UTAH GEOLOGICAL SURVEY

SURVEY NOTES

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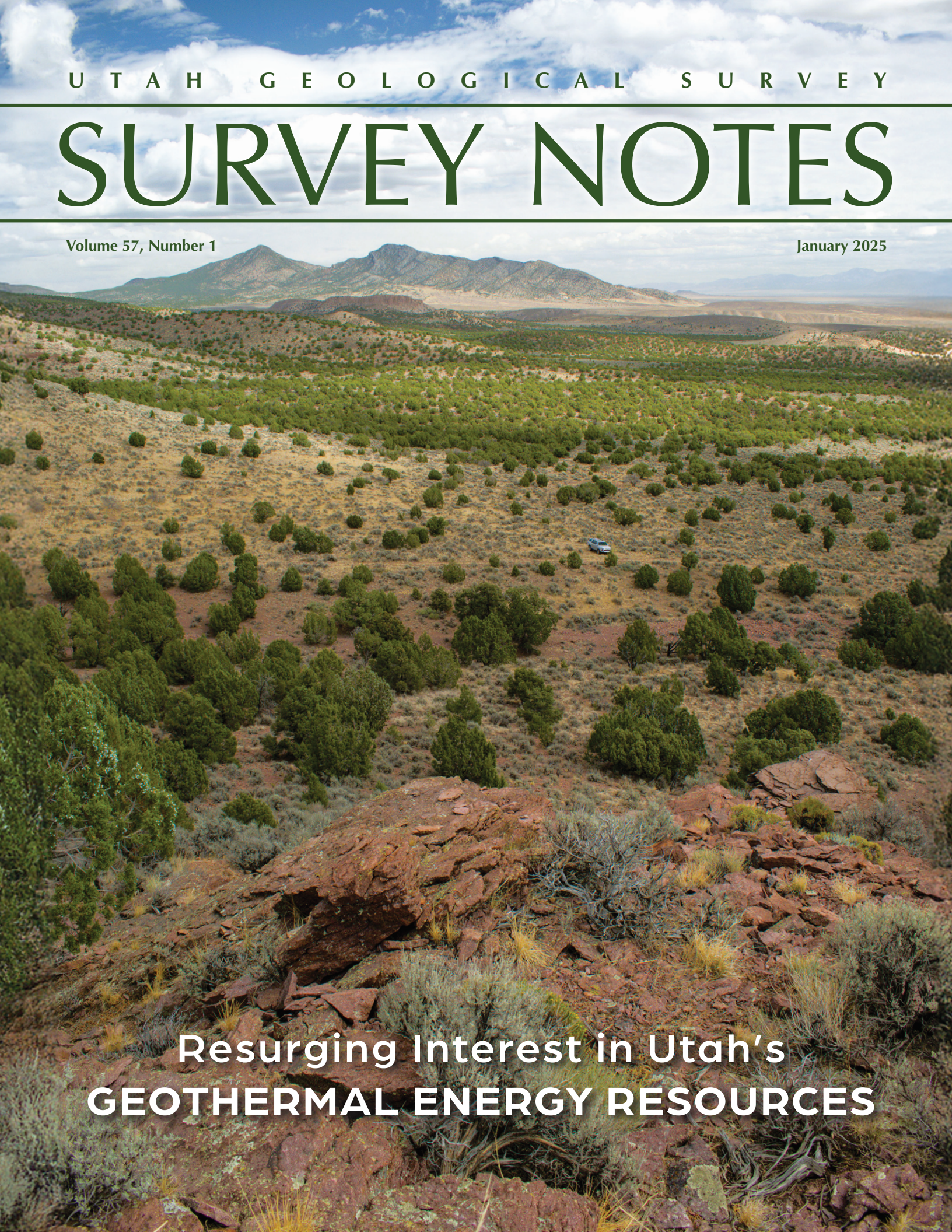

Resurging Interest in Utah's GEOTHERMAL ENERGY RESOURCES

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Design | *John Good*
Cover | Blue Mountain, where the UGS is conducting geothermal resource reconnaissance. View looking north from the southernmost Wah Wah Range in Beaver County.

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DIRECTOR'S PERSPECTIVE

by Bill Keach

"Just the facts."

Some of you may remember the old TV show (and later a movie) *Dragnet* and the detective who was only interested in "just the facts." Like that detective, we all appreciate the value of good information, particularly on important issues. Geoscientists at the UGS are also like detectives in search of facts about the natural world around us, and over the past six years I have come to appreciate the quality and the value of the science they provide. The UGS is the go-to institution for factual information on a wide range of geoscience topics that matter to the well being of Utah.

As 2025 begins, a couple of hot topics to watch are *water* and *energy* as growth in our state brings demand for more of both. The UGS is intimately involved in providing science-based information that will help the State navigate both of these topics. In the past year we have participated in and published critical research on groundwater and energy, and two new authoritative resources having current information for these high priority issues were added to our website this year.

The **Groundwater Data Hub** offers interactive maps along with the ability to download comprehensive Utah groundwater data, including GIS datasets, well trends, and current research. The studies and reports by the UGS and agency partners cover a variety of groundwater-related topics such as Great Salt Lake, watershed restoration, and more!

The **Utah's Energy Resources Web Experience** highlights Utah's diverse energy portfolio using interactive maps, charts, and imagery. Current topics include coal, natural gas, petroleum, solar, hydroelectric, biomass, wind, and geothermal. More topics will be added in the future.

In addition to the release of these web-based data resources, the UGS completed multiple groundwater studies that were published and presented to the public, including "Groundwater of Pahvant Valley, Millard County, Utah" (Special Study 173) and "Characterization of Groundwater in Johns and Emery Valleys, Garfield and Kane County, Utah, with Emphasis on the Groundwater Budget and Groundwater–Surface-Water Interaction" (Special Study 172).

Other examples of the amazing work UGS staff completed this past year include working on hazard mitigation using data collected via drone near Marysvale after the Silver King fire, and completing and publishing nine new geologic maps. Two of these are updated maps in the greater Salt Lake City area.These maps provide geologic insights for city planners, developers, citizens and consultants that will allow them to properly mitigate varied geologic hazards. In the coming year we will be working with the Navajo Nation to map a quadrangle on reservation lands.

The number of visits to our website last year was more than 1.2 million views, which shows that the next time you need "*just the facts*," look to the great science of the UGS.

Many thanks to **Sam Quigley** for his many years of service to the Board of the Utah Geological Survey from 2015–2024. A warm welcome to our newest Board member **Neil Burk** who brings his expertise in groundwater resources.

Resurging Interest in Utah's Geothermal Energy Resources

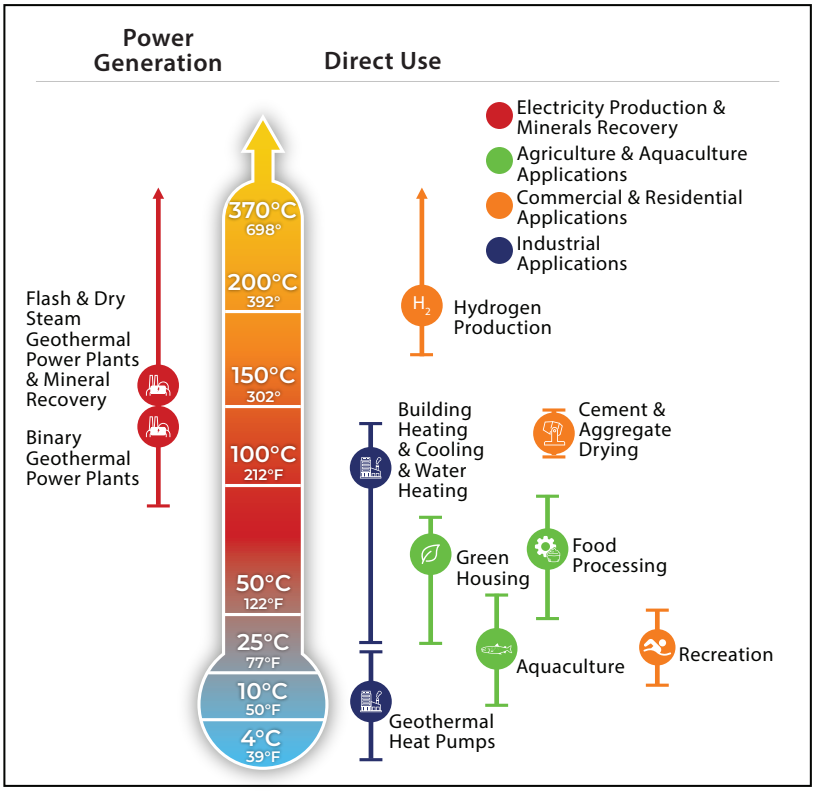
by Eugene Szymanski, PhD and Christian Hardwick

Utah is a state naturally gifted with bountiful geothermal energy resources. Our location along the eastern boundary of the Great Basin, a physiographic region defined geologically as having abundant geothermal heat close to the Earth's surface, is fortunate for our population since geothermal energy is a renewable, mostly carbon-neutral, domestic resource that can produce electricity 24 hours per day, seven days per week. Utah has historically harvested this "heat from the earth" and is one of only seven states that generates electricity from geothermal resources, contributing about 1% to Utah's total electricity generation mix. And while Utah's geothermal power plants have a present capacity of 73 megawatts (MW), that is only 0.1% of the total estimated undeveloped potential of 49,400 MW, indicating that geothermal energy resources within our borders hold practically unlimited potential to power our electricity needs well into the future.

However, geothermal energy is useful for much more than just utility-scale commercial electricity generation. Geothermal heat manifests naturally at a range of different temperatures beneath the Earth's surface; high-temperature sources are used for electricity production whereas relatively low-temperature sources may be leveraged for "direct-use" applications wherein heat is used directly in agricultural, industrial, commercial, and residential sectors. For example, heat anomalies in the shallow subsurface may be plumbed to bring geothermal water to the surface for uses such as radiantly heating agricultural greenhouses (examples in Utah are found in Newcastle, Iron County, and Pleasant View, Weber County), maintaining favorable ambient water temperatures in raceways for farm-raised fish, and residential space heating in the form of both in-room radiators that carry warm water directly and heat exchangers that extract geothermal energy from the ground and then convert it to warm air that heats homes, businesses, and public buildings.

Most of the known geothermal resources in Utah occur along the transition from the Colorado Plateau to the Basin and Range Province, and the Utah Geological Survey (UGS) has a strong record of discovering and assessing the scale of geothermal energy resources in the state, including aiding Utah's first electric utility resource (Blundell) to come online in 1984. As geoscientists, we interpret geological evidence for geothermal systems, publish seminal data and interpretive articles to support development by private industry, and champion the growth and application of this natural resource at all scales. Multiple avenues of research are underway by the UGS to better understand where else this valuable and under-utilized energy resource is located and how it can be used for the benefit of all Utahns.

The UGS published their first hydrothermal-related special studies in 1963 (https://doi.org/10.34191/SS-4; https://doi.org/10.34191/SS-6), and the first assessment of Utah's geothermal power potential followed in 1966 (https://doi.org/10.34191/SS-14). Since then, the UGS has been involved with more than 150 scientific publications on geothermal resources. The foundational geological and geophysical data products that supported the original publications (e.g., geologic maps, groundwater studies, and well/spring databases) have been updated and enriched continuously throughout the years and have been leveraged by both academia and the private sector for geothermal resource assessment. Improved and expanded data products include statewide magnetic and gravity data networks (see *Survey Notes* v. 50, no. 2) that collate legacy data with novel collection points to create useful maps of various scales statewide. The *Utah Geological Survey GeoData Archive* (https://geodata.geology.utah.gov/) serves as the main clearinghouse for all quality assured geophysical data and information while complementary UGS data resources are actively being developed and publicly released.

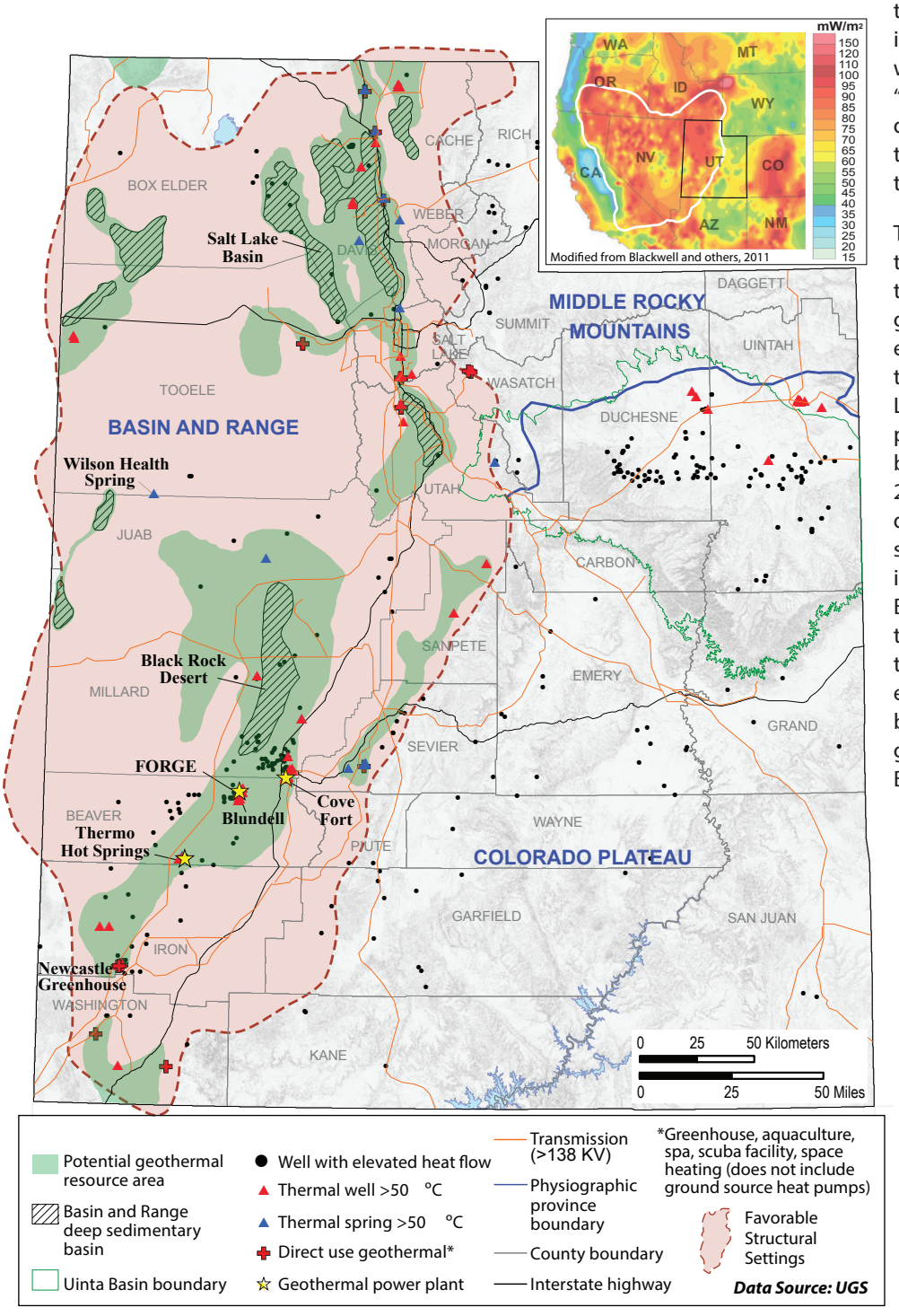


Direct steam and flash steam power plants use the highest temperature resources (>175°C). Binary phase power plants can operate at lower temperatures. Direct-use applications, below 100°C, include agriculture and aquaculture applications, building heating and cooling systems, and recreational use. Adapted from U.S. Department of Energy (2019).

The UGS has been involved in state-of-the-art science and methods to identify and better understand both conventional and unconventional geothermal resources in Utah. Research conducted on sedimentary-hosted geothermal systems throughout western Utah and the eastern Great Basin identified unconventional reservoirs with temperatures of 350°–400°F (175°–200°C) at depths of 10,000–13,000 feet (3–4 km) that can support several power plants in excess of 100 MW, providing a significant contribution to the state's energy portfolio. UGS research on water in the Uinta Basin (produced as a byproduct of oil and gas extraction) shows that ~97% of the 776 wells analyzed exceed standard direct-use temperature requirements (>120°F/50°C) and 5% of those are capable of geothermal electric power production (>285°F/140°C), providing an avenue to utilize wastewater and repurpose existing well infrastructure all through the area.

In 2018, the U.S. Department of Energy (DOE) committed $220 million to research and development at the Utah Frontier Observatory for Research in Geothermal Energy (FORGE) site in Milford, Utah, which is actively working to successfully produce geothermal electricity from hot, low-permeability crystalline rock and demonstrate new technologies, many from the oilfield, for enhanced geothermal systems (EGS). In 2024, the DOE committed another $80 million to research at the FORGE site to continue the project through 2028. Additionally, Utah benefitted directly from federal investment in FORGE in the form of economic gains. In September 2023, Fervo Energy leased land adjacent to FORGE and announced plans to develop a 400 MW power plant called Cape Station that will produce around-the-clock, carbon-free electricity beginning in 2026. Developing the same EGS play that was proven by FORGE, Fervo claims that "Cape Station will provide roughly 6,600 jobs during construction and 160 full-time jobs throughout its operations, generating more than $437 million in earned wages".

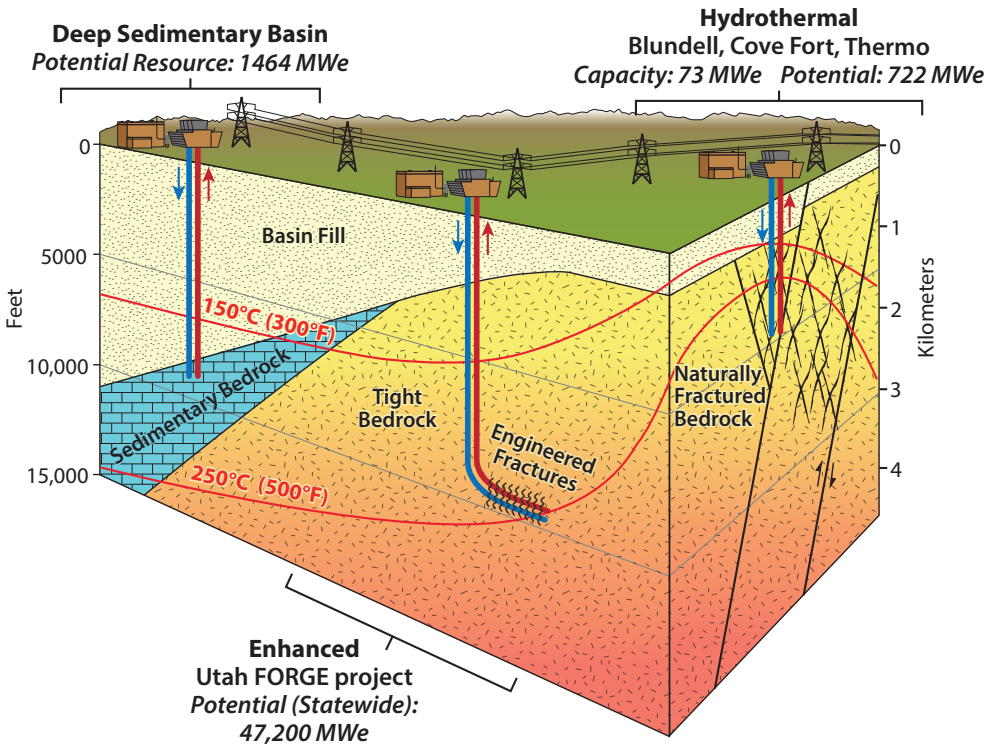
The UGS served as a key scientific partner to the Energy and Geoscience Institute (EGI) in the early competitive phases of the FORGE grant producing critical research works, eventually landing FORGE in Utah. In 2020, the UGS was involved in a DOE, National Laboratories-funded project that built upon previous geothermal research conducted by the UGS and partners (going back to 2010), which leveraged existing and new datasets to identify favorable localities for sedimentary-hosted geothermal resources in deep, sedimentary basins such as the Black Rock Desert of Utah. In 2021, as part of the DOE INnovative Geothermal Exploration through Novel Investigations Of Undiscovered Systems (INGENIOUS) project, the UGS began work supporting a multidisciplinary geothermal resource analysis of the Great Basin to develop input datasets and analysis



Most of the known geothermal resources in Utah occur along the transition from the Colorado Plateau to the Basin and Range Province. Resources in current use include direct-use and power generating geothermal resources. The green regions show well-characterized areas where new resources can be developed. The pink region outlines a part of the Great Basin that has potential prospects defined by surface fault architecture. The black dots are wells that have elevated heat flow measurements, indicating a potential for geothermal resource. The Black Rock Desert has the most attractive potential for future development.

techniques to target blind geothermal systems, which are geothermal resources with no surface expression like hot springs. More recently, the UGS has been working closely with academia and private industry on multiple research collaborations on geothermal grants from the DOE and the National Science Foundation.

These research programs will help advance geothermal development in Utah, however, exploring for and identifying viable subsurface resources is a time-consuming and costly endeavor, and one that takes teamwork from geoscientists possessing a variety of specialties. The geothermal industry is vying for geothermal development opportunities, however, our insights from working with industry partners is that they require a minimum dataset to "prove" viability before investing in onsite exploration and development. To aid exploration and entice further investment by the private sector, the UGS is requesting a one-time $5 million Geothermal Research Initiative appropriation from the Utah State Legislature to expand its holistic scientific program to collect, interpret, and publish valuable geothermal resources data across Utah's part of the Great Basin and other statewide focus areas. Sufficient support will allow the UGS to continue setting the pace for understanding the "heat beneath our feet" and make use of our massive undeveloped geothermal resource potential, all while decarbonizing the energy sector, supporting rural communities, and generating new economic opportunities across the state.



Types of geothermal systems found in Utah and their respective resource potential.

Further Reading:

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4. Idaho National Laboratory, 2006, The future of geothermal energy: impact of enhanced geothermal systems (EGS) on the United States in the 21st Century, https://www1.eere.energy.gov/geothermal/pdfs/future_geo_energy.pdf.

ABOUT THE AUTHORS

Dr. Eugene Szymanski is a Senior Geologist in the UGS Energy & Minerals Program and a licensed Professional Geologist in Utah, with 14+ years of professional experience in basin analysis, landscape evolution, and chronostratigraphy. Eugene currently leads several DOE-funded initiatives that focus on energy resources including the geothermal energy-focused INGENIOUS project in the Great Basin, carbon management projects at the Iron Mountain Mine in Iron County, Utah, and a direct-air capture feasibility project in the Milford Valley in partnership with Houston-based Fervo Energy. He holds an Adjunct Faculty appointment at The University of Kansas, works synergistically with many academic groups and analytical laboratories, and enjoys serving on Geological Society of America committees.

Christian Hardwick is a Senior Geophysicist and Geologist who joined the UGS in 2011. He has 15+ years of experience globally in geothermal geophysics, is the Geothermal Section manager within the Energy & Minerals Program, and provides geophysical support for the Groundwater, Hazards, and Geologic Mapping Programs. Christian specializes in applied geophysical research methods of gravity, electromagnetics, and thermal fields integrated with geology in a multidisciplinary approach. He has a B.S. in geoscience and an M.S. in geophysics from the University of Utah. He maintains that while having abundant data can be favorable, it is crucial to have the right data to better understand our natural resources and the management of such.

UTAH–The Geoheritage State

by Mark Milligan, Jim Davis, Mackenzie Cope, and Stefan Kirby

The Old Paria townsite and movie set in the Grand Staircase Escalante National Monument, Kane County, is a strong candidate for geoheritage designation.

Geoheritage sites are significant geologic features, landforms, and viewscapes that are valuable for scientific research, outdoor classrooms, education, and public enjoyment. These sites are important to preserve for the worth that society places on them, including scientific, aesthetic, cultural, ecosystem, education, recreation, and tourism. The Utah Geological Survey (UGS), as part of a U.S. Geological Survey STATEMAP grant, is inventorying and ranking potential geoheritage sites in Utah to assist and promote the recognition and protection of these areas.

Our inventory process started by compiling a database of places or geologic-related features that might fit the criteria of a geoheritage site. We added sites from existing sources such as *Survey Notes*' "GeoSights" and "Rockhounder" (which preceded "GeoSights") articles, the Utah Geological Association's (UGA) publication *Geosites*, and an inventory of geologic road signs. We also solicited UGS staff to help brainstorm for suitable sites. To gather ideas from the public we crowdsourced potential sites at the 2024 Geological Society of America Joint Cordilleran and Rocky Mountain Section Meeting by setting up an exhibitor's table, creating a poster, and handing out fliers with a QR code link to a survey that allowed attendees to recommend sites. We continue to solicit input, and readers can recommend potential sites by completing our brief survey below.

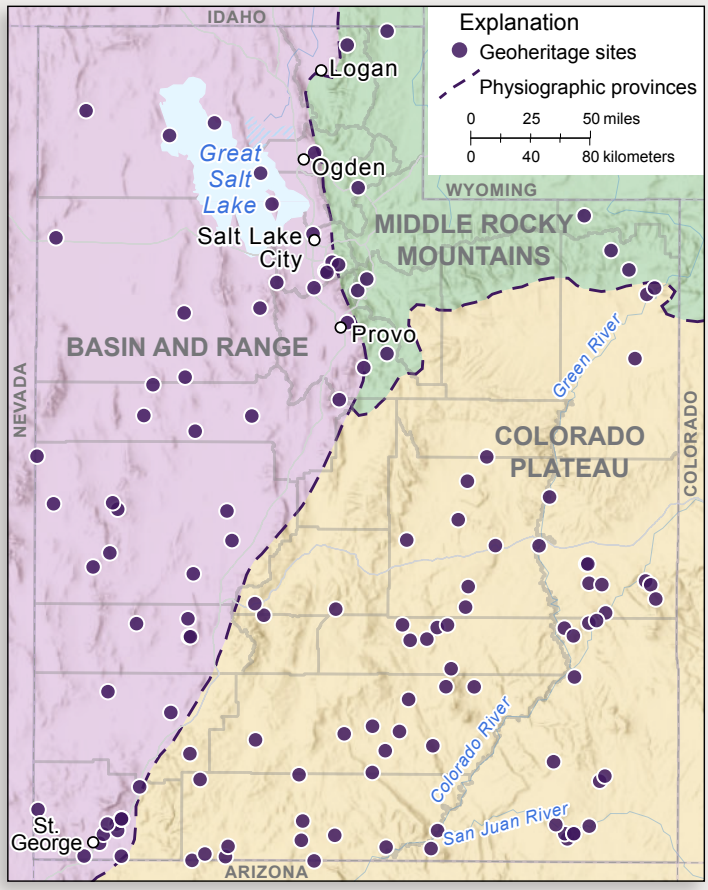
Utah is a geologic wonderland. Its diverse landscapes with outstanding rocky outcrops make Utah a treasure trove of prospective geoheritage sites. As you might guess, our all-inclusive list is long, having 734 locations and counting! However, we have begun to create a shorter and more tenable list. This process began by deleting redundancies (e.g., Thistle Landslide is featured in a UGS "GeoSight" article and is also on the UGA road sign list) and any entries that did not qualify based on the ranking attributes described below. The current shortlist contains 128 sites and includes a wide array of geologic and geomorphic feature types, such as canyons, water features, pinnacles, volcanic features, mines, mineral collecting areas, geothermal sites, cultural features, and many others.

All potential sites in our dataset include: name, brief description, latitude and longitude coordinates, basic lithology, geologic age, land ownership, and additional notes. For the current shortlist, we are assigning a 1 to 5 rank for the following attributes: scientific, educational, cultural, economic, and aesthetic value. Sites are also being assigned a low, medium, or high value for threat of significant alteration or destruction, social significance, and proximity to other sites. For example, the attributes and scoring for the Bonneville Salt Flats made it one of our top 5 ranked sites thus far.

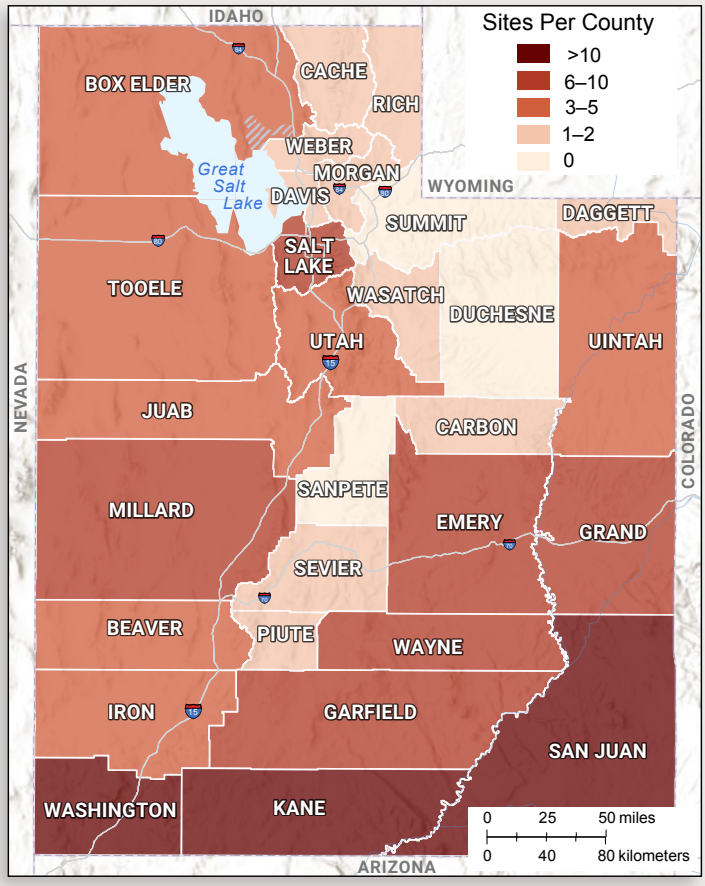
Site ID	Name	Description	Latitude	Longitude	Lithology and Age	Land Ownership	Scientific Value	Educational Value	Cultural Value	Economic Value	Aesthetic Value	Total Score	Threat/ Sensitivity	Social Significance	Proximity to Other Sites	Notes
G-008	Bonneville Salt Flats	Large Salt Pan	40.76	-113.89	Holocene playa salts	BLM State Private	3	3	4	5	5	20	High	High	Low	Movies, commercials, land speed records, archery, model rockets

The Bonneville Salt Flats, the largest salt flats in North America, has been the setting for land speed records and numerous Hollywood films, television shows, and commercials. The salt flats have also been declining and are at risk of further deterioration. For more information see https://doi.org/10.34191/PI-106 or https://geology.utah.gov/bsf-research.

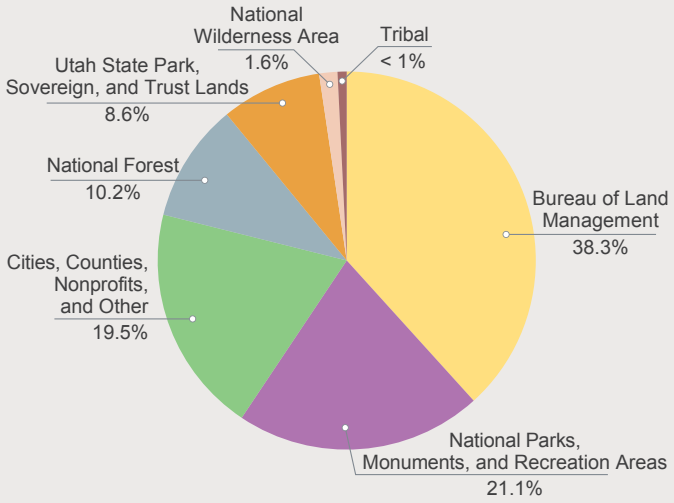
Potential geoheritage sites are distributed across the state and Utah's three physiographic provinces. Surprisingly, thus far we have fewer sites in the Rocky Mountains than the Basin and Range, with the Rocky Mountains having 10 of the sites on our list, Basin and Range having 51, and Colorado Plateau having 67. This distribution may be attributed to the relative geographic expanse of each province. Within Utah, the Basin and Range is much larger than the Rocky Mountains. However, there are many amazing outcrops and features in the Wasatch Range and Uinta Mountains that may have been missed.



Most Utah counties contain at least one potential geoheritage site, with some notable exceptions shown on the map below.



Potential geoheritage sites are located on federal, state, tribal, county, city, and non-profit owned lands. Some sites have multiple landowners. Any potential sites on tribal or private lands will need owner approval before listing or assigning any future designation.



The UGS is not the only organization that has considered Utah sites worthy of geoheritage designation. The International Union of Geological Sciences' extensive list of world Geological Heritage Sites includes three in Utah: Great Salt Lake, the Henry Mountains, and The Carnegie Quarry Exhibit Hall, situated in Dinosaur National Monument. For more information on these sites visit https://iugs-geoheritage.org/.

This project is a work in progress. We look forward to receiving additional site recommendations from the public, completing our list and rankings, and posting our data and conclusions on the UGS website by the end of 2025.

Submit Geoheritage Sites!

We need your help in identifying more Utah sites for potential geoheritage designation. If you have a site to nominate, please fill out the survey with the site's name, its map location, and a brief explanation of why you believe it could be a geoheritage site. Scan the QR code or go to geology.utah.gov/submit-geoheritage to submit your suggestions.

Lake Blanche, a possible geoheritage site, lies in a glacial cirque in the Wasatch Range, Salt Lake County.

Update on Utah's Earthquake Early Warning Efforts

by Steve D. Bowman

Utah ranks 4th in the U.S. for having severe seismic risk. About 85% of Utah's residents, infrastructure, and economy are concentrated within 15 miles of the state's most active fault, the Wasatch fault, making the Wasatch Front the highest risk area in the state. A recent publication (*Earthquake Probabilities for the Wasatch Front Region in Utah, Idaho, and Wyoming*; https://doi.org/10.34191/mp-16-3) reported that Utah has more than a 50% chance of a large magnitude 6.5 or greater earthquake occurring along the Wasatch Front within the next 50 years. This paper also reported that the Wasatch fault can generate an earthquake as large as a magnitude 7.6! A large earthquake (6.5 magnitude or greater) would be devastating to our homes, businesses, infrastructure, and livelihoods, with effects that would last for several decades. Although Utah does not currently have an earthquake early warning (EEW) system (see *Survey Notes* v. 47, no. 3), equipment and infrastructure are in place that make implementing a system a feasible reality with appropriate upgrades.

An EEW system uses a network of seismograph stations to detect earthquakes and provide residents with seconds to minutes of warning ahead of strong ground shaking, which could be enough time to act (such as temporarily shutdown machinery and critical infrastructure like trains, open fire station truck doors, "Drop, Cover, and Hold On," etc.). The University of Utah Seismograph Stations (UUSS), in partnership with the U.S. Geological Survey (USGS), has over 200 seismograph stations deployed across Utah. Using this seismograph network system, the UUSS generates public alerts and information after an earthquake event. However, the current system is not intended or designed to work as an early warning system.

Currently, an EEW system known as ShakeAlert (https://www.usgs.gov/programs/earthquake-hazards/science/early-warning) is in operation along the West Coast of the U.S. This system was built and implemented by the USGS in partnership with the states of California, Oregon, and Washington and began operation in 2021. Due to the severe seismic risk in Utah, multiple agencies, researchers, businesses, and residents have asked if an EEW system could be built in Utah.

The Utah Legislature, in the 2022 General Session, appropriated funding to the Utah Earthquake Program (https://earthquakes.utah.gov/ussc/earthquake-program) to study the feasibility of implementing an EEW system in Utah. The Utah Geological Survey (UGS) collaborated with the Utah Division of Emergency Management and the UUSS to generate a report detailing

1. When a fault ruptures and creates an earthquake, the fault sends out different types of seismic waves. The fast-moving, but less damaging, P-wave is the first to arrive. This wave is used to issue a warning before the slower but more damaging waves (S-wave and surface) arrive.
2. Sensors detect P-waves and immediately transmit data to an earthquake alert center.
3. The location, size, and estimated shaking of the earthquake are determined at the earthquake alert center.
4. A message is sent to partners, such as transportation agencies, emergency facilities, and hospitals, to alert people to Drop, Cover, and Hold On as well as trigger automated actions, such as shutting down a train or halting industrial processes.

Illustration showing how an earthquake early warning system could work in Utah. From Bowman et al., 2023, On the feasibility of implementing an earthquake early warning (EEW) system in Utah: Online, doi.org/10.34191/EEW-2023.

what is needed to build and implement such a system in our state. Research for the study consisted of

(1) reviewing the history and development of EEW systems within the U.S. and around the world,

(2) assessing the potential performance of an EEW system in Utah,

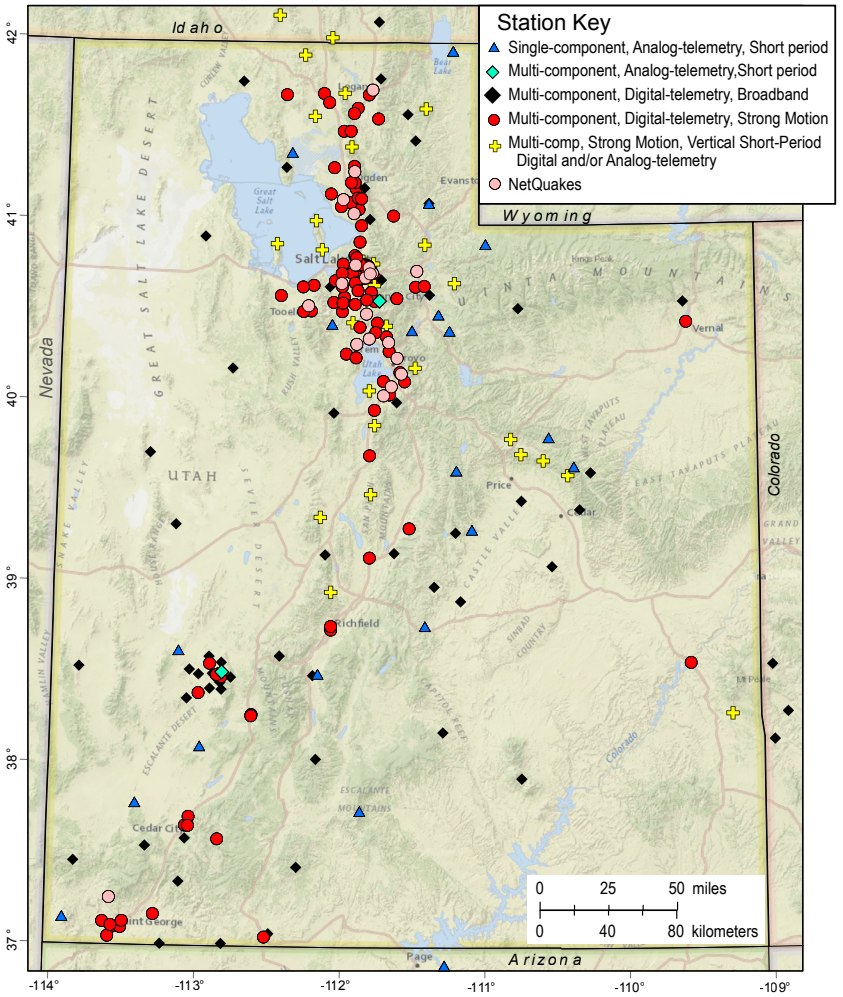
(3) determining what enhancements to the existing UUSS seismic network would be needed to implement an EEW system, and

(4) conducting an online survey of various Utah stakeholders to assess their knowledge of and potential interest in an EEW system.

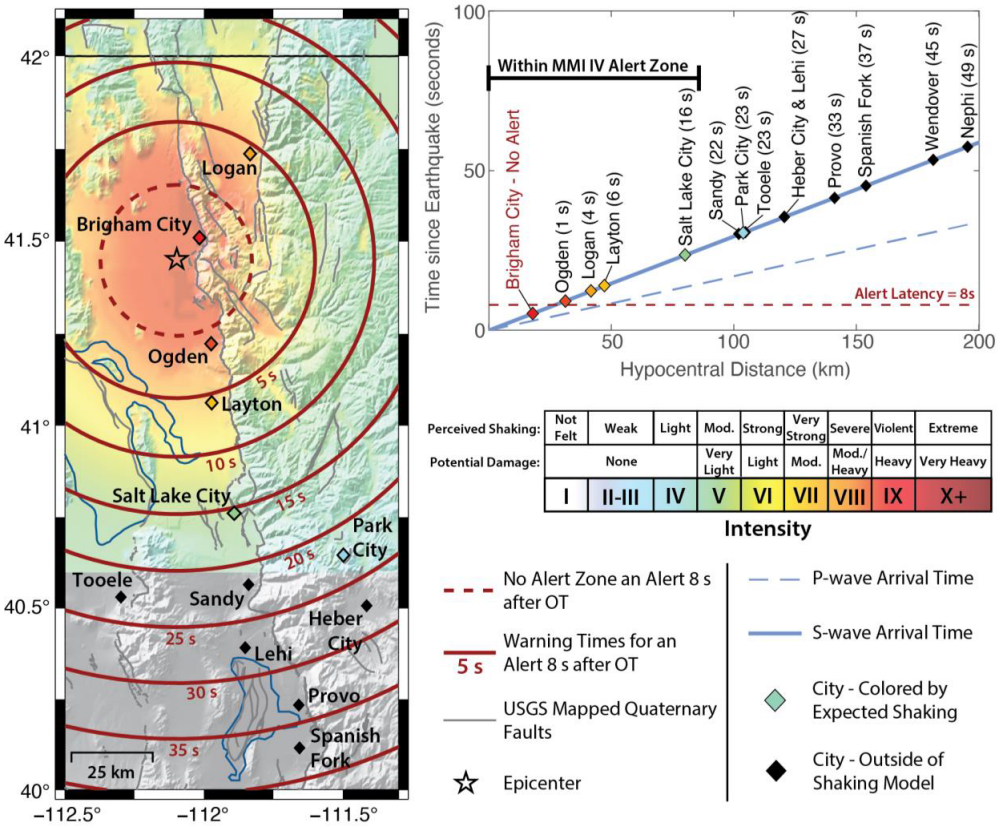
The report (https://doi.org/10.34191/eew-2023) was completed in November 2023 and found that an EEW system would be practical along the Wasatch Front and elsewhere in Utah.

Subsequently, the UGS requested $5 million in one-time (for construction) and $1 million in on-going (for operation) funding from the Governor's Office to begin building and implementing a system in Utah. However, due to estimates of slower economic growth anticipated at that time, the funding was not included in the Governor's 2024 budget proposal to the Utah Legislature, although the Legislature approved $40 million in funding for earthquake-related aqueduct improvements to protect vital infrastructure.

This year, the UGS's request for $5 million in funding for an EEW system has been included in the 2026 Governor's budget proposal, for consideration by the Legislature. If funding is approved, it will be used to upgrade the existing seismograph network in preparation for developing an EEW system in Utah that would provide a warning to Utahans immediately before a major earthquake is felt.



Locations of UUSS seismograph stations in the Utah region as of 23 March 2023. Stations that meet the requirements for use in EEW systems include broadband (black diamonds) and strong motion (red circles and yellow plus symbols). From Bowman et al., 2023, On the feasibility of implementing an earthquake early warning (EEW) system in Utah: Online, doi.org/10.34191/EEW-2023.



Warning time scenario if a magnitude 7 (M7) earthquake occurred on the Brigham City segment of the Wasatch fault zone. The red circles show how much warning time would be provided at that location before shaking begins. The dashed red circle is the "no-alert zone" for an alert latency of eight seconds. Colors indicate the maximum intensity of expected shaking caused by "shear wave" energy created by the earthquake. OT = origin time. From Bowman et al., 2023, On the feasibility of implementing an earthquake early warning (EEW) system in Utah: Online, doi.org/10.34191/EEW-2023.

What is the Salt Lake Base and Meridian?

by Jay Hill

Glad You Asked!

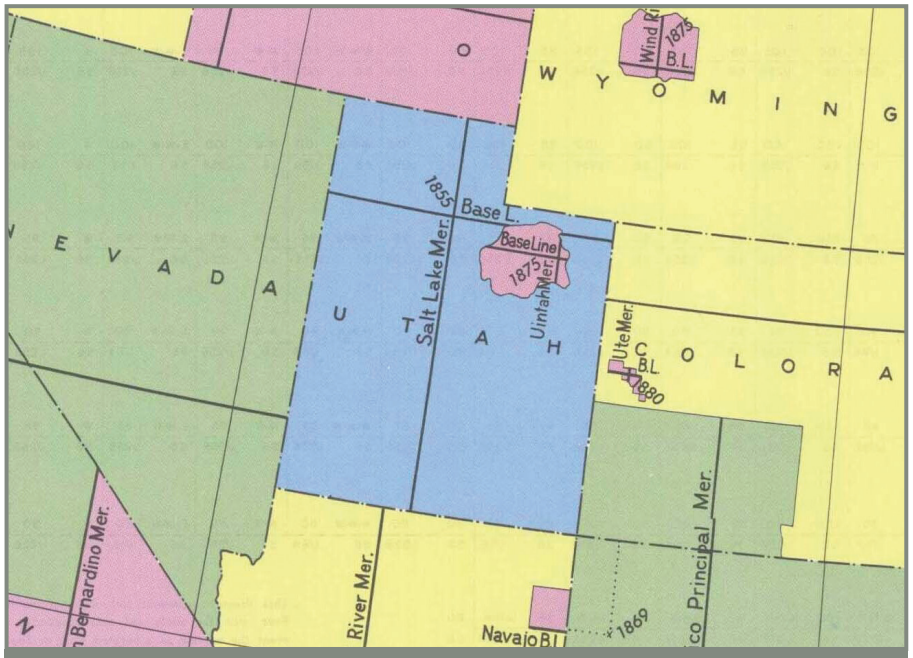
In the heart of Salt Lake City, a small stone monument marks a point of great historical and geographical significance: the Salt Lake Base and Meridian. This small unassuming landmark, located near the southeast corner of Temple Square in the center of downtown Salt Lake City, represents the starting point for land surveys in Utah, a system that has shaped the state's landscape for more than 170 years.

View of the Salt Lake Meridian and Base Line landmark in the southeast corner of the Temple Square in downtown Salt Lake City. Photo courtesy of the Center for Land Use Interpretation.

The story of the Salt Lake Base and Meridian begins in 1847 when much of the southwest remained within Mexico's claimed territory and the first Mormon pioneers arrived in the Salt Lake Valley. Orson Pratt and Henry G. Sherwood began surveying the site of "Great Salt Lake City" from a central point designated by Brigham Young, president of the Church of Jesus Christ of Latter-Day Saints. Young aimed to create the "Plat of Zion," reflecting the Mormons' vision of an ideal, divinely ordered community. By creating their own survey system, the Mormons were asserting their independence and distinct identity in their new homeland, symbolically establishing what they saw as a new Zion in the American West. This initial survey laid the groundwork for the city's grid system of named and numbered streets, and remains a defining characteristic of Salt Lake City to this day.

In 1855, David H. Burr, the first U.S. Surveyor-General of Utah, officially designated the point as the beginning of the Public Land Survey System (PLSS) in the Utah Territory, setting a stone monument to mark the spot. This monument, known as the Salt Lake Base and Meridian, became the reference point for property descriptions, gridded streets, and land records throughout the state.

The Salt Lake Meridian is unique among principal meridians in the United States because it is the only one with its initial point situated in a major city. The meridian runs north-south through the entire state of Utah and its accompanying baseline extends east-west to the state borders. This meridian serves as the reference for survey townships running north and south, and ranges extending east and west, effectively creating a grid system across most of Utah. The township and range system is a grid-like method for surveying and organizing land that divides areas into 6-mile square townships and 1-mile square sections. The Salt Lake Meridian governs all PLSS surveys in the state, with one notable exception: the northeastern region, which falls under the jurisdiction of the Uintah Special Meridian. This unique meridian was created in 1875 to address the surveying needs of the reservation lands (Uintah and Ouray Indian Reservation), which were given to Native American tribes as part of the U.S. government's land allotment policies in the late 19th century.



Map showing the Salt Lake Base and Meridian lines created in 1855 and the Uintah Special Meridian created in 1875 (area in red). Image courtesy of the Center of Land Use Interpretation.

Close-up view of the Salt Lake Base and Meridian landmark in the southeast corner of Temple Square in downtown Salt Lake City. Photo courtesy of the Center for Land Use Interpretation.

Lying 100 feet north and 50 feet west of the Salt Lake Base and Meridian monument is the remnant of an astronomical station used to determine the true latitude and longitude of the marker. The station was set by George W. Dean of the U.S. Coast and Geodetic Survey in 1869 and was used until 1897 to obtain the correct time by observing stars passing by the meridian with a transit telescope.

Today, the monument marking the Salt Lake Base and Meridian serves as a link to Utah's surveying history and shows the enduring influence of early Mormon urban planning. It stands as a reminder of the foresight that shaped Salt Lake City's development and underscores the lasting importance of thoughtful land use strategies.

Note: As of the writing of this article, the monument is temporarily inaccessible due to ongoing renovations at Temple Square.

• Teacher's Corner •

EARTH SCIENCE WEEK 2024

In October UGS scientists, staff, and volunteers hosted over 400 second- to seventh-grade students for the annual Earth Science Week (ESW). Spanning two weeks, ESW provided students from Salt Lake and Tooele Counties with a two-hour field trip to the Utah Core Research Center, where they engaged in five hands-on, interactive stations including learning about earthquakes and discovering where and how they happen, examining dinosaurs and ice age fossils in the paleontology lab, and panning for pyrite (also known as fool's gold) and other minerals.

Since initiating ESW for schools in 2001, the UGS has welcomed over 15,000 elementary and middle school students from over 80 Utah schools. Thousands of teachers, parents, and geoscience volunteers have also participated in this educational event. Many thanks to everyone who helped make ESW 2024 a success. For more information, including details on attending or volunteering, please visit https://geology.utah.gov/teachers/earth-science-week/.

CALL FOR NOMINATIONS FOR THE 2025 UTAH EARTH SCIENCE TEACHER OF THE YEAR AWARD

For Excellence in the Teaching of Natural Resources in the Earth Sciences

The Utah Geological Association (UGA) is seeking nominations for the 2025 Utah Earth Science Teacher of the Year Award. The winning teacher is awarded $1,500 and is automatically entered in the regional contest sponsored by the Rocky Mountain Section of the American Association of Petroleum Geologists (AAPG). All K–12 teachers of natural resources in the earth sciences are eligible. Application deadline is January 15, 2025. Additional information, requirements, and entry forms are available on the UGA website at utahgeology.org/outreach/teacher-of-the-year.

GEOLOGY OF THE INTERMOUNTAIN WEST
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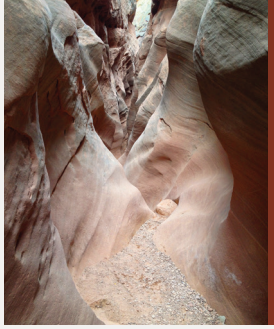


GeoSights

Slot Canyons of the San Rafael Swell, Emery County

Magnificent Badlands of Colorful and Highly Eroded Sandstones

by Torri Duncan

Image of Little Wild Horse Canyon. Photo by Adam McKean

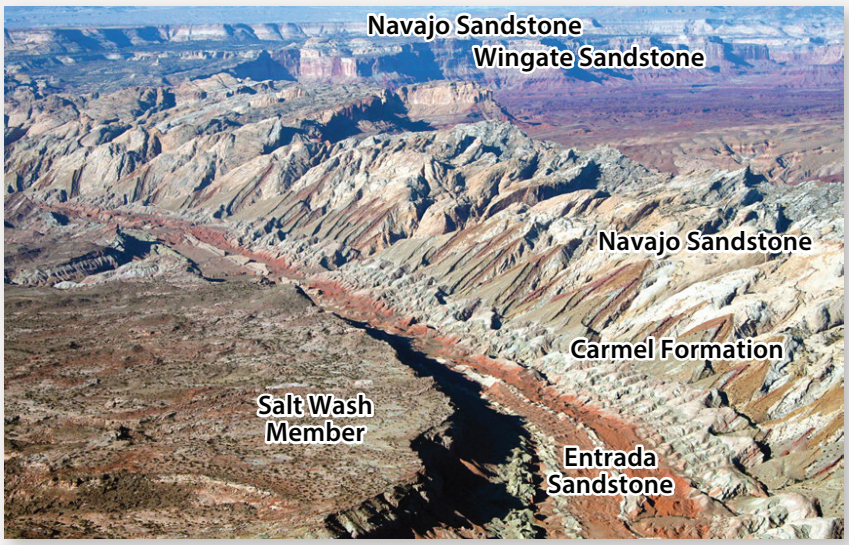
Did you know Utah has one of the highest concentrations of slot canyons on Earth? There are well over one thousand slot canyons in the southern part of the state. Slot canyons are long, narrow channels with steep rock walls typically eroded into sandstone or other sedimentary rocks over millions of years. Most slot canyon walls are at least 10 times as high as the width—think of dropping a coin into a coin slot. These narrow geologic features can offer a colorful display of geology, adventurous hikes and rappels, and unique potential hazards.

Some of Utah's best slot canyons are in the San Rafael Swell (the Swell) where at least forty slot canyons have been explored. They range in difficulty from roadside strolling to technical rappels and canyoneering. U.S. Interstate 70 runs through the center of the Swell and has many scenic viewpoint pullouts to marvel at the meandering slots.

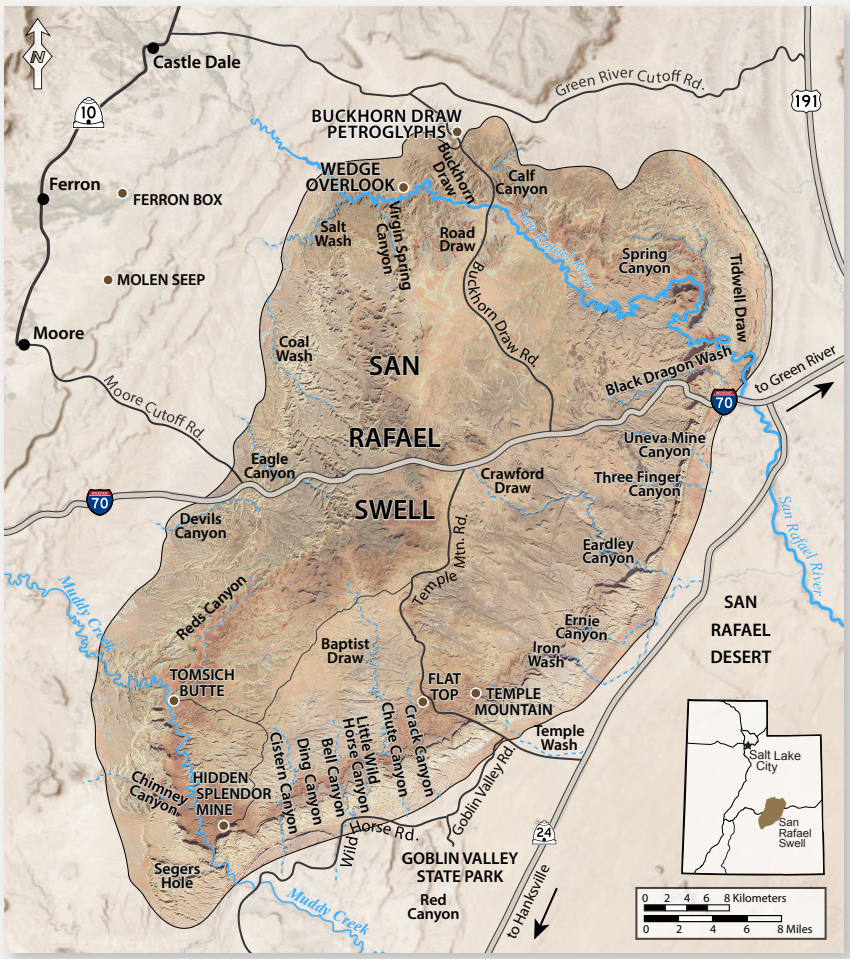
Geologic Information:

The Swell is a broad, kidney-shaped convex-upward fold of sedimentary rock that contrasts with the surrounding flat-lying rock layers of the Colorado Plateau. This elongated dome-like structure, known as an anticline, is roughly 75 miles long (extending northeast-southwest) and 30 miles wide. The limbs or sides of this anticline are not symmetric. The southeastern limb, called the San Rafael Reef, is steeply inclined to nearly vertical, in contrast with the more gently sloped western limb. The Swell formed in response to compressional forces in the Earth's crust during the Laramide orogeny, a mountain-building event that lasted from 70 to 40 million years ago. During this interval, other areas in Utah were also uplifted, such as the Uinta Mountains to the north and the Waterpocket Fold in Capitol Reef National Park to the southwest.

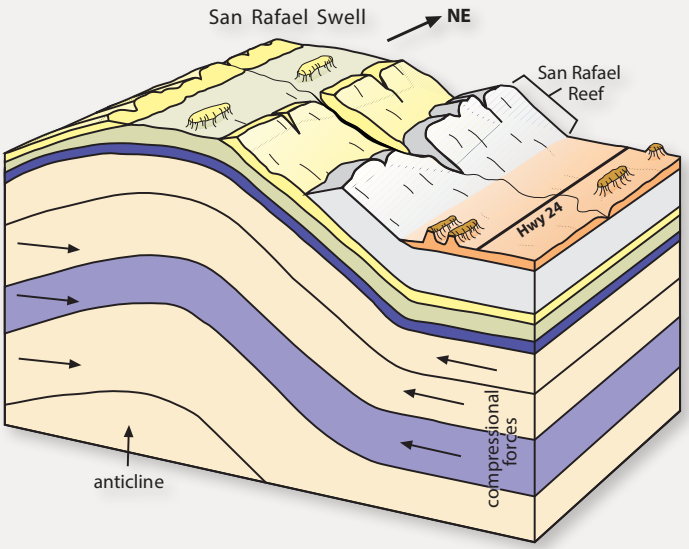
After the anticline formed, the Colorado Plateau began rising around 23 million years ago during the Miocene Epoch. This regional uplift created a landscape subject to massive erosion. Over millions of years, running water and wind removed up to 8,000 feet of material from the crest of the Swell and left behind a showcase of slot canyons, towers, and cliffs. The oldest rocks (about 300 million years old) are exposed in the center of the Swell, surrounded by a ring of progressively younger rocks (ranging from 100 to 230 million years old). From oldest to youngest, the strata include mostly sandstones of Moenkopi and Chinle Formations, the Wingate Sandstone, Kayenta Formation, Navajo Sandstone and the Carmel Formation.



Aerial view west of the San Rafael Reef at the south end of the Swell.



Generalized map of San Rafael Swell and surrounding areas.



Diagrammatic illustration of the structure of the San Rafael Swell. Because they have been partially removed by erosion, the uppermost rock layers are no longer continuous over the anticline.

Today, the Swell is a diverse desert landscape. The San Rafael Reef (the steep eastern flank of the anticline) contains many narrow, winding slot canyons, whereas the central part of the Swell hosts vast flat areas, cliffs, and towers. Remnants of human history can be found throughout the Swell as well and include indigenous rock art and more recent evidence of homesteading and uranium mining.

Slot canyons in the Swell offer a fantastic opportunity to admire geologic history. The steeply tilted beds showcase the rock layers like books on a shelf. Canyons here also exhibit honeycomb or "tafoni" weathering, a process that creates small cave-like features that pockmark the canyon walls. Each slot canyon tells a different story!

Exploring Slot Canyons:

Located in the southern part of the Swell, Little Wild Horse Canyon is a well-known slot canyon hike and an excellent choice for non-technical canyoneering. The trail can be made into a loop hike by returning down through Bell Canyon. The loop hike includes slickrock and sandy terrain, narrow winding slots, and panoramic views.

Ding and Dang Canyons are a bit more difficult and require route finding through steep down-climbs. For more advanced and technical adventures, the Upper Black Box or Cistern Canyons are scenic options requiring expert rope and canyoneering skills.

Image showing tafoni weathering in the Navajo Sandstone walls of Bell Canyon. Photo by Elisabeth Stimmel.

Before You Go:

Thoroughly research and understand the difficulty and specific gear requirements of the canyon you intend to explore ahead of time. Consult maps and guides, and check the weather forecast before, during, and after your trip. Flash floods are a particularly serious hazard: Check the weather forecast before you go, and plan and prepare for emergency situations in backcountry areas.

Slot canyons can be dangerous! Due to their unique shape and remote location, they contain many potential hazards including:

- falling rocks
- flash floods
- unstable terrain
- narrow passageways
- slippery surfaces
- steep descents or ascents
- keeper potholes, and
- long swims in cold water.

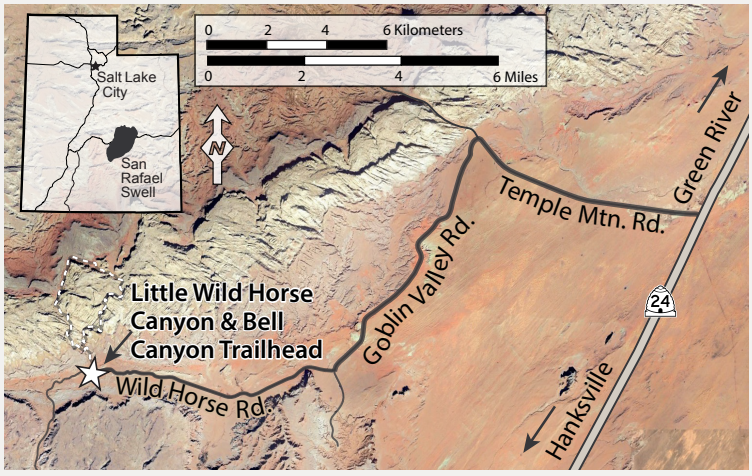
The Swell offers a plethora of recreational activities and primitive camping. Remember to practice Leave No Trace and pack out anything you pack in. Cell service is very limited. Plan and prepare for your adventure.

Resources:

Visit the Price Bureau of Land Management (BLM) Field Office at 125 South 600 West Price, UT Phone: 435-636-3600 for directions, maps, driving conditions, and a list of other must-see sites in the Swell.

How to Get There

To access Little Wild Horse Canyon and Bell Canyon, travel west from Green River on I-70 to the junction with State Route (SR) 24 (exit 160). Head south on SR-24 toward Hanksville for about 25 miles. Near mile post 35, turn west onto Temple Mountain Road and travel about 5 miles toward Goblin Valley State Park. Turn left (south) onto Goblin Valley Road and travel about 6 miles to the junction of Wild Horse Road. Turn right and head west for another 5.5 miles to the marked Little Wild Horse trailhead and parking area.



Useful Maps:

- ***Little Wild Horse Mesa***, UT USGS 7.5 Minute Topographic
- ***Utah Road & Recreation Atlas*** by Benchmark Maps
- ***San Rafael Swell, BLM - Price Field Office***, National Geographic Trails Illustrated Topographic Map 712

• SURVEY NEWS •

Awards

The Utah Geological Association (UGA) and the Utah Geological Survey (UGS) presented the **2024 Lehi Hintze Award** to **Bob Biek** for his outstanding contributions to Utah geology. Bob received his B.A. in geology from the University of California at Berkeley and M.S. in geology from Northern Illinois University and spent four years with the North Dakota Geological Survey before joining the Utah Geological Survey (UGS) Geologic Mapping Program in 1996. Bob's geologic mapping focused on southwestern Utah and along the Wasatch Front, and he has authored or co-authored more than forty 7.5-minute and four 30 x 60-minute geologic maps. Bob's professional life changed in the late 2000s when he discovered the fabulous and enigmatic geology of Haycock Mountain. He along with colleagues Pete Rowley and David Hacker soon realized that they stood at the toe of one of the world's largest landslides, naming it the Marysvale gravity slide complex (MGSC). They convened a GSA-sponsored Thompson Field Forum to recruit other specialists, which led to a multi-university, multi-disciplinary NSF-sponsored research effort now in its final year. Bob was UGA Secretary in 2002; UGA Newsletter Editor from 2002 to 2018, and co-editor of UGA's Publication #43 *Geology of Utah's Far South* (2014) and Publication #48 *Utah Geosites* (2019). He has been a member of the Geological Society of America since 1991 and a GSA Fellow since 1997. After 26 years with the UGS, Bob retired in 2022 but continues to work with colleagues to revise the Beaver and Panguitch 30 x 60-minute geologic maps, with an eye toward incorporating new MGSC discoveries.

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.

Congratulations to **Diane Menuz** who was selected by her peers as the UGS 2024 Employee of the Year. Diane has been part of the Groundwater & Wetlands Program since 2013 and is an exemplary scientist, report writer, grant writer, colleague, and supervisor. Diane's success in the process of writing proposals for the EPA's Wetland Program Development Grant program has resulted in more than $3,400,000 of funding to the UGS and has benefited the people and the wetlands of Utah. Diane has also taken on additional projects including innovative collaborative work in the Great Salt Lake Shorelands Preserve and Matheson Wetlands Preserve. In her current role data scientist, she has transformed how we manage our groundwater data, bringing order to chaos. Her positive personality, professionalism, and productive engagement with colleagues within and outside of DNR make her an invaluable contributor to the UGS, an outstanding employee, and deserving recipient of this special recognition.

In October **Jim Kirkland** was honored as a recipient of the **Governor's Award for Excellence** at a ceremony held at the Governor's Mansion. This award recognizes Jim's career spanning almost 50 years, including his service the past 20 years as Utah's state paleontologist. Jim's dedicated work in understanding Utah's Mesozoic geology has transformed the state into a premier destination for researchers worldwide and his advocacy to conserve Utah's paleontological treasures has ensured that these resources will be preserved for future generations.

Congratulations to **Kate Baustian** who received the **Utah Department of Natural Resources 2024 Newcomer of the Year Award** in recognition of her exemplary work as part of the UGS Groundwater & Wetlands Program. Kate is a forward thinker and is always thinking about the best ways to better the UGS and to help the people of Utah.

The American Association of Petroleum Geologists Rocky Mountain Section Annual Meeting was held October 6–8 in Park City and hosted by the Utah Geologic Association (UGA). This year's conference theme was Elevating Energy, and the technical program included talks and posters featuring the latest research on Utah's Uinta and Paradox Basins, Rocky Mountain unconventional plays, the Covenant field in Utah's thrust belt, geologic carbon storage, and myriad aspects of geothermal, and much more. Congratulations to the UGS geologists who were honored with awards. **Eugene Szymanski** received the Steve Champlin Memorial Award for best poster presentation at the 2023 meeting, **Michael Vanden Berg** received the 2024 Distinguished Service Award and **Ryan Gall** was presented the 2024 Outstanding Young Professional Award.

Employee News

Jeffrey Quick retired in December after 27 years of service as a Project Geologist with the Energy & Minerals Program. Prior to joining the UGS in 1997, he worked at the Coal Research Section at Penn State University and the Energy and Geosciences Institute at the University of Utah. He has B.S. and M.S degrees from the University of Toledo and a Ph.D. from the University of Canterbury in New Zealand. Jeff's contributions include over 50 publications related to the origin, distribution, and industrial use of coal and other fossil energy resources. Jeff has been a great asset to the Survey, and his talent and knowledge will be greatly missed. We wish him well in his retirement.

The Geologic Hazards Program welcomes **Tara Shreve** as the new Interferometric Synthetic Aperture Radar (InSAR) Specialist monitoring the different geologic processes that drive ground displacement throughout Utah. She has a B.S. in mathematics and graduated with a Ph.D. in geophysics from the Institut de Physique du Globe de Paris in 2020. **Adam McKean** has accepted the position of Program Manager of the Geologic Hazards Program replacing **Steve Bowman** who will pursue a new role as Senior Scientist with the UGS. Adam joined the UGS in 2010 and has a B.S. and M.S. degree in geology from Brigham Young University. His work focuses on mapping the geology of the greater Wasatch Front urban area. Besides geologic mapping Adam has also been involved in Lake Bonneville and Great Salt Lake research, lidar mapping of the Wasatch fault zone, geologic hazard emergency response and monitoring, paleoseismic trenching, and geologic data preservation. Steve managed the Hazards Program since joining the UGS in 2008 and has a Ph.D. in geoengineering from the University of Nevada, Reno, and 28 years of experience as geological engineer. He recently co-led the acquisition of over 20,000 square miles of lidar elevation data in Utah and manages the geologic hazards data preservation activities at the UGS. **Diane Menuz** has accepted a position as Data Scientist with the Groundwater & Wetlands Program. She has a B.S. from the University of California, Santa Cruz, and a M.S. from Utah State University, both in ecology. She has worked at the Utah Geological Survey since 2013, most recently as the State Wetlands Coordinator. In her new role, she will help manage and analyze high frequency climate and water level data from monitoring stations around the state. A warm welcome to Tara and congratulations to Diane, Adam, and Steve.

In October UGS staff members gathered at the G.K. Gilbert Geologic View Park for a fall cleanup and managed to fill a 2-ton dumpster with weeds and trash. Many thanks to all that volunteered and their willingness to help keep the park a beautiful, well-maintained, informative, and safe place for our geoscience community, neighbors, and students to learn about the amazing geology in our backyard! For more information about G.K. Gilbert Geologic View Park please visit our website at: geology.utah.gov/apps/geosights/.

Recent Outside Publications

by UGS Authors

Sulfate-Rich Spring Seeps and Seasonal Formation of Terraced, Crystalline Mirabilite Mounds Along the Shores of Great Salt Lake, Utah: Hydrologic and Chemical Expression During Declining Lake Elevation, by **E.A. Jagniecke**, **M.D. Vanden Berg**, E.S. Boyd, D.T. Johnston, and B.K. Baxter: Chemical Geology, v. 636, https://doi.org/10.1016/j.chemgeo.2023.121650

One Million Years of Climate-Driven Rock Uplift Rate Variation on the Wasatch Fault Revealed by Fluvial Topography, by A.G.G. Smith, M. Fox, J.R. Moore, S.R. Miller, L. Goren, **M.C. Morriss**, and A. Carter: American Journal of Science, v. 324, no. 1, https://doi.org/10.2475/001c.92194

Dinosaur Biostratigraphy of the Nonmarine Cretaceous of Utah, by **J.I. Kirkland**, J.J.W. Sertich, and A. Titus: Geological Society of London Special Publications, v. 545, no. 1, https://doi.org/10.1144/SP545-2023-211

Great Salt Lake Wetland Vegetation and What It Tells Us About Environmental Gradients, Drought, and Disturbance, by **B. Downard**: Utah Geological Association Publication 51, 25 p., https://doi.org/10.31711/ugap.v51i.140

Estimate of Groundwater Flow and Salinity Contribution to the Great Salt Lake Using Groundwater Levels and Spatial Analysis, by H. Zamora and **P. Inkenbrandt**: Utah Geological Association Publication 51, 24 p., https://doi.org/10.31711/ugap.v51i.141

Great Salt Lake Desert Landscape Change Over Multiple Temporal Scales—A Field Trip Guide Covering the Bonneville Salt Flats and Knolls Sand Dunes, by J. Bernau, B. Bowen, C.G. Oviatt, and **D. Clark**: Utah Geological Association Publication 51, 21 p., https://doi.org/10.31711/ugap.v51i.145

Use of Remote Imagery to Map Microbialite Distribution at Great Salt Lake, Utah: Implications for Microbialite Exposure, by L. Wilcock, C. Frantz, **M.D. Vanden Berg**: Utah Geological Association Publication 51, 26 p., https://doi.org/10.31711/ugap.v51i.136

The first dinosaur postcranial body fossils from the Lower Jurassic Kayenta Formation of Utah, by A.D. Marsh, **D.D. DeBlieux**, and **J.I. Kirkland**: Geology of the Intermountain West, v. 11, p. 45–57, https://doi.org/10.31711/giw.vll.pp45-57

$^{40}Ar/^{39}Ar$ Chronostratigraphy and Geochemistry of Harrats Ishara and Kura in the Hamd-Jizl Basin, Madinah, Saudi Arabia, by **E. Szymanski** and D.F. Stockli: Geological Society of London, Special Publications, v. 550, https://doi.org/10.1144/SP550-2024-45

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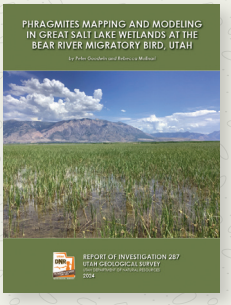
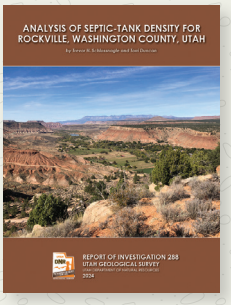
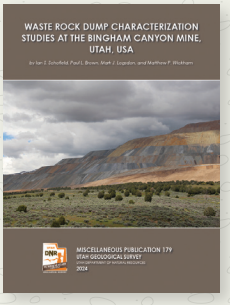


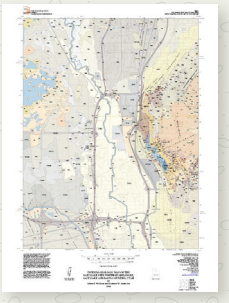
Phragmites Mapping and Modeling in Great Salt Lake Wetlands at the Bear River Migratory Bird Refuge, Utah, by Peter Goodwin and Rebecca Molinari, 18 p., 1 appendix, **RI-287**, https://doi.org/10.34191/RI-287



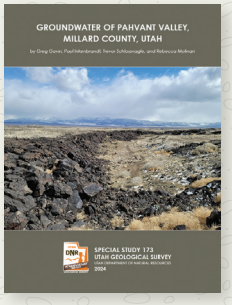
Analysis of Septic-Tank Density for Rockville, Washington County, Utah, by Trevor H. Schlossnagle and Torri Duncan, 14 p., **RI-288**, https://doi.org/10.34191/RI-288



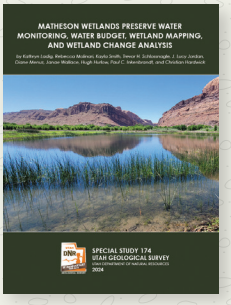
Waste Rock Dump Characterization Studies at the Bingham Canyon Mine, by Ian S. Schofield, Paul L. Brown, Mark J. Logsdon, and Matthew P. Wickham, 19 p., **MP-179**, https://doi.org/10.34191/MP-179



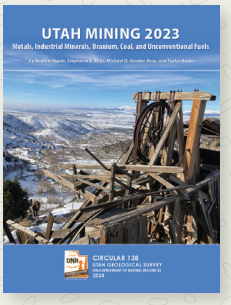
Interim Geologic Map of the Salt Lake City North Quadrangle, Salt Lake and Davis Counties, Utah, by Adam P. McKean and Zachary W. Anderson, 38 p., 2 plates, scale 1:24,000, **OFR-768DM**, https://doi.org/10.34191/OFR-768DM



Groundwater of Pahvant Valley, Millard County, Utah, by Greg Gavin, Paul Inkenbrandt, Trevor Schlossnagle, and Rebecca Molinari, 57 p., 4 appendices, **SS-173**, https://doi.org/10.34191/SS-173



Matheson Wetlands Preserve Water Monitoring, Water Budget, Wetland Mapping, and Wetland Change Analysis, by Kathryn Ladig, Rebecca Molinari, Kayla Smith, Trevor H. Schlossnagle, J. Lucy Jordan, Diane Menuz, Janae Wallace, Hugh Hurlow, Paul C. Inkenbrandt, and Christian Hardwick, 81 p., 6 appendices, **SS-174**, https://doi.org/10.34191/SS-174



Utah Mining—2023 Metals, Industrial Minerals, Uranium, Coal, and Unconventional Fuels, by Andrew Rupke, Stephanie E. Mills, Michael D. Vanden Berg, and Taylor Boden, 27 p., **C-138**, https://doi.org/10.34191/C-138

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