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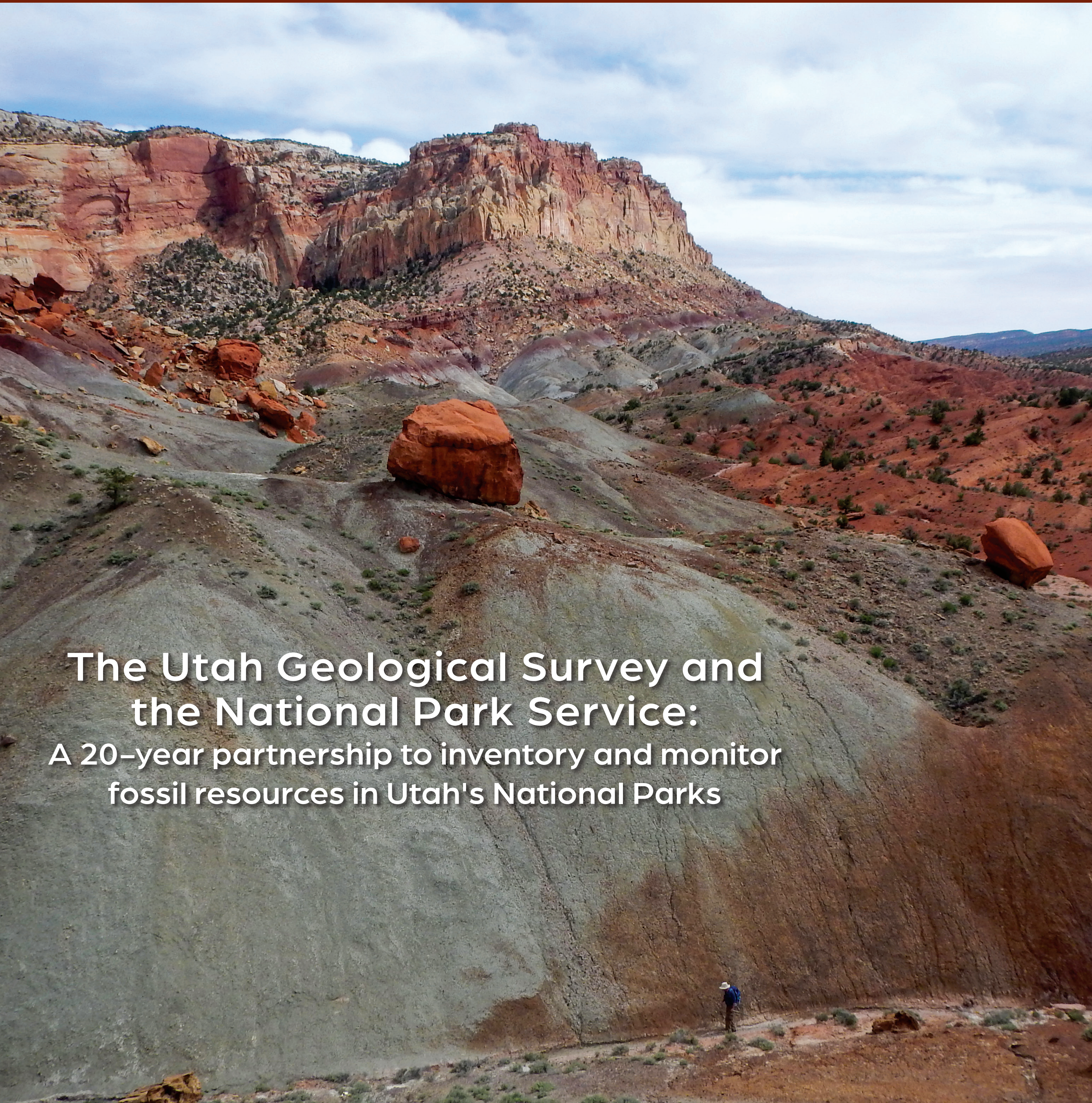

The Utah Geological Survey and the National Park Service:

A 20-year partnership to inventory and monitor fossil resources in Utah's National Parks

Contents

Design | *John Good*
Cover | A UGS paleontologist surveys for fossils in the Chinle Formation of Capitol Reef National Park. Photo by Don DeBlieux.

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DIRECTOR'S PERSPECTIVE

by Bill Keach

Isn't Geology Fun?!

About 16 years ago I decided to take a leave of absence from my job in Houston. My wife, a native of Utah, felt the need to return home to be closer to family and aging parents. She had followed me for over twenty years from Utah to New York to Houston to Denver and back to Houston. It felt like the right thing to do at the time. Before leaving Houston, my then boss approached me with an idea. He asked, "Can you create a field course to help our mid-career folks to remember why they got into geology in the first place?" To put it into perspective, we worked for a company that delivered high-tech solutions to the petroleum industry, mostly on the exploration side of the business. Though armed with degrees in geology, geophysics, and petroleum engineering, most of our staff spent their days in front of a computer screen. We were a long way from what drew us to the sciences: walking and talking about the rocks!

His question was a catalyst that led to a week-long course examining the geology of the Colorado Plateau in Utah. One of the first things I did was to reach out to a couple of professors from a local university, Dr. Tom Morris and Dr. Scott Ritter. Collectively and individually they had led an untold number of students on hundreds of field trips across the state. I pulled out Lehi Hintze's *Geologic Map of Utah* and posed to them: "Where are your favorite places to take students? Where would you go?" We marked locations on the map, each tied to a unique aspect of Utah geology, and then started to connect the dots with a route. Scott and I then jumped into a car and traversed the entire route in two days; I drove and Scott created a road log of every geologic feature, every stop to explore more, and every rest stop.

No Colorado Plateau field course is complete without first stopping at the Utah Core Research Center at the UGS offices in Salt Lake City to examine cores taken from deep below the surface of the Colorado Plateau. From there we headed south to examine the Wasatch fault, then turned east and traveled through Spanish Fork Canyon. First to see evidence of the Sevier orogeny (thrusting) and then to examine coal in the Book Cliffs near Price. Before heading south through the San Rafael Swell, we spent some time looking at wells that produce coal bed methane gas on the west side of the Swell, where approximately 500 wells produce this gas from coal seams too thin to mine.

The San Rafael Swell is a mecca for enthusiasts of the outdoors, be it rock hounding, ATV riding, or just camping out. For geologists the Swell represents a large dome-like structure formed during the Laramide orogeny about 60 million years ago. Buckhorn Draw is a canyon that cuts deep into the anticline, exposing rock formations from a time when Utah was covered by shallow seas and sand dunes. Our trip included a stop at the Buckhorn Panel, which has petroglyphs and pictographs exquisitely displayed on the Wingate Sandstone. From there we headed east and south to Arches National Park for a day hike amongst the Entrada Sandstone.

The next day, perhaps the highlight of the trip, was a San Juan River raft trip from Bluff to Mexican Hat through the heart of the Raplee anticline. Here, these now computer nerdy geologists were able to see hydrocarbon source rocks and reservoir rocks that they spent so much time modeling on their computers. Of course we did more, but space does not allow the rest of the story.

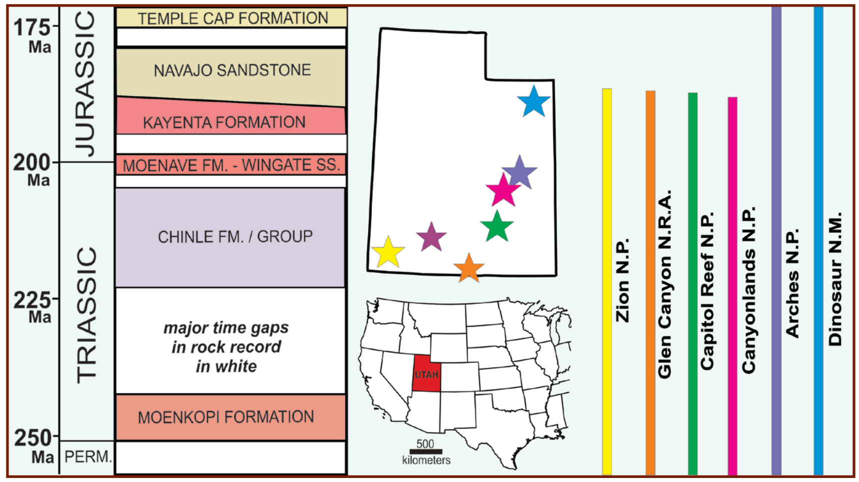
What joy it was for me to see the allure of geology returning to faces. We ran that trip twice a year for almost ten years. Each time geologists young and old were reinspired by Utah geology. Isn't geology fun?!

The Utah Geological Survey and the National Park Service:

A 20-year partnership to inventory and monitor fossil resources in Utah's National Parks

by Donald DeBlieux, James Kirkland, and Vincent Santucci

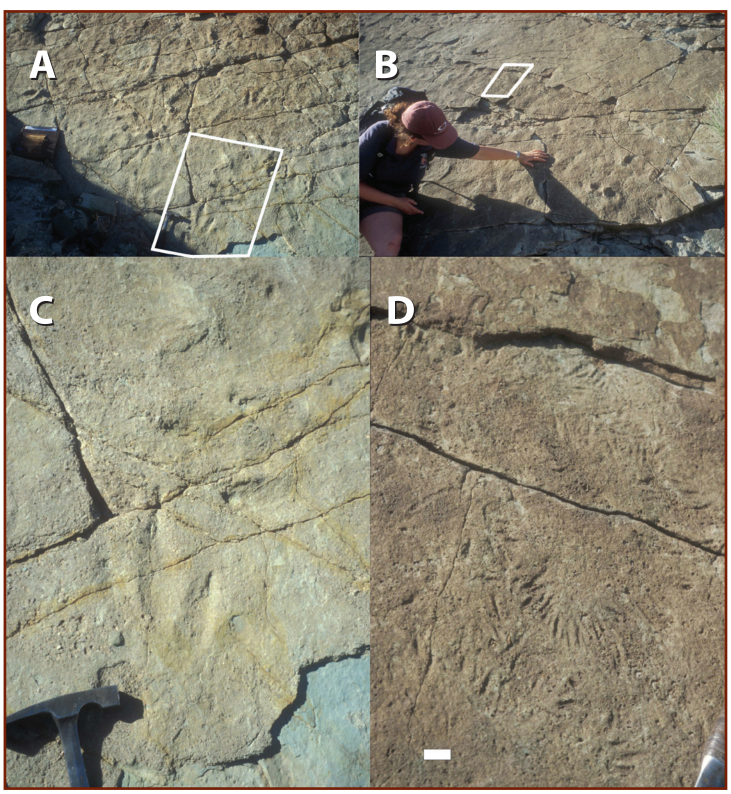
During the past 20 years, the Paleontology Section of the Utah Geological Survey (UGS) has worked with the National Park Service (NPS) to inventory and monitor paleontological resources in many of the national parks in Utah. The NPS has been at the forefront of paleontological resource management on public lands and the UGS has been a valuable partner in this effort. This partnership has been remarkably successful and serves as a great example of what can be accomplished when government agencies work together towards a common goal that benefits shared public resources. Our work has helped park personnel more effectively manage the paleontological resources in their parks, enhance visitor experiences, and provide geological and paleontological information to reconstruct past life and ecosystems. Our partnership began in 2002 with a fossil inventory of Zion National Park. After the success of this project, we continued to work in additional NPS units including Arches National Park, Glen Canyon National Recreation Area, Capitol Reef National Park, and Canyonlands National Park. Because of the size and scope of paleontological resources in these parks, many of these inventories were done in several phases.



The Utah Mesozoic rock units discussed in the text with a key (vertical color bars) to the rocks of the national parks of Utah that we surveyed.

Utah has one of the best fossil records of any place on Earth and our national parks contain amazing fossil resources. Fossils found in Utah's national parks range in age from the Paleozoic Era through the Holocene Epoch (541 million years ago [Ma] to recent). Many of the parks showcase the spectacular Mesozoic-age (252 to 66 Ma) red-rock scenery of the Colorado Plateau, and most vertebrate fossils are found in these rocks. Rocks of Triassic (252 to 201 Ma) and Jurassic (201 to 145 Ma) age are particularly well represented. The Triassic Period and the Triassic-Jurassic transition have been the focus of considerable research because this interval is associated with a major evolutionary radiation and subsequent extinction event linked with the rise of most modern terrestrial animal groups. Because the Colorado Plateau preserves so many rocks of this age, it is a unique locale to study the strata of these time periods. One of the most fossil-rich formations on the Colorado Plateau is the Triassic-age Chinle Formation, which is exposed in many of Utah's national parks. Much of what we know about Late Triassic terrestrial ecosystems has been discovered by studying fossils found in this formation, and we have concentrated many of our surveys in that formation because of the high potential for scientifically significant fossils. We have collaborated with researchers from many different universities and our research dovetails with other research being done on these rocks. Many of the Jurassic-age rocks we have surveyed are sandstones that rarely preserve body fossils but instead preserve tracks. The surveys we have conducted have led to important discoveries that help to refine our knowledge of the geologic history of the region. Through our partnership and work with the NPS, we have found and documented hundreds of new fossil localities in Utah's national parks. The following are a few highlights from our past and ongoing work with the NPS.

Arches National Park — Along with Dinosaur National Monument, Arches is one of the few Utah parks to contain significant amounts of Late Mesozoic-age dinosaur-bearing strata. These include the world-famous Jurassic-age Morrison Formation and the Early Cretaceous-age Cedar Mountain Formation. Numerous dinosaur sites have been documented at Arches, but one highlight of our work in the park was the discovery of a tracksite in the Cedar Mountain Formation that preserves several kinds



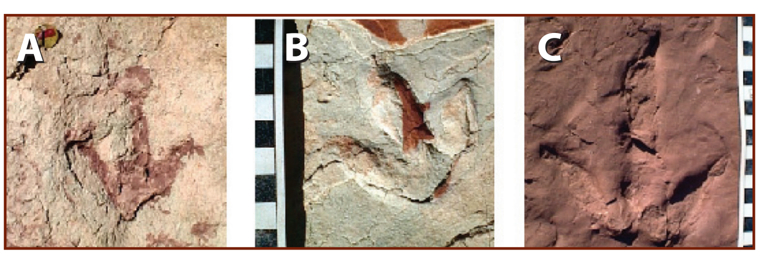
Dinosaur tracks and enigmatic feeding traces from the Cedar Mountain Formation in Arches National Park. ***A)*** *Overview of theropod track area. White box indicates area of detail in C.* ***B)*** *Overview of a portion of the feeding trace area. White box indicates area of detail in D.* ***C)*** *Detail of lower theropod track.* ***D)*** *Detail of some of the best examples of feeding traces. White scale bar = 1 cm.*

of dinosaur footprints, including the two-toed track of a sickle-clawed meat-eating dinosaur. We have also found interesting trace fossils at this site that we think are feeding traces made by an animal such as a bird or pterosaur that was floating in shallow water and probing the bottom with its beak. Many other tracksites have been found in Lower Mesozoic strata at Arches including in the Moenkopi, Chinle, Wingate, and Kayenta Formations and the Navajo Sandstone. One noteworthy find in Arches was a portion of a dinosaur skeleton in the Kayenta Formation, the first dinosaur body fossil found in the Kayenta of Utah. The fossil is currently under study and is thought to belong to a theropod dinosaur similar to *Dilophosaurus*.

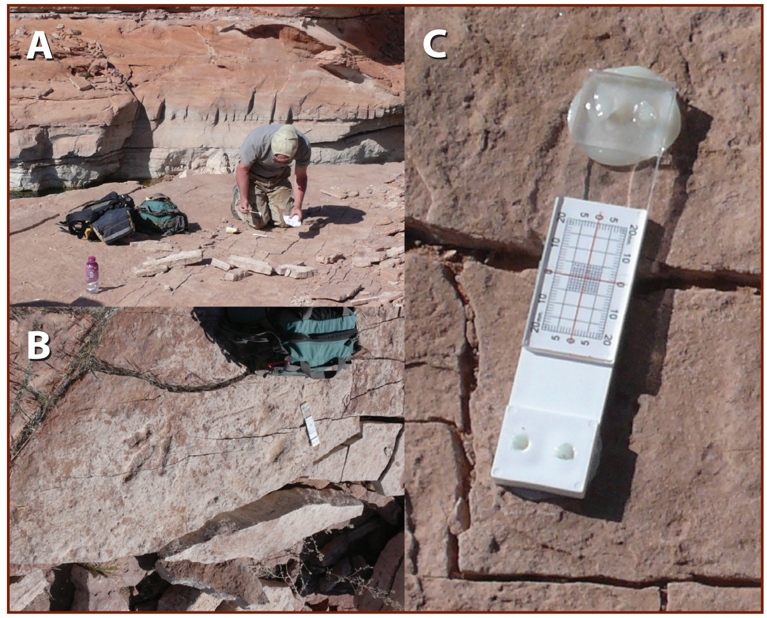
Zion National Park — In terms of parks to work in, it doesn't get much more spectacular than Zion. The western part of the main park area near Mount Kinesava contains excellent outcrops of Triassic-age Chinle Formation. This formation has the greatest potential for body fossils in the park, and we have documented many sites having fossils of phytosaurs (crocodile-like reptiles), aetosaurs (armored plant-eating reptiles), metoposaurs (large amphibians), and fish. This area has many petrified logs along a trail formerly known as the Petrified Forest Trail.

Other collaborative work in Zion includes measuring a section and sampling for isotope geochemistry in Blacks Canyon with Celina Suarez (University of Arkansas) to identify the Triassic-Jurassic boundary in the Moenave Formation and correlate it with global climate events. In Zion Canyon, we located and documented dozens of dinosaur tracksites primarily in the Early Jurassic-age Moenave and Kayenta Formations. At the top of the Springdale Sandstone Member of the Kayenta Formation we found that tracks are very common, and that this interval constitutes a megatrack surface that likely contains thousands of dinosaur tracks. We provided the park with PFYC (Potential Fossil Yield Classification) maps based on recently completed UGS 7.5-minute-quadrangle geologic maps to help park management identify areas of high paleontological sensitivity.

Glen Canyon National Recreation Area — Our work in Glen Canyon National Recreation Area was done primarily along the shores of Lake Powell using boats for access. Once again, Triassic- and Jurassic-age rocks form the bulk of the strata found at Glen Canyon. We found many wood and bone sites in the Chinle Formation and many tracksites in the Kayenta and other formations. During our work we found and documented 50 new fossil localities. The importance of documenting these sites becomes ever more critical as lake levels drop and these sites are threatened by erosion and vandalism. We also established several monitoring sites to quantify the amount of movement of fractures in tracksite surfaces to get an idea of erosion rates.



Dinosaur tracks from the Moenave and Kayenta Formations of Zion National Park found during paleontological surveys conducted by the UGS. ***A)*** Grallator *track from the Moenave Formation. Keys for scale.* ***B)*** Grallator *track from the Moenave Formation. Scale bar in centimeters.* ***C)*** Eubrontes *track from the Navajo Sandstone. Scale bar in centimeters.*

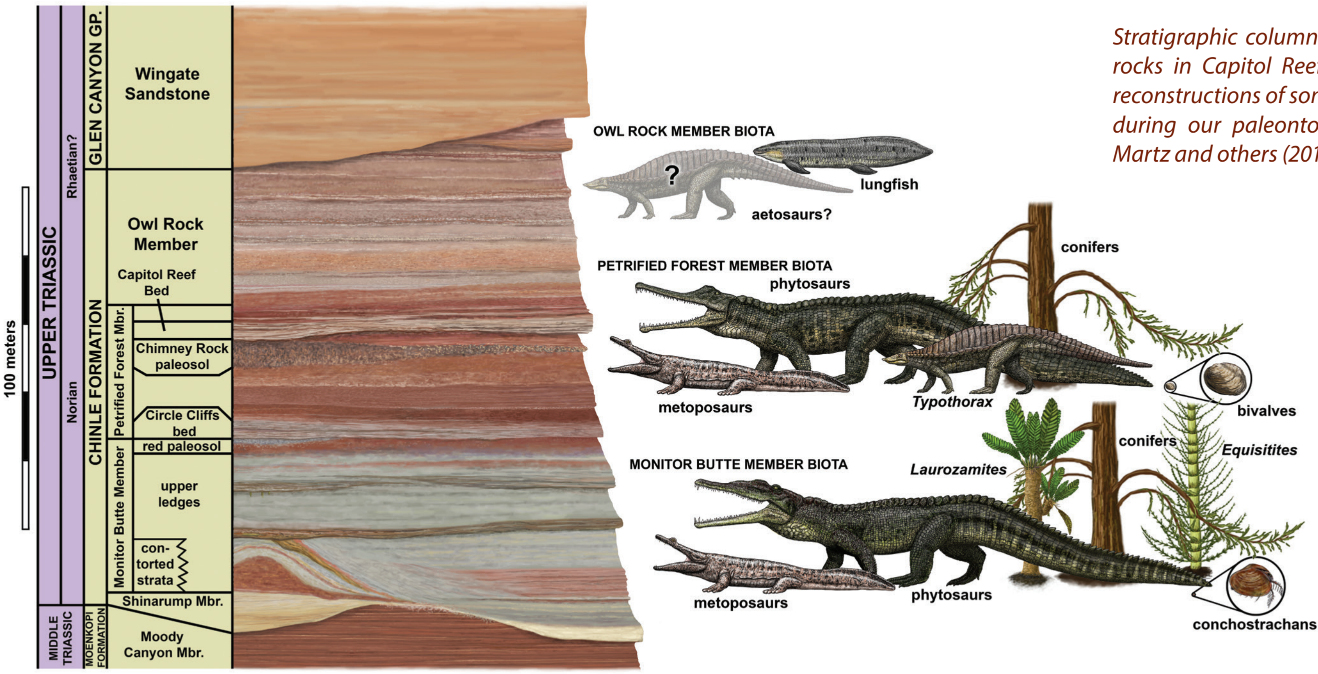


Installing crack monitors at Glen Canyon National Recreation Area. ***A)*** *Installing a crack monitor by dinosaur tracks.* ***B)*** *Crack monitor by* Anchisauripus *tracks.* ***C)*** *Close-up of an installed crack monitor showing initial setting of 0,0. The rate at which these cracks enlarge can be assessed by periodic monitoring.*

Capitol Reef National Park — The spectacular outcrops of the Monitor Butte Member and the Capitol Reef Bed of the Chinle Formation at Capitol Reef National Park are some of the most fossiliferous in Utah. We documented dozens of new localities and enlisted the help of Jeff Martz (University of Houston, Downtown) to measure several stratigraphic sections that contain these fossils. This stratigraphic context allows us to chart the evolution of the plants and animals and changes in climate through time. The rocks at Capitol Reef tell a fascinating story of climate change driven by plate tectonics as the supercontinent Pangea drifted northward from the humid tropical belt into the arid subtropical belt during the Late Triassic. Also, during our survey we rediscovered a site that was first documented during the 1980s that preserves a standing "grove" of the giant horsetail *Equisetites*. With the help of Jack Wood of the NPS, we collected three-dimensional (3D) photogrammetric data and generated a 3D model of the site. Comparing this to photos of the site when originally found allows us to assess the vulnerability of the site to erosion.

During work in the northern region of the park, we recognized that a large area of rocks from the Cretaceous-age Cedar Mountain Formation are present in an area that had been previously mapped as Jurassic-age Morrison Formation. We returned to the park to document these rocks and with the help of UGS mapping geologist Grant Willis, we are in the process of updating the geologic map of the area. This illustrates how these park surveys can yield unexpected benefits to our knowledge of geology.

Canyonlands National Park — Our most recent work at Canyonlands National Park began in the fall of 2020 with a survey of the Island in the Sky District. Prior to our survey, the Utah Paleontological Database, managed by the UGS, had two paleontological localities in the Island in the Sky District. We found and documented over 70 new sites during our two 10-day field expeditions. Once again, the Chinle Formation was the primary focus of our explorations. We found several bone-bearing sites with fossils of phytosaurs, metoposaurs, and fish, and identified several stratigraphic levels that commonly preserve petrified wood and logs.



Stratigraphic column of Chinle Formation rocks in Capitol Reef National Park with reconstructions of some of the fossils found during our paleontological survey. From Martz and others (2015).

Although we concentrated our efforts on the Chinle, Canyonlands has a large amount of Early Triassic Moenkopi Formation, and one of the most successful parts of our work was the discovery and documentation of many scientifically significant tracksites, most commonly "swim tracks," in the Torrey Member. These tracks are made by buoyant and semi-buoyant reptiles padding along the bottom while floating in water. Moenkopi swim track expert Tracy Thomson (University of California, Davis) helped us during the project and remarked that these are some of the best-preserved swim track sites on the Colorado Plateau. Our work in the park was so successful that we were funded for a second phase of the project in 2022 and a third phase in 2023.

Our collaboration with the NPS over the years has resulted in many important scientific discoveries and documented important fossil resources. These fossils are a significant feature of Utah's national parks and are a draw for tourists who help to support rural economies in Utah. We plan to continue our partnership so these resources can be managed for the benefit of the American people and all visitors to the spectacular national parks of Utah.

Tracy Thomson points to chirotheriid swim tracks in the Torrey Member of the Moenkopi Formation in the Island in the Sky District of Canyonlands National Park.

ABOUT THE AUTHORS

Don DeBlieux has been with the UGS for 21 years and serves as the Utah Assistant State Paleontologist. Don oversees the UGS field paleontology program and fossil preparation lab. He has authored or co-authored over 20 professional papers and helped discover and name six new dinosaurs and two new fossil mammals from Utah. Over the last 30 years, he has helped to lead dozens of field expeditions searching for vertebrate fossil in the western U.S., Egypt, Madagascar, Namibia, and Tanzania.

Dr. James Kirkland is the Utah State Paleontologist with the UGS. He issues permits for paleontological research on Utah state lands, keeps tabs on paleontological research and issues across the state, and promotes Utah's paleontological resources for the public good. An expert on the Mesozoic Era, Jim has spent nearly 50 years excavating fossils across the southwestern U.S. and Mexico, authoring and co-authoring more than 90 professional papers which include the naming of 23 new dinosaurs.

Vincent Santucci is the Senior Paleontologist and Paleontology Program Coordinator for the National Park Service (NPS). Since 1985, Vince has held assignments at Badlands, Petrified Forest, Grand Canyon, Yellowstone, Fossil Butte, Tule Springs Fossil Beds and other national parks, as well as supported geology and paleontology projects in over 280 national park areas. Vince has been a leader for paleontological resource management, protection, education, stewardship, and science in the U.S. and has published more than 275 articles and reports related to NPS paleontology.

Great Salt Lake's Gunnison and Cub Islands Come into Focus

by Donald L. Clark (UGS Geologic Mapping Program) and Bonnie K. Baxter (Great Salt Lake Institute at Westminster College)

Location, Setting, and Mapping

The islands of Great Salt Lake (see *Survey Notes*, 2010, v. 42, no. 2) provide glimpses into the geology as well as the scenic and biologic diversity of the lake's basin. Gunnison Island and its smaller neighbor Cub Island are located near the west shore of Great Salt Lake in the part of the lake's north arm called Gunnison Bay. The north arm is currently cut off from freshwater inputs by a railroad causeway and is thus the saltiest part of the lake, almost ten times the salt content of the world's oceans. The islands are a surreal landscape of low rocky ridges with sweeping sandy and gravelly beaches currently flanked to the east and north by an expanse of pink waters, blowing white foam, and miles of mudflats on the west dotted with remnant carbonate mounds (microbialites).

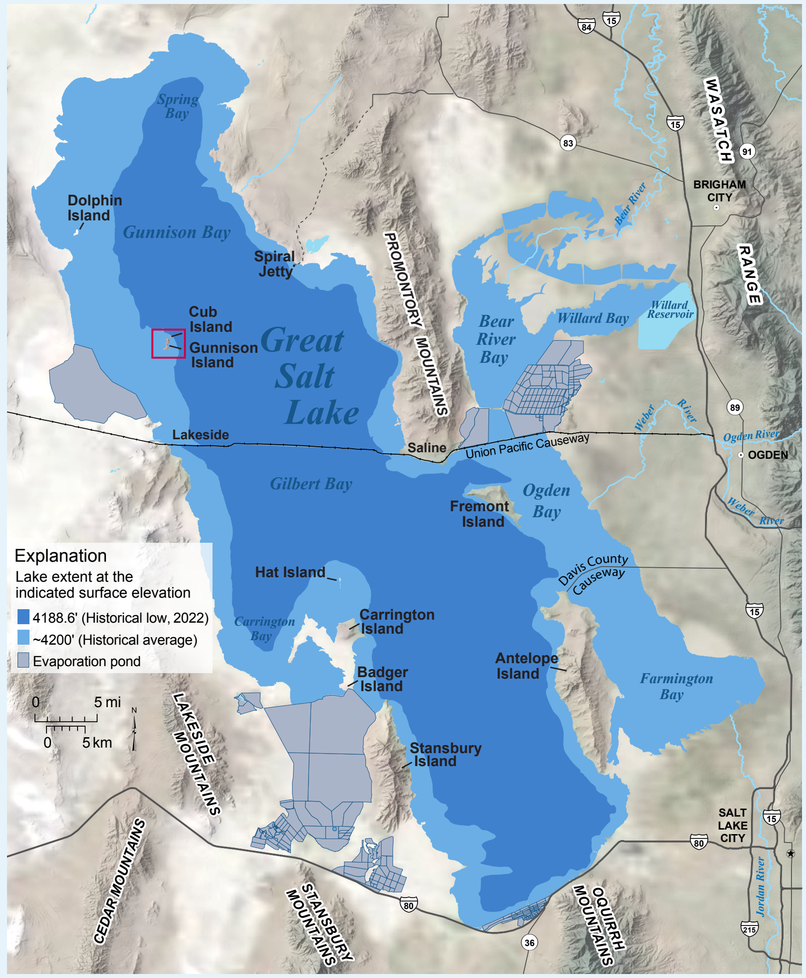
Both islands (roughly one mile long and one-half mile wide) are a designated State Wildlife Management Area that is strictly off-limits to public access. However, during 2020–21 the Utah Geological Survey (UGS) had the rare opportunity to accompany scientists with the Utah Division of Wildlife Resources (UDWR) and Great Salt Lake Institute at Westminster College (GSLI) to visit Gunnison and Cub Islands. We were able to conduct geologic mapping on the islands as part of our continued effort to map the geology of the entire state at an intermediate scale. To prevent disturbance to the resident pelicans of the island, we completed our fieldwork after the birds had migrated and before their return.

Biological and Historical Significance

When surveying the lake in the early 1850s, Captain Howard Stansbury, of the U.S. Army Corps of Topographical Engineers, and his crew visited Gunnison Island and recorded notes and drawings regarding the pelicans who were breeding there. Today we know that this rookery is one of the largest breeding colonies of American white pelicans in North America. GSLI and UDWR have monitored the pelicans using trail cameras since 2016, providing insight into the unusual behavior of fish-eating birds that nest in a location having no available on-site food.

In addition to remarkable wildlife, Gunnison Island is host to several important historical sites including Stansbury's topographic survey triangulation station, still located on the high point at the north end of the island. Foundational remnants (cemented-gravel slabs) where the artist and writer, Alfred Lambourne, spent a year (1895–96) also remain visible. Other sites of human activity include a former guano (bird excrement used for fertilizer) collection area on the east beach.

American white pelicans and California gulls at central Gunnison Island. Photo from Gunnison Island PELIcams, courtesy of Utah Division of Wildlife Resources–Great Salt Lake Ecosystem Project and Great Salt Lake Institute at Westminster College, 2019.



Overview map of Great Salt Lake and surrounding area. The map depicts Great Salt Lake at the historical average elevation of about 4200 feet (1280 m) and the new historical low of 4188 feet (1277 m). Red box shows location of Gunnison and Cub Islands; see enlarged geologic map on page 5.

Geology

The geology of the islands was previously known only through regional geologic mapping (W.L. Stokes in 1963 and H.H. Doelling in 1980). The 2020–21 geologic reevaluation found an ascending section of Upper Cambrian-, Ordovician- and Silurian-age dolomite and limestone bedrock that ranges from about 500 to 430 million years old. These rocks formed during part of a period of long-lived marine conditions when western Utah sat along a passive continental margin. Later, northern Utah was broken into a series of large sheets of rock that moved several miles along low-angle, east-directed thrust faults during the Sevier orogenic mountain building event, about 150 to 50 million years ago. Due to limited bedrock exposures in the vicinity, it is uncertain which thrust sheet the islands are located on. In spite of this uncertainty, the subsurface geology east of the islands was investigated most recently from 1978 to 1980 for the Rozel oil field (see *Survey Notes*, 1995, v. 27, no. 3). A large northwest-trending fault bisects Gunnison Island, cutting out a section of Ordovician strata including the Kanosh Shale. Cub Island has more exposed limestone, yet microfossils there indicate the limestone is correlative to rocks at the north end of Gunnison Island. Geophysical gravity data show that the islands lie on an uplifted bedrock block (horst) that projects northward from Strongs Knob and the northern Lakeside Mountains. This part of Utah was broken into a series of mountains/hills (horsts) and basins (grabens) over the last 20 million years. The islands' rocky core is flanked by loose and cemented gravel and oolitic sand comprising the beach deposits that formed during the rising and falling of Great Salt Lake waters over the past 13,000 years. Surrounding the islands are fields of modern microbialites (see *Survey Notes*, 2022, v. 54, no. 1), rocky structures built by photosynthesizing microorganisms that once powered the lake's ecosystem, but they are now vestiges due to the high salt content of the north arm waters. The results of this mapping are shown on the interim geologic map of the southwestern part of the Promontory Point 30′ x 60′ quadrangle (UGS Open-File Report 739).

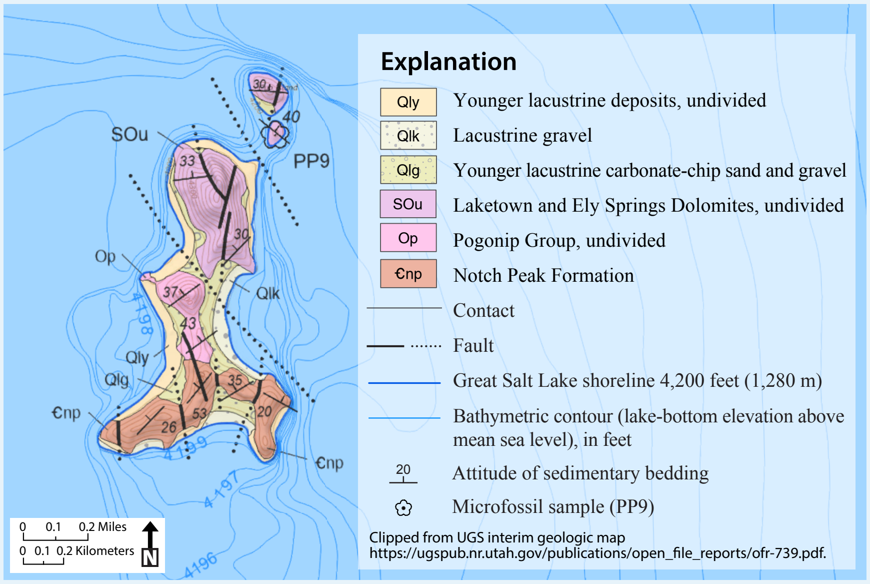
A Fluctuating Great Salt Lake

Great Salt Lake is a terminal lake at the very bottom of the watershed, like the bottom of a bathtub, that rises and falls in elevation in response to varying precipitation and evaporation. Over the past 13,000 years the lake elevation has fluctuated between about 4,250 and 4,170 feet (1,295–1,271 m) above sea level, but the timing of specific rises and falls is not well documented due to limited sediment and landform information. One substantial rise to 4,250 feet (1,295 m) about 12,000 years ago is called the Gilbert episode. Since the lake elevation has been measured starting in the mid-19th century, scientists have recorded a historical average of 4,200 feet (1,280 m). The lake recently went from a historic low level in 1963 of 4,191 feet (1,278 m) to a historic high of 4,212 feet (1,284 m) in 1986–87, but has since declined to a new historic low currently near 4,188 feet (1,277 m). The new low follows a century of water diversions for consumptive uses, coupled with the ongoing drought and changing climate.

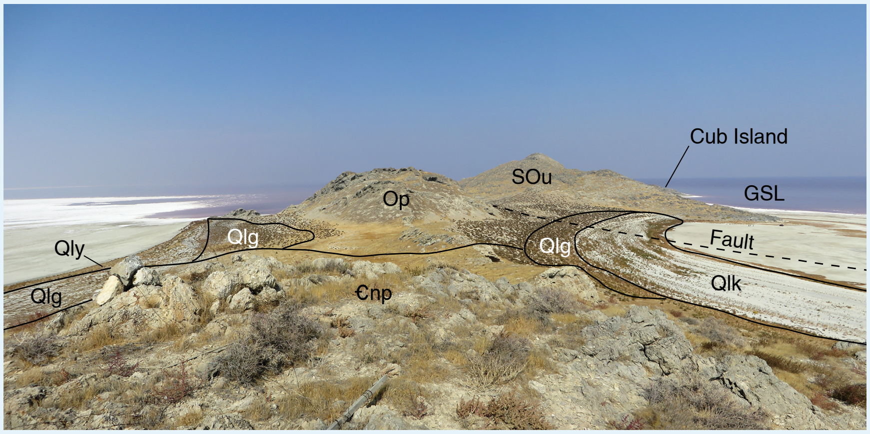
Impacts of the water-level decline on the Great Salt Lake ecosystem are being monitored in the south arm of the lake, which is less saline than the north arm and hosts a food web including brine shrimp, brine flies, and many of the ten million birds hosted at Great Salt Lake and its surrounding wetlands that eat them. This biology is absent from the saltier north arm where the rose-colored brine present near Gunnison and Cub Islands is due to microorganisms. However, lower water levels have led to the formation of landbridges to the islands, allowing predators such as coyote and fox access to the nesting pelicans, as well as exposing mudflats and playa, which could source dust storms as well as small-particle and heavy-metal pollution, impacting human health.

Future projections for Great Salt Lake remain dire with decreased inflows. In 2022, the Utah State Legislature recognized the importance of our "inland sea," and passed several bills to address the issue of getting water to the lake. They also appropriated $40 million to fund a water trust to address lake issues (Utah House Bill 410).

Our geologic mapping and collaborative work are part of the science undertaken to understand the complex composition of Great Salt Lake and its environs. This work shows that Gunnison and Cub Islands are an integral part of a fluctuating Great Salt Lake, and in turn, a multifaceted asset of the State of Utah.



An enlarged geologic map of Gunnison and Cub Islands.



View north of southern and central Gunnison Island. Geologic map unit symbols correspond to above figure. GSL is Great Salt Lake. Photo by D.L. Clark, 2020.

View to the east of remnant microbialites and foam along the east shore of Gunnison Island. The carbonate mounds have the appearance of "mega-biscuits" and are about two to three feet across. Photo by B.K. Baxter, 2021.

Views northward of Gunnison and Cub Islands. Top photograph: Islands in May 1986 (lake elevation 4,210.8 feet) surrounded by water. Bottom photograph: Islands in July 2021 (lake elevation 4,191.3 feet) with exposed mudflats. Photographs courtesy of the Utah Division of Wildlife Resources.

ENERGY NEWS

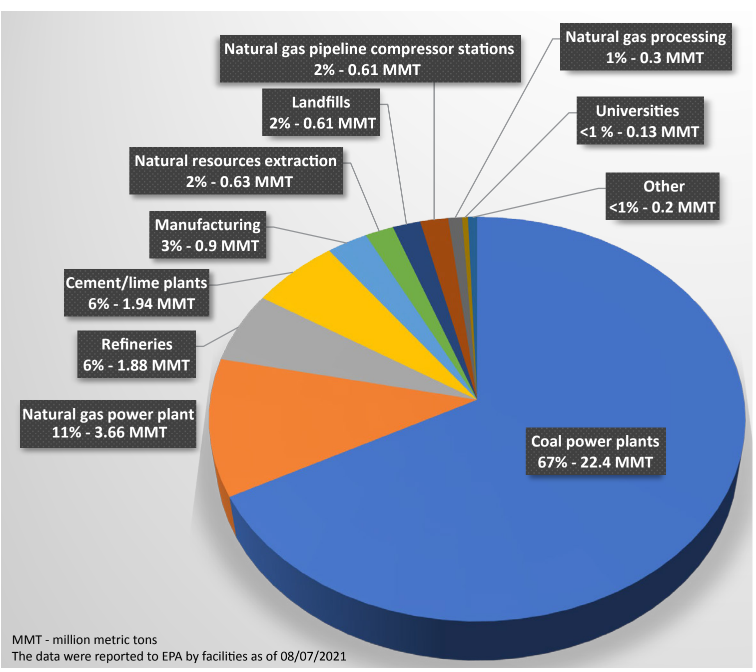
Potential Impacts of the Inflation Reduction Act on Carbon Capture and Storage in Utah

by Julia Mulhern, Ph.D.

The Inflation Reduction Act (IRA), which aims to reduce U.S. greenhouse gas emissions by roughly 40 percent by 2030, was signed into law in August 2022. The act increases the economic incentives of Carbon Capture Utilization and Storage (CCUS) for the private sector by introducing a variety of provisions that increase the magnitude and applicability of "45Q tax credits" associated with CCUS projects.

What is CCUS?

CCUS generally describes all parts of the process of gathering carbon dioxide (CO_2) from the atmosphere or other point sources (e.g., power plants and petroleum refineries) and either using it (utilization) or storing it (sequestration) in underground geological formations (see *Survey Notes*, 2022, v. 54, no. 2). Industrial facilities, such as power plants, chemical plants, and iron, cement, and gas processing plants are fundamental to society and the economy; however, they produce significant CO_2 emissions that contribute to global warming. These industrial facilities are considered point sources of emissions because they emit a relatively dense volume of greenhouse gas into the atmosphere at a single location. These facilities can be designed or retrofitted with carbon capture technology to gather CO_2 on site and pump it into underground rock formations, where it is trapped for long periods of time, rather than allowing it to enter the atmosphere. CO_2 can also be removed from the atmosphere through direct-air-capture (DAC) technology, a flexible and scalable burgeoning technology that involves building complex machinery that removes CO_2 directly from the air, but this technology currently requires more energy to capture CO_2 than re-designing or retrofitting point-source facilities. CCUS was proposed as early as 1977, but it has not yet been widely deployed due to lack of incentives—the process takes considerable energy to capture, compress, and reinject CO_2 into the ground and these energy costs, as well as infrastructure costs, have been previous and persistent hurdles for economically viable CCUS projects. However, the IRA increases relevant tax credits, thus making projects more viable and encouraging greater participation in CCUS by the private sector.



Emissions data for Utah showing the percentage of emissions from various large-scale industrial facilities based on EPA FLIGHT dataset https://ghgdata.epa.gov/ghgp.

What are the 45Q tax credits and how were they changed in the Inflation Reduction Act?

The "45Q tax credits," named after Internal Revenue Code Section 45Q, are tax credits provided for the capture and either storage or utilization of carbon oxides (CO), which are a more generalized group of gases that includes and is dominated by CO_2. These credits were originally established in 2008, reformed in 2018 as part of the Build Back Better Act, and adjusted in 2021 to further incentivize participation in the program. The 2022 IRA makes the following changes to 45Q credits:

- Increases the credit amounts per metric ton captured from:
  - o $50 to $85 per metric ton for point-source capture,
  - o $35 to $60 per metric ton for point-source CO used for enhanced oil recovery (EOR),
  - o $85 to $180 per metric ton for direct-air-captured (DAC) CO that is stored, and
  - o $35 to $130 for direct-air-captured CO that is utilized.
- Lowers the annual carbon emissions threshold for facilities to qualify for the credit from:
  - o 500,000 to 18,750 metric tons for power plants,
  - o 100,000 to 12,500 metric tons for industrial facilities, and
  - o 100,000 to 12,500 metric tons for DAC facilities.
- Allows direct pay (payments rather than tax deductions) and transferability for tax credit amounts:
  - o corporate projects receive direct pay for the first 5 years after the carbon capture equipment is placed in service, and
  - o non-profit organizations and co-ops can receive direct pay for all 12 years of the credit.
- Extends the start date deadline for project construction from January 1, 2026, to January 1, 2033.

In summary, the tax credit value per metric ton of CCUS has increased, more facilities are eligible for sequestration tax credits, DAC is additionally incentivized, and these credits are easier for companies to realize through direct pay, allowing companies to redeem offsets independent of their other tax burden. Combined, these measures may give industrial facilities for steel, cement, refining, and other manufacturing, which produce hard-to-abate CO_2 emissions, an economically viable option for CCUS. Although the cost specifics of CCUS are situational, the increased credits give companies the added incentive to market their products as being produced with low or no emissions.

How do these changes impact CO_2 storage feasibility in Utah?

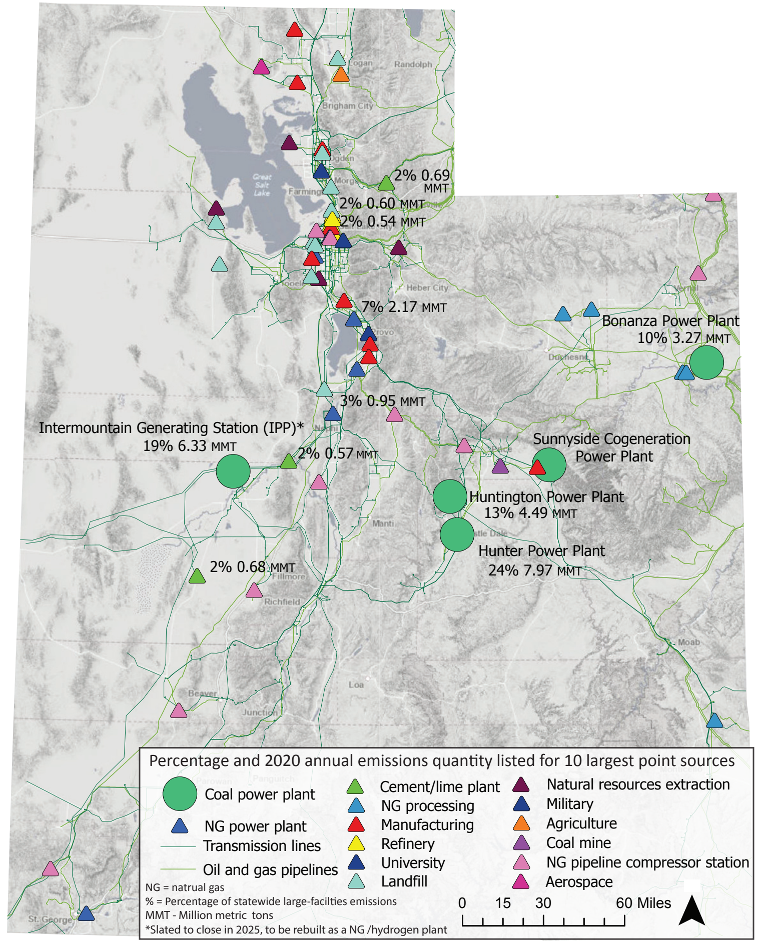
With an abundance of sandstone, limestone, and basalt rock layers, Utah has favorable geology for long-term geologic sequestration of CO_2 which requires both porous reservoir rock layers into which CO_2 may be injected and non-porous confining seal rocks, such as mudstone or salt, that overlie the reservoir rocks and trap the CO_2 in place underground. This geology makes Utah a great location for both adding CCUS facilities to existing infrastructure (such as coal-fired power plants) and developing future industrial facilities close to emissions point sources where sequestration could take place on site. The new IRA provisions increase the potential for CCUS in Utah, specifically:

- The IRA increases the number of eligible facilities in Utah from 41 to 62 based on the reduced thresholds for annual emissions, resulting in qualifying facilities distributed across the state.
- The increase in 45Q credits to $85 per metric ton for point-source emissions could have substantial economic benefit to businesses across the state, including increasing the viability of retrofitting coal-fired power

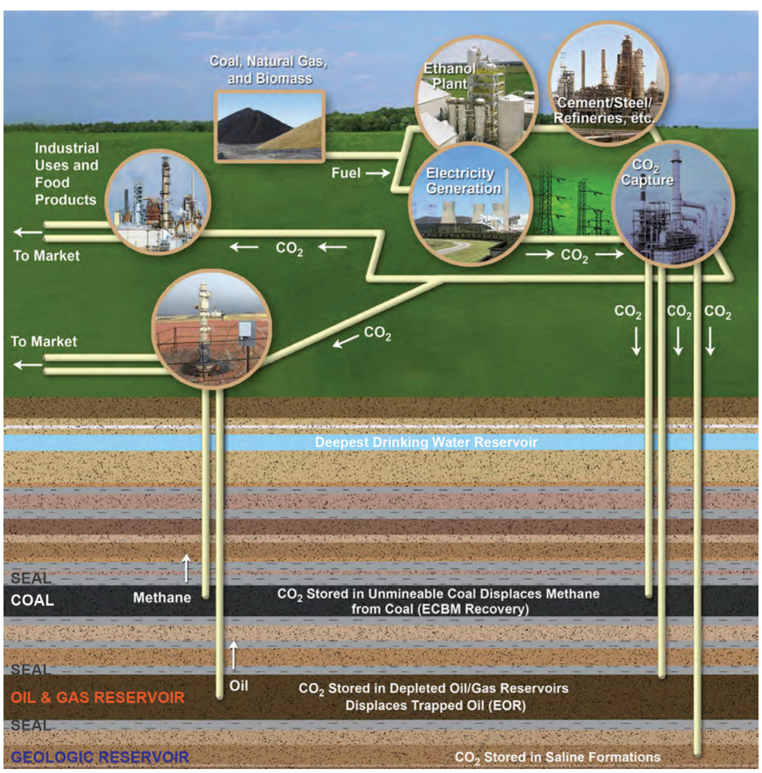
plants with CCUS technology. Emissions from coal-fired power plants currently make up 67 percent of Utah's annual greenhouse gas emissions, a total of 22.4 million metric tons (MMT) annually. These emissions will decrease as Intermountain Power Project is closing its coal-fired power plant near Delta, Utah, by 2025; however, the plant is being rebuilt as a natural gas/hydrogen power plant which could include CCUS. Retrofitting power plants with CCUS would lessen the environmental impacts of electricity generation in the state. For example, the Hunter Power Plant in Emery County emits about 8 MMT of CO_2 each year. If roughly 80 percent of that CO_2 was captured and stored geologically it would lead to a credit of about $538 million annually.

- Detailed, site-specific cost assessments for infrastructure installation and operational expenses would need to be done to determine retrofit feasibility and economic upside.
- With the increased 45Q credits, active and declining oil and gas fields in the Uinta Basin could become targets for enhanced oil recovery (EOR). EOR, which is the injection of CO_2 into oil and gas reservoirs to increase pressure and bolster production, allows hydrocarbon resources to be fully extracted from existing oil and gas fields, making best use of existing resources and infrastructure.
- Utah has abandoned oil and gas wells which can be accessed by existing well infrastructure that could be retrofitted and utilized for CO_2 storage without incurring significant, new environmental impacts.
- In addition to having geology that favors CCUS, Utah is rich in geothermal resources. CCUS has the potential to couple with geothermal energy production; however, this technology is currently in the developmental stages.
- DAC facilities could be developed in Utah to take advantage of the attractiveness of geologic reservoir-seal pairs not near CO_2 point sources.

The 45Q tax credits create more economically viable opportunities for industrial facilities and companies in Utah to reduce emissions and meet the climate goals set forth by the federal government.



Industrial facilities eligible for the revised IRA 45Q tax credits in Utah based on 2020 annual emissions data from EPA FLIGHT dataset https://ghgdata.epa.gov/ghgp.



Schematic diagram showing how CO_2 is captured, utilized, and stored. Modified from Gray, 2012, U.S. Department of Energy, Office of Fossil Energy, Carbon Utilization and Storage Atlas, fourth edition.

How is the Utah Geological Survey involved?

The Utah Geological Survey (UGS) has been involved in CCUS projects since 2003, often partnering with the Energy & Geoscience Institute at the University of Utah. In the past few years, the UGS has contributed geological expertise to Department of Energy-funded grants that assess the viability of geological CO_2 sequestration in Utah. Specifically, the UGS is currently performing a statewide assessment of CCUS potential as well as more detailed projects assessing the viability of injection in specific locations. Moving forward the UGS will continue to provide geologic support for feasibility and implementation projects, advance CCUS research, and gather and disseminate information on CCUS opportunities within Utah.

For more information see:

Inflation Reduction Act of 2022: https://www.congress.gov/bill/117th-congress/house-bill/5376/text

The Global CCS Institute: https://www.globalccsinstitute.com/resources/publications-reports-research/the-us-section-45q-tax-credit-for-carbon-oxide-sequestration-an-update/

Dindi and others, 2022, Policy-driven potential for deploying carbon capture and sequestration in a fossil-rich power sector, https://doi.org/10.1021/acs.est.1c08837

Gu and Deo, 2009, Applicability of carbon dioxide enhanced oil recovery to reservoirs in the Uinta Basin, Utah: UGS Open-File Report, https://doi.org/10.34191/OFR-538

Jones and Lawson, 2021, Carbon capture and sequestration (CCS) in the United States: https://crsreports.congress.gov

What is a Dropstone?

by Jim Davis

Glad You Asked!

A dropstone is an oversized stone deposited in a fine-grained sediment that would seem a paradox. Ordinarily, the amount of energy in moving water sorts sediments by size. Quiet, calm waters deposit tiny sediment particles, such as the mud found on lake beds and ocean floors. Raging waters deposit larger rocks, such as the cobbles and boulders in steep mountain stream beds. So how can comparatively large, exotic stones end up within an otherwise fine-grained rock matrix? Dropstones are indeed dropped from above.

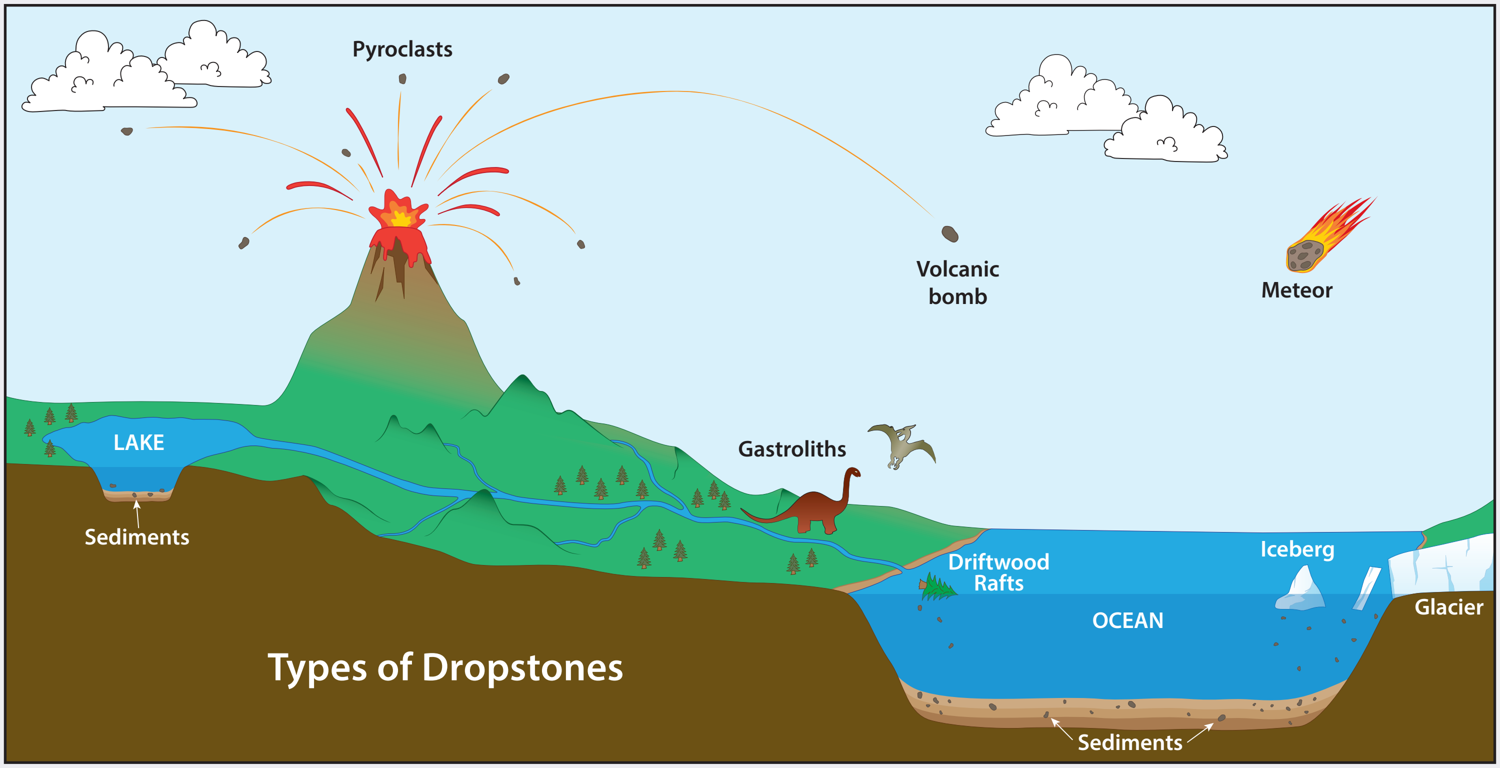
A quartzite dropstone weathers out in positive relief in Mineral Fork Canyon, Salt Lake County. Dropstone is 6 inches on the long axis.

Dropstones indicate that a rock was, by some agency, relocated to a still, low-energy environment. Once a stone is transported to a body of water and then released into it, it drops through the water column and lands on fine-grained sediments. It is eventually buried over seasons or centuries as additional fine-grained sediment and other tiny particles settle out of the water column and the dropstone is locked in as its surroundings lithify over time. The presence of the oversized stone amid fine, sometimes laminar or varved sedimentary rock, appears a contradiction unless evidence of its emplacement can be found—for example, deformation or truncation of underlying sediments from impact, or the draping of overlying sediments—denoting its overhead origins.

Ice is the most common source of dropstones. However, dropstones can also come from animals, plants, volcanoes, landslides, and avalanches.

The most prevalent and largest dropstones are rafted by ice. When glacial, shoreline, or river ice incorporates rocks and becomes seafaring, these rock-rich ice masses release stones into the marine sediments as the ice melts and the integrated rocks are freed. Since icebergs can be of massive size, they can hold immense quantities of rock that are regularly dropped onto the ocean floor, potentially over the course of months or even years.

Dropstones from animals come from gastroliths, or stomach stones. Aquatic animals such as Mesozoic Era marine reptiles, crocodilians, and present-day seals, sea lions, walruses, and penguins consume rocks to help grind down food, particularly fish bones, or the stones are used as ballast for stabilization in the water. Terrestrial animals such as reptiles and herbivorous birds, as well as Mesozoic-age sauropod dinosaurs, also ingest gastroliths for pulverizing vegetation. Animal dropstones often occur in clusters because of multiple stones in the digestive system, in some instances numbering up to hundreds of stones, sometimes up to cobble-size in larger creatures.



Trees often wrap their roots around stones in the soil. If uprooted and swept away into a river or the ocean, they become driftwood. The root-bound rock drops once the wood is waterlogged. Similarly, brown kelp and seaweed offshore attach to substrate with holdfasts. With air sacks for floatation and "leaves" (blades) for sailing, kelp can carry rocks far into the sea. Tangled, and sometimes massive, mats of vegetation provide a raft for stones, particularly in the tropics.

Dropstones can come from volcanoes and on occasion from space, in the form of meteorites. During eruptions, volcanoes eject rocks as pyroclasts. Pyroclasts can be small to quite large, and airborne rocks from violent eruptions can crash-land miles distant from their departure point. Some pumice will float until waterlogged, and then sink.

Landslides are known to generate dropstones in the ocean as do snow avalanches spilling out onto frozen lakes. Recently and increasingly, far-reaching human activity places a wide variety of dropstones that might one day be preserved in the geologic record.

Gastroliths in the Upper Jurassic Morrison Formation from Jurassic National Monument, Cleveland-Lloyd Dinosaur Quarry, Emery County, Utah. U.S. quarter for scale.

A dropstone is older than the rock it is encased in. The source of the rock or the geological formation from which it came may not be known, or it may no longer exist, having eroded away. The dropstone could be any kind of rock—yet enduring the journey from initial site to the watery depths favors the resilient, such as quartzites and other metamorphic, igneous, and siliceous rocks. Oftentimes the dropstone is rounded from tumbling and abrasion within a glacier, a river, or on a beach. Glacial dropstones can be scored or striated from being ground against bedrock while in the ice stream. Gastroliths are ordinarily more highly polished than water-rounded stones and could be accompanied by fossil bone from the animal. Kelp-derived dropstones can have crusts and burrowing from shallow marine organisms. Volcanic bombs, ejected partially molten, can be aerodynamically shaped through flight or show impact features such as flattening and distortion.

A green quartzite dropstone from the Mineral Fork Formation, Pine Creek Canyon, Wasatch County. U.S. quarter for scale.

An ideal place to see dropstones in Utah is anywhere the Precambrian-age Mineral Fork Formation outcrops, such as the upper Mineral Fork Canyon in Big Cottonwood Canyon (the formation's namesake), northern Antelope Island, west of Hellgate and at the mouth of and west of Peruvian Gulch in Little Cottonwood Canyon, Pine Creek Canyon in Wasatch County, near the mouth of Rock Canyon northeast of Provo, in Tank Canyon on the north side of American Fork Canyon, and in the equivalent Dutch Peak Formation constituting much of the Sheeprock Mountains in Tooele and Juab Counties. Other Precambrian-age rocks with dropstones are in the Deep Creek Range in Juab County and in the Perry Canyon Formation in and south of Perry Canyon in Box Elder County and between North Ogden and Pineview Reservoir in Weber County. These units represent a time known as the Cryogenian period, or "Snowball Earth" that occurred three-quarters of a billion years ago and lasted, with intermissions, some 100 million years. Utah at that time was positioned in the Tropical Zone, at sea level, and was overrun by glaciers—with embedded stones—calving icebergs into the ocean.

Teacher's Corner

This October, 700 students from elementary schools along the Wasatch Front, and as far away as Gunnison and Price, participated in the Utah Geological Survey's Earth Science Week (ESW) activities held at the Utah Core Research Center. Students explored geology and paleontology through fun, hands-on activities like "gold" panning for colorful minerals, getting up-close and personal with real dinosaur bones, and learning about earthquakes and discovering where and how they happen. Many thanks to our volunteers from professional associations, public- and private-sector institutions, other divisions within the Utah Department of Natural Resources, and individual geology enthusiasts who helped make ESW 2022 possible.

Since its creation in 1998 by the American Geosciences Institute (AGI), ESW has encouraged people everywhere to explore the natural world; promote Earth science understanding, application, and relevance in our daily lives; and encourage stewardship of the planet. For more information on ESW, see the AGI web page at www.earthsciweek.org; for information on next year's ESW activities at the Utah Geological Survey, see our web page at geology.utah.gov/teachers/earth-science-week.

Fossil Mountain

Millard County, Utah

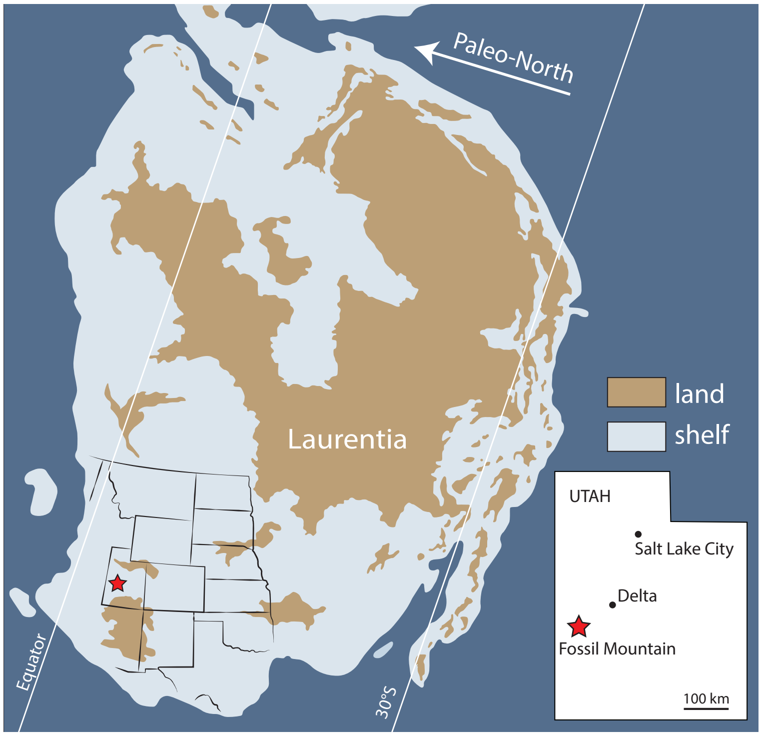
by Mackenzie Cope

Fossil Mountain is a peak on the south end of the Confusion Range in Millard County, Utah, named after the abundance of marine fossils found on its slopes. The locality is popular for rockhounds and fossil hunters because of the variety of finds included in a desert wilderness experience.

View of Fossil Mountain from the northeastern slope.

Geology

Fossil Mountain has a collection of geologic strata exposed in neat layers. At the base of Fossil Mountain are strata of the upper Pogonip Group, which consists of four formations. From oldest to youngest these are the poorly exposed Wah Wah Limestone, Juab Limestone, Kanosh Shale, and Lehman Formation. The upper Pogonip Group is a mix of limestone, calcium-rich siltstone, sandstone, conglomerate, and shale. These formations were deposited during the early and middle Ordovician Period (485 to 458 million years ago) when nearly one-half of Utah existed as a shallow, carbonate marine shelf near the equator. Utah's section of this shelf was only a fraction of the vast carbonate platform on the western margin of the paleocontinent of Laurentia. There were different stages of shallow sea environments during the approximately 27-million-year duration of deposition of the upper Pogonip Group rocks, which is evident in the varying rocks and fossils of each formation.



Simplified reconstruction of the paleocontinent of Laurentia, during the Middle Ordovician. During this time, Utah was part land and part carbonate shelf at the equator. (Modified from Marenco and others, 2016, Increasing global ocean oxygenation and Ordovician radiation—Insights from Th/U of carbonate from the Ordovician of western Utah: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 458)

Eventually, quartz-rich sands that were eroded from the northeast overwhelmed the carbonate platform, depositing sediments into the shallow water and beaches. These sediments formed the Watson Ranch Quartzite, Crystal Peak Dolomite, and Eureka Quartzite, all of which are composed of various mixes of quartzite, limestone, and dolomite. They overlie the upper Pogonip Group, and the Eureka Quartzite forms the peak of Fossil Mountain.

Fossils and Collecting

During the Ordovician, Utah's shallow sea and carbonate shelf environment had a humid and hot atmosphere at the equator that enabled a vast number of diverse organisms to flourish. The diverse fossils correlate with the Ordovician Radiation, a biodiversification event that happened after the more famous Cambrian Radiation or "Explosion." Although the Cambrian Radiation was the beginning of many major phyla showing up in the fossil record, the Ordovician Radiation was biodiversification at the family, genus, and species levels. Fossil Mountain has many specimens that showcase this diversification, including trilobites, graptolites, conodonts, brachiopods, echinoderms, ostracods, gastropods, cephalopods, pelecypods, sponges, bryozoans, corals, cyanobacteria, and trace fossils.

The fossils at Fossil Mountain are often fragmentary due to being accumulated in a high-energy, wave-dominated shoreline environment. They are also usually cemented together with other fossils. Brachiopods,

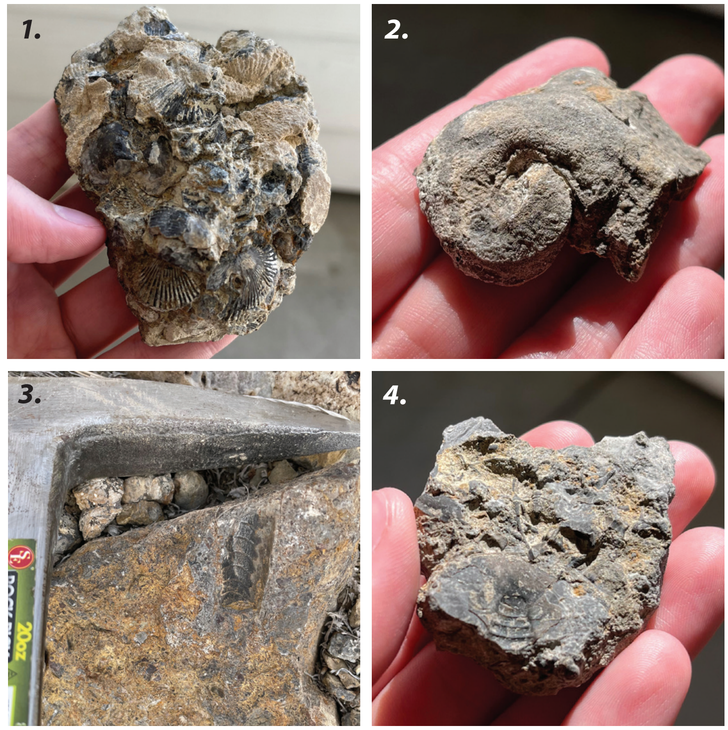
View of Fossil Mountain and its formations from the south. Fossils can be found in the Juab Limestone, Kanosh Shale, and Lehman Formation. The Wah Wah Limestone, being the oldest formation in the upper Pogonip Group, is under the Juab Limestone and not well exposed at Fossil Mountain.

gastropods, crinoids, cephalopods, and trilobites are the easiest to find and identify. You can find them in the loose rocks on the slopes of Fossil Mountain. Although specimens are plentiful on all slopes, fossil hunters report finding better quality fossils the higher they search up the hill.

Fossil Mountain is part of the King Top Wilderness Area and only surface collecting is allowed. Digging is prohibited. The U.S. Bureau of Land Management Fillmore Field Office manages the site and allows reasonable amounts of collection for personal use with no intent to sell. It is important to limit collection so future visitors can also appreciate the abundant fossils.

Fossils found at Fossil Mountain

Fossil	Description	Fossil Mtn. Occurrence
Brachiopods	Hinged mollusk-like animals	Common
Bryozoans	Colonial organisms that leave behind plant-looking colony exoskeletons	Less common
Cephalopods	Squid-like animals with chambered hard shells	Less common
Conodonts	Microscopic tooth-like structures	N/A (microscopic)
Corals	Colonial marine animals, regionally thumb-sized and forming beds	Rare
Cyanobacteria	Aquatic, photosynthetic microorganisms	N/A (microscopic)
Echinoderms	Diverse phylum of crinoids, starfish, and others	Common
Gastropods	Snails, fossil remnants are curled shells and shell impressions	Common
Graptolites	Colonial marine organisms with sawtooth or leaf-like exoskeletons	Rare (very small)
Ostracods	Bivalved crustaceans, pinhead- to bean-size	Less common
Pelecypods	Oyster-like shelled animals, regionally occur as thin, crushed shell beds	Rare
Sponges	Simple, multicellular organisms, regionally formed patch reefs	Rare
Trace Fossils	Roots, burrows, borings, and others	Less common
Trilobites	Bottom-dwelling arthropods, similar to pill bugs	Less common



Common fossils found at Fossil Mountain. (1) Brachiopods, (2) gastropod, (3) cephalopod shell segments, and (4) fragmented trilobite.

Calling All Rockhounds!

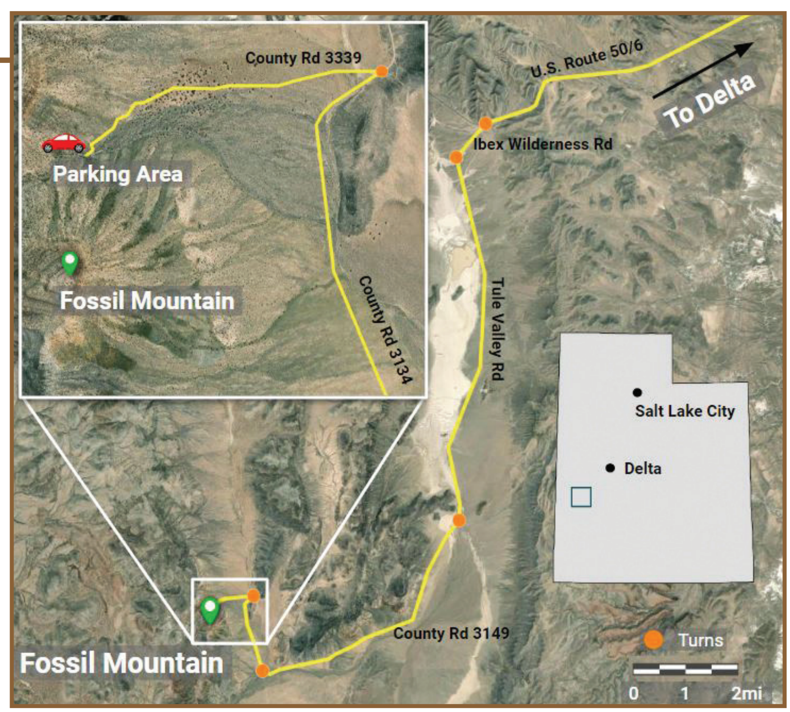
Fossil Mountain is only one of over 100 rockhounding sites on the UGS's new online interactive map—Utah Rockhounder. This new web application has a map of rock, mineral, fossil, and landscape rock localities, as well as location coordinates, site descriptions, and photos. You can also read updated collecting rules and regulations for public lands and find resources for identifying your find! Check it out at geology.utah.gov/apps/rockhounder.

HOW TO GET THERE

From Delta, Utah, travel southwest on U.S. Route 50/6 for 49.4 miles, turn left onto Ibex Wilderness Road, and left again on Tule Valley Road. After 7.5 miles, turn right onto County Road 3149 and travel for 5.6 miles before turning right onto County Road 3134. After 1.7 miles, you will find an intersection of dirt roads. Turn left on County Road 3339 and you can drive as close to the mountain as your vehicle can safely travel and park. There are primitive campsites on this road where you can park and walk in.

For access to Fossil Mountain, 4-wheel-drive is not necessary but helpful if you want to drive the rougher roads closer to the site. Parking farther away and walking in is also an option. There are no services, so be prepared with water, sun protection, plenty of fuel, and vehicle emergency essentials. The closest services are in the town of Delta to the northeast or Milford to the southeast. It is highly recommended to have a paper map or downloaded map, as phone and internet service in this area is unreliable.

Coordinates: 38.881279° N, 113.468271° W



SURVEY NEWS

2022 Hintze Award

The Utah Geological Association (UGA) and the Utah Geological Survey (UGS) presented the 2022 Lehi Hintze Award to **Ken Krahulec** for his outstanding contributions to Utah geology. Ken earned a B.S. in geology from the University of Minnesota Duluth and an M.S. in geology from South Dakota School of Mines and Technology. After graduating, Ken began a 24-year career in minerals exploration with the BP—Kennecott—Rio Tinto group companies and was involved in discoveries in multiple mining districts, such as Resolution in Arizona, Bingham Canyon, and Tintic, his most notable being the discovery of the Stockton porphyry deposit on the west side of the Oquirrh Mountains in 1995.

Following his exploration career, Ken joined the UGS in 2005 as metals geologist and spent 14 years researching Utah's major ore systems until his retirement in 2019. During this time, Ken set the highest possible standard for working with operators, communicating with the public, and conducting research on Utah's mineral resources. He authored numerous reports including the annual *Utah Mining Report* and UGS Open-File Report 695, *Utah Mining Districts*, which is the go-to guide for Utah's metalliferous mineral resources detailing the history, geology, potential, and further references of all 189 mining districts of Utah. He also published numerous field guides and papers through the Society of Economic Geologists, Geological Society of Nevada, and the UGA. He co-edited UGA Publication 45, *Resources and Geology of Utah's West Desert*, which is one of the most substantial records for some of Utah's greatest ore deposits.

Named for the first recipient, the late Dr. Lehi F. Hintze of Brigham Young University, the Lehi Hintze Award was established in 2003 by the UGA and UGS to recognize outstanding contributions to the understanding of Utah geology. Ken's contributions to Utah geology in terms of industry impact, academic achievement, publication record, and human legacy illustrate that he is very deserving of this honor.

2022 Employee of the Year

Congratulations to **Mackenzie Cope** who was selected by her peers as the 2022 UGS Employee of the Year. Mackenzie is a huge asset to the UGS and is consistently willing to take on extra duties and share her knowledge and passion for geology. Her organizational and project management skills help her and her teammates excel at multiple projects and her contagious enthusiasm encourages the people she works with to outperform themselves. In her role as web manager with the Data Management Program, Mackenzie was integral to the redesign of the UGS's website, which consistently receives praise and is often the first interaction the public has with the UGS. Mackenzie is hardworking and efficient and is constantly looking for new and creative ways to share our data in interactive web applications. Aside from her outstanding work as web manager and geologist, her leadership with the UGS and DNR Equity, Diversity, Inclusion, and Accessibility (EDIA) committees speaks volumes about her caring and concern for coworkers and the work environment at UGS. Mackenzie has a strong work ethic and friendly personality that endears her to coworkers; she is an excellent role model and a deserving recipient of the UGS Employee of the Year award.

Employee News

The Geologic Mapping Program welcomes **Matthew Morriss** and **Lauren Reeher** who have accepted positions as mapping geologists. Matthew received his Ph.D. from the University of Oregon and worked with the USGS Utah Water Science Center before joining the UGS. Lauren is finishing her Ph.D. at the University of Arizona with a focus on structural geology of several areas of the Colorado Plateau and adjoining areas in Arizona and Wyoming. Prior to this she completed an M.S. at the University of San Antonio with a focus on sequence stratigraphy and basin analysis.

The Energy & Minerals Program bids farewell to **Will Hurlbut** who accepted a job with the University of Utah and welcomes **Julia Mulhern** as a project geologist focusing on carbon sequestration projects. Julia received a B.A. in earth and environmental science from Wesleyan University, a Ph.D. in geology from the University of Utah, and worked as a petroleum geologist at Shell before joining the UGS. **Winnie Pan** joins the UGS as a financial analyst. Winnie earned a B.S. degree in accounting from the University of Utah and previously worked with another state agency. **Martha Jensen** has accepted the position of GIS Manager with the Data Management Program. A warm welcome to Matthew, Lauren, Julia and Winnie, congratulations to Martha, and best wishes to Will.

Grant Willis retired in December after 40 years with the UGS Geologic Mapping Program, including 12 years as a field geologist and 27 years as program manager. He has been a part of the Mapping Program since its formation in 1983, helping to make it a program that is now recognized by state geological surveys nationwide as one of the most advanced and innovative programs in the nation. During his career Grant has overseen the review, production, and publication of hundreds of geologic maps and has been an author or co-author on more than 50 geologic maps throughout Utah. He has also served in many roles in the professional community, including as president of the Utah Geological Association (UGA) and as chair of the UGA Earthquake Safety Committee. Over the years, Grant has led or contributed to numerous geologic field trips for the UGA, UGS, and other organizations and has been the driving force behind annual field reviews of new geologic mapping, helping to expose new maps to a broad audience. Grant recently stepped down as the Geologic Mapping & Paleontology Program Manager and plans to continue his passion for mapping during his retirement, and we wish him all the best!

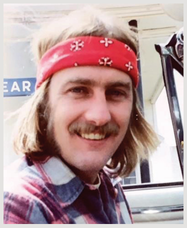
Jon King retired in December after 31 years of service with the UGS. Jon joined the Geologic Mapping Program in 1992 and is a co-author on the Ogden 30- x 60-minute geologic quadrangle map, 14 detailed geologic maps within the quadrangle, and 2 detailed geologic maps adjacent to the quadrangle. Jon was the project manager on the Millard County Bulletin and geologic maps, and was a top-notch map reviewer and researcher. Prior to 1992, Jon worked for the Wyoming State Geological Survey for 7 years investigating industrial minerals, construction materials, uranium, thorium, rare earth elements, and gold (everything from abrasives to zeolites) and generating about 30 publications. We wish Jon all the best in his retirement.

Rich Giraud retired in December after 25 years of service with the UGS. As a senior geologist with the Geologic Hazards Program, Rich worked on a variety of landslide and debris-flow projects and had a specific interest in fire-related debris flows. His more current work involved landslide inventory mapping on the Wasatch Plateau. Rich received his B.S. and M.S. degrees at the University of Idaho in Moscow and worked during the summers for the Juneau Icefield Research Program. After graduating college, he worked in mineral exploration for several years in Alaska and then worked for Kennecott here in Utah and surrounding states. Prior to joining the UGS in 1997, he worked in environmental consulting. Rich's knowledge and expertise will be greatly missed, and we wish him well in his retirement!

In Memoriam

Carolyn Olsen, former curator of the Utah Core Research Center, passed away July 28, 2022. Carolyn read and wrote poetry, and loved and taught about music. She excelled in higher education and its broad areas of learning, graduating from the University of Utah with honors. She found the perfect fit working at the Utah Geological Survey amongst the fascinating rocks of Utah.

Former UGS employee **Dan Burke** passed away on September 15, 2022. Dan worked as an assistant with the Energy & Minerals Program from 1991 through 1993. We express our sincere condolences to Dan's family.



Michael Wright, former assistant with the UGS Geologic Mapping Program, passed away on October 29, 2022. Mike made every day brighter with his paintings that he would often bring and hang around the work area, he truly made the world an interesting place.

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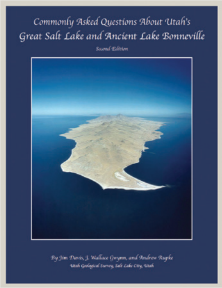

Commonly Asked Questions About Utah's Great Salt Lake and Ancient Lake Bonneville, by Jim Davis, J. Wallace Gwynn, and Andrew Rupke, 21 p., **PI-104,** https://doi.org/10.34191/PI-104

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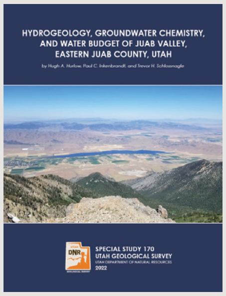
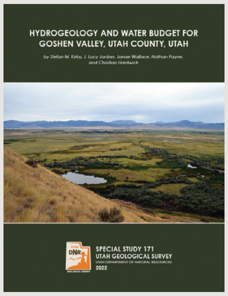


Hydrogeology, Groundwater Chemistry, and Water Budget of Juab Valley, Eastern Juab County, Utah, by Hugh A. Hurlow, Paul C. Inkenbrandt, and Trevor H. Schlossnagle, 101 p., 1 appendix, 2 plates, **SS-170**, https://doi.org/10.34191/SS-170



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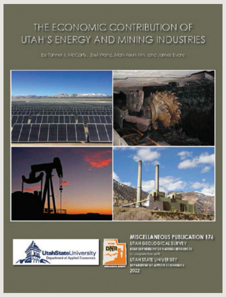

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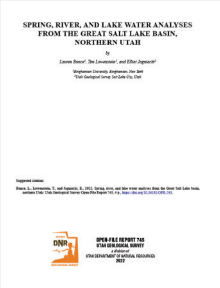

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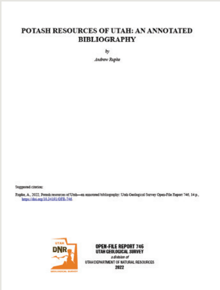

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