UTAH GEOLOGICAL SURVEY

SURVEY NOTES

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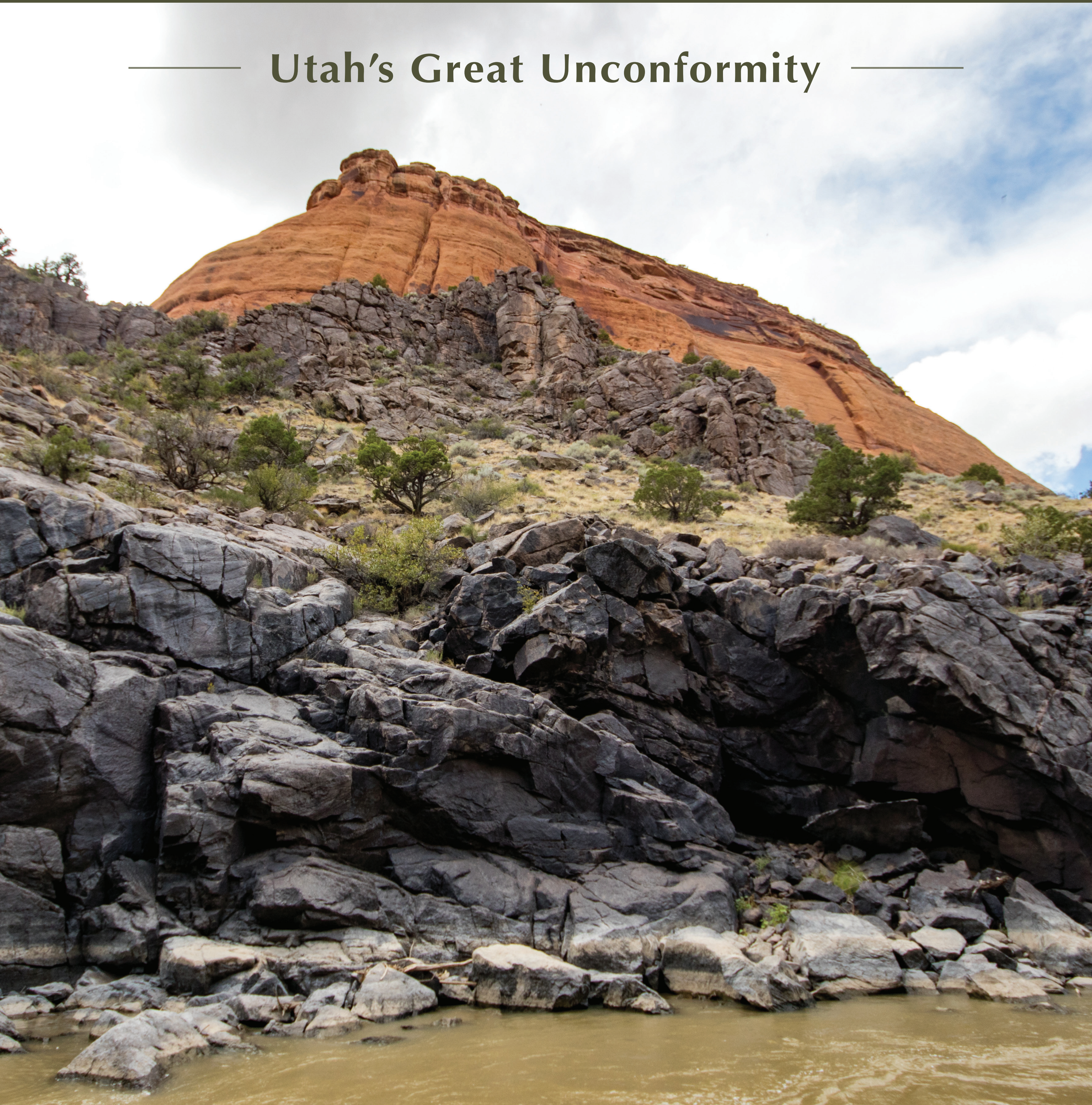
Utah's Great Unconformity



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Design | *John Good*
Cover | The Jurassic-Triassic Wingate Sandstone towers over Paleo- to Mesoproterozoic metamorphic and igneous rocks in the inner gorge of Westwater Canyon of the Colorado River. A thin bed of Triassic Chinle Formation and the actual unconformable surface are just out of sight. Photo by Adam Hiscock.

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DIRECTOR'S PERSPECTIVE

by Bill Keach

"The times they are a-changin'."

These are the first words that came to mind when I sat down to pen thoughts for this column. Deep in my past I remember hearing Bob Dylan sing them. It is a song about generational changes, and many were happening at that time. I'm old enough to remember, having witnessed them and at times participated in them.

In my career, I have witnessed many things that have fundamentally changed how and what we do in the geosciences. As a graduate student at Cornell, I was one of the first to type an M.S. thesis on a word processor. The machine was gathering dust in the corner just waiting for someone to make the leap. While working at BP, I received one of the first five computer workstations to interpret 3D seismic data. Interpretations were previously done on paper sections, meticulously tied and then posted onto paper maps, and contours were drawn by hand. These newfangled workstations were the brainchild of a native Utahn, Roice Nelson. In the late 1960s he was a bright, young freshman from Cedar City at the University of Utah when he penned (typed?) a paper on the use of computers to interpret seismic data. He would later go on to co-found Landmark Graphics which developed software and hardware to interpret seismic data. He was "a-changin'" the way we work. Today his technology is routinely used around the world.

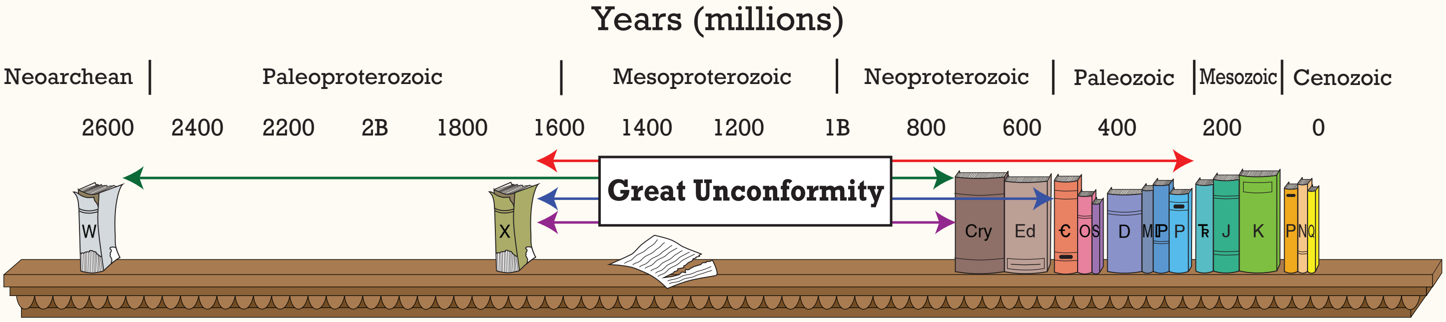
In the sciences, things continue to be "a-changin'." Artificial Intelligence (AI) is used to analyze large volumes of data looking for relationships and trends that otherwise might not be visible or understood, thus enabling scientists to solve complex problems. New technologies are generating massive amounts of data, including in the field of geology. New data brings new insights and new challenges.

The challenges of acquiring all this data include where and how to store it, how to use it, and ultimately how to share it for the benefit of the citizens of Utah. At the UGS we are embracing the changes that are coming. Eddy covariance flux towers, installed by the UGS, are a type of weather station that provides data to understand the exchange of water from the land (evaporation) and plants (transpiration) to the atmosphere. They are giving us better insights into groundwater systems. Lidar (light detection and ranging) is used to measure subtle elevation differences at the surface, thus providing images in tremendous detail of features that may be potential geologic hazards. We use underwater cameras in Great Salt Lake to image salt growth and dissolution. Imagery and data from unmanned aerial systems (drones) allow us to calculate the volume of rock moved in a landslide or debris flow. These examples are a few ways the UGS is using new technology to generate data that will provide better insights to the world around us. Indeed, the world around us, and our understanding of it, is "a-changin'."

Utah's Great Unconformity

by Grant C. Willis

Most articles in *Survey Notes* address some part of Utah's fantastic geologic rock record. This article, however, highlights a large **gap** in that rock record. Imagine your favorite book—but with many missing pages. Frustrating yes, but if the gaps are not too long you can still follow the plot. Rock records have many gaps, but throughout Utah (and many other places around the world) one gap is huge. Geologists call this gap the "Great Unconformity." An unconformity is typically an erosional surface carved across older rocks below and overlain by younger rocks, and thus represents missing rock and missing time. The amount of missing time is determined by calculating the difference between the ages of the underlying and overlying rocks. In Utah, the Great Unconformity spans 1 to 2 billion years of missing time (many entire books are missing!). During the past few decades, the Utah Geological Survey Geologic Mapping Program has conducted several mapping projects that included this huge but poorly understood gap. The Great Unconformity is deeply buried in most parts of the state but is well exposed in a few uplifted blocks: the Beaver Dam Mountains west of St. George, the Uncompahgre uplift northeast of Moab, the Wasatch Range from Willard to Bountiful and near Big Cottonwood Canyon and Santaquin, Antelope Island, the Grouse Creek and Raft River Mountains, and near Browns Park on the northern side of the Uinta Mountains east of Flaming Gorge. Most exposures are remote or difficult to access, but the massive cliffs of the Wasatch Range visible from any unobstructed vantage point west of Interstate 15 between North Ogden and Willard showcase a world-class example that has been featured in several textbooks. Most up-close views require hiking, steep scrambles, and in some cases, technical climbs. The unconformity is relatively accessible along some hiking trails of Antelope Island State Park, though exposures are overprinted by Cretaceous-age tectonic deformation.



The Great Unconformity, a period of missing rock and time, varies from approximately one-half to nine-tenths of Utah's 2.6 billion-year geologic story (many entire books are missing). Although our rock record from 770 million years ago to present is one of the best in the world for an equal-size area, many pages and some chapters are missing (it has many shorter unconformities). The colored arrows represent the span of the Great Unconformity in different parts of the state. The single torn page represents a tiny exposure of rock possibly about 1.4 billion years old that we are still struggling to interpret.

About the Rocks

Rocks on the "old side" of the Great Unconformity are of two distinct ages—about 2.5 to 2.6 billion years old and about 1.7 billion years old. These rocks at the base of the geologic column are naturally called the "basement" and form the foundation of our state, and our continent. Most of these "crystalline" rocks (with visible crystals like in granite and gneiss) formed 8 to 15 miles (40,000 to 80,000 feet) deep in the metamorphic and igneous cores of ancient mountain belts.

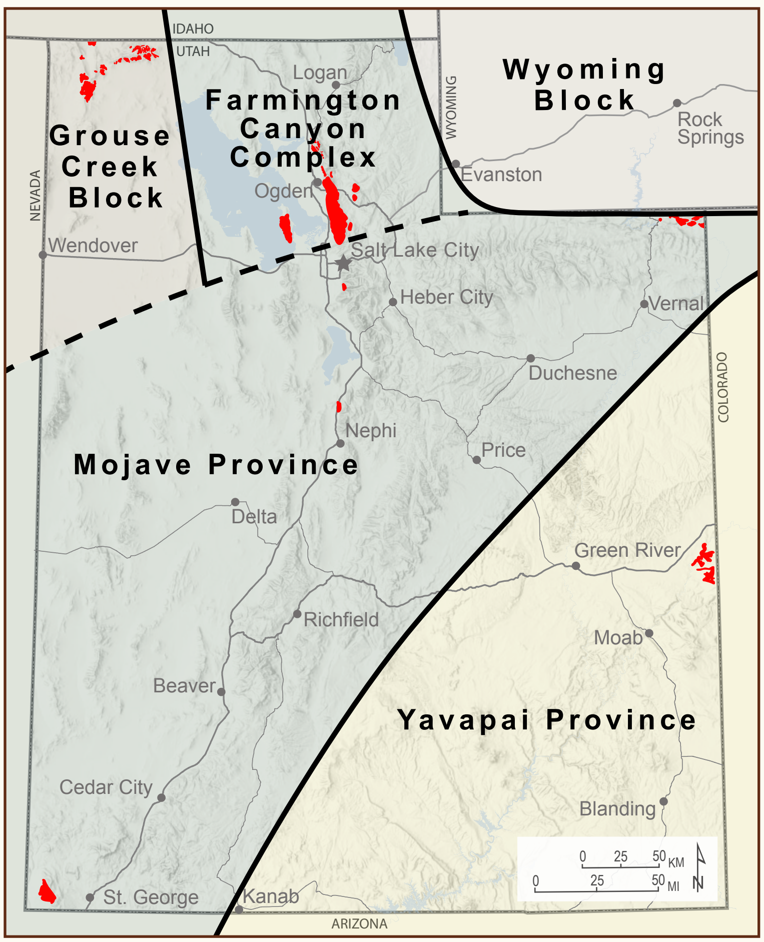
Rocks on the "young side" formed from sediments deposited near sea level—thus the unconformity represents a mind-boggling 8 to 15 vertical miles of eroded or tectonically removed rock and corresponding time. The overlying sedimentary rocks are of three primary ages—about 700 to 770 million years old in much of the western half of the state and the Uinta Mountains, about 520 to 540 million years old in most of the eastern half of the state, and about 220 million years old in the Uncompahgre area near the Colorado border, creating a 1- to 2-billion-year gap.

Geologists have long wondered what happened during all that time. Was it a long period of slow, continuous uplift and erosion, or were there pulses of rapid uplift and erosion? What was the composition of the eroded rocks? Were there also periods of subsidence and deposition? Were mountain ranges built and eroded flat without leaving a clue? What was life like during this time? In Utah we have few rocks that tell us the story, but fortunately the story is not completely lost. Rocks from key sites in other parts of North America and around the world have allowed geologists to gradually piece together at least a rudimentary story.

Piecing Together the Story

Many people have heard of the supercontinent Pangea, which formed as plate tectonics drove all the continents of the world into one huge landmass about 300 million years ago. Less well known is that Pangea was only the most recent supercontinent—several others predated it. Most of our story involves the formation and later breakup of such supercontinents.

Our Utah basement rocks consist of five major blocks or terrains. The oldest blocks, about 2.5 to 2.6 billion years old, are the Grouse Creek block, now exposed in the northwestern corner of Utah, and possibly a deeply buried sliver of the Wyoming block that may extend slightly under our northeastern borders. These and other blocks collided and sutured together over a long, complex history, forming proto-North America, including Utah, about 1.7 billion years ago. During this global upheaval, the Grouse Creek block moved toward the Wyoming block, pinching masses of rock and sediment into a jumbled terrain we now call the Farmington Canyon Complex (exposed in the Wasatch Range and on Antelope Island), the Mojave Province collided from the southwest, and the Yavapai Province plowed in from the southeast. After these collisions, North America was much larger, and Utah's "basement" or "foundation" was complete.



The five major Precambrian-age crustal blocks and terrains that make up Utah's basement. Exposures of basement rocks are shown by red spots—the Great Unconformity is well exposed in many places along the edges of these outcrops. Distant views are common, but most locations are remote and/or difficult for close-up access.

About 1.4 billion years ago, according to the prevailing hypothesis, part of a supercontinent called Columbia gradually tore away from the western coast of North America along a rift through what are now western Idaho, central Nevada, and western Arizona, forming faulted and tilted basins that locally collected great thicknesses of sediment, volcanic rocks, and igneous intrusions. Direct evidence is lacking in Utah, but postulated nearby examples of these rocks are the 1.1- to 1.4-billion-year-old Unkar Group exposed in the Grand Canyon and the 1.4-billion-year-old Belt Group in northwestern Montana and northern Idaho. Both consist mostly of argillite, shale, mudstone, sandstone, and dolomite up to 8 miles thick. These sedimentary rocks tell us that Earth was a barren place with only simple life forms such as algae and bacteria. We are unsure if such basins formed in Utah but a poorly understood wedge of rock called the Facer Formation exposed near Willard may include rocks of this age. Other rocks of this age may be present in northwestern Utah but they also have not been successfully dated. In summary, we speculate that this period from 1.4 to 1.1 billion years ago was a particularly active time in Utah, with possible rifting, subsiding basins, tilting, intrusions, uplift, and erosion, though we have little direct evidence.

The next supercontinent, Rodinia, finished assembling about 1.1 billion years ago. What are now Antarctica and Australia had merged with the western side of North America (the suture is in Nevada and western Arizona), whereas parts of what are now Africa and northern Europe collided with the eastern side of North America. We have not discovered direct evidence of this event in Utah, but the collisions must have contributed to the miles of uplift and erosion that caused the Great Unconformity. As supercontinents do, Rodinia broke apart from about 800 to 550 million years ago. In Utah, the rifting began about 770 million years ago with a fault-bounded basin subsiding and filling with thick layers of sediment (locally totaling more than 10,000 feet) in what is now the location of the uplifted Uinta Mountains. Rifting and volcanic activity continued along western Utah, weakening the basement foundation, which subsided and provided space for deposition of thick sediment, ending the Great Unconformity in the western half of the state.

Whether due to later erosion or non-deposition, the unconformity continued in the eastern part of the state for an additional 150 to 200 million years until about 520 to 540 million years ago when a Cambrian-age sea crept across the state, blanketing the land with a huge swath of beach sand and related coastal sediment, and ending the Great Unconformity. Where exposed, these Cambrian-age rocks (Tintic Quartzite in north to central Utah, Prospect Mountain Quartzite in west, Tapeats Sandstone in south, Geertsen Canyon Quartzite in northeast) form some of our most prominent formations, though in most parts of the state they remain deeply buried in the subsurface.

In one area of the state the gap of the Great Unconformity extends an extra 300 million years. During the Pennsylvanian and Permian periods (about 300 million years ago), uplift in the Uncompahgre area of eastern Utah near the Colorado border (part of the Ancestral Rockies) led to erosion that stripped off great thicknesses of rock, including the Cambrian rock that once capped the Great Unconformity. The denuded basement was finally re-covered in the Late Triassic about 220 million years ago, extending the Great Unconformity about 300 million years longer than in nearby areas where the Cambrian is still present.

Though only represented by a single sharp surface, the Great Unconformity represents over half of our geologic history and many geologic events. Utah contains limited direct evidence of this huge slice of time (only a few pages of many missing books), but we can piece together some of the story from other key sites around the world. Though this older part of the story is largely missing, Utah still has one of the most complete records of the last 770 million years of Earth's geologic history (the part that covers the entire evolution of complex life) of any similar size area anywhere in the world—an incredible rock record that we admire every time we visit our mountains, deserts, and parks.

The pinkish-tan Tintic Quartzite (about 520–540 million years old) directly overlies an erosional surface carved across the dark-gray Farmington Canyon Complex (1.7 billion years old) near Willard, forming one of the most spectacular exposures of the Great Unconformity in the western United States. Photo by Adam McKean.

Majestic orange-brown cliffs of Jurassic-Triassic-age Wingate Sandstone and a narrow slope of red-brown Triassic-age Chinle Formation (together about 190 to 220 million years old) tower over nearly black mostly Paleoproterozoic (1.7 billion-year-old) metamorphic and meta-igneous rocks, forming a stunning backdrop for river trips down Westwater Canyon of the Colorado River. The missing roughly 1.5 billion years defines the largest gap for the Great Unconformity anywhere in the eastern part of Utah. Photo by Adam Hiscock.

The Great Unconformity is exposed near a few trails in Antelope Island State Park. Here, glacier-derived mega-boulders of the Neoproterozoic-age Mineral Fork Formation sit directly on the Paleoproterozoic-age Farmington Canyon Complex, a gap of about a billion years. The entire mass was intensely sheared by Cretaceous thrust-faulting, obscuring the subhorizontal contact near the geologist's waist. Photo by Adolph Yonkee.

ABOUT THE AUTHOR

Grant Willis has been a mapping geologist with the UGS for 38 years, including 26 years as manager of the Geologic Mapping Program. He has authored or coauthored over 40 geologic maps and has supervised the publication of more than 320 geologic maps and dozens of geologic reports. Grant has also managed the development and advancement of digital geologic mapping at the UGS, a program that is now recognized by state geological surveys nationwide as one of the most advanced and innovative programs in the nation.

STATEMAP Just Got a Lot Bigger

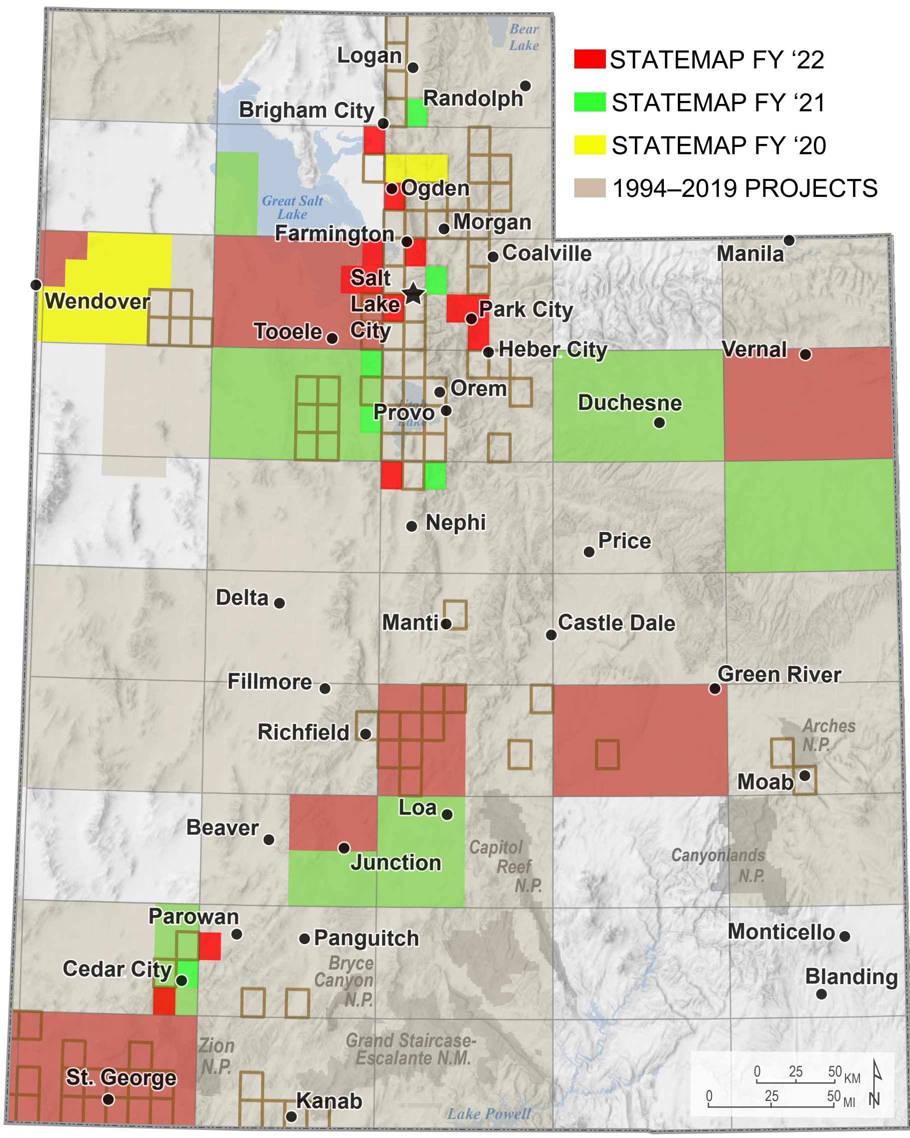
by Grant C. Willis

The STATEMAP component of the National Cooperative Geologic Mapping Program (NCGMP), administered by the U.S. Geological Survey (USGS), has been a major source of funding for geologic mapping in Utah for nearly 30 years, providing about one-sixth of our total mapping budget as a federal 50-percent match. STATEMAP and the NCGMP just got a lot bigger, generating big changes for geologic mapping at the UGS.

You may have noticed that the world is in a new "Cold War"—this one centered in part around "critical minerals" that are essential for technology and industry of many types. Adding critical minerals to energy resources, water resources and protection, geologic hazards, environmental challenges, land management, and many other concerns creates a daunting list of geologic issues facing our nation in coming years. Better geologic maps are at the foundation of solutions for many of these issues. Recognizing this, national political leaders recently significantly increased funding for geologic mapping, which will be administered through the USGS.

In Utah, the federal matching portion of our STATEMAP funding increased from $157,273 for the fiscal year that ended June 2020, to $458,577 for fiscal year 2021 (just ended), to $574,456 for fiscal year 2022 (ending June 2022). This funding allows the Geologic Mapping Program to expand our key goals—detailed 1:24,000-scale mapping of high growth, development, resource, hazards, and other high-priority areas, and regional 1:62,500–100,000-scale mapping for resources, land management, and research across the entire state, emphasizing better accuracy, better precision, more detail, and updating the old maps. Some of the funds come tied to new tasks—training staff, developing new procedures, contributing to the national geologic map database, converting old and new maps into a new national geologic map schema called GeMS, and developing three-dimensional map products. All these new projects, tasks, and objectives have presented us with many challenges, including finding the match for the 50:50 funding, adding and training staff, completing and reviewing more maps, and developing new procedures.

It is an exciting time for geologic mapping! Look for details about some of these new projects and objectives in future issues of *Survey Notes*.



Geologic mapping program STATEMAP-funded projects from fiscal years ending in June 2020 (before increased funding), 2021 (start new funding), and 2022 (our current year) showing the large increase in projects over the last two years. Projects include new mapping, map revision, and conversion of existing maps into the new national GeMS database schema. Small boxes are 1:24,000-scale 7.5' quadrangle projects and most larger boxes are parts of or full 1:62,500- and 1:100,000-scale 30' x 60' quadrangle projects. Light brown boxes are cumulative projects since STATEMAP began in 1993.

ENERGY NEWS

Geothermal in Utah and the USA: Is a Sleeping Energy Giant Awakening?

by Christian L. Hardwick

Geothermal heat has immense potential to provide clean, sustainable energy to Utah and the rest of the country. Western Utah is one of the more prospective areas for development of geothermal resources due to its unique geology and often anomalous subsurface heat flow. Geothermal energy resources are not as well known as other utility-scale renewables such as photovoltaic solar or wind, but they have been in use longer and are finally getting back into the public spotlight after a decade-long hiatus since the last geothermal boom. Renewed interest is due to the rising awareness of the magnitude of geothermal potential, the push for energy security and stability, and the desire for carbon-free sustainable base-load electricity. The U.S. Department of Energy (DOE) Geothermal Technologies Office (GTO) GeoVision analysis report, published in 2019, provided a comprehensive guide to evaluating future geothermal deployment opportunities. The GeoVision report supports a 26-fold increase in geothermal power generation by 2050, to be achieved through technology improvements and reduced costs.

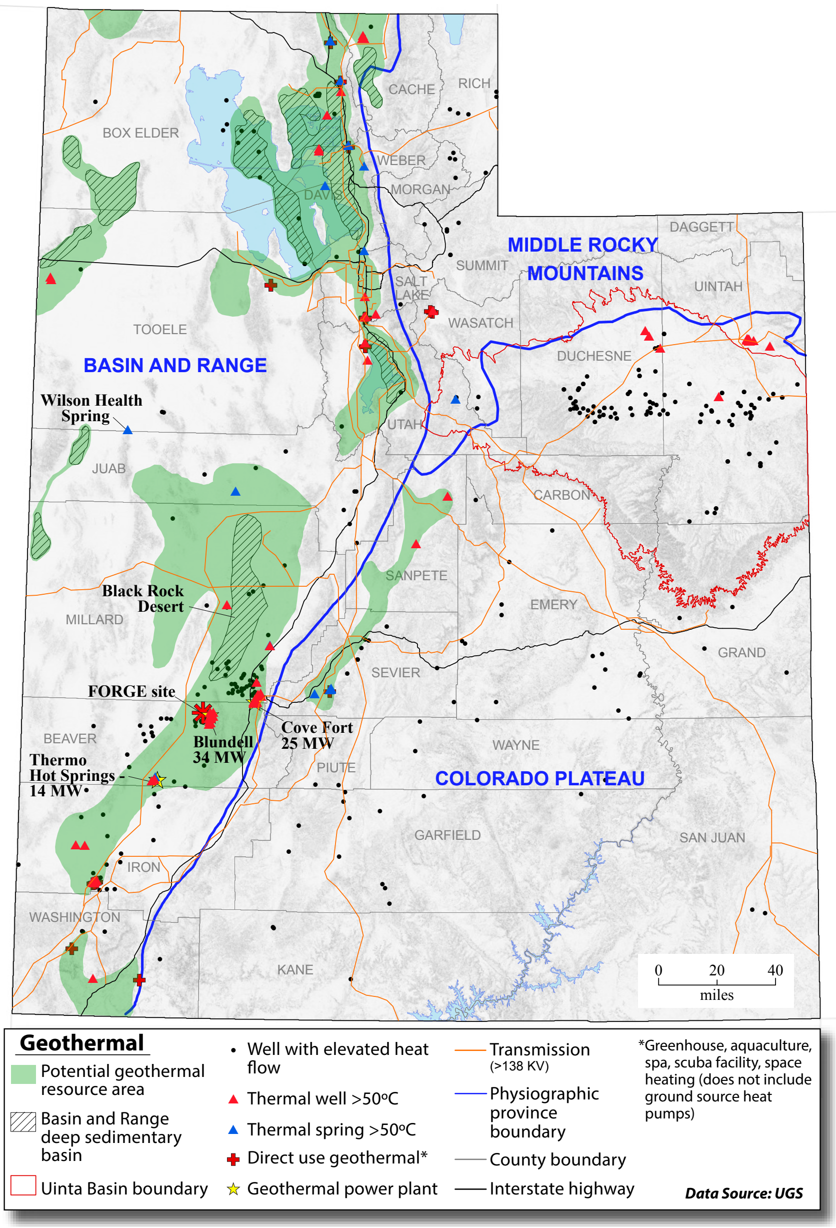
Early geothermal exploration targeted hydrothermal systems historically manifested by surface hot springs. These systems represented "low hanging fruit," and many existing geothermal power plants make use of this hot water to generate electricity. In 1904, the first geothermal-derived electricity was used to light up five lightbulbs in Larderello, Italy. In 1922, the first geothermal electricity production well in the United States was drilled at The Geysers in California. The first geothermal power plant in Utah, PacifiCorp's Blundell plant, came online in 1984 using dry steam technology at Roosevelt Hot Springs, just outside of Milford, Utah. Currently Utah has three active geothermal power plants—Blundell, Cove Fort, and Thermo—that have capacities of 34 megawatts (MW), 25 MW, and 14 MW, respectively. For general reference, one megawatt can power between 750 and 1,000 homes.

When water temperatures and/or fluid output volumes are not high enough to support utility-scale electricity generation, "direct-use" technologies can still take advantage of geothermal resources. Active direct-use geothermal in Utah includes greenhouses (Newcastle), aquaculture (Crystal Lake), and space heating/cooling (i.e., heat pumps) for both small (home) and large-scale (Utah State Prison) applications.

Renewed interest in geothermal research and development over the past 10 years has contributed to several technological advancements, particularly those in a synergistic relationship with the petroleum exploration industry. These advancements include improved exploration methods, downhole tools, drilling methods, and drilling equipment. Most of the UGS geothermal research has been funded by the U.S. DOE GTO (www.energy.gov/eere/geothermal) and these projects vary in scale from basin to regional extent. Most current UGS research focuses on nonconventional geothermal resources such as deep sedimentary basins and enhanced geothermal systems (EGS). The UGS is also exploring the possibility of "co-produced fluids," which is the extraction of energy from lower-temperature water associated with oil and gas wells.

Deep sedimentary basins are prevalent in the Basin and Range physiographic province of western Utah and the best studied example within Utah is the Black Rock Desert. In this setting, thick basin-fill sediments act as a thermal insulator on top of

Blundell Geothermal Power Plant situated on an alluvial fan of the Mineral Mountains near Milford, Utah.

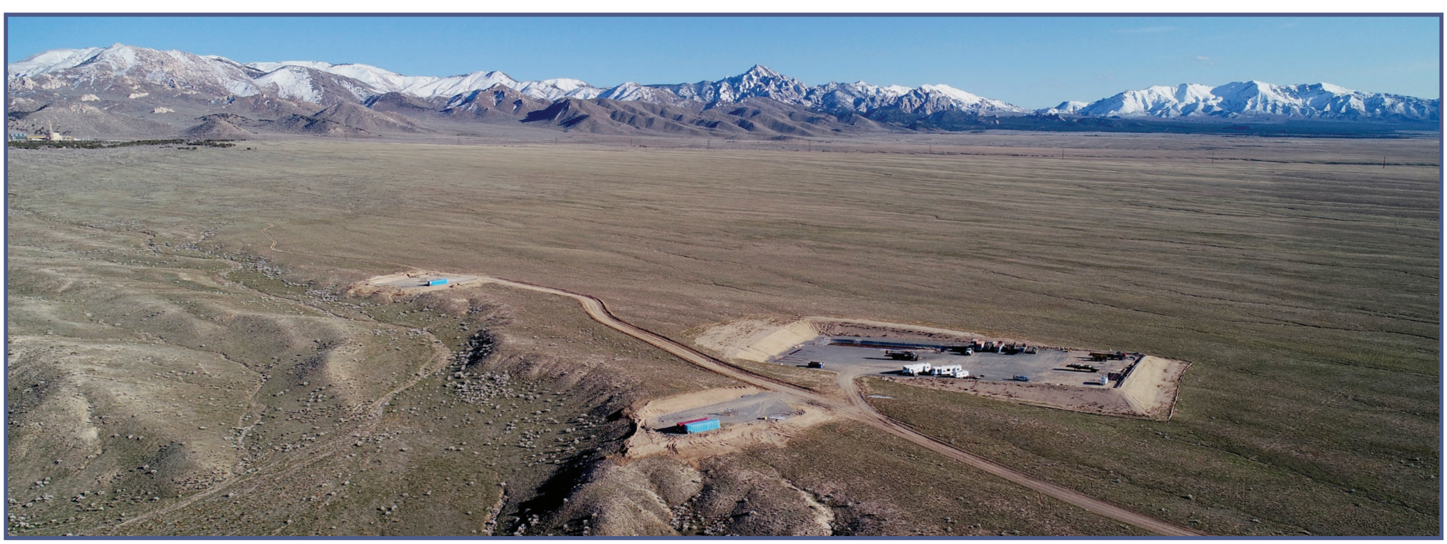


Geothermal resource map of Utah indicating active resources in use and areas of significant resource potential.

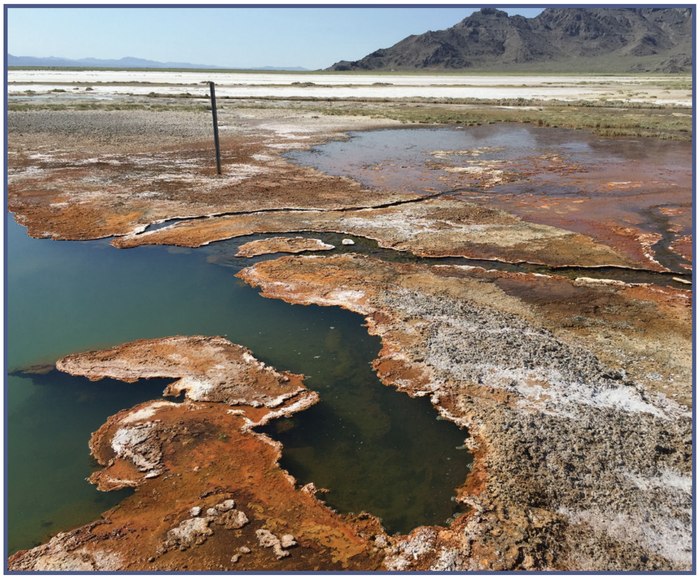
bedrock resulting in elevated temperatures at 2 to 3 kilometers (6,500 to 9,800 feet) in depth inside of sedimentary rock aquifers. Sandia National Laboratory, together with the UGS, is currently working on a GTO subsurface imaging research project in Steptoe Valley, Nevada, building upon previous UGS work in the area using novel approaches with geophysical methods. The results of this research will be used as a direct analog to the geothermal potential of Utah's Black Rock Desert.

EGS resources are typically known as "hot dry rock" and occur where high temperatures are present in subsurface rocks of relatively low permeability. EGS is the focus of the Frontier Observatory for Research in Geothermal Energy (FORGE) site near Milford, Utah—a DOE initiative, headed by the Energy and Geoscience Institute at the University of Utah, to locate and create a dedicated research laboratory where scientists and engineers can develop and test EGS technologies and techniques. The Utah FORGE project, now in its sixth year, focuses on an EGS target of tight crystalline rock that is between 175 and 225 degrees Celsius (347 to 437 degrees Fahrenheit) at 1.5 to 4 kilometers (5,000 to 13,000 feet) in depth. The goal of this project is to test and develop novel techniques to stimulate the reservoir rock, via hydraulic fracturing techniques developed by the petroleum industry, and create permeable pathways that can allow for extraction of heat energy in these rocks. The heat energy will be extracted from the hot reservoir rock by pumping natural, briny subsurface waters in a closed loop system that reinjects the slightly cooled brines after running through a power plant generator.

Geothermal resources derived from co-produced fluids can be found in the Uinta Basin of Utah and provide a unique opportunity to repurpose oil and



Aerial photograph of the FORGE site, Blundell Geothermal Power plant (top left) and Mineral Mountains in background.



Outflow of hot water (about 80 degrees Celsius [about 176 degrees Fahrenheit]) from Wilson Health Spring in Utah's west desert, one of Utah's largest hot springs by flow rate. Photo by Stefan Kirby.

gas field infrastructure and wells. A previous UGS study concluded that numerous wells in the Uinta Basin are deeper than 2 kilometers (6,500 feet) and reach temperatures more than 50 degrees Celsius (122 degrees Fahrenheit), ideal for direct-use applications. Out of a well-distributed sampling of 776 sites studied, 36 of the wells recorded temperatures greater than 140 degrees Celsius (284 degrees Fahrenheit) and could be suitable for small-scale binary power production. Preliminary thermal models of the Uinta Basin support existing interpretations that the thermal regime characteristics are more predictable and likely are uniformly spread across the basin, resulting in a larger geothermal prospect.

The UGS is also involved in the GTO-funded "Innovative Geothermal Exploration through Novel Investigations of Undiscovered Systems" (INGENIOUS) project led by the University of Nevada, Reno. The primary goal of this project is to accelerate discoveries of new, commercially viable, hidden geothermal systems while significantly reducing the exploration and development risks for all geothermal resources. This project will integrate both regional-scale reconnaissance and local-scale reservoir characterization based on numerous datasets that include Quaternary-age faults, various measures of heat and heat flow, and a range of geophysical datasets. INGENIOUS is a 4.5-year project with a budget of $10 million that anticipates drilling several test wells in Utah and Nevada to prove the existence of these resources.

Geothermal power generation and direct-use development offers significant potential to a variety of rural Utah areas, and the UGS is involved in several research initiatives that could help unlock this potential. In addition, this carbon-free, clean energy source will only increase in importance as the country moves toward more sustainable energy resources. More information about geothermal in Utah can be found at geology.utah.gov/resources/energy/geothermal.

Teacher's Corner

EARTH SCIENCE WEEK:

Hands-on Activities for School Groups

Come celebrate Earth Science Week with the Utah Geological Survey! This popular annual event features educational activities that are particularly suited for the 4th and 5th grades.

When: October 4–6 and 12–14, 2021*

Where: Utah Core Research Center in Salt Lake City

Activities:

- "Gold" panning, where students find pyrite, magnetite, and other minerals.
- Rock cycle, where students learn about igneous, sedimentary, and metamorphic rocks.
- Stream trailer, where students experiment with erosion and deposition.
- Paleontology lab, where students examine dinosaur and other fossils and learn about geologic history.
- New this year: Earthquake lab, where students learn about earthquakes in Utah, earthquake preparedness and safety, and create their own "kidquake"!

Groups are scheduled for 2-hour sessions. Reservations typically fill early; to inquire about an available time slot for your group, contact Jim Davis at jmdavis@utah.gov or 801-537-3300.

Launched by the American Geosciences Institute (AGI) in 1998, Earth Science Week is an international event highlighting the vital role earth sciences play in society's use of natural resources and interaction with the environment. For more information, please visit our web page at https://geology.utah.gov/teachers/earth-science-week/.

* Times and availabilities are subject to change depending on current COVID-19 pandemic conditions and CDC recommendations.

Where is Shaw Arch?

Glad You Asked!

How a simple question led me to a deeper appreciation of Utah's great outdoors.

by Mark R. Milligan

At the UGS we often field questions not only about Utah's geology but also about Utah's geography. The inquiries can be quite interesting, such as the one I received in 2016 when a gentleman named Kent Ahlstrom called and asked for the precise location of Shaw Arch. It is in Grand Gulch, 11 miles from the San Juan River in San Juan County. The arch is known for the amazing pictographs (painted or drawn images) and petroglyphs (carved images) found at its base. What set this inquiry apart was that Mr. Ahlstrom had not only been to the arch long ago but indicated that he was integral in naming the arch. The following is his account as recorded in my notes from our phone conversation.

Many years ago, Merlin Shaw started a youth group with the goal of taking as many youths down the Colorado River through Glen Canyon as he could before Glen Canyon Dam was completed and Lake Powell was filled. The eight-day river trips led by Mr. Shaw cost $50! Kent took the trip when in high school in 1962 or 1963. He described Glen Canyon as eight days of paradise…beautiful beaches the whole trip…they camped two nights near Rainbow Bridge, taking a day hike up to the bridge.

Tragically, Mr. Shaw died in 1963 while riding in the back of a truck that rolled when on its way to meet a river trip at the bottom of the Hole-in-the-Rock trail [a now-submerged very remote and difficult-to-reach location about 3.5 hours from Panguitch, Utah]. Several Boy Scouts also died in the accident. In 1964 Mr. Ahlstrom was among a group that hiked to a remote arch that they believed Mr. Shaw had recently discovered* and placed a placard naming it and dedicating it to him. Someone at the Bureau of Land Management (or perhaps the U.S. Geological Survey) helped with the paperwork to make this an official name.

**Other reports state that the arch was previously known locally as Grand or Wetherill Arch, after the Wetherill brothers who explored Grand Gulch in the 1890s.*

Shaw Arch, located in Grand Gulch, 11 miles from the San Juan River in San Juan County. Photo by Dana Hollister.

My conversation with Mr. Ahlstrom piqued my interest in the history of this youth group and Merlin Shaw, and an internet search soon revealed more details about Mr. Shaw. In the late 1940s he and his cousin bought a ten-man raft at a military surplus auction and started a non-profit outdoor adventure group "…for the purpose of guiding the youth and providing a meaningful relationship with nature." They named the group SOCOTWA, an acronym for the South Cottonwood Ward in the Murray area of Utah. By the mid-1950s, when plans for Glen Canyon Dam were announced, SOCOTWA was leading about a half-dozen river trips at a time and had over 30 rafts and associated equipment.

The success of SOCOTWA made the sudden loss of Merlin Shaw all the more acute. The accident happened on a steep grade out of Carcass Wash near Hole-in-the-Rock in Kane County. The engine of the large truck, carrying 38 people, stalled, causing it to roll backwards, out of control, and off the road. The truck overturned, ejecting passengers and gear and then rolling over some of them. Twelve people died, four trip leaders and eight scouts. Twenty-six more were injured, some critically. The remote location meant a slow and daunting rescue and recovery. Noted river historian Roy Webb gives many more details about SOCOTWA in a 2003 historical essay that he wrote for *The Confluence: Journal for Colorado River Guides* titled, "'Set My Spirit Free'—A History of SOCOTWA" (http://www.riverguides.org/Confluence/27/27SocotwaWebb.pdf).

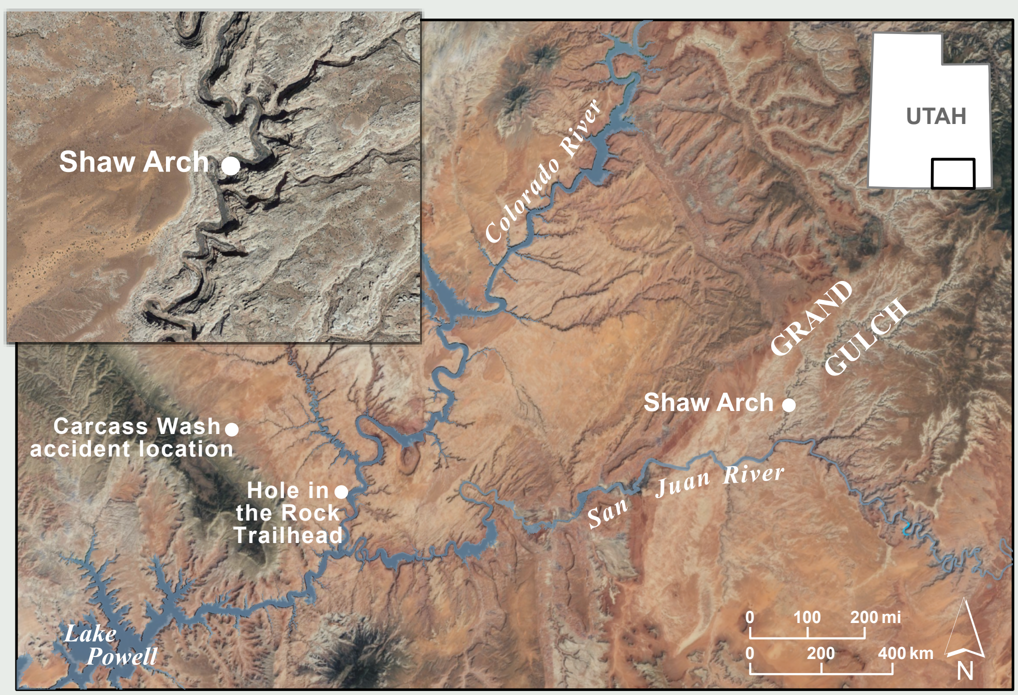
One of many petroglyphs found near the base of Shaw Arch in Grand Gulch. Photo by Dana Hollister.

> *"…dad's love of the outdoors was instilled in all of us, and we have passed that on to our children."*

Upon recently rediscovering my notes, I was wondering if this would be a good "Glad You Asked" article. I also wondered if I could find Mr. Ahlstrom to confirm and clarify the details of my notes. Sadly, my search found his recent obituary: "Alonzo 'Kent' Ahlstrom (1946–2020). Our tenderhearted dad who was fierce and adventurous was taken tragically in a car crash on Christmas Day, 2020." According to details of his obituary, in much the same way that Kent's mentor Merlin Shaw had passed on his love of the outdoors to so many, "…dad's love of the outdoors was instilled in all of us, and we have passed that on to our children."

If you are reading this, there is a good chance that you too have a passion for the outdoors. Merlin Shaw "provided a meaningful relationship with nature" to Kent Ahlstrom who in turn instilled a love of the outdoors in his children, who then passed this to their children. Be sure to hand down your passion for Utah's great outdoors.

This article was written with the approval of Kent Ahlstrom's family.



Shaw Arch, which is more specifically a natural bridge, is located at 37°21'57.0"N, 110°11'21.5"W.

Kent Ahlstrom, April 05, 1946 - December 25, 2020. Due to the COVID-19 pandemic, the family did not have a large memorial but did ask family and friends to wear a plaid shirt in his honor and post pictures on social media using #plaidfordad.

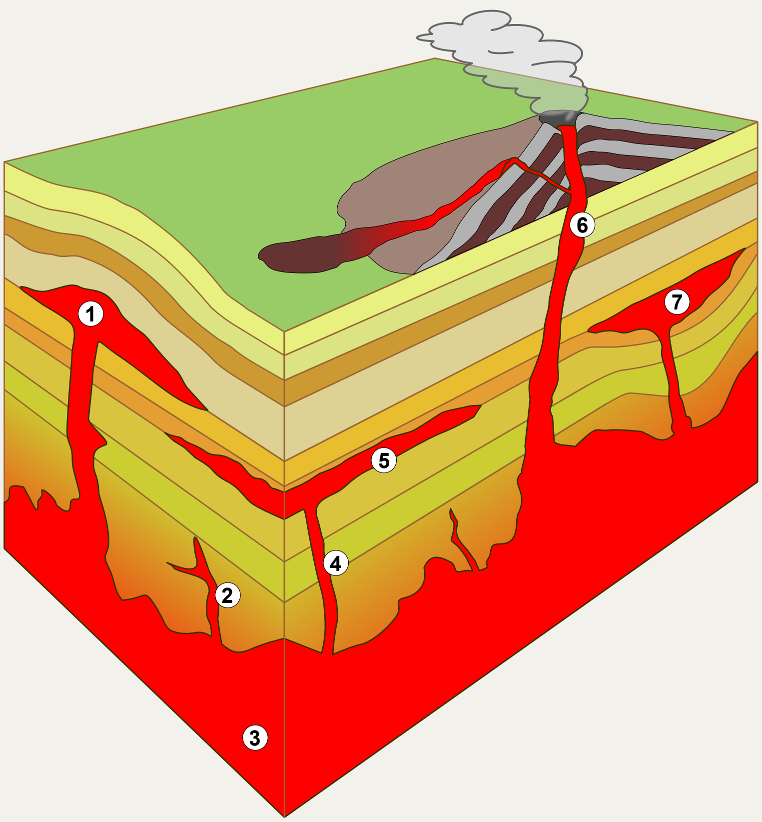
GEO SIGHTS

The Henry Mountains

by Lance Weaver

Nestled in south-central Utah is a remote mountain range which epitomizes an entire era of unique volcanism in Utah and was one of the last mountain ranges in the United States to be fully explored and mapped. In fact, these intrusive volcanic mountains were the last mountain range in the United States to be named. It wasn't until 1872 that the range was named and still three years later when the mountains were finally explored by the great American geologist G.K. Gilbert who first wrote about the incredibly unique geology of the Henry Mountains.

Utah's Henry Mountains are in Garfield and Wayne Counties east of the Waterpocket Fold between Capitol Reef National Park and Glen Canyon National Recreation Area. They are composed of about a half dozen high peaks, three of which make the list of Utah's top thirty highest. Mount Ellen at 11,522 feet above sea level is the 13th highest peak in the state. But what makes the Henry Mountains so interesting is not so much their height but their geology. Most of Utah's mountain ranges were formed from large faulted or folded blocks of sedimentary rock. The Henry Mountains, however, are one of only a few volcanic mountains in Utah that were formed by large magma chambers injected between layers of sedimentary host rock. Geologists characterize these volcanic structures that make up the Henry Mountains as "laccoliths."



Basic types of igneous intrusions: 1. Laccolith 2. Small dike 3. Batholith 4. Dike 5. Sill 6. Volcanic neck, or pipe 7. Lopolith

Note: As a general rule, in contrast to the smoldering volcanic vent in the figure, these names refer to the fully cooled and usually millions-of-years-old rock formations, which are the result of the underground magmatic activity shown. (mediawiki, GNU Free Documentation License)

Unlike a typical volcano, which forcefully ejects the contents of a magma chamber onto the surface of the earth, or a batholith, which is a very large magma chamber that cools beneath the surface, a laccolith is a sizable magma body which attempts to come to the surface through a neck or conduit but spreads horizontally between sedimentary layers on its way up, pushing the host rock layers up into a dome shape before cooling beneath the surface. As a result, the "textbook" laccolith can look a little bit like an impact crater as the surrounding dome-shaped, upwarped eroding layers of sedimentary rock often form concentric circles around the underlying magma chamber in a way that resembles the central dome of a meteor impact.

When a laccolith is pushed even closer to the surface by subsequent pressure after it cools, steep faults can form around its periphery. Geologists refer to the resulting feature with the even more specific term of "bysmalith." Table Mountain on the northwest corner of the Henry Mountains is a great example of a bysmalith feature.

The Henry Mountains formed between 23 and 29 million years ago during the Oligocene epoch when portions of subducted oceanic crust melted beneath Utah to form huge viscous masses of rising magma. During the period of about 20 to 30 million years ago, many large igneous bodies were emplaced in Utah and the surrounding region. These include the nearby laccoliths and stocks (similar to batholiths but smaller) of the Abajo and La Sal Mountains, as well as Navajo Mountain and the Pine Valley Mountains in Utah, and the La Plata Mountains in Colorado. Other large igneous intrusions were also emplaced during this time in the Wasatch Range, Oquirrh Mountains, and Pilot Range.

Most of these enormous magma bodies made their way to, or near the surface within about a 10-million-year window of time during the Oligocene and Miocene epochs.

Geologists come from all over the world to study the unique properties of Utah's laccoliths. For instance, the Pine Valley Mountains laccolith in southwestern Utah is thought to be one of the largest in the world (see *Survey Notes*, v. 34 no. 3). Its northern flanks are bordered by massive landslides which occurred when the laccolithic magma was rapidly injected into the subsurface, sufficiently steepening the ground surface and causing the overlying layers to slide off in a rapid mass-wasting event. The speed of emplacement of laccoliths like the Henry and Pine Valley Mountains is unknown, but features such as the North Pine Valley landslides suggest that laccoliths can form quite rapidly.

The Henry Mountains are also notable for the free-roaming herd of bison that live there, one of only three such herds in the country. The population was established in 1941 after relocation of 18 individuals from Yellowstone National Park. The herd is often grazing in the saddles between the central peaks of the range. The mountains are also home to antelope, mule deer, bighorn sheep, wild burros, and mountain lions. As one of the most isolated high mountain ranges in the United States, the unique geology of the Henry Mountains makes them worth the effort to explore and enjoy.

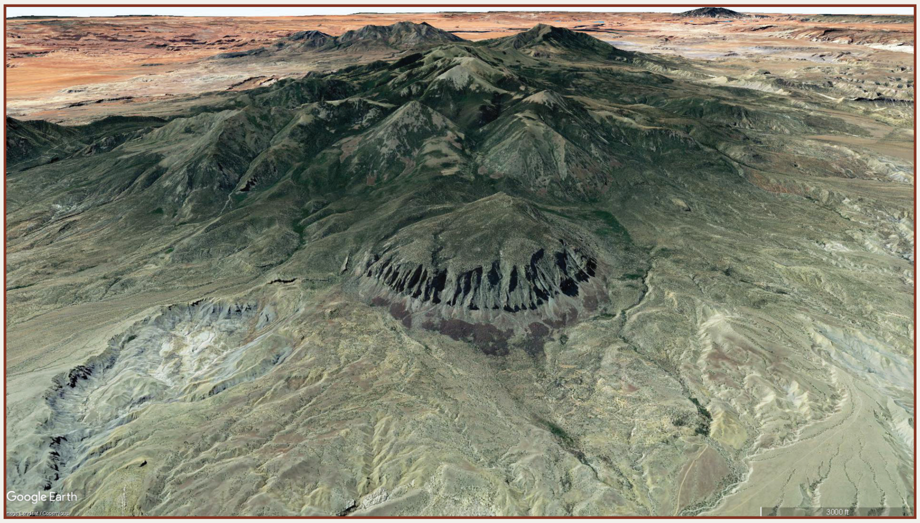
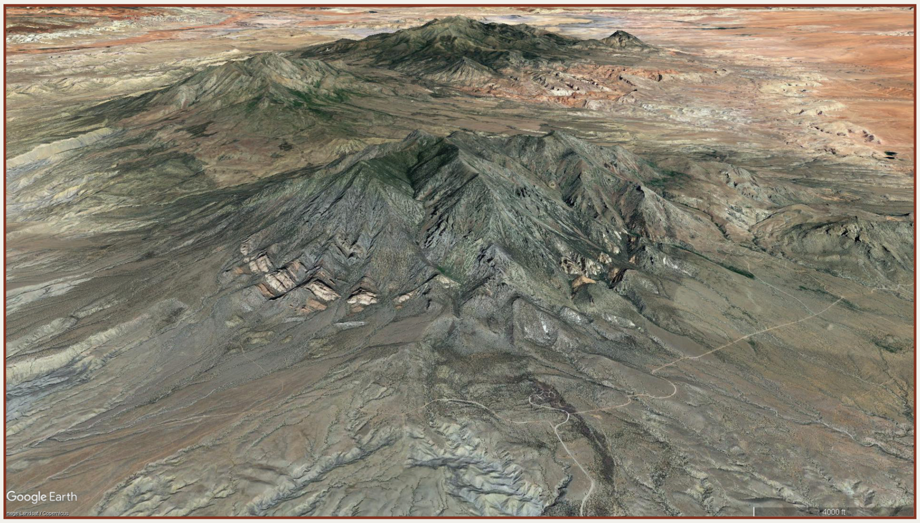


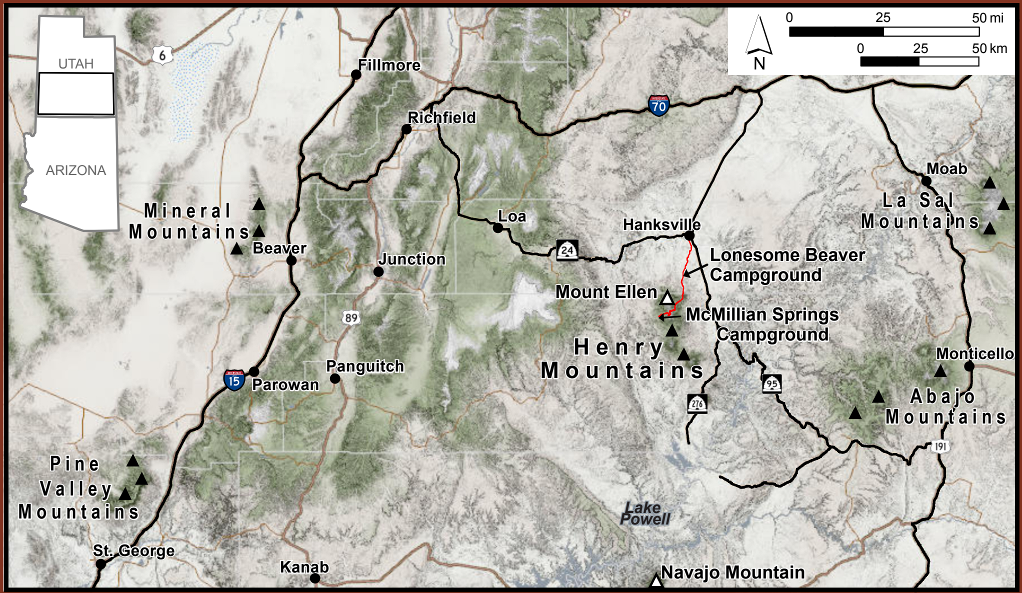
Table Mountain on the northwestern edge of the Henry Mountains is a textbook example of a laccolithic bysmalith. (Image credit. Google Earth)



View from the southeast of Mount Hillers in the central Henry Mountains. Colored bands around the periphery are Mesozoic-age sedimentary layers folded into a near-vertical attitude from the rising magma of the main igneous stock. (Image credit. Google Earth)

HOW TO GET THERE

The Henry Mountains are best accessed from the east by paved Utah State Routes 95 and 276 or from the north by Utah State Route 24. One of the best dirt access roads is accessed by traveling south on 100 East Street in Hanksville. This street becomes Sawmill Road and winds south for approximately 23 miles before reaching the Lonesome Beaver Campground. The road then gets considerably steeper and rougher as it climbs south and then west to the McMillan Springs Campground on the west slopes of Mount Ellen.



2021 Crawford Award

The Utah Geological Survey's prestigious Crawford Award was presented to **Stephanie Mills** and **Andrew Rupke** in recognition of their work on the outstanding publication, *Critical Minerals of Utah* (UGS Circular 129). Since its release in 2020, this thorough and timely summary has become the "go-to" source for current Utah-specific critical mineral information and has been used extensively by state legislators, state government agencies, trade organizations, various county organizations, universities, and others. Circular 129 has helped establish the UGS as a leader and authority in understanding these scarce and highly sought-after resources as the idea of critical minerals continues to be a very important topic at both the state and national level.

The Crawford Award recognizes outstanding achievement, accomplishments, or contributions by current UGS scientists to the understanding of some aspect of Utah geology or earth science. The award is named in honor of Arthur L. Crawford, first director of the UGS.

Employee News

Gordon Douglass retired after six-and-a-half years of service with the Utah Geological Survey and 28 years with the State of Utah. Prior to joining the UGS in 2014, Gordon worked as a geographic information system (GIS) analyst for the Utah Automated Geographic Reference Center and Rio Tinto Kennecott. While at the UGS, Gordon served as the GIS analyst for the Geologic Hazards Program and became the UGS's first GIS manager, providing critical expertise and guidance for GIS projects across the division. He also played a key role in UGS emergency response communications and activities. In retirement, Gordon plans to continue pursuing his passions for technical rock climbing, playing banjo and guitar, and serving on the ski patrol at Alta Ski Area, and we wish him all the best!

Jackson Smith and **Torri Duncan** have accepted the positions of bookstore manager and assistant manager, respectively, with the Natural Resources Map & Bookstore. Jackson has a B.S. in geology from Weber State University and previously worked as a field geologist with McKay Mineral Exploration. Torri received her B.S. in geology from Brigham Young University and has a background in geologic field research. Jackson and Torri are replacing **Brian Butler** and **Gentry Hammerschmid** who both left to pursue other career opportunities. The Energy & Minerals Program bids farewell to **Peter Nielsen** who accepted a position with the Utah Division of Oil, Gas and Mining, and the Editorial Section bids farewell to **Anna Farb** who has taken a job with the Nevada Department of Transportation. A warm welcome to Jackson and Torri, and best wishes to Brian, Gentry, Peter, and Anna.

In Memoriam

Dr. John Wallace (Wally) Gwynn, former saline minerals geologist with the Utah Geological Survey, passed away on Thursday, July 15, 2021. Wally worked at the UGS for 34 years before retiring in 2009. He spent most of his career at the UGS studying Utah's saline resources, focusing mostly on Great Salt Lake but also Sevier Lake and the bedded deposits of the Paradox Basin. He edited two comprehensive volumes on the scientific, historical, and economic aspects of Great Salt Lake, and helped the Department of Natural Resources in the formulation of a management plan for the lake. Even after retirement, Wally continued his research of brines and saline minerals of Great Salt Lake and Utah.

Digital Survey Notes

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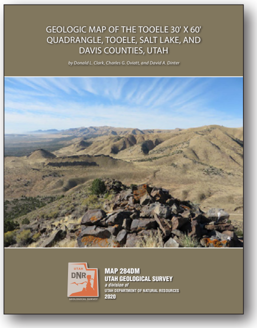
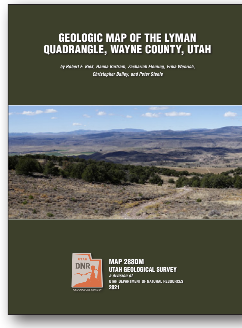
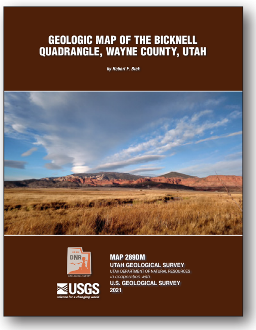
NEW PUBLICATIONS



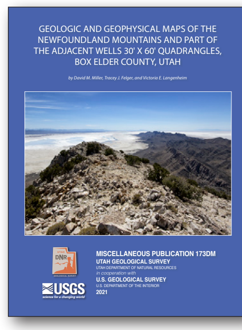
Geologic Map of the Tooele 30' x 60' Quadrangle, Tooele, Salt Lake, and Davis Counties, Utah, by Donald L. Clark, Charles G. Oviatt, and David A. Dinter, 48 p., 2 appendices, 4 plates, scale 1:62,500, **M-284DM**, https://doi.org/10.34191/M-284DM.



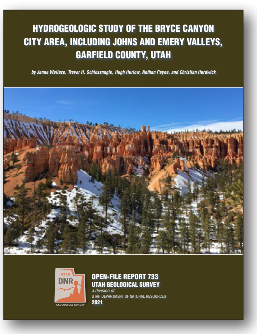
Geologic Map of the Lyman Quadrangle, Wayne County, Utah, by Robert F. Biek, Hanna Bartram, Zachariah Fleming, Erika Wenrich, Christopher Bailey, and Peter Steele, 15 p., 2 plates, scale 1:24,000, **M-288DM**, https://doi.org/10.34191/M-288DM.



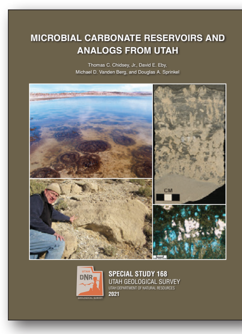
Geologic Map of the Bicknell Quadrangle, Wayne County, Utah, by Robert F. Biek, 19 p., 2 plates, scale 1:24,000, **M-289DM**, https://doi.org/10.34191/M-289DM.



Geologic and Geophysical Maps of the Newfoundland Mountains and Part of the Adjacent Wells 30' x 60' Quadrangles, Box Elder County, Utah, by David M. Miller, Tracey J. Felger, and Victoria E. Langenheim, 27 p., 2 plates, scale 1:62,500, **MP-173DM**, https://doi.org/10.34191/MP-173DM.



Hydrogeologic Study of the Bryce Canyon City Area, Including Johns and Emery Valleys, Garfield County, Utah, by Janae Wallace, Trevor H. Schlossnagle, Hugh Hurlow, Nathan Payne, and Christian Hardwick, 55 p., 6 appendices, 2 plates, scale 1:62,500, **OFR-733**, https://doi.org/10.34191/OFR-733.



Microbial Carbonate Reservoirs and Analogs from Utah, by Thomas C. Chidsey, Jr., David E. Eby, Michael D. Vanden Berg, and Douglas A. Sprinkel, 112 p., 14 plates, 1 appendix, **SS-168**, https://doi.org/10.34191/SS-168.

Available for download at **geology.utah.gov** *or for purchase at* **utahmapstore.com**.

RECENT OUTSIDE PUBLICATIONS

BY UGS AUTHORS

Spring Origin of Eocene Carbonate Mounds in the Green River Formation, Northern Bridger Basin, Wyoming, USA, by **E.A. Jagniecki**, T.K. Lowenstein, R.V. Demicco, M. Baddough, A.R. Carroll, B.L. Beard, and C.M. Johnson: Sedimentology, v. 68, https://doi.org/10.1111/sed.12852.

A Non-Averostran Neotheropod Vertebra (Dinosauria: Theropoda) from the Earliest Jurassic Whitmore Point Member (Moenave Formation) in Southwestern Utah, by A.D. Marsh, A.R.C. Milner, J.D. Harris, **D.D. DeBlieux**, and **J.I. Kirkland**: Journal of Vertebrate Paleontology, https://doi.org/10.1080/02724634.2021.1897604.

Differentiating Early from Later Diagenesis in a Cretaceous Sandstone and Petroleum Reservoir of the Cedar Mountain Formation, Utah, by C. Robertson, G.A. Ludvigson, R.M. Joeckel, S. Mohammadi, and **J.I. Kirkland**, Rocky Mountain Geology, v. 56, no. 1, p. 19–36, https://doi.org/10.24872/rmgjournal.56.1.19.

Onshore Groundwater Spring Carbonate Mounds to Lacustrine Microbialites, the Perplexing Record of a Transitional Great Salt Lake Carbonate Shoreline at Lakeside, Utah, by P. Homewood, M. Mettraux, **M.D. Vanden Berg**, A. Foubert, R. Neumann, D. Newell, and G. Atwood: The Depositional Record, https://doi.org/10.1002/dep2.148.

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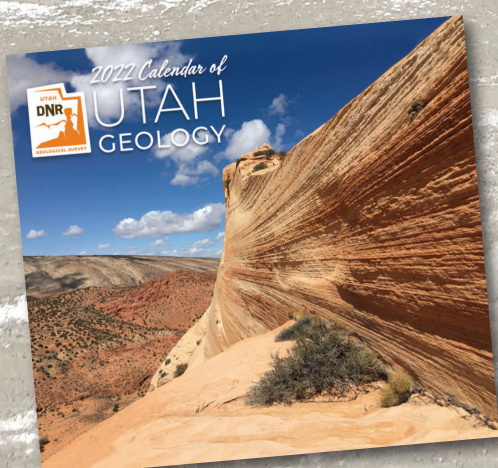

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