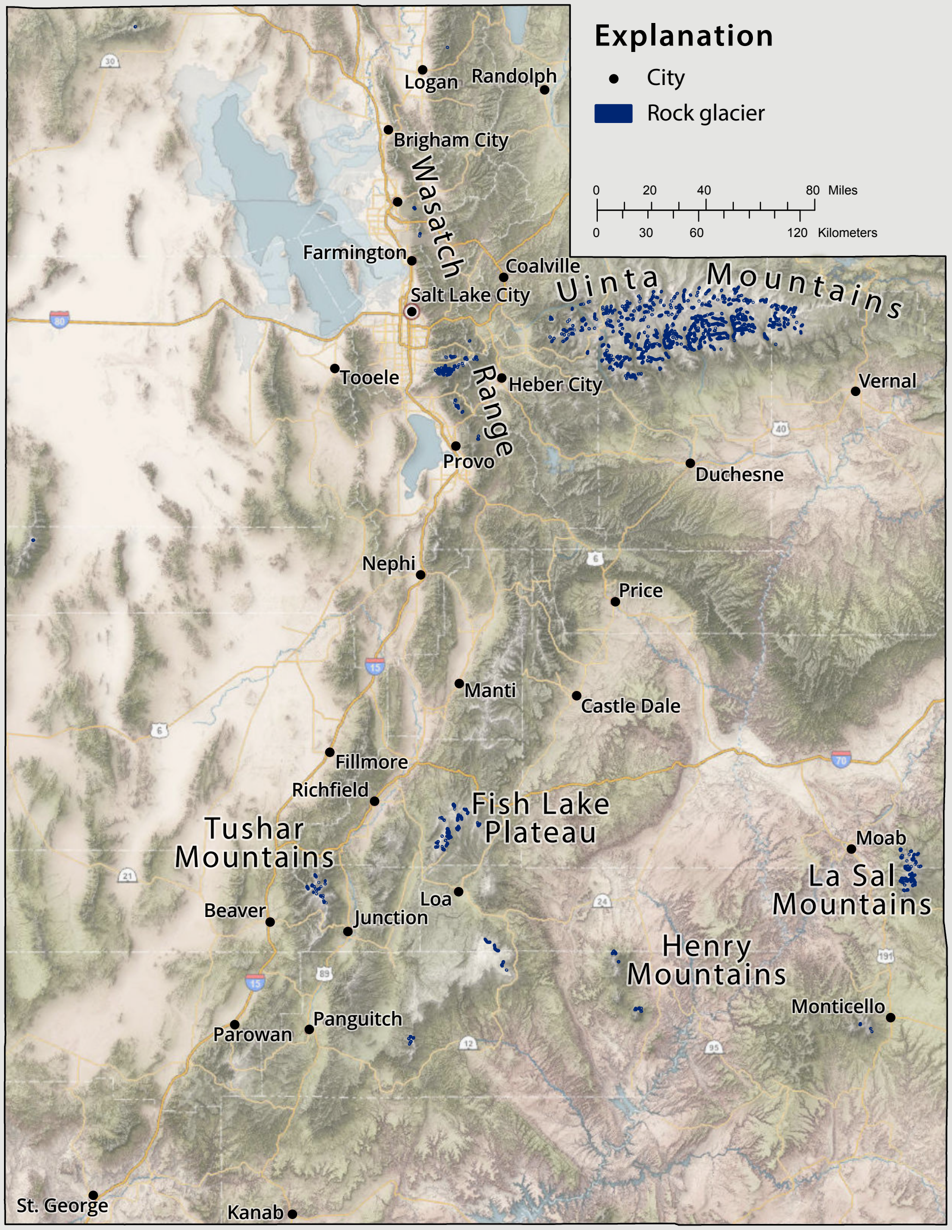
Cross-sectional diagram of a rock glacier, depicting the internal ice mass or permafrost core overlain by rocky debris. Meltwater sources contribute to both surface runoff and groundwater recharge into underlying aquifers.

Example of an automated water sampler deployed below a rock glacier in Little Cottonwood Canyon. These programmable devices collect water samples at set intervals to monitor the chemical changes between snowmelt-dominated runoff and ice-melt-dominated runoff.

Utah is the 5th most mountainous state in the conterminous United States with numerous high elevation, mountainous areas. So, with time and climate oscillations through the Holocene period, more than 800 rock glaciers have developed throughout the state. These rock glaciers are mostly located within the Uinta Mountains, Wasatch Range, and La Sal Mountains. Other pockets of rock glaciers are in the Tushar Mountains, Fish Lake Plateau, and a couple in the Henry Mountains.

In addition to their widespread presence, rock glaciers may play an important role in Utah's water systems. They are found in the headwater reaches of watersheds we rely on for drinking and irrigation water. Local to Salt Lake City, this includes Little Cottonwood Creek and Big Cottonwood Creek. These same high elevation regions at the headwaters have experienced more rapid warming due to climate change than lower elevation areas, which is a phenomenon known as elevation-dependent warming. This makes rock glaciers highly sensitive to warming temperatures.

To better understand how a changing climate impacts rock glacier meltwater, the UGS is involved in several studies of alpine regions of the Wasatch Range near Salt Lake City. The UGS began a pilot study in 2023, in partnership with researchers at Utah State University and the Water Resources Division of the Utah Department of Natural Resources, to evaluate the amount of water that may be sourced from rock glacier melt during late summer. This work builds on a recent study in the Uinta Mountains that showed meltwater from rock glaciers could make up to ~25% of late summer runoff in alpine catchments. This topic is particularly important to a dry state like Utah, which has historically relied on snowmelt for our water supply through the summer. Moreover, given that about 25% of Salt Lake City's water supply comes from Big and Little Cottonwood Canyons and these two catchments have around 70 rock glaciers, a previously unaccounted part of Utah's largest city's water supply could come from these rock glaciers.



Distribution of rock glaciers (shown in blue) across Utah. Most rock glaciers are located in the Uinta Mountains, Wasatch Range near Salt Lake City, and the La Sal Mountains.

About the Author

Matthew Morriss is a mapping geologist at the Utah Geological Survey, working on a broad array of projects around the State including making geologic maps of the Vernal NE and Blanding North quadrangles. His background is geomorphology with 2.5 years at the USGS Utah Water Science Center, earning a PhD from the University of Oregon; MSc. from North Carolina State, and a B.A. from Whitman College. He's actively engaged in the research of rock glaciers throughout Utah and the intermountain west. Originally from Austin, Texas, Matthew has explored geology in the west and east and as far away as Thailand and Mongolia; he's happy to have called Salt Lake home for 5 years and loves reading a book on the couch and spending as much time as possible in our local mountains with his partner Sarah and dog Hauk.

Climate change has already had an effect on rock glaciers, and the mountainous areas of Utah will continue to experience accelerated warming compared with the lower elevations. This warming could lead to destabilizing melt within some rock glaciers. Several rock glaciers in Europe have either collapsed into large landslides or triggered debris flows through rapid melting. A recent 2022 landslide of a rock glacier-like feature at high elevation in Rocky Mountain National Park, Colorado, has the UGS on the lookout for similar types of destabilizations in the Wasatch Range. To better understand the potential hazard, water resource questions, and make better, more up-to-date geologic maps, the UGS has started to conduct annual lidar (light detection and ranging) drone flights of the Gad Valley rock glacier in the Snowbird ski area to monitor its movement. Our goal is to better understand if Utah's rock glaciers are accelerating or slowing with increased warming, or showing other signs of instability that could threaten the infrastructure in Little Cottonwood Canyon.

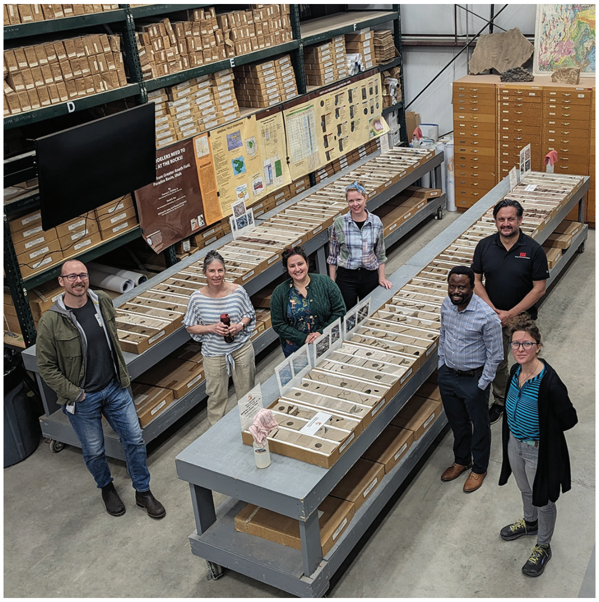
The study of rock glaciers in Utah is a multifaceted endeavor, representing both a window into the state's glacial history and a preview of how these landforms may respond to future climate changes. As temperatures continue to rise, understanding the potential for destabilization, changes in water contributions, and overall behavior of rock glaciers will be crucial. Rock glaciers are an anachronism; they are smaller glacial-esque landforms reminding us of large alpine glaciers that inundated our mountains across Utah. Rock glaciers remain dynamic alpine features, prompting the UGS and other researchers to explore their profound impact on Utah's mountains and hydrology through cutting-edge research.

BENEATH UTAH'S SURFACE

Harnessing Geologic Carbon Storage for a Sustainable Future

by Gabriela St. Pierre, Ph.D

In early 2024, the Utah Geological Survey (UGS) was awarded a $1.1 million cooperative agreement from the U.S. Department of Energy (DOE) Office of Fossil Energy & Carbon Management to study geologic carbon storage in Utah. So, what is carbon storage and what does it mean for Utah and its residents? Geologic carbon storage, a crucial component of Carbon Capture, Utilization, and Storage (CCUS; see *Survey Notes*, v. 54, no. 2), offers a promising solution to the challenge of reducing CO_2 emissions worldwide. Carbon dioxide [CO_2] emissions can be captured at a source (i.e., from industrial, manufacturing, and energy generation processes) and then either used in a commercial product or injected underground for permanent storage. This innovative approach not only promises to mitigate environmental impacts by reducing greenhouse gases, but also holds the potential to transform Utah's energy landscape. The goal of our project is to provide a detailed assessment of the geologic carbon storage resources available in Utah and make this information available in a web application that can be used by industry, government officials, and the public.



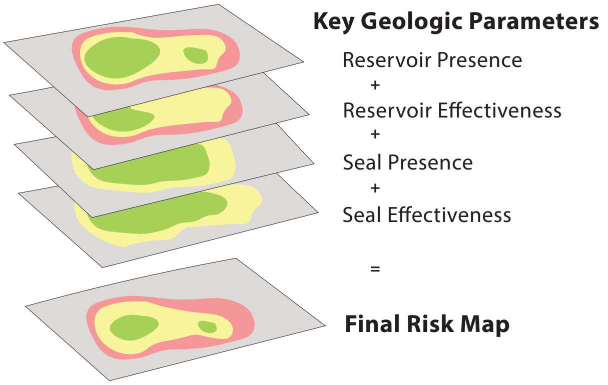
The project team at our kickoff meeting in April 2024. The team consists of an interdisciplinary mix of geologists from the UGS, subsurface geology experts from the University of Utah Geology and Geophysics Department and Energy and Geoscience Institute, and environmental justice experts from the University of Utah Anthropology and Sociology Departments.

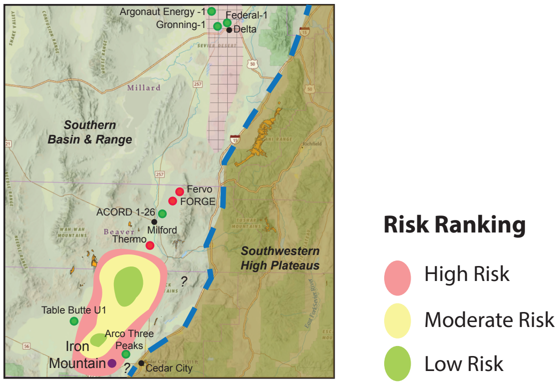
Project Overview

Utah has a variety of rock formations that may be suitable for long-term carbon storage. The UGS has partnered with the University of Utah Energy & Geoscience Institute and Department of Geology & Geophysics to research and assess potential geologic storage sites in the state. Our study will begin by compiling geologic data about Utah's rock reservoirs (i.e., porous rock formations such as sandstones) and their associated sealing formations (i.e., impermeable rocks such as mudstones that can "trap" liquid CO_2 and other fluids) into a geodatabase while also identifying regions with data gaps. Once all relevant data are collected, the project team will examine the carbon storage potential by "geo-region," or areas of the state with similar geologic histories and structural styles (e.g., southern Basin and Range, Uinta Basin, etc.). This research will also draw on findings and data from over two decades of carbon storage projects in Utah, including a newly funded CarbonSAFE Phase II project in the Uinta Basin (see all UGS CCUS projects at geology.utah.gov/energy-minerals/ccus).

Within the geo-regions that are determined to be best suited for geologic carbon storage, the project team will complete a more detailed analysis of key reservoir and seal pairs. These reservoir and seal pairs will be ranked by "geologic risk" to identify specific areas that are highly favorable for carbon storage. "Geologic risks" can include less-favorable factors, such as whether a rock reservoir has low porosity but high permeability (a higher risk reservoir because there is little pore space to hold carbon, and stored CO_2 may quickly leak out); and whether faults create pathways within a sealing rock that may cause the CO_2 to leak back to the surface (also high risk). Reservoirs with high carbon storage potential could include rocks like basalt, sandstones deposited in river or near-shore environments, eolian (wind-blown) sandstones, and limestones. Areas that have the greatest number of low-risk reservoirs and seals will be ranked as being highly favorable for carbon storage activities. The project team will also identify areas that need more geologic information to understand the reservoir quality and/or seal leakage risk and will fill in data gaps by analyzing rock samples from outcrops and rock core samples housed within the Utah Core Research Center.

The final product will be a publicly accessible interactive website application and database that allows users to visualize and download the UGS carbon storage assessments and their associated geological metadata. The website application will be a useful tool for everyone to learn more about CCUS opportunities in the state, and the detailed geologic information will provide a bank of reliable data to assist scientists, businesses, and government agencies seeking to research and potentially build regional carbon management hubs.





Example Risk Map in SW Utah

Risk maps consider geologic parameters around geologic rock reservoirs and their associated seals. This map of southwest Utah shows a hypothetical risk map of the Navajo Sandstone in the Escalante Desert and is an example of the kind of map that will be displayed in the web application along with its associated metadata available for download.

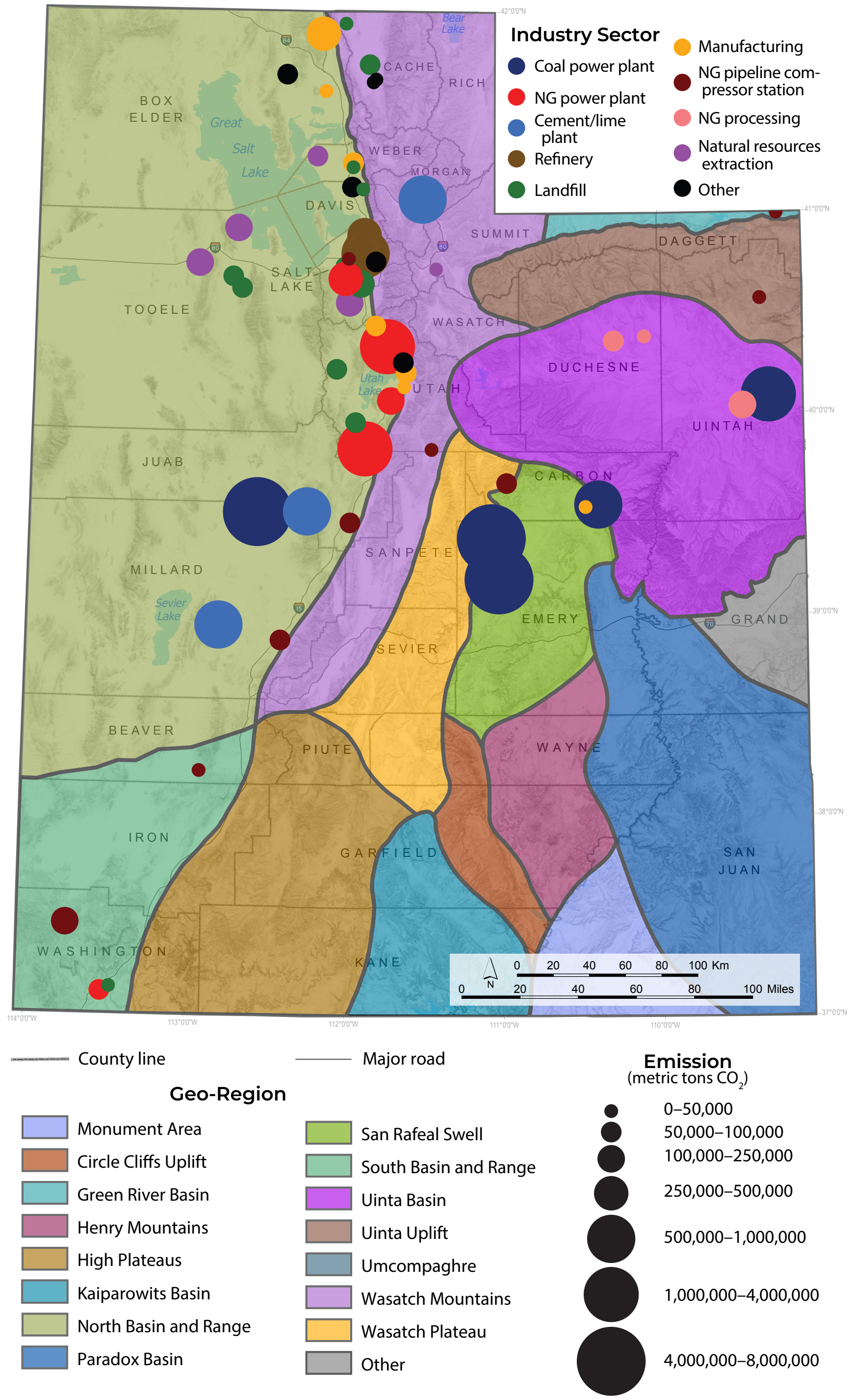
Where would the CO_2 come from?

Understanding where sources of CO_2 are, and how far they are from possible geologic storage sites, is key to understanding the economic viability of future CCUS in Utah. So where would CO_2 in Utah come from? In general, three types of CO_2 sources are targeted for sequestration: 1) industrial facilities, 2) energy facilities, and 3) direct air capture. Existing facilities such as power plants, chemical plants or refineries, and materials processing plants are considered point sources of emissions because they emit a relatively dense volume of CO_2 into the atmosphere at a single location. These facilities could be retrofitted with carbon capture technology to gather CO_2 for transportation and storage in nearby underground rock reservoirs. Currently, most Utah industrial and energy facilities qualify for significant 45Q tax credits (see *Survey Notes* v. 55, no. 1) based on 2022 EPA greenhouse gas emissions data.

CO_2 can also be removed from the atmosphere through a new technology called direct air capture (DAC). Although this is an energy-intensive process, the advantage of DAC is that it can be placed anywhere, such as directly over ideal subsurface storage reservoirs, which lessens the need for transporting CO_2 over long distances. Additionally, DAC technology could be powered by carbon-free energy sources such as solar, wind, or geothermal, making it a potential carbon neutral technology.

Involving the Utah Community

An integral part of this project's mission is to engage with people who may be impacted by future CCUS development in Utah. As part of this project, the UGS is collaborating with the Anthropology and Sociology Departments at the University of Utah, who will lead outreach efforts including assessing potential environmental justice issues as well as opportunities for economic progress in communities impacted by carbon storage development. Project tasks will include surveying communities that may be impacted by CCUS projects, planning educational events, and publishing in accessible peer-reviewed journals. The proposed community engagement plan aims to address the needs of stakeholders across the state and to understand how future CCUS projects may play a role in the anticipated economic advancement of Utah.



"Geo-regions" and CO_2 emissions by energy sector (emissions data from EPA 2022). The geo-regions represent areas in Utah with similar geologic histories, basin histories, and/or structural styles and each will be evaluated for carbon storage potential. The largest CO_2 emitters in Utah are coal and natural gas power plants, which tend to be concentrated along the Wasatch Front and in Emery County. With the increase in subsidies from the Inflation Reduction Act 45Q tax credits, nearly all CO_2-emitting facilities qualify for 45Q tax credits in Utah.

Looking Forward

CCUS has the potential to fit in well with Utah's current energy landscape. By completing this study, the UGS and its partners will provide a detailed assessment of the geologic factors that affect carbon storage resources in the state and help reduce the risks and uncertainties of subsurface carbon storage. Looking to the future, this project could help Utah meet national decarbonization goals by facilitating low-risk, economic, commercial-scale CCUS projects and highlighting opportunities for economic revitalization and job creation in Utah communities.

PALEO NEWS *by Don DeBlieux*

UGS Paleontologists Find a Bonanza of Fossil Footprints in Canyonlands National Park

The Utah Geological Survey's (UGS) partnership with the National Park Service to inventory paleontological resources is still going strong (see *Survey Notes,* v. 55, no. 1)! Our most recent collaboration has taken place over the last several years in the spectacular rocks of Canyonlands National Park. Canyonlands is made up of three districts— Island in the Sky, the Needles, and the Maze—all of which preserve a late Paleozoic- and early Mesozoic-age rock record. We have completed surveys in all three districts, but have spent the most time in the Island in the Sky District because of the large volume of accessible fossil-bearing, Triassic-age strata.

Initially, we were most excited about exploring rocks of the Late Triassic-age Chinle Formation because it is one of the most fossiliferous rock units in Utah and has yielded many significant scientific discoveries. We also examined the Early-Middle Triassic-age rocks of the Moenkopi Formation since we would have to traverse these rocks to access the Chinle strata, even though fossils are generally quite rare in the Moenkopi. As expected, we discovered fossil sites in the Chinle Formation, but it seems that fossils are not as common here as in some other regions. The Moenkopi Formation, however, turned out to be loaded with exceptional fossil sites. These sites did not have fossil bones but rather tracks and traces of ancient life.

The Moenkopi Formation was deposited in a nearshore coastal environment about 240 million years ago. In Utah and Arizona, the formation is well-known for preserving a diverse array of reptile tracks that predate dinosaurs. Rocks of the Torrey Member of the Moenkopi Formation, which is made up of primarily sandstone and siltstone deposited in a tidally influenced deltaic setting, crop out extensively in Canyonlands and are known to preserve reptile tracks as well as many other trace fossils. One of the most common types of tracks are swim tracks. These tracks were not made by animals walking on land but by animals moving in or under the water. So instead of preserving a footprint, they preserve scratches made by the animal's fingers and toes as they contacted the sediment at the bottom of a water body. The Torrey Member of the Moenkopi in Canyonlands preserves what is likely the largest concentration of swim tracks ever found in the Moenkopi Formation and the number of tracksites rivals those of any other region of Moenkopi Formation outcrop on the Colorado Plateau. Not a single Moenkopi tracksite was known from Canyonlands when we began our survey, and now we have documented over 50 track localities! Most of these sites preserve swim tracks and some have hundreds or even thousands of traces. The swim tracks are thought to have been made by reptiles closely related to the ancestors of dinosaurs and crocodiles informally called "chirotheres" for the ichnotaxon (track name) *Chirotherium.* In addition to the swim track sites, we also found several important sites that preserve tracks made by animals walking on land.

Dr. Tracy Thomson (UC Davis), a Moenkopi swim track expert, stands in front of a swim track site in Canyonlands National Park. Each of the small overhangs above him are covered in swim tracks.

An orthomosaic close-up photo of a three-toed swim track showing striations made by scales on the toes. Scale bar is 10 cm.

One interesting feature of the tracks in the Torrey Member is that most of them are preserved as natural casts. So instead of being preserved as a true footprint like you might make when walking on the beach, these are preserved by sediment filling in the track. In other words, they are "outies" instead of "innies." So, instead of the track being on the surface of a rock layer, they are on the underside. To search for these traces, you must either find a block of rock that has fallen and flipped over or look on the undersides of rock overhangs. Luckily in Canyonlands there are plenty of rocks that have flipped over and even more overhangs to look at!

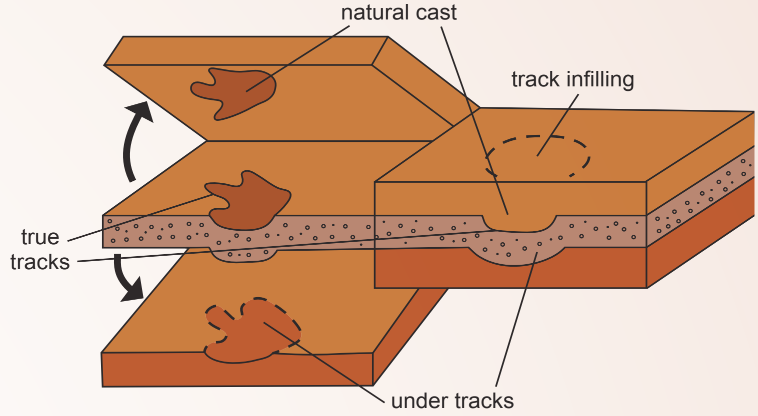
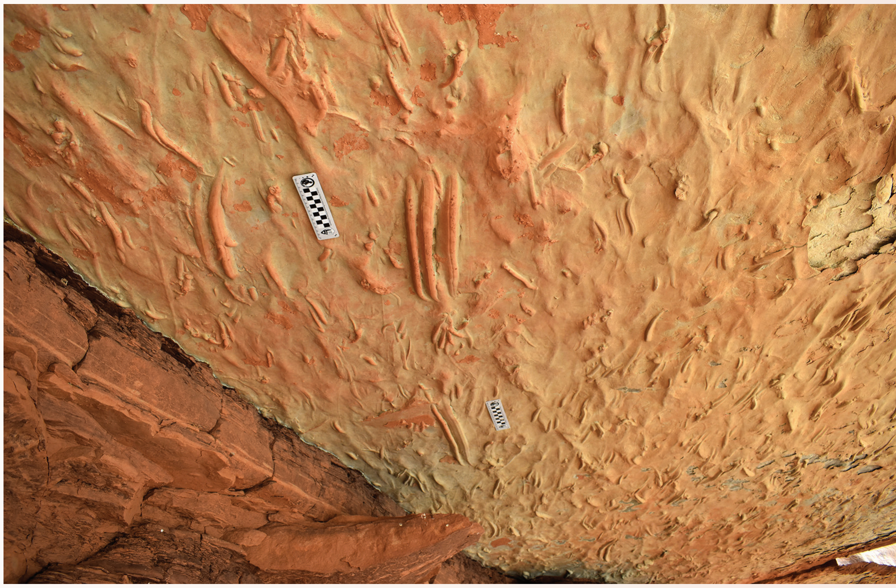


Diagram of track types showing true tracks "innies" and natural casts "outies."

Because of the vast number of swim tracks and traces found in the Torrey Member we suspect that if we had X-ray vision and could see all the tracks buried in the rock, they would show innumerable trackways that crisscrossed the ancient water-body bottoms. This begs the question of what these animals were doing when they left so many underwater tracks. Some swim tracks were made by animals that were floating in water at a depth that they could touch the bottom and push themselves along. The St. George Dinosaur Discovery Site in southern Utah preserves an array of tracks made by Early Jurassic-age dinosaurs floating on the surface of a shallow lake and using their feet to push off the bottom (*Survey Notes*, v. 34, no. 3). Because it is doubtful that the water depth during deposition of the Torrey Member was always the right depth for these animals to be floating on the surface and pushing off the bottom, we hypothesize that these animals could sink down and essentially walk along the bottom pushing off with some combination of their hands and feet. The scientific literature calls this sub-aqueous walking or punting. Because they were semi-buoyant, they did not leave complete footprints, but scratch marks made by the fingers and toes. This kind of behavior is seen today in animals such as crocodiles, hippos, and capybaras.

The many tracksites we have documented in Canyonlands will allow us to investigate these ideas in more detail and will help park managers to protect these important resources. We plan to continue to study these sites to learn more about these fascinating traces and the animals and behaviors that made them.


An overhang in Canyonlands National Park with a spectacular array of swim tracks. Scale bar is 10 cm.

CALL FOR VOLUNTEERS
Earth Science Week 2024
October 7–10 and 15–17

Do you have an interest in promoting the future of geological sciences? Come celebrate Earth Science Week with the Utah Geological Survey by volunteering to help with hands-on activities that are particularly suited for 4th and 5th grade elementary school students. Earth Science Week activities take place at the Utah Core Research Center in Salt Lake City and include panning for "gold," identifying rocks and minerals, experimenting with erosion and deposition on a stream table, examining dinosaur bones and other fossils, and learning about earthquakes. No experience is needed and anyone with an interest in geology can help. For more information, please visit our website at geology.utah.gov/teachers/earth-science-week.

Glad You Asked

Can U.S. Interstate Highway 15 Be Used as a Metaphor for Geologic Time?

SOUTH INTERSTATE UTAH 15

by Mark R.Milligan

We have been asked, *"Are all Glad You Asked* articles based on actual questions the UGS has received?" No, sometimes the articles answer questions that we, UGS geoscientists, have asked ourselves, such as "what is the best way to visualize geologic time?" Geologic time is immensely deep and sometimes warrants a really big analog to understand it.

It is very difficult to comprehend time spans beyond a few generations, much less thousands, millions, or billions of years. Yet an appreciation of deep time is vital to understanding geologic processes and evolution. One approach to getting a better grasp of the scale of geologic time is to use a time-scale metaphor. Year-long calendars are common metaphors, but distance analogs also work. Students attending the Utah Geological Survey's Earth Science Week walk along a 216-foot geologic timeline and their reactions at seeing the distance between geologic eras and periods are amazing. But bigger is better for geologic time, so here we chose to use Interstate 15 (I-15) through Utah as a metaphor for geologic time.

From the Idaho border in the north, south to the Arizona state line, I-15 traverses approximately 401 miles across Utah. From its formation to the present day, the Earth is approximately 4.6 billion years old. Using a ratio of 4,600,000,000 years/401 miles: 1 mile equates to nearly 11.5 million years, 1 foot is roughly 2,175 years, 1 inch is roughly 180 years, and the thickness of a penny is approximately 11 years. When driving the 5½ to 6½ hours it typically takes to cross the state, modern humans appear at the last 1 second of your trip!

This gives new meaning to kids asking, "Are we there yet?"

Eon	Era	Period	Years Ago
Hadean (Also known as the Precambrian)	~	~	4.6 billion
Archean (Also known as the Precambrian)	~	~	4 billion
Proterozoic (Also known as the Precambrian)	~	~	2.5 billion
Phanerozoic	Paleozoic	Cambrian	541 million
Phanerozoic	Paleozoic	Ordovician	485 million
Phanerozoic	Paleozoic	Silurian	444 million
Phanerozoic	Paleozoic	Devonian	419 million
Phanerozoic	Paleozoic	Mississippian	359 million
Phanerozoic	Paleozoic	Pennsylvanian	323 million
Phanerozoic	Paleozoic	Permian	299 million
Phanerozoic	Mesozoic	Triassic	252 million
Phanerozoic	Mesozoic	Jurassic	201 million
Phanerozoic	Mesozoic	Cretaceous	145 million
Phanerozoic	Cenozoic	Paleogene	66 million
Phanerozoic	Cenozoic	Neogene	23 million
Phanerozoic	Cenozoic	Quaternary	2.6 million

Simplified geologic time scale with age estimates.

# on Map	Distance to Arizona Border	Point of Interest	Event	Geologic Timeframe/ Calendar Year	Years Ago	
1	401 miles	Idaho Border	Formation of the Earth.		4.6	
2	348 miles		Earth's crust has cooled enough for continents to form.	Archean Eon	4.0	
3	344 miles	Ogden			3.9	
4	308 miles	Salt Lake City			3.5	billion
5	305 miles		Earliest fossil evidence of life on Earth (bacteria and blue-green algae).	Archean Eon	3.5	
6	265 miles	Provo			3.0	
7	235 miles		Oldest rocks in Utah–Schist of the Green Creek Complex.	Archean Eon	2.7	
8	200.5 miles		Halfway to the present day.	Proterozoic Eon	2.3	
9	112 miles	Beaver			1.3	
10	58 miles	Cedar City			661	
11	47 miles		Cambrian explosion—animals with hard body parts appear. Trilobites that scuttled on the seafloor are now fossils found west of Delta.	Cambrian Period	541	
12	40 miles		First land plants appear.	Ordovician Period	460	
13	22 miles		Dinosaurs started to roam Earth, now fossils found in eastern Utah.	Triassic Period	252	million
14	17 miles		Sand dunes covered most of eastern and southern Utah, now the Navajo Sandstone appears as the red cliffs of Zion National Park.	Jurassic Period	190	
15	8 miles	St. George			87	
16	6 miles		Non-avian dinosaurs go extinct.	Cretaceous Period	66	
17	1.5 miles		Uplift on Wasatch fault starts and begins creating the Wasatch Range.	Neogene Period	17	
18*	138 feet		Modern humans (*Homo sapiens*) appear.	Quaternary Period	300,000	
19	10 feet		People likely arrived in Utah.	Quaternary Period	22,000	
20	8 feet		Ancient Lake Bonneville at its deepest.	Quaternary Period	18,000	
21	2.5 inches		First Spanish expedition into what is now Utah.	1541	483	
22	1 inch		Latter-day Saint pioneers arrive in Salt Lake Valley.	1847	177	
23	2/3 inch (11 pennies on edge)		Oldest living person born.	1907	117	
24	1/8 inch (2 pennies on edge)		Utah hosted the 2002 Winter Olympics.	2002	22	
25	0 inches	Arizona Border		2024	0	

*If you are traveling at this location's posted 75 miles per hour speed limit, this is the last second of your 5½ to 6½ hour trip.

All mileage and drive time approximations are from Google Maps.

Using the 401 miles of I-15 across Utah as an analogy for the age of the Earth, the thickness of these two pennies equates to the 22 years that have passed since Utah hosted the 2002 Olympics.

SALT LAKE 2002

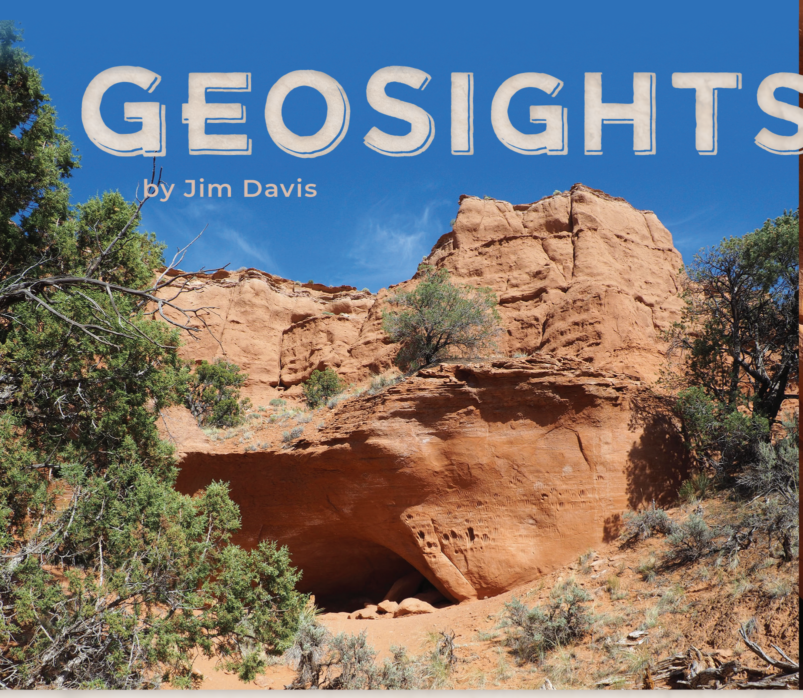
CAUTION

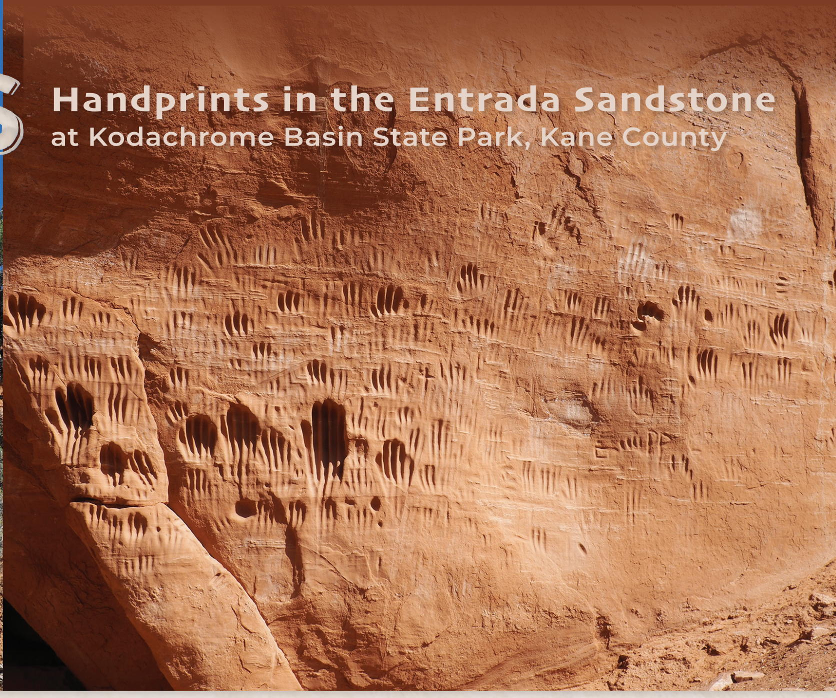
FOR THE SAFETY OF YOURSELF AND OTHER DRIVERS, **NEVER** STOP ON THE SHOULDER OF A HIGHWAY, UNLESS IT IS AN EMERGENCY AND UNAVOIDABLE!

GEOSIGHTS

Handprints in the Entrada Sandstone
at Kodachrome Basin State Park, Kane County

by Jim Davis





The Kodachrome Basin State Park petrosomatoglyphs can be seen to the right of the rock shelter from the Panorama Trail. The lowest handprint on this wall is 17 inches above the ground.

A small rock shelter off a 40-foot spur from the Panorama Trail in Kodachrome Basin State Park could go unnoticed in this remarkably scenic park. Yet with a keen eye you will discover at the shelter more than one hundred handprints scored into the sandstone, as if hands had scooped out the rock.

These handprints are a type of petroglyph called petrosomatoglyphs. Greek for “stone,” “body,” and “to carve,” they depict human or animal body parts. When you press your hand into clay or wet cement, you have made a petrosomatoglyph. Many petrosomatoglyphs around the world are tied to folklore or sanctified and are thought to be footprints of pilgriming spiritual figures or are the marks of mythical creatures.

The earliest petrosomatoglyphs were documented in 2018 and are located at 14,000 feet elevation at Quesang on the Tibetan Plateau. Radiometric dating places their creation to between 169 to 226 thousand years before present. Locals there believe the prints are linked to Buddha. The prints were made by two humans, or a closely related species, about ages seven and twelve that deliberately pressed their feet and hands, respectively, into calcareous mud at an ancient hot spring. Once the mineral-rich flow of spring water changed course, the muck dried and eventually lithified into travertine, preserving the group of prints.

Some petrosomatoglyphs, like petroglyphs, are carved, struck, or pecked into stone using a tool. However, the prints at Kodachrome Basin are distinctive in that they were created by the originator’s hands rubbing the wall of sandstone. With each swipe of the hand across the rock, sand grains are dislodged as the brittle cement holding them together fails from the stress of friction. With repetition, imprints advance deeper into the rock. The most extreme handprints at Kodachrome are etched 4 to 5 inches into the stone and are several hand lengths long.

Not every rock type is suitable for making these hand impressions. It must be weak enough for fingers to hollow out. The orange-red to orange-brown-colored Gunsight Butte Member of the Jurassic-age Entrada Sandstone is a very fine to fine-grained wind-blown (eolian) deposit of quartz sandstone that erodes into slickrock, walls, overhangs, pillars, and rock shelters such as the alcove at Kodachrome. The sand grains are barely cemented together with calcite making the sandstone so friable that a species of native bee excavates nests directly into the rock.

A three finger petrosomatoglyph from a child is 28 inches above the ground—one of the lowest to the right of the rock shelter. The print was probably even lower to the ground at the time of creation due to subsequent trail erosion, particularly since 1962 after the founding of the state park. Small adult male fingers for scale.

Anthophora pueblo *is a native bee that ranges from Mesa Verde, Colorado, through southern Utah, to Death Valley, California. They were first described by Utah State University researchers in 2016. The bees have tunneled hundreds of holes into the Entrada Sandstone on a boulder along the Panorama Trail.*

The quantity of handprints at Kodachrome is extraordinary. Although similar petrosomatoglyphs exist in the Intermountain West and American Southwest, the nearest groupings of hands in stone are found 335 miles to the northeast at White Mountain, north of Rock Springs, Wyoming, where an assemblage of handprints is in a water-laid (fluvial) quartz sandstone of the Early Eocene-age Wasatch Formation. A south-facing cliff of the outcrop is peppered with cavities and hollows and several rock shelters are at the ground level. The petrosomatoglyphs are on a boulder, sometimes referred to as the "birthing rock," a few feet from the base of a cliff that has extensive petroglyphs from different time periods.

In 2009, Kodachrome-type petrosomatoglyph groupings were also documented at Meseta Tutacachi, Oruro Department, Bolivia. There, an estimated 187 handprints are on seven panels on walls of a plateau. The prints are in the Miocene-age Crucero Formation—a light- to dark-brown water-laid (fluvial and lacustrine) sandstone with volcanic influences and clay lenses. Although the time required to create a handprint in the Gunsight Butte Member is unknown, researchers found that Meseta Tutacachi prints took approximately 3 to 5 minutes to make.

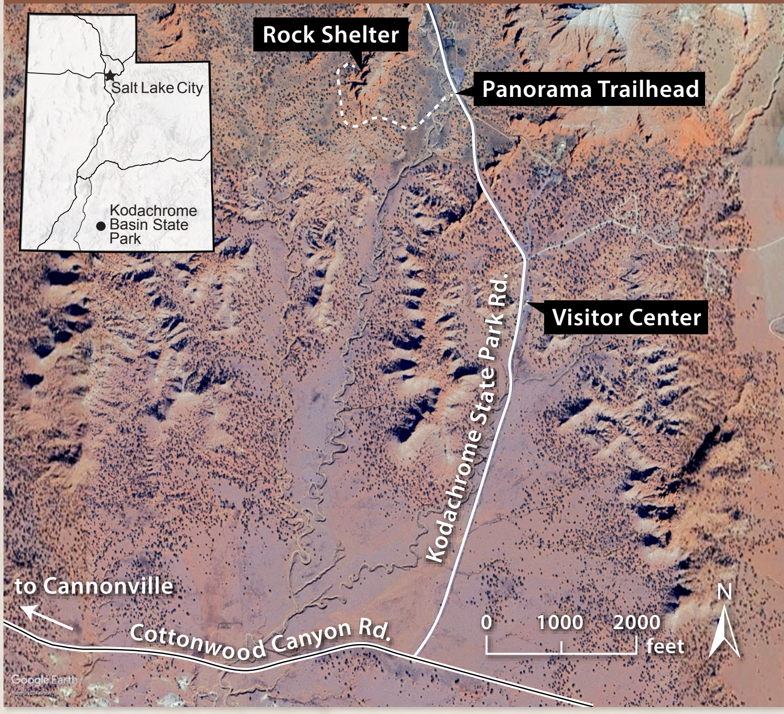
The process of forming the Kodachrome petrosomatoglyphs might not have been completed at one point in time. They could have evolved, perhaps spanning generations. At Kodachrome, most of the finger grooves are smooth whereas the surrounding sandstone, such as that above the handprints, is highly spalled and flaking off the surface. This weathering is the result of subflorescence, where water percolates through the sandstone and mineral salts crystalize within the rock as the water dries, prying thin surface layers of sandstone apart. Spalling is also enhanced by temperature, freeze-thaw, and wetting-drying cycles.

Some handprints at Kodachrome are not smooth and some are barely evident, nearly blending in with the adjacent unworked sandstone. The advanced weathering of these handprints indicates an older age for the surface of the stone. Though the smooth prints could have old origins, park visitors appear to be actively scouring the surface of the sandstone. When one encounters the hands, there is a natural impulse to touch and mirror the method of the original facilitator*. Accordingly, their subsequent deepening is akin to the pervasive human phenomena of "statue rubbing," where solid stone or bronze statues are visibly worn down due to ritualistic rubbing through the centuries or millennia.

The most conspicuous handprint at White Mountain Petroglyphs, Sweetwater County, Wyoming, is in sandstone of the Eocene-age Wasatch Formation.

HOW TO GET THERE

Drive north from the Kodachrome Basin State Park visitor's center to the Panorama trailhead. From there hike 1,900 feet to a fork in the trail. Take the right fork and go another 1,250 feet. The rock shelter will be visible at the beginning of a bend in the trail.



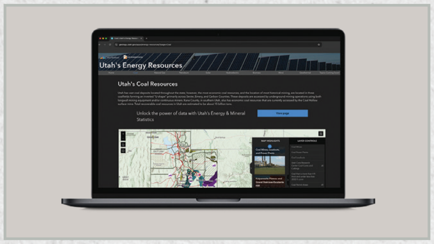
A handprint at Kodachrome Basin State Park displays extensive weathering.

*Please view them with thoughtfulness and respect. The Kodachrome petrosomatoglyphs are a place of significance to local tribal communities, including the Southern Paiute. These petroglyphs are a scarce and valuable part of American heritage. All petroglyphs are protected by State and Federal laws.

SURVEY NEWS

AWARDS

The Utah Geological Survey's prestigious **Crawford Award** was presented to **Janae Wallace**, **Trevor H. Schlossnagle**, **Kathryn Ladig**, **Paul C. Inkenbrandt**, **Hugh Hurlow**, and **Christian Hardwick** in recognition of their research on groundwater conditions near Bryce Canyon National Park, culminating in the outstanding publication: *Characterization of Groundwater in Johns and Emery Valleys, Garfield and Kane County, Utah, with Emphasis on the Groundwater Budget and Groundwater–Surface-water Interaction*. This research leverages hydrogeology, hydrogeochemistry, geophysics, soil-water balance modeling, and water quality analyses to characterize the water resources of an environmentally sensitive area adjacent to Bryce Canyon National Park. Results quantify the groundwater and surface water resources, water quality, and surface water–groundwater interactions of the area, providing data essential for science-based water-resource management decisions. Significantly, the project results demonstrate the limited storage capacity of the principal valley-fill aquifer and the close temporal and spatial connections among climate, streams, and groundwater.



The Utah Geological Survey and the Office of Energy Development were honored to receive the **Best Use of GIS award** for Utah's Energy Resources Web Experience at the 2024 Utah Digital Government Summit. This online resource provides an in-depth exploration of Utah's diverse and abundant energy portfolio, offering detailed descriptions, maps, statistics, photographs and more for each unique energy resource within the state. Congratualations to **Mackenzie Cope**, **Jackie DeWolfe**, and **Claire Decker** for their excellent work on this project.

RETIREMENTS

Mike Hylland retired in July after a 35-year career in geology, including 30 years with the UGS. Between earning degrees in geology (B.S., Western Washington University and M.S., Oregon State University) and starting with the UGS in 1994, Mike worked as an engineering geologist for the U.S. Forest Service and GeoEngineers. Mike served in a variety of roles at the UGS, including geologist with the Geologic Hazards and Geologic Mapping Programs, manager of the Geologic Information & Outreach Program, UGS Technical Reviewer, and Deputy Director. Mike's research focused on Quaternary geology and geologic hazards, specifically landslides, liquefaction, and paleoseismology. He authored or co-authored 80 publications including UGS reports and maps, scientific journal papers, field guides, and newsletter articles, as well as 40 conference/meeting abstracts. In addition to his work at the UGS, Mike also taught geology part-time at Salt Lake Community College and the University of Utah Lifelong Learning program. In retirement, Mike looks forward to indulging his passions for travel, outdoor recreation, music, and writing.

Lori Steadman retired in June after 33 years of service. She began her career in 1991 as a cartographer in the UGS Editorial Section when most of our maps were produced by hand. She successfully transitioned to the digital age by learning many generations of mapping software. She later became a GIS analyst and assisted in creating many digital maps and figures for the UGS. Lori has been a great asset to the Survey, and her talent and knowledge will be greatly missed. We wish her well in her retirement.

Congratulations to **Basia Matyjasik** who retired in August after 26 years of service. She joined the UGS Geologic Mapping Program in 1998 and completed GIS work on dozens of intermediate- and large-scale geologic maps covering a large part of the state. Basia received an M.S. degree in geology from the University of Warsaw, Poland, and is a licensed Professional Geologist in the state of Utah. We will miss the dedication and passion that Basia put into every project she worked on and wish her the best in her retirement.

IN MEMORIAM

Former UGS employee Ronald Neeley passed away on May 26, 2024, at his home in Heber City, Utah. Ronald worked in the Utah Core Research Center from 1985 to 1998. We express our sincere condolences to Ronalds family.

STAFF UPDATES

Darlene Batatian has accepted the position of Deputy Director replacing Mike Hylland, who retired in July. Darlene is a Utah-licensed Professional Geologist with over 35 years of professional experience in both the private and public sector. Darlene has a B.A. from the University of California in Santa Cruz where she spent summers drilling paleomagnetic cores and mapping on remote Alaskan islands; and an M.S. in geology from Idaho State University, where her thesis focused on mapping stratigraphy and structure in the upper plate of the Pioneer Mountains Core Complex. Darlene joins the UGS with a wealth of geologic experience, including field mapping and report publication, geologic hazards management, environmental and groundwater investigations, mineral resources, land development, and public policy. Her work as the Salt Lake County Geologist, where she spearheaded legislation for professional licensure of geologists in Utah and implemented new geologic hazards ordinances (including co-authoring statewide guidelines published by the UGS), have earned her widespread respect across the spectrum of Utah's geologic professionals. Darlene has always been impressed with the technical excellence of the UGS and is delighted to be supporting the UGS in a leadership role.

The Geologic Information & Outreach Program welcomes **Michelle Ricketts** as the new manager of the Natural Resources Map & Bookstore. Michelle has a background in sales and marketing with strong customer service experience and a love for the outdoors. She replaces **Torri Duncan** who accepted the position as Geological Technician with the Geologic Hazards Program. **Rachel Adam** joined the Geologic Hazards Program as a geologist focusing on active fault mapping. Rachel earned her undergraduate and graduate degrees in geological sciences from Arizona State University. **Jim McVey** joined the Energy & Minerals Program as a project geologist working on metallic minerals projects. Jim earned his B.S. degree from the University of Utah and has worked for several years as an exploration geologist in Utah's mining districts. A warm welcome to Michelle, Rachel, and Jim and congratulations to Torri.

2024 AASG ANNUAL MEETING

In June, the UGS proudly hosted geologists from around the country at the 116th annual meeting of the Association of American State Geologists (AASG). This meeting brings together state geological survey leaders to share knowledge and collaborate. The 2024 meeting was held in Park City which is known for its stunning scenery, rich mining history, and spectacular travel opportunities through a vast array of geologic landscapes. Scenic and informative field trips were held in conjunction with the meeting to highlight the unique geology and history of the area. Photo by Bill Keach: Field trip participants near the Snowbird ski resort in Little Cottonwood Canyon.

NEW PUBLICATIONS

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

Airborne Geophysical Survey of the Oquirrh Mountains, Utah, by Stephanie E. Mills, William Schermerhorn, Donald Hinks, and Geoffrey Phelps, 2 p., 2 appendices, 1 plate, **DS-1**, https://doi.org/10.34191/DS-1.

Groundwater-Level Trends in Snake Valley and Adjacent Basins, Utah and Nevada, by Hugh A. Hurlow, Rebecca Molinari, Paul C. Inkenbrandt, and J. Lucy Jordan, 33 p., 1 appendix, **RI-285**, https://doi.org/10.34191/RI-285.

Fault Trace Mapping and Surface-Fault-Rupture Special Study Zone Delineation of the East and West Cache Fault Zones and Other Regional Faults, Utah, by Adam I. Hiscock, Emily J. Kleber, Susanne U. Jänecke, Greg N. McDonald, Robert Q. Oaks Jr., and Tammy Rittenour, 27 p., 1 appendix, **RI-286**, https://doi.org/10.34191/RI-286.

Geologic Map of the Cedar City 7.5-Minute Quadrangle, Iron County, Utah, by Tyler R. Knudsen, 18 p., 2 plates, scale 1:24,000, **M-302DM**, https://doi.org/10.34191/M-302DM.

Interim Geologic Map of the Midvale Quadrangle, Salt Lake County, Utah, by Adam McKean, 12 p., 2 plates, scale 1:24,000, **OFR-761**, https://doi.org/10.34191/OFR-761.

Interim Geologic Map of the Vernal NE Quadrangle, Uintah County, Utah, by Matthew C. Morriss, 10 p., 2 plates, scale 1:24,000, **OFR-762**, https://doi.org/10.34191/OFR-762.

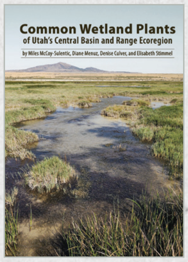
Interim Geologic Map of the Kamas Quadrangle, Summit and Wasatch Counties, Utah, by Lauren J. Reeher, 16 p., 2 plates, scale 1:24,000, **OFR-763**, https://doi.org/10.34191/OFR-763.

Interim Geologic Map of the Parowan Quadrangle, Iron County, Utah, by Tyler R. Knudsen, 21 p., 2 plates, scale 1:24,000, **OFR-764**, https://doi.org/10.34191/OFR-764.

Interim Geologic Map of the Plain City Southwest 7.5' Quadrangle, Weber and Box Elder Counties, Utah, by Emily J. Kleber, Greg M. McDonald, W. Adolph Yonkee, and Elizabegth A. Balgord, 8 p., 2 plates, scale 1:24,000, **OFR-765**, https://doi.org/10.34191/OFR-765.

Interim Geologic Map of the Ogden Bay 7.5' Quadrangle, Weber and Davis Counties, Utah, by Emily J. Kleber, Greg M. McDonald, W. Adolph Yonkee, and Elizabegth A. Balgord, 8 p., 2 plates, scale 1:24,000, **OFR-766**, https://doi.org/10.34191/OFR-766.

Interim Geologic Map of the Fort Douglas Quadrangle, Salt Lake, Davis, and Morgan Counties, Utah, by Zachary W. Anderson, Adam P. McKean, and W. Adolph Yonkee, 32 p., 2 plates, scale 1:24,000, **OFR-767**, https://doi.org/10.34191/OFR-767.



Common Wetland Plants of Utah's Central Basin and Range Ecoregion, by Miles McCoy-Sulentic, Diane Menuz, Denise Culver, and Elisabeth Stimmel, 220 p., **MP-178**, https://doi.org/10.34191/MP-178.

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