UTAH GEOLOGICAL SURVEY

SURVEY NOTES

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The Utah Flux Network

Contents

Utan Flux Network 1
Wetland Mapping Improves Across Utah 4
Hazard News 6
Glad You Asked 8
GeoSights 10
Survey News 12

Design | *John Good*
Cover | "BFLAT" eddy covariance station on the Bonneville Salt Flats. View is to the north. Photo by Paul Inkenbrandt.

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DIRECTOR'S PERSPECTIVE

by Bill Keach

Maybe a better word is envision

The word *vision* has been on my mind lately. At the Utah Geological Survey (UGS) we challenge ourselves to look down the road (and sometimes around the corner), into the future. Our work and expertise touches many sectors of society. Examples of our areas of expertise include *Groundwater and Wetlands* (the theme for this issue of *Survey Notes*); *Geologic Hazards* including earthquakes, landslides, and radon gas; *Energy* including geothermal, petroleum, gas and mining; and *Information* for citizens and government leaders, which is critical for sound policy decisions. The gathering, interpreting, and sharing of good scientific data is a vital part of what we do. Data collection requires careful planning and forward thinking. At the UGS we challenge ourselves to visualize the future with a goal to anticipate societal needs. We have the opportunity and privilege to positively impact the daily lives of Utah's citizens.

The 2021 Utah Legislature engaged the UGS to research and prepare a report with recommendations on 1) ways to increase public awareness about the risks of radon gas, and 2) ways to mitigate Utah residents' exposure to radon. This project was a direct result of the UGS suggesting they be included in proposed radon-related legislation. Working with multiple stakeholders, including the Department of Environmental Quality's Radon Program, the report was delivered in May of this year. The dangers of radon have long been an area of interest for the UGS and future mitigation efforts are essential. Areas having radon potential can be found by visiting the UGS's *Geologic Hazards Portal*.

In July 2022, the UGS excavated two research trenches across the Taylorsville fault of the West Valley fault zone. The work will add to our knowledge of the magnitudes and frequency of major earthquakes in the greater Salt Lake Valley area. This type of data will provide government leaders with better insights to plan for the future.

Recently we participated in a tour for legislators of a major water aqueduct. This aqueduct crosses the Wasatch fault zone multiple times, and is the primary water source for hundreds of thousands of people. Imagine the impact on the citizens and economy of Utah if this line were to rupture during an earthquake. Looking to the future we can better plan for redesigning and/or retrofitting our major aqueducts.

In the 2022 legislative session we pushed for, and received, funding to do a feasibility study of an earthquake early warning system. The goal of the study is to understand if such a system will work in Utah, what gaps in data collection we might have, and what it would take to implement.

Coming back to water, the UGS is actively engaged in many projects that provide insights on how to better manage our water resources. The projects range from how to save Great Salt Lake and the Bonneville Salt Flats to building a better understanding of the state's aquifers.

Each of these projects is a reflection of having a vision of what is needed, both for today and for the future. *Vision* is a noun. Maybe a better word is *envision*, which is a verb, meaning to imagine something. Envision connotes action, which is what UGS scientists do.

Highway 191 by Flaming Gorge Dam. View is to the south.

The Utah Flux Network

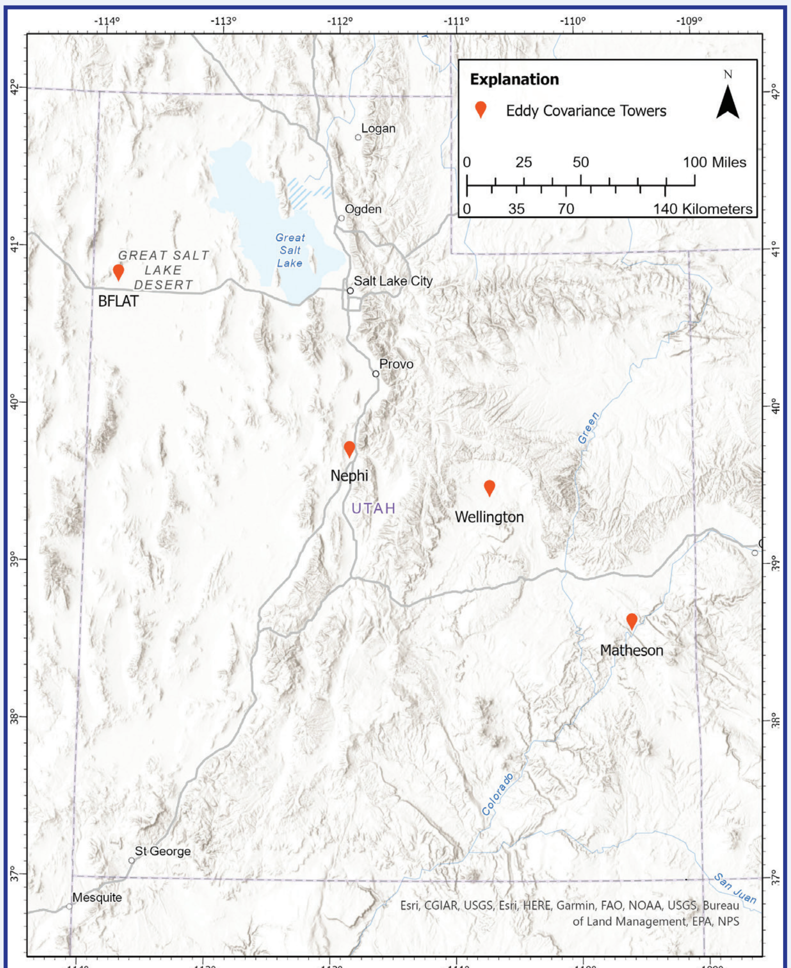
A Hydrometeorological Network Maintained by the Utah Geological Survey

by Paul Inkenbrandt and Kathryn Ladig

Introduction

The Utah Geological Survey (UGS) is establishing a network of weather stations throughout the state of Utah, known as the Utah Flux Network (UFN), to measure evapotranspiration. Evapotranspiration is water that is evaporated from the land's surface and transpired by plants, and it is an important part of Utah's water budget, as it is one of the main ways water leaves Utah. We will collect long-term baseline measurements of evapotranspiration, compile existing data to make it widely available, and compare our data with remotely sensed (satellite-based) models.

The main goal of the UFN is to provide ground-truth data for satellite-measurement-based estimates of evapotranspiration, though the network will serve many additional purposes. These data will give water managers tools to deal with drought, allowing them to accurately measure water conserved or used by agriculture. Data from the UFN will also support long-term water conservation and management strategies, such as water banks—for example the pilot Price Water Bank project which converts conserved agricultural water into instream flow near Price, Utah—and measuring consumptive use in the Upper Colorado Basin to help administer the Colorado River Compact. Our data can also be used for hydrologic and climate models because these stations measure important components of the atmosphere, including carbon dioxide (CO_2), water (H_2O), and available energy.

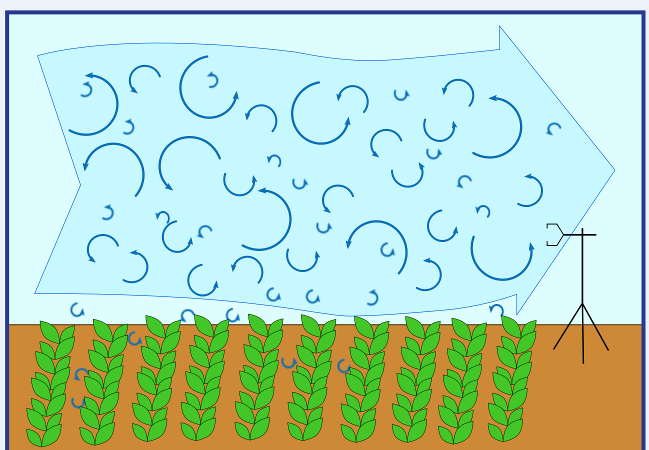


Utah Flux Network station locations.

Evapotranspiration and Eddy Covariance

A large portion of evapotranspiration in vegetated areas, including croplands, is due to consumptive use, which is the water that cannot be recovered or reused, including water consumed by plants and water evaporated. Winds blow over the land surface, removing evapotranspired water, allowing more water to be evapotranspired in its place. The wind carries the water vapor and other gasses in turbulent, whirling, circuitous paths known as "eddies." The UFN uses the eddy covariance technique to measure these rapidly changing eddies.

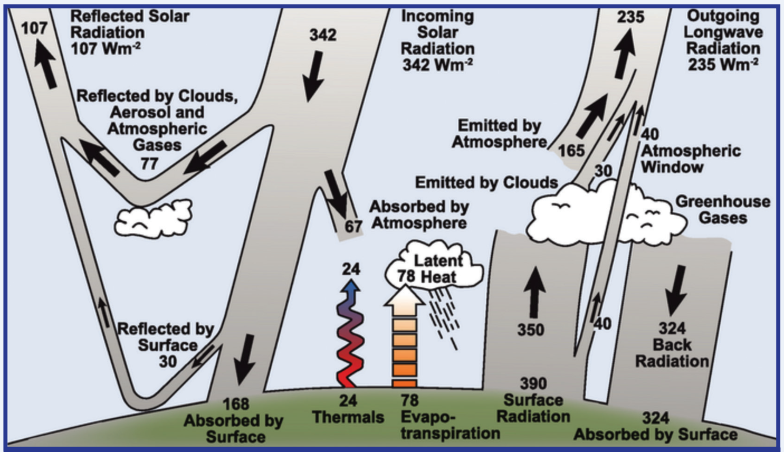
The eddy covariance technique requires accuracy in data collection and correction to calculate valid evapotranspiration values, which is dependent on available energy. Our measurement goal is energy balance, which occurs when all incoming and outgoing energy components are accounted for and the following equation is met: $Rn-G=LE+H$, where Rn is net radiation, G is ground heat flux, LE is latent heat flux, and H is sensible heat flux. Latent heat is the energy required for a substance to change state, such as from liquid to vapor during evapotranspiration, and sensible heat is the energy required to change the temperature of a substance. Net radiation is the sum of incoming and outgoing shortwave and longwave radiation. Shortwave radiation is energy emitted by the sun, some of which is reflected by the earth's surface and some absorbed. The ability of a substance to reflect shortwave radiation, controlled by the substance's color and texture, is called albedo. Absorbed shortwave radiation warms the earth's surface, which then emits longwave radiation. Clouds and greenhouse gasses, such as CO_2, absorb the outgoing longwave radiation, warming the lower atmosphere. Balancing these energy fluxes is difficult to achieve and requires great effort to collect quality data, as well as a lengthy data post-processing protocol.



Conceptual movement of wind eddies near a field. Modified from George Burba.

UFN eddy covariance stations are built from common weather station instruments, including devices that measure the wind speed and direction (anemometers), precipitation buckets, thermometers, and humidity probes. In addition, each station includes equipment to precisely measure the movement of water vapor, CO_2, and energy in and out of the area of the station. Net radiometers and soil heat flux plates help estimate energy stored and released by the soil. Sensible heat flux is calculated using multiple thermometers placed on the station at different heights, as well as some buried in the soil at different depths. All of these instruments are highly accurate, and many of them can measure very rapidly.

The UFN is also investigating the viability and applicability of the surface renewal technique, which is less costly, but not as well documented as the eddy covariance approach. The surface renewal method uses high-speed temperature and wind measurements to calculate sensible heat flux, from which latent heat flux and evapotranspiration can be calculated.



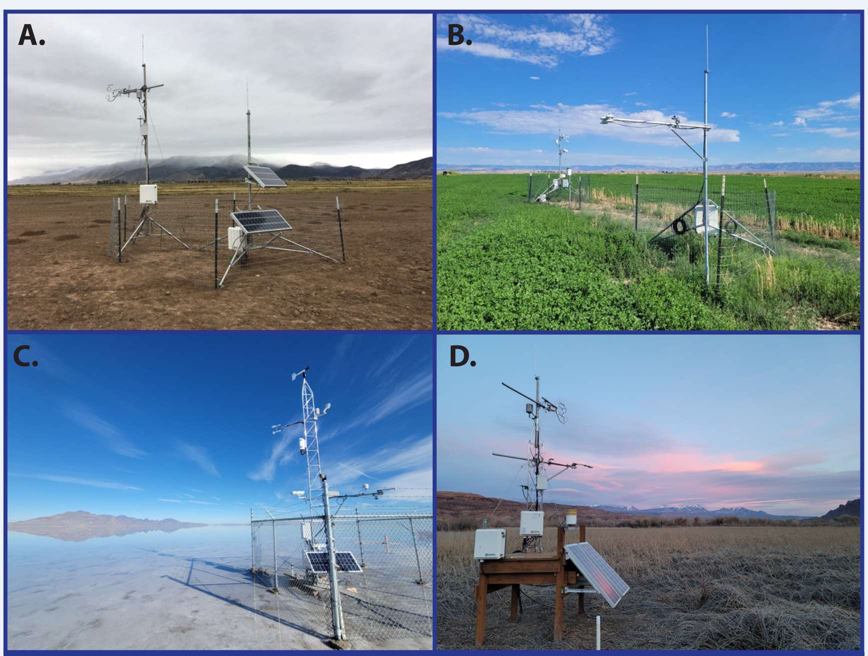
Earth's energy balance. Solar radiation is predominantly shortwave radiation. Some of this is reflected by clouds and the earth's surface, and some of this energy is absorbed. Long-wave radiation is emitted by the earth's surface and captured by greenhouse gasses. From the Intergovernmental Panel on Climate Change.

Our Progress

So far, we have constructed four eddy covariance stations in Utah, which comprise the UFN. The stations have been placed in a variety of ecosystems. Two of our stations are on agricultural sites, one is on a wetland, and one is on a salt flat (i.e., playa dominated by halite and gypsum deposits). With the emplacement of these stations, and the potential for more, we are working to develop an effective protocol for managing the stations and their data.

We constructed our first stations in 2018 in Juab Valley, funded and supported by the Utah Division of Water Rights. One station was constructed in a wetland ecosystem near Mona and the other was placed in between three pivot-irrigated fields west of Nephi. These stations were intended for short deployment and originally had only anemometers and hygrometers (which measure water vapor), with no way to measure energy balance. We have since invested in upgrading these stations with four-way net radiometers and soil heat flux plates so that we can measure energy balance. The station in Mona was decommissioned in 2020.

In early March of 2021, with significant funding and support from the Central Utah Water Conservancy District and technical assistance from Trout Unlimited, we installed our first fully equipped eddy covariance station between two pivot-irrigated alfalfa fields near Wellington, Utah, in Carbon County. Part of the impetus for this station was to provide ancillary data to a water banking study with Carbon Canal irrigation water, where instream flow is preserved by providing water conservation incentives to farmers.



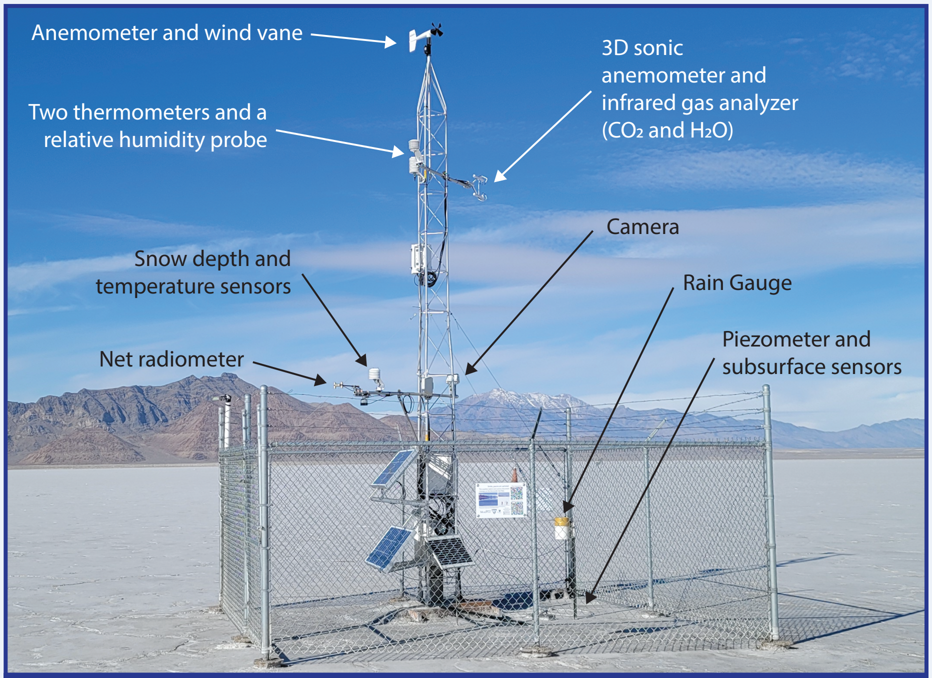
Current active stations of the Utah Flux Network: ***A)*** *Nephi agricultural station;* ***B)*** *Wellington agricultural station;* ***C)*** *Bonneville Salt Flats (BFLAT) station;* ***D)*** *Matheson Wetlands Preserve station.*

In September 2021, we assumed control of a weather station on the Bonneville Salt Flats (BFLAT), previously operated by the University of Utah. We disassembled the old station and installed an eddy covariance tower in its place. This station is surrounded by salt flats and, in addition to being used for our research efforts, it provides important weather information for the Bonneville Speedway. This station is also part of the Mesowest weather network and includes a time-lapse camera that takes photographs of the salt flats every five minutes. Mesowest compiles weather data from many public weather data sources, providing access to current and past conditions across Utah.

In early October of 2021, we installed a station in the Matheson Wetlands Preserve in Moab, Utah, using some of the components from the decommissioned Mona station. The Matheson station was placed on a deck because the area is subject to periodic flooding and the tower is surrounded by bulrushes. This station is part of a larger study to understand the water budget of a wetland system adjacent to the Colorado River.

In fall of 2021, we were awarded a U.S. Bureau of Reclamation (USBR) WaterSmart grant. This grant will allow us to purchase upgraded equipment for the Matheson and Juab stations, making them consistent with the Wellington and Bonneville stations. The USBR funding will also allow us to purchase equipment to calibrate our instruments. Most importantly, the grant will help us develop our data processing and site maintenance workflows.

The stations are already measuring large amounts of data and station programs allow for rapid on-the-fly estimates of evapotranspiration over time. These data are available immediately on the UFN website (https://geology.utah.gov/utah-flux-network). We are currently working on post-processing workflows to find and remove erroneous measurements. With the support of eddy covariance expert Dr. Larry Hipps at Utah State University, we strive to ensure a good quality assurance program is in place.



The Bonneville Salt Flats station.

We will upload our data to the AmeriFlux webpage once we have a year of post-processed data that we feel is a competent representation of the conditions at our sites. AmeriFlux is a network of eddy covariance stations in the Americas that focuses on measuring methane and carbon dioxide fluxes. AmeriFlux is part of a global network called FluxNet, which consists of over 1,000 stations located all over the globe. Data from these networks are used to calibrate global models of climate change and hydrology, including models compiled for the OpenET ensemble of models (https://openetdata.org/).

OpenET is a massive collaborative effort between NASA, JPL, USBR, and many others that was developed recently and made available to the public in 2021. It uses remotely sensed energy data to estimate evaporation through a compilation of models. UFN stations will help ensure that models like the ones used in OpenET are representative of the conditions observed in Utah.

In July 2022, the Colorado River Authority of Utah entered into an agreement with the UGS to build six more stations in the Upper Colorado River basin. These new stations will significantly improve our measurement of evapotranspiration in Utah.

Where to Find Our Data

To see the most recent UFN data, go to our website at https://geology.utah.gov/utah-flux-network. Data for the Bonneville Salt Flats and Wellington stations can be accessed through Mesowest (https://mesowest.utah.edu) as stations BFLAT and WLGTN, respectively. In the future, our high-frequency and post-processed data will be available through Ameriflux (https://ameriflux.lbl.gov/). Only BFLAT (US-UTB) and Wellington (US-UTW) are listed on Ameriflux currently.

ABOUT THE AUTHORS

Paul Inkenbrandt has been a hydrogeologist with the UGS Groundwater & Wetlands Program since 2009. He has an M.S. degree in geology from Utah State University and a B.S. degree from the University of Southern Indiana. Paul is experienced in database management, geographic information systems, and Python scripting. He also teaches introductory geology at Salt Lake Community College. In his personal time, he is actively involved in the Utah Geological Association, maintains his vegetable garden, and spends time with his family.

Kathryn Ladig joined the UGS Groundwater & Wetlands Program in 2021. She has a B.A. degree in geology and environmental studies from Gustavus Adolphus College and an M.S. degree in earth science from the University of Maine. Kathryn has studied geology throughout the globe and was employed previously by the National Park Service to examine water quality of lakes and streams, calculate glacier mass-balance, mitigate geologic hazards, maintain weather stations, and map surficial geology. Her passions lie in tracking the impacts of climatic variability through both proxy and direct observation.

New, Novel, and Updated!

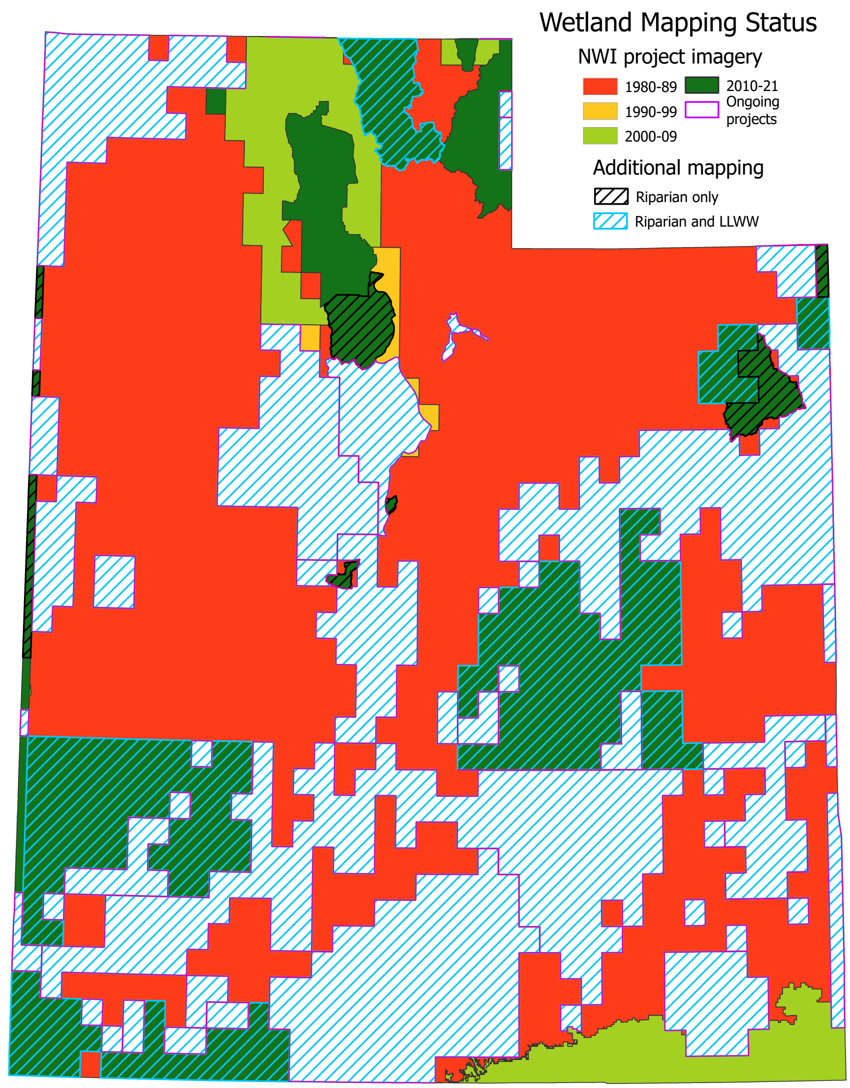
Wetland Mapping Improves Across Utah

by Peter Goodwin

Ask folks about Utah's wetlands and they will either reply, "What wetlands? We live in a desert!" or mention Great Salt Lake. However, Utah contains a stunning variety of wetlands, from the bleak playas of the Bonneville Salt Flats to verdant wet meadows in the High Uinta Mountains supporting plants and wildlife more typically found in Arctic tundra. Their distribution is just as varied and wetlands can be found along rivers, dry valley bottoms, montane slopes, and occasionally people's backyards. Wetland mapping attempts to capture this broad distribution and provide decision makers, resource managers, and the general public with an accurate depiction of wetland types and their locations. There are many ways to map wetlands and several datasets for each method, but the National Wetland Inventory (NWI) is the most used mapping dataset for a few reasons: seamless coverage across the U.S., imagery-based mapping that intuitively captures wetland boundaries, and a free and publicly accessible data portal and web map.

NWI mapping relies on interpretation of aerial imagery to identify areas supporting wetland vegetation like cattails, rushes, or cottonwoods and areas with flooding, standing water, or persistently saturated soils. This imagery-interpretation-based method produces legible mapping depicting wetlands that match expectations—rounded blobs with boundaries clearly following visible landscape features. However, this method also produces mapping with a "shelf-life" where the mapping represents a static snapshot of the moment the imagery was collected that can become outdated as changing hydrology, shifting land uses, or encroaching development reduce or replace wetlands. Much of the NWI for Utah was mapped using imagery collected during the 1980s and is severely outdated and inaccurate in several parts of the state.

Since 2014, the Utah Geological Survey (UGS) has been remapping parts of the state using modern, high-resolution imagery and updating the NWI to reflect current conditions and improve mapping accuracy (see *Survey Notes*, v. 49, no. 1, p. 1–2). Original NWI mapping only included features with true wetland vegetation and hydrology and failed to capture riparian areas near streams and lakes supporting distinct vegetation and wildlife communities. Recent UGS mapping projects have mapped riparian areas to identify these important, non-wetland habitats. The Bureau of Land Management (BLM) recently recognized the need for updated wetland mapping to support sound resource management and has started funding additional NWI mapping projects focusing on BLM-managed lands throughout the western U.S., with several projects occurring within Utah. Several of the UGS and BLM mapping projects are currently ongoing with an expected completion date in early 2024. Combined, these BLM and UGS projects will cover 51 percent of the state and will provide updated NWI mapping to 70 percent of the population. These ongoing BLM and UGS projects will also map riparian areas and enhance the NWI mapping by applying additional descriptions to each mapped wetland.

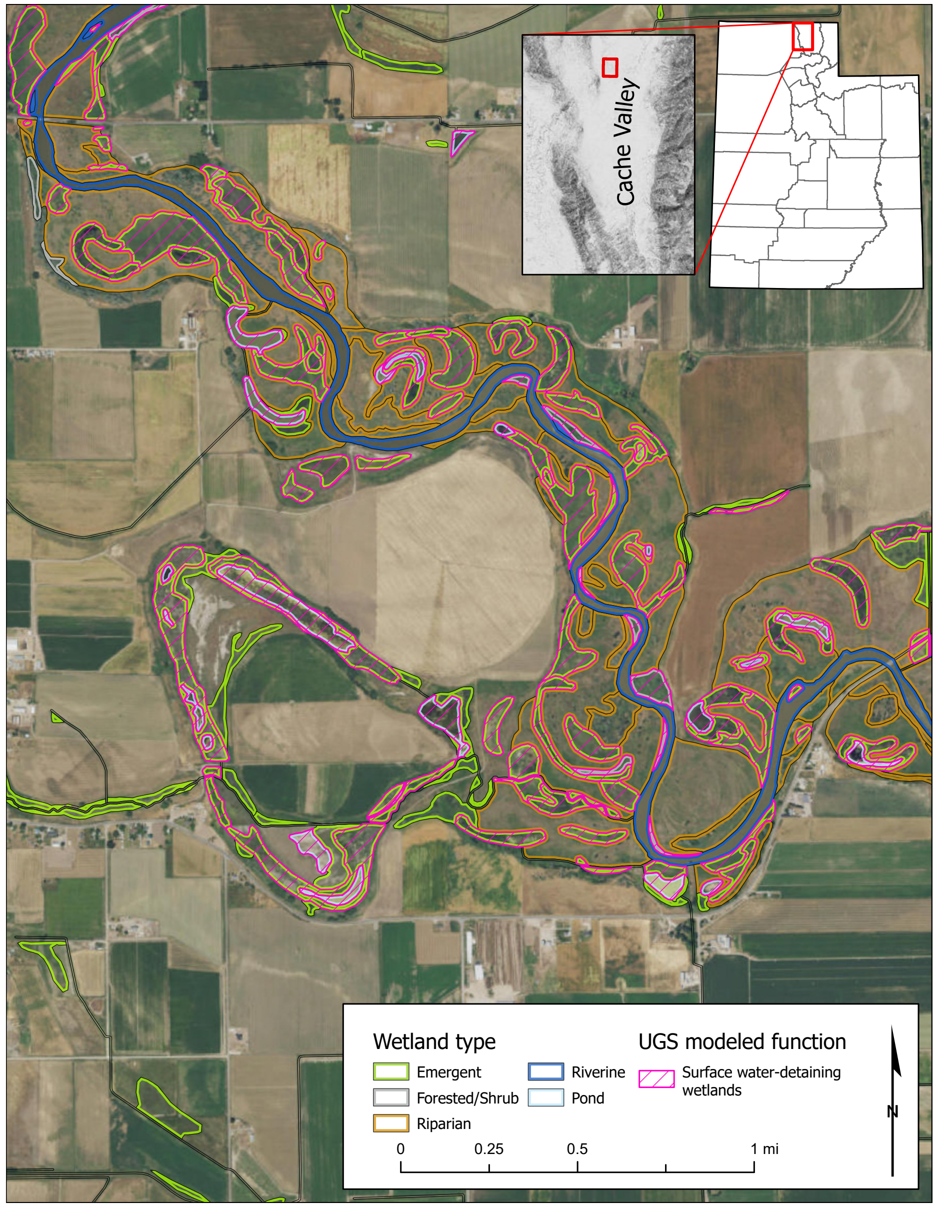


Age of National Wetland Inventory mapping projects across the state. The map also shows where ongoing projects are expected to replace outdated mapping by 2024 and the location of projects where riparian areas are also mapped and LLWW descriptions are applied.

NWI mapping describes wetlands according to characteristics easily seen in imagery (dominant vegetation, flooding duration, and typical human impacts) but misses several characteristics such as the water source, geomorphic setting, and connectivity to other wetlands that are important for habitat management and resource conservation. To address this gap, the UGS and other organizations working on NWI mapping projects in the state have been enhancing recent NWI mapping with Landscape Position, Landform, Water Flow Path, and Waterbody Type (LLWW) descriptions. These LLWW descriptions identify the geomorphic setting, shape and form, and connectivity of a given wetland and include detailed modifiers to describe unique human impacts and wetland water sources. Combined, the NWI and LLWW descriptions provide detailed information about a wetland and allow identification of unique wetland types that would be unidentifiable with a single set of descriptions, such as isolated wet meadows supported by near-permanent groundwater, emergent wetlands temporarily inundated by river flooding, and montane forested wetlands. The combination of improved accuracy with the ability to distinguish a wide variety of wetlands supports several novel landscape-level analyses and greatly enhances the dataset's utility for planning and management.

The most common use of wetland mapping assesses wetland presence or absence on individual properties as an initial screen for wetland permit applications (see *Survey Notes*, v. 52, no. 1, p. 4–5). This use mostly ignores the wetland descriptions, but other uses such as setting management priorities, performing inventory and consequence analyses for environmental impact statements, establishing floodplain protection ordinances, or identifying conservation and restoration opportunities benefit from the flexibility of combined NWI and LLWW descriptions. Increasingly, local communities are considering the beneficial functions of wetlands in land use decisions and are prioritizing conservation of high-functioning wetlands. To support these decisions, the UGS leveraged the NWI and LLWW descriptions to identify which wetlands were likely to provide beneficial functions such as unique habitats, filtering sediments from runoff, or detaining floodwaters to create a spatial dataset that can be easily added to existing maps or analyses.

By 2024, about one-half of Utah will have modern NWI mapping, mapped with increased accuracy standards and imagery collected within the past 10 years. This NWI wetland mapping dataset is invaluable for permitting, planning, and resource management and can be freely accessed and downloaded through the NWI Wetlands Mapper (https://fwsprimary.wim.usgs.gov/wetlands/apps/wetlands-mapper/) or the UGS Wetlands web app (https://geology.utah.gov/apps/wetlands/index.html). LLWW descriptions have only been recently applied to wetland mapping in Utah and there currently is no online portal to access and download the LLWW-enhanced mapping. However, the UGS can provide copies of the mapping to anyone interested in using the enhanced mapping or exploring possible applications. For more information about wetland mapping or Utah's wetlands, visit https://geology.utah.gov/water/wetlands.



Mapping from UGS's most recent mapping project showing updated wetland mapping along the floodplain of the Bear River in Cache Valley of northern Utah. Pink highlighting indicates wetlands likely to detain surface waters and attenuate floods.

Extent of outdated, modern, and LLWW and riparian mapping summarized by total project area, total amount of mapped wetlands, and percent of population potentially using mapping.

Mapping Status Summary		Outdated	Modern-Complete	Modern-Ongoing	LLWW[1,2]	Riparian[2]
Project Area	Acres	26,691,486	8,818,176	18,807,314	25,463,352	26,237,368
	Percent of Utah	49.1	16.2	34.6	46.9	48.3
Mapped Wetland Area	Acres	3,763,051	820,828	528,749[3]	659,376	NA[4]
	Percent of total mapping	73.6	16.1	10.3	12.9	NA[4]
Population	Percent	29.3	45.3	25.4	31.8	69.8

[1] Wetlands mapped with Landscape Position, Landform, Water Flow Path, Waterbody Type attributes
[2] LLWW and riparian mapping are descriptions or features added to modern mapping
[3] Data from ongoing projects is unavailable and this value estimated from previous mapping
[4] Riparian data separate from wetland mapping and not included in summary of wetland area

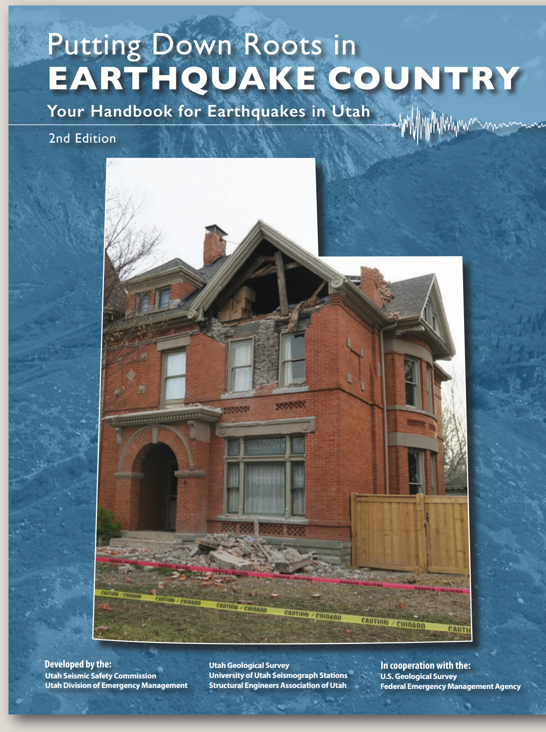
HAZARD NEWS

Putting Down Roots in Utah's Earthquake Country

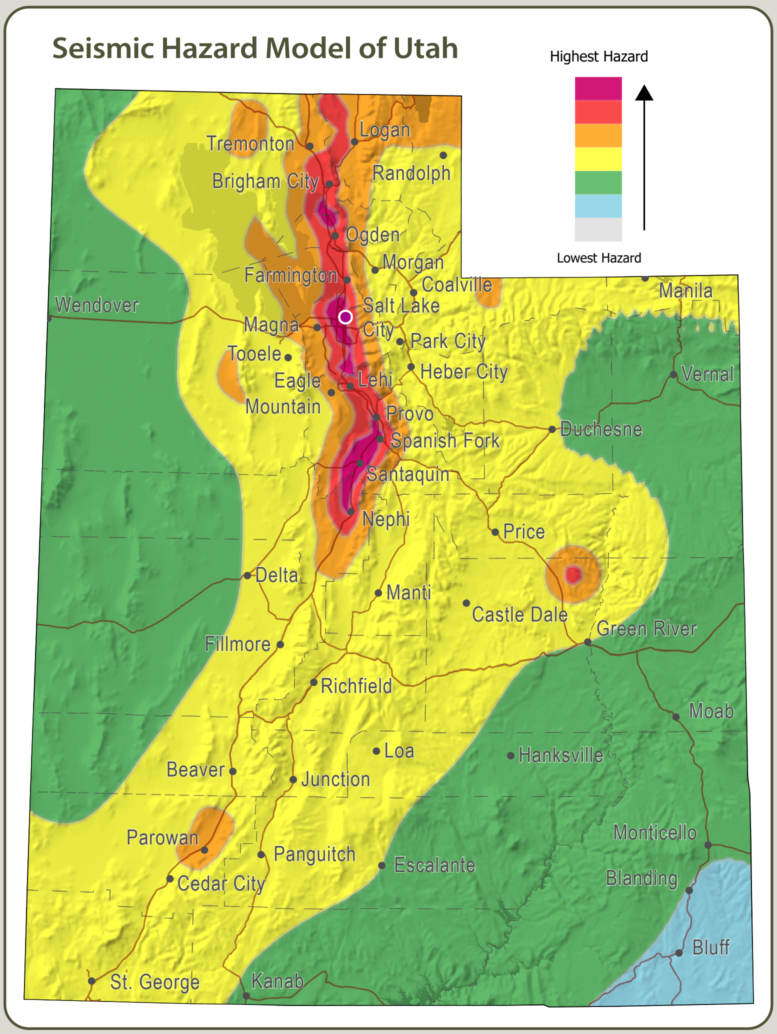
Second Edition Provides Updated and New Information

by

Emily Kleber, John Good, Adam Hiscock, and Steve Bowman



When the ground starts shaking from an earthquake, do you know what to do? Do you know why we have earthquakes in Utah, how we monitor them, and how we mediate their effects? The Utah Seismic Safety Commission (USSC; ussc.utah.gov) recently released the second edition of the booklet, *Putting Down Roots in Earthquake Country—Your Handbook for Earthquakes in Utah*, to help Utahns understand earthquake hazards, and prepare their family, friends, and community for a disaster. This booklet reminds Utahns that a major earthquake does not have to ruin life as we know it—we can take steps as individuals, families, and entire communities to be ready.



This map shows the relative hazard from earthquake ground shaking in Utah. Areas that have experienced several historical earthquakes felt by Utahns, like the Wasatch Front, have the highest hazard. Data source: U.S. Geological Survey.

Putting Down Roots in Earthquake Country (a.k.a. "*Roots*") was first published for Utah in 2008 and is based on the successful booklets of the same name published by the U.S. Geological Survey for the San Francisco Bay area, northern, and southern California. Similar publications are available for Oregon, Idaho, Alaska, Nevada, and the central United States, and some states also include translated versions for non-English speakers. The last time *Roots* for Utah was updated was in 2014, when additional scientific data was added. Since then, there have been multiple scientific, preparedness, and engineering advances, as well as several notable earthquakes in Utah, including the March 18, 2020, magnitude 5.7 Magna, Utah, earthquake. In 2021, the USSC decided that the time was right to update *Roots* with the latest earthquake information available for Utah, with the Utah Geological Survey (UGS) leading the effort. This edition of *Roots* benefited immensely from strong partnerships with individuals representing organizations making up the USSC. The effort to update *Roots* was led by the UGS and the Utah Division of Emergency Management (DEM), with input on content from the experts at the University of Utah Seismograph Stations, Be Ready Utah, Envision Utah, the Structural Engineers Association of Utah, the U.S. Geological Survey, and the Federal Emergency Management Agency. This second edition represents countless hours of discussion, editing, and care to bring the best information to the people of Utah.

The second edition of *Roots* contains several new pages that address important topics for the growing state of Utah. Utah's population is growing on the Wasatch Front, but more people are also moving to areas like southern Utah and Cache Valley, which also have seismic hazards. New pages in *Roots* address the location of faults, history of past earthquakes in southern Utah and Cache Valley, and note special seismic hazard considerations for each area. Additionally, there is an expanded page on the hazard of liquefaction, which will affect areas having high groundwater levels and could cause an immense amount of damage to critical infrastructure in Utah, like water, sewer, and energy.

Key updates addressing earthquake probability and response in Utah have been added to the second edition of *Roots*. A 2016 report from the Working Group on Utah Earthquake Probabilities compiled scientific data to create an "earthquake forecast" for the Wasatch Front. This group determined that there is a 1-in-2 chance (essentially a coin flip) of one or more earthquakes of magnitude 6.0 or larger in the Wasatch Front region in the next 50 years. Additionally, a 2015 report led by the Earthquake Engineering Research Institute and partners indicates the potential losses from a magnitude 7.0 earthquake on the Salt Lake City segment of the Wasatch fault, including economic losses, casualties, and impacts to infrastructure. This report has chilling implications, and the potential impacts have only worsened over time. These facts about our earthquake hazard in Utah are jarring, but knowledge is power, and with proper knowledge, we can address these big issues.

A significant problem for Utah with regards to earthquakes is our history of constructing buildings and homes using unreinforced masonry, mostly as brick. The second edition of *Roots* includes an in-depth explanation of what unreinforced masonry construction is, how to identify it, how it performs poorly when shaken by earthquakes, and how Utah came to have so much of this dangerous construction for an area with high earthquake hazard. This issue is important in Utah, and one that the USSC has been working hard on for decades. Two recent reports highlighted in the second edition of *Roots* include the *Wasatch Front Unreinforced Masonry Risk Reduction Strategy* and the *Utah K-12 Public Schools Unreinforced Masonry Inventory*. This new information aims to educate readers, inspire them to take proactive steps for themselves and their communities, and to improve unreinforced homes and buildings for all.

This new edition of *Roots* includes a new page discussing a technology called "earthquake early warning." Earthquakes cannot be predicted, but earthquake early warning technology can detect earthquakes quickly and broadcast a warning of the predicted arrival times of ground motion (shaking) and the severity (intensity) of shaking in the general region of the earthquake epicenter. Even if only seconds before strong shaking arrives, alerts can prompt critical actions to protect life and property. The technology has been used for decades in countries like Mexico, Japan, and Chile, and is currently being implemented in California, Oregon, and Washington. In the 2022 Utah legislative session, the UGS, University of Utah Seismograph Stations, and the DEM were funded to do a feasibility study for an earthquake early warning system in Utah to determine how this technology could be most effectively used in the Beehive State. The informational page in the second edition of *Roots* aims to educate the public about this technology and what it could mean for Utah.

The most important part of any earthquake emergency plan is learning and practicing the appropriate protective actions. Learn to Drop, Cover, and Hold On, or for people in wheelchairs and using walkers, Lock, Cover, and Hold On!

A significant problem for Utah with regards to earthquakes is our history of constructing buildings and homes using unreinforced masonry, mostly as brick.

Structural damage to an unreinforced masonry building in downtown Magna caused by strong ground shaking from the Magna earthquake. Utah Geological Survey photo.

The second edition of *Roots* is available as a print copy for free at the Natural Resources Map & Bookstore, and online as a PDF document, as well as in an online interactive version. Copies will be distributed among agencies of the Utah Seismic Safety Commission, including the Division of Emergency Management and the University of Utah Seismograph Stations. The UGS is currently working on creating a Spanish language version, with the goal of translating into other languages in the future. The USSC plans to update *Roots* as new scientific data is gathered and analyzed, best practices change, and the public asks for more information. Please take some time to read through *Roots*, and also visit earthquakes.utah.gov for any additional questions or information about earthquake hazards in Utah.

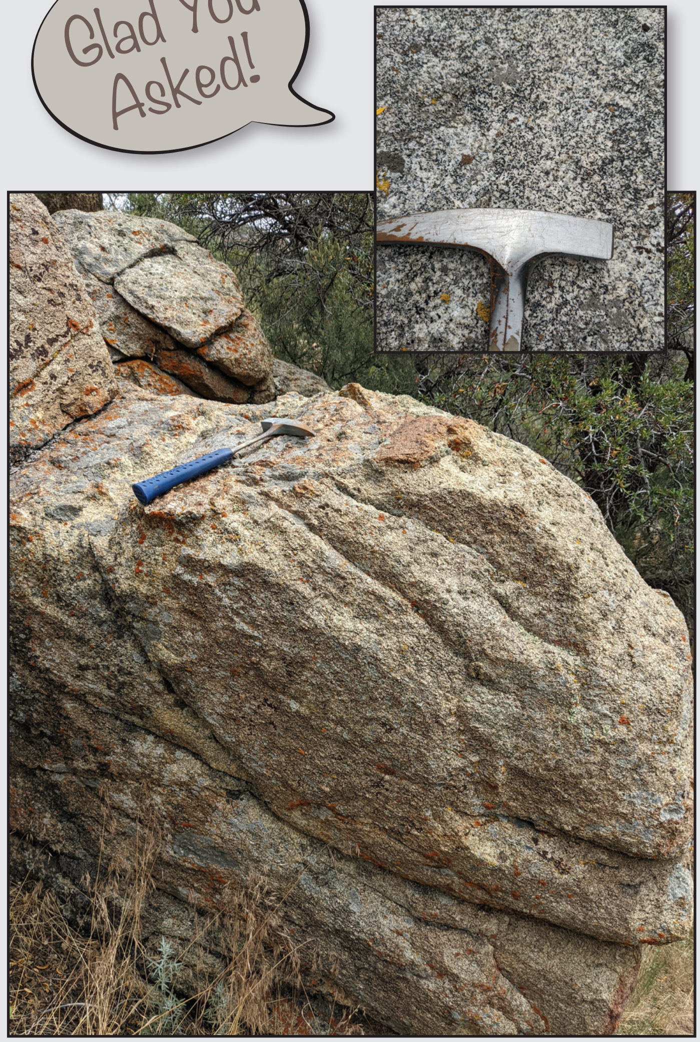
How to get a copy of *Roots*:

Natural Resources Map & Bookstore
Department of Natural Resources Building
1594 W. North Temple, Salt Lake City, Utah 84116-3154
Local: 801-537-3320; Toll Free: 888-UTAHMAP (882-4627)
Hours: Monday–Friday 10 a.m. to 5 p.m.
https://www.utahmapstore.com/

Glad You Asked!

What are the Oldest Rocks in Utah?

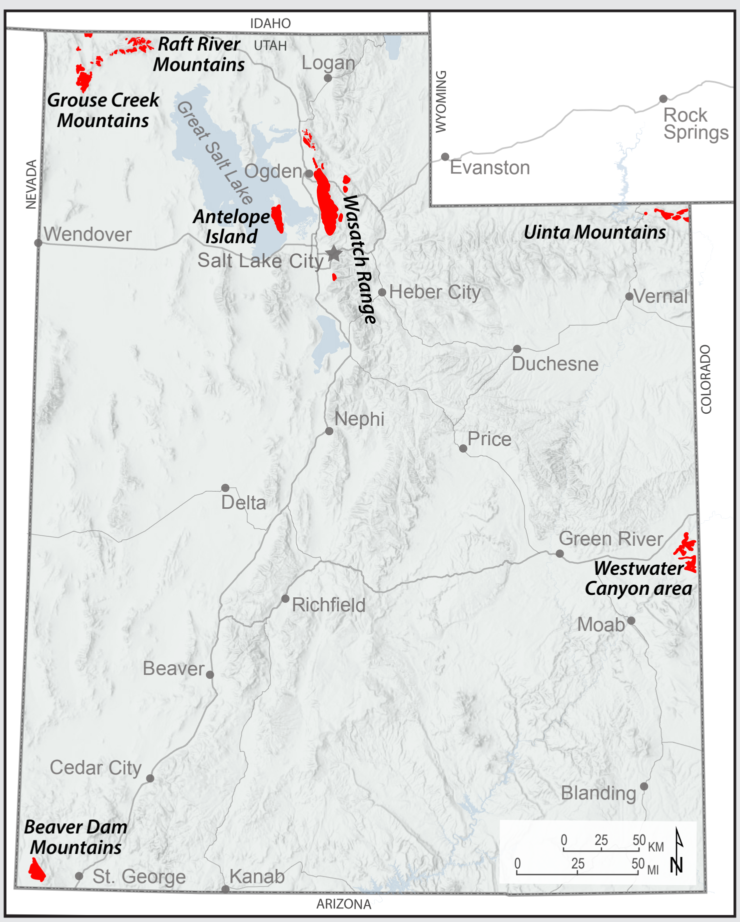
by Stephanie Carney



Outcrop of the Green Creek Complex monzogranite in the Raft River Mountains; inset is close-up view.

Utah's oldest rocks formed during the Precambrian, a time in Earth's history that occurred 4,600 to 540 million years ago and was characterized by simple, single-celled organisms before the "Cambrian Explosion" of complex organisms around 540 million years ago. Many of Utah's Precambrian outcrops are well studied and have been radiometrically dated. The results of these studies and analyses indicate that the oldest known rocks in Utah belong to the Green Creek Complex in northwestern Utah.

The Raft River and Grouse Creek Mountains in Box Elder County are home to the Green Creek Complex, which comprises a 2.7-billion-year-old (Ga) schist (metamorphosed sedimentary rock) and a 2.5 Ga monzogranite (an igneous pluton that intruded the schist). These rocks were deposited and formed during the late Archean Eon of the Precambrian. The schist originated as sediments deposited on a passive margin (where virtually no tectonic activity is taking place, like the present-day Atlantic Coast) of the North American craton (the ancient core of the North American continent). The 2.7-Ga age records the maximum time of deposition of these sedimentary rocks. The monzogranite began as a magma body that intruded into the older sedimentary rocks from below, therefore sedimentation took place between 2.7 and 2.5 Ga. The minerals that make up the granite slowly crystalized as the magma body cooled in the subsurface, and the 2.5-Ga age records when the minerals formed.



Location of select Precambrian-age outcrops (red) in Utah discussed in this article.

The rocks of the Green Creek Complex were subjected to multiple metamorphic events since 2.5 Ga. The first of these events was when the Grouse Creek block, a tectonic terrane which the Green Creek rocks are a part of, collided with the North American craton around 1.7 billion years ago during the early Proterozoic Eon of the Precambrian. The rocks also record later metamorphic events that affected the complex during the Late Cretaceous Period, around 95 and 82 million years ago. These later events would have been related to the Sevier orogeny, which was a mountain building event that lasted from about 160 to 80 million years ago.

Other Noteworthy Precambrian-age Rocks in Utah

The Farmington Canyon Complex is not quite as old as the Green Creek Complex, but is more accessible to Utahns, especially those living along the Wasatch Front. The Farmington Canyon Complex is exposed in the Wasatch Range east of Ogden, Layton, and Farmington, as well as on Antelope Island in Great Salt Lake, and consists of a suite of metamorphic rocks including schist, gneiss, and quartzite. Zircons from the Farmington Canyon Complex have yielded ages of about 2.4 Ga and the rocks were subjected to the same metamorphic event that affected the Green Creek Complex 1.7 billion years ago. The Frary Peak trail on Antelope Island winds through some of these impressively metamorphosed rocks.

Other notable Precambrian rocks are the Red Creek Quartzite and the Owiyukuts Complex, in the eastern Uinta Mountains; metamorphic rocks in the Beaver Dam Mountains in southwestern Utah; and metamorphic rocks in east-central Utah. The Red Creek Quartzite is in Daggett County near Clay Basin and the Wyoming and Colorado borders. It is composed of the metamorphic rocks quartzite, mica schist, and amphibolite and has yielded metamorphic ages around 1.7 Ga. A little south and east of the Red Creek outcrops is a relatively small exposure of highly metamorphosed gneiss called the Owiyukuts Complex. The gneiss there has yielded a metamorphic age of about 1.8 Ga.

In southwestern Utah, ancient metamorphic gneiss, schist, and pegmatite are exposed in the Beaver Dam Mountains west of St. George. These rocks have a metamorphic age of about 1.8 to 1.7 Ga as well. Similarly, Precambrian gneiss, schist, and amphibolite rocks near Westwater Canyon of the Colorado River and the Coach Canyon area near the Utah-Colorado border in eastern Utah have metamorphic ages of about 1.7 Ga.

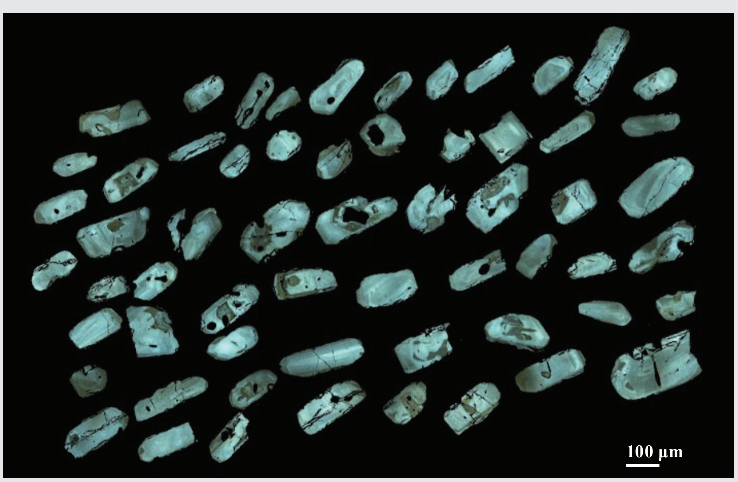
Schist of the Green Creek Complex in the Raft River Mountains. Pen for scale.

Outcrop of the Farmington Canyon Complex gneiss in the Wasatch Range. Compass for scale. Photo courtesy of Zach Anderson, Utah Geological Survey.

How Are Ages Determined?

Radiometric or isotopic dating is one of the best ways to determine the age of an igneous or metamorphic rock. This dating technique measures how much of a radioactive isotope of an element has decayed over time. An isotope is a different form of the same chemical element; i.e., it is the same element but has a different mass (extra neutrons). An unstable or radioactive isotope (called a parent isotope) is one that decays over time to become a different stable elemental isotope (daughter isotope). The length of time it takes for one-half of the parent isotope to decay into its daughter isotope is called the half-life. For example, the unstable argon isotope ^{39}Ar will decay to the stable form of ^{39}K and has a half-life of 269 years, and the unstable samarium isotope ^{147}Sm will decay to stable neodymium (^{143}Nd) and has a half-life of 106 billion years!

One of the most reliable methods for determining the age of very old rocks is uranium-lead (U-Pb) zircon geochronology. Igneous rocks often contain the mineral zircon, which is an accessory mineral that crystallizes at high temperature inside a magma body. During crystallization, zircon incorporates uranium in its crystal structure but not lead. Lead is created and added to the crystal solely from the radioactive decay of uranium. Uranium has two radioactive isotopes, ^{238}U and ^{235}U. The isotope ^{238}U decays to ^{206}Pb and has a half-life of 4.47 billion years, and ^{235}U decays to ^{237}Pb and has a half-life of 710 million years. Because these two different decay series occur in the zircon, two ages can be determined by measuring the ratio of parent and daughter isotope for each decay track. The results of each measurement can then be compared to verify the age of the mineral and, therefore, the rock.



Example of zircon grains under cathodoluminescence microscope. Photo courtesy of Dr. Liz Balgord of Weber State University.

An approximate age for sedimentary rocks can also be obtained using zircon geochronology. Zircon is a durable and hard mineral, and grains that have weathered out of igneous rocks are often deposited along with other minerals and sediments that eventually will form a sedimentary rock. A maximum age of the sedimentary rock can be determined from the age of the zircons within it. The age of the zircon grains can also point to where they came from, or their provenance, by comparing them to other known ages of local or regional igneous rocks.

Trek to Fremont Island
(Disappointment Island)

by Torri Duncan

Fremont Island, with its fascinating geology, is one of eleven commonly recognized islands in Great Salt Lake, but is not always an island. When the lake surface drops below 4,195 feet above sea level, it exposes a stable sandbar that extends south from Fremont Island, connecting to the Davis County Causeway. When the lake level is higher, Fremont stands as one of its largest islands. Historically, Fremont Island has been privately owned and closed to public access. In 2020 the land was donated to the State of Utah with a conservation easement held by The Nature Conservancy that prevents development and maintains the natural environment. Now the island is managed by the Utah Department of Natural Resources, Division of Forestry, Fire & State Lands (FFSL). With careful planning and by following FFSL rules, people can travel to and explore the mysterious Fremont Island.

Castle Rock and the prominent ridgeline of Fremont Island, overlooking Circle Valley. Note the parallel arcuate shorelines below the ridge, which were etched by Lake Bonneville. Snowy peaks of the Wasatch Range in the background. Photo taken from Beacon Point, looking east.

Brief Island History

The remoteness of this island in an "inland sea" and land-locked state means that few visitors have made the journey; the ones who did left notable stories. Several cultural artifacts in pristine condition indicate the presence of Indigenous Peoples on this island before 1800. Early explorers of the western United States, John C. Frémont and Kit Carson, searched for freshwater springs on the island during their exploration of the Bear River in 1843. When the search turned unsuccessful and morale was low, Fremont dubbed the land "Disappointment Island." Kit Carson etched a cross into a rock, which can still be seen today on the island's highest point. In 1846, Albert Carrington, namesake of Carrington Island in Great Salt Lake, and other pioneer settlers of Salt Lake City boated the lake and called this island "Castle Island" due to the castle-like resemblance of the island's high point, now called Castle Rock. A few years later, Captain Howard Stansbury embarked on a scientific expedition to survey Great Salt Lake and surrounding areas for a suitable route for the future transcontinental railroad. It was Stansbury's expedition in 1850 that named Fremont Island, and the name stuck.

In the 1860s, the first Salt Lake City Cemetery grave digger, Jean Baptiste, was sentenced to be banished to Fremont Island on charges of robbing over 300 graves. A few months after leaving Baptiste on the desolate island, a group sailed to Fremont Island to check on him, but he was nowhere to be found. Although the fate of Baptiste remains unknown, people say he still haunts the island and the cemetery.

Fremont Island was purchased by Judge Uriah J. Wenner in the 1880s, beginning a long succession of private ownership. Wenner and his wife are buried on the island—their gravesite on the southern tip of the island is visibly marked and surrounded by a wire fence. Another homesteader built a log cabin that remains as the only standing structure on the island. Recent owners had been planning for the 3,000-acre island to host homes and other development before The Nature Conservancy announced its securing a donor to buy the island, placing it in a conservation easement, and turning it over to the State.

Aerial view (looking north) of Fremont Island and the nearby Promontory Mountains. This photo was taken in the 1980s, when the lake levels were higher and the island was inaccessible by way of the sandbar. Photo courtesy of Don Currey, University of Utah.

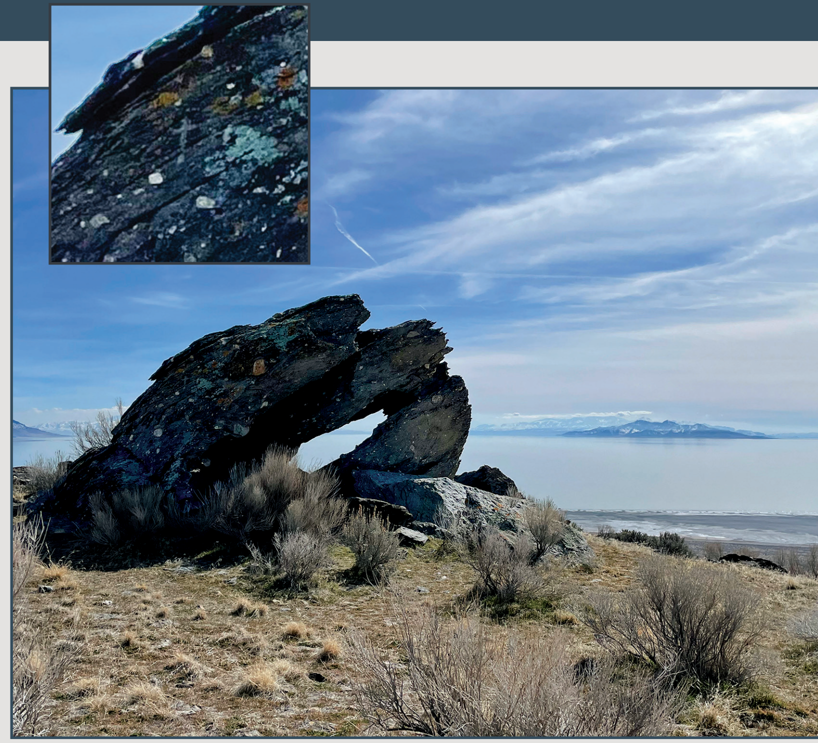
A slab of slate showing alteration banding and cubes of pyrite weathering to goethite. The cubes in this image are 0.25 inch wide.

Geology of Fremont Island

Fremont Island consists mostly of 635- to 720-million-year-old rocks (Late Precambrian) of the Perry Canyon Formation. This geologic unit contains a host of different rock types, including slate, quartzite, volcanic rocks, minor carbonate rocks, and diamictite. Diamictite is a type of sedimentary rock that contains rock fragments (clasts) of various shapes, sizes, and types embedded in a matrix of sand or mud. On Fremont Island, the diamictite rock represents glacial till deposited at a unique time in Earth history when glaciers are believed to have covered the globe. Kit Carson's cross is etched into this "tillite," near a natural arch.

Within the slate and quartzite, you can find pyrite cubes up to one inch in length. Most of the pyrite cubes have been weathered to other iron minerals, predominantly goethite, which do not have the shiny appearance of fool's gold (pyrite).

Additionally, Fremont Island displays evidence of ancient Lake Bonneville, a huge freshwater lake that existed from approximately 30,000 to 13,000 years ago. Shorelines of Lake Bonneville's fluctuating levels left behind conspicuous beach terraces on the hillsides. Prominent Lake Bonneville shorelines that can be identified on Fremont Island include the Provo level at about 4,880 feet elevation, and the Stansbury level which comprises multiple shorelines between 4,500 and 4,600 feet elevation.



Diamictite arch on Castle Rock, with Kit Carson's cross etched on the left side. Stansbury Island on the right in the distance. View is to the south.

HOW TO GET THERE

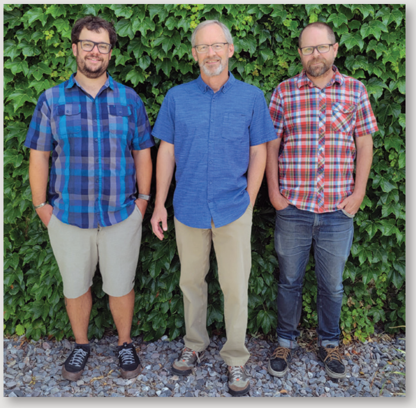
Fremont Island is only accessible by foot or bike if the Great Salt Lake water level is lower than an elevation of 4,195 feet. Check the lake level before you go at https://waterdata.usgs.gov/ut/nwis/uv. If the lake level were to come back up, access to Fremont Island may be possible via boat.

From Salt Lake City, travel north on I-15 and take exit 332 for Antelope Drive in Layton. Continue west on Antelope Drive and across the Davis County Causeway. There is no parking along the causeway, so you must park your car on Antelope Island at the U.S. Army Ranger and Air Force Memorial and walk or bike east on the causeway for three miles. You will reach a sign informing you that Fremont Island is now State-owned land. This is where you leave the causeway to head north on the sandy lake bed. The trek is 6 miles on the sand toward the obvious mountain of Fremont Island, with no vegetation to provide shade along the way. Be prepared and bring plenty of water—there are no water sources on Fremont Island (*remember why it was named Disappointment Island?*). From mid-April to June, biting gnats emerge and may ruin your day. For conditions updates, contact Antelope Island State Park Information at 801-773-2941 or visit the current conditions webpage: https://stateparks.utah.gov/parks/antelope-island/current-conditions.

Important Information:

FFSL Rules: Walking, boating, and bicycling are allowed. Motorized vehicles are not allowed on the sandbar or the island itself. Overnight camping is not allowed. Visiting Fremont Island is a serious undertaking and potentially dangerous. Due to the remoteness of the location, emergency services would take considerable time to reach anyone in need of help. For more information see the FFSL website at https://ffsl.utah.gov/Fremont-island/ or call 801-538-5418.

2022 Crawford Award



The Utah Geological Survey's (UGS) prestigious Crawford Award was presented to **Michael Hylland**, **Adam Hiscock**, and **Greg McDonald** in recognition of their work on the outstanding publication, *Paleoseismic Investigation of the Taylorsville Fault at the Airport East Site, West Valley Fault Zone, Salt Lake County, Utah* (UGS Special Study 169). The research published in UGS Special Study 169 provides the most detailed and comprehensive paleoseismic data available for the West Valley fault zone, and is extremely important for understanding and accurately modeling seismic hazard and risk in the most densely populated part of the Wasatch Front urban corridor.

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

Bob Biek retired in early June 2022, after a 26-year career with the UGS. 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 UGS Geologic Mapping Program in 1996. Most of his geologic mapping is in southwestern Utah and along the Wasatch Front, where he has authored over 40 7.5' geologic maps and four 30' x 60' geologic maps. He is continually amazed at what one can learn simply by making a geologic map based on simple field observations. In retirement, Bob plans to continue pursuing his passions for backcountry travel, gardening, and spending time with friends and family. We wish him many happy years of retirement!

Kent Brown retired in late July 2022, after 39 years of service with the UGS. Kent joined the UGS in 1983 and served as senior cartographer in the Editorial Section before transferring to the Geologic Mapping Program in 1990. Since then he has specialized in up-to-date digital photogrammetry methods, methods for standardized geologic data creation that is compatible with GIS software, and all things cartographic at the UGS. It is largely through Kent's efforts and leadership that the UGS is recognized as one of the leaders in using digital mapping technology. He has spent countless hours training other staff on the latest GIS techniques and helping geologists incorporate new computer software and hardware into their field mapping. Kent's knowledge and expertise will be greatly missed, and we wish him well in his retirement!

The Energy & Minerals program welcomes **Jake Alexander**, who accepted a position as economic geologist. Jake received his degrees from Texas A&M (Corpus Christi) and the University of Tennessee and has two years of experience working in the mineral resource industry. **Greg Gavin**, **Hector Zamora**, and **Jeremiah Bernau** have accepted positions as hydrogeologists with the Groundwater & Wetlands Program. Greg received his B.S. in geological sciences from the University of Utah, has a background in private consulting, and previously worked at the Utah Department of Environmental Quality. Hector received his Ph.D. in geosciences from the University of Arizona, has a background in private consulting, and previously worked with the Tucson Water Department. Jeremiah received his Ph.D. in geological sciences from the University of Utah and previously worked as an intern in the oil & gas industry. The Data Management Program bids farewell to **Cyndi Andersen** who has taken a job with the City of Meridian, Idaho. A warm welcome to Jake, Greg, Hector, and Jeremiah, and best wishes to Cyndi.

In Memoriam

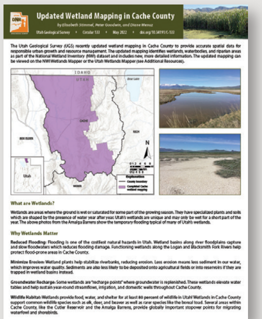
Former UGS employee **Valerie Vaughn** passed away on July 2, 2022. Valerie worked as a technician with the Energy & Minerals Program before retiring in 2011. She dedicated much of her time serving her community including her most cherished work: founding and establishing the highly successful Liberty Park Farmers Market, a dream she'd had for many years. We express our sincere condolences to Valerie's family and will miss her big heart, her devotion to her causes, and her sincere care for others including her many animal pets.

Best of Utah IT Award

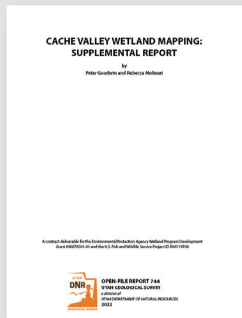
The UGS was honored to receive an award for "Best Use of Social Media - Utah Arch Challenge" at the 2022 Utah Digital Government Summit. This campaign advertised a fun, online game experience in parallel with college basketball's March Madness to introduce people to Utah's unique geology.

NEW PUBLICATIONS

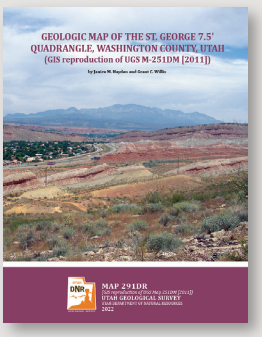
Available for download at geology.utah.gov *or for purchase at* utahmapstore.com.



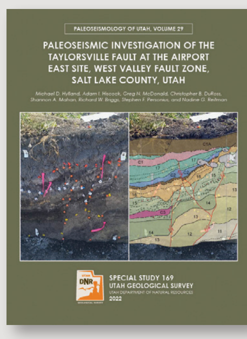
Updated Wetland Mapping in Cache County, by Elisabeth Stimmel, Peter Goodwin, and Diane Menuz, 2 p., **C-133**, https://doi.org/10.34191/C-133



Cache Valley Wetland Mapping: Supplemental Report, by Peter Goodwin and Rebecca Molinari, 28 p., 2 appendices, **OFR-744**, https://doi.org/10.34191/OFR-744



Geologic Map of the St. George 7.5' Quadrangle, Washington County, Utah (GIS Reproduction of UGS Map 251DM [2011]), by Janice M. Hayden and Grant C. Willis, 21 p., 2 plates, scale 1:24,000, **M-291DR**, https://doi.org/10.34191/M-291DR



Paleoseismic Investigation of the Taylorsville Fault at the Airport East Site, West Valley Fault Zone, Salt Lake County, Utah, by Michael D. Hylland, Adam I. Hiscock, Greg N. McDonald, Christopher B. DuRoss, Shannon A. Mahan, Richard W. Briggs, Stephen F. Personius, and Nadine G. Reitman, 29 p., 2 plates, 7 appendices, **SS-169**, https://doi.org/10.34191/SS-169

Teacher's Corner

CALL FOR NOMINATIONS FOR THE 2023 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 2023 Utah Earth Science Teacher of the Year Award. The winning teacher and their school will receive monetary contributions for procuring resources related to earth science education. All K–12 teachers of natural resources* in the earth sciences are eligible. Application deadline is December 31, 2022. Additional information, requirements, and entry forms are available on the UGA website (www.utahgeology.org) under the Outreach tab.

*Natural resources are defined as earth materials used by civilization past and present, such as natural gas, petroleum, coal, oil shale, mineral ores, building stone, and energy resources from the earth such as geothermal energy.

CALL FOR VOLUNTEERS

Earth Science Week
October 3–6 and 10–13

Do you have an interest in promoting the future of geological sciences? Come celebrate Earth Science Week with the Utah Geological Survey by volunteering to help with hands-on activities that are particularly suited for 4th and 5th grade elementary school students. Earth Science Week activities take place at the Utah Core Research Center in Salt Lake City and include panning for "gold," identifying rocks and minerals, experimenting with erosion and deposition on a stream table, examining dinosaur bones and other fossils, and new for this year, learning about earthquakes.

No experience is needed and anyone with an interest in geology can help. For more information, please visit our website at https://geology.utah.gov/teachers/earth-science-week/.

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