UTAH GEOLOGICAL SURVEY

SURVEY NOTES

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Great Salt Lake Wetlands

The Director's Perspective

by Richard G. Allis

Ten years ago, the Utah Geological Survey had a very simple website, and access to geological information, databases, or publications typically required a phone or email inquiry or a visit to the UGS office. Today, most Utahns have access to the Internet, and our goal is to have all UGS publications, maps, and databases accessible through the web. Remote access to geological information raises awareness of Utah's unique geology, facilitates wise land-use planning, can assist natural-resource exploration investment decisions, and can be an educational aid to teachers and students. The challenge for an agency like the UGS, which is responsible for maintaining and serving large volumes of information, is how to meet the needs of diverse customers. The new interactive database for groundwater conditions in Snake Valley (Millard County) and along the Wasatch Front (see sidebar on p. 7) is a good example of making high-interest data readily available to diverse groups—in this case the interested public, local government, and the State Engineer's Office.

Ten years ago we sent most of our publications out for commercial offset printing, and the minimum print run of 300 copies required considerable physical storage

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In this 1964 photograph, UGS mapping geologist Hellmut Doelling (at left) provides assistance to a customer in the UGS "sales office," precursor to today's Natural Resources Map and Bookstore.

Contents

Design: *Stevie Emerson*
Cover: *Numerous types of wetlands, including open-water, fringe, emergent, and playa, are present in Bear River Bay and Willard Bay Reservoir in the northeastern part of Great Salt Lake. Photo by Richard L. Emerson.*

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NEW CLASSIFICATION SCHEME PROVIDES AN IMPROVED TOOL FOR MANAGING GREAT SALT LAKE WETLANDS

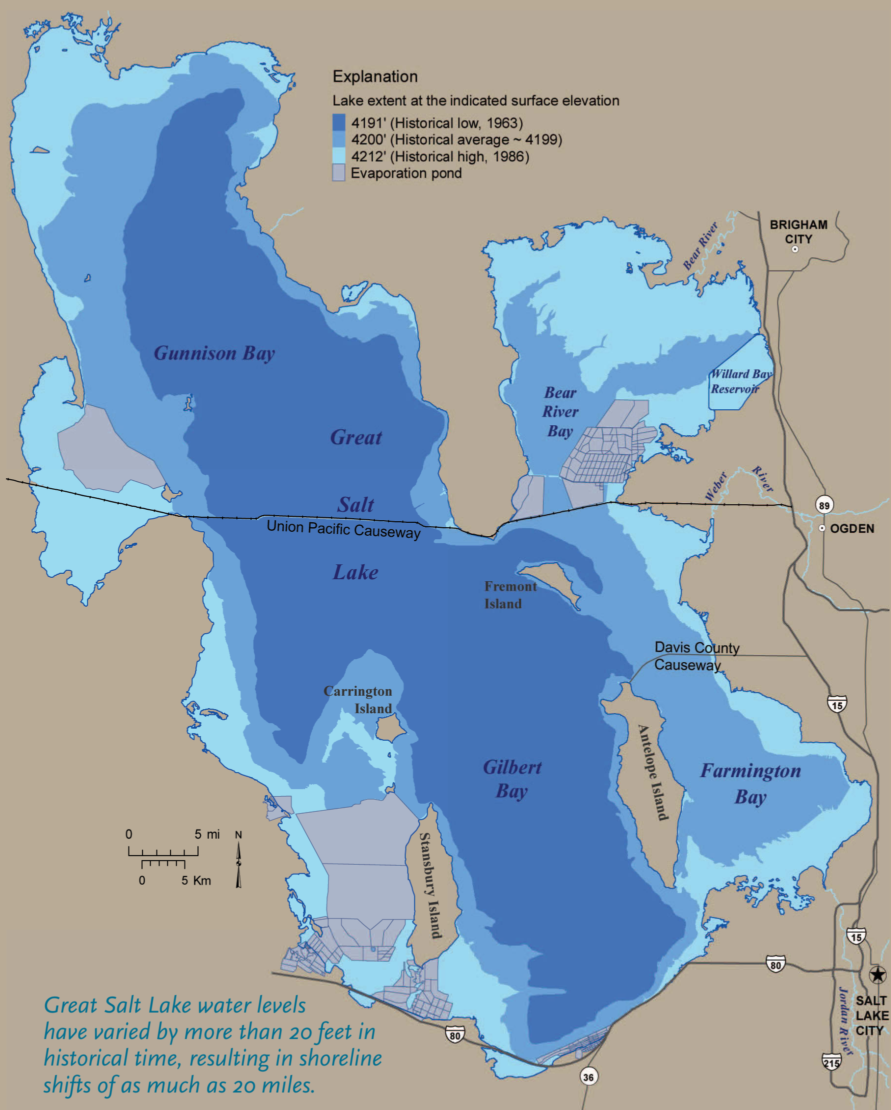
Richard Emerson and Toby Hooker

Located on the Pacific Flyway, Utah's Great Salt Lake is one of North America's most important waterways. The peripheral wetlands of Great Salt Lake serve as critical nesting areas and feeding grounds for millions of migratory birds. At least 250 avian species breed or stop to feed here on their annual migrations. Half of the world's population of some species, such as the Wilson's phalarope, rely on the lake's wetlands each year. However, despite the international importance of the wetlands that support these birds, little has been done to maintain a spatial record of the Great Salt Lake ecosystem.

Scientific study has become increasingly reliant on geographic information systems (GIS) to process complex environmental information, and wetland studies are no exception. Essential wetland information, such as water characteristics, vegetation, and landform type stored in a GIS database, provides critical knowledge for evaluating wetland health and change over time. The most widely distributed wetland classification for the United States is the National Wetland Inventory (NWI), which includes the Great Salt Lake area. However, the NWI has been updated very little since its release in the 1980s. Also, with a dependence on vegetation, water depth, and inundation period, the NWI is well suited for environments such as tidal estuaries where predictable vegetation and water patterns exist but is not well suited to the highly variable environments of Great Salt Lake wetlands.

As a terminal water body, Great Salt Lake water levels respond to climatic variations on multiple time scales affecting vegetation and water inundation period. Water levels can fluctuate by as much as 4 feet from fall to spring and commonly fluctuate 10 feet or more on decadal scales. An extreme change in water level can dramatically alter the wetland landscape of Great Salt Lake as it did in 1987 when the lake surface reached its historical high of 4212 feet above sea level. In some locations this rise resulted in a shoreline shift of 20 miles relative to the shoreline during the lake's historical low of 4191 feet in 1963. This surface area increase of 40 percent inundated over 1300 square miles of previously exposed mudflats, playas, and vegetated wetlands, flooding waterfowl management areas and structures near the lake and spurring the State of Utah to build a multi-million dollar pumping system to expel lake water into the west desert in an effort to evaporate it. The saline water of Great Salt Lake kills most vegetation and infuses the soil with salt, hindering plant growth for years after the water has receded.

This variability makes it difficult to apply the NWI classification system to Great Salt Lake wetlands, and many agencies have either neglected the NWI or modified it to meet their unique needs. The Environmental Protection Agency has recognized that many agencies would benefit from a clear and simplified, standardized classification for Great Salt Lake wetlands and asked the Utah Geological Survey to simplify the NWI classifica-



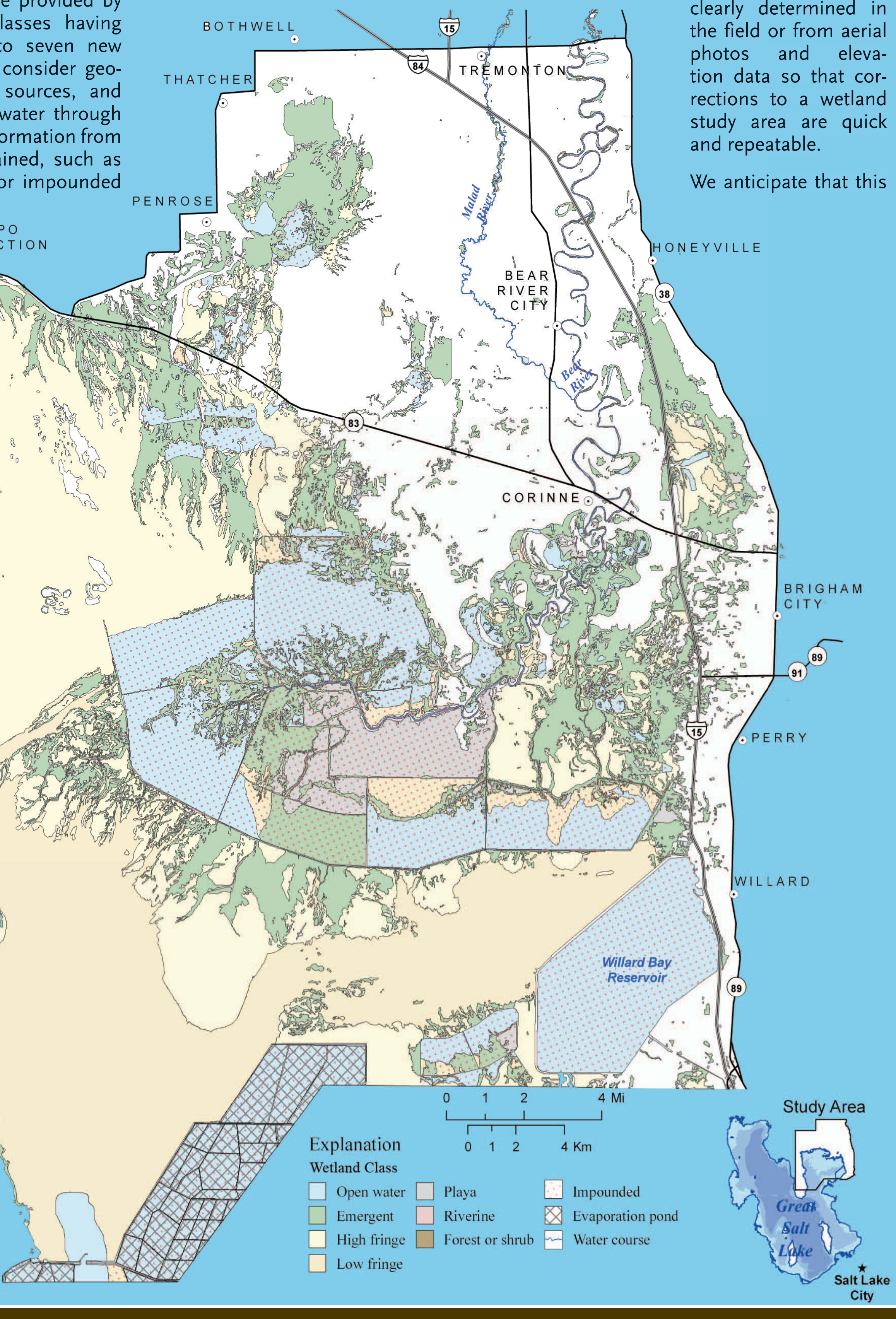
Great Salt Lake water levels have varied by more than 20 feet in historical time, resulting in shoreline shifts of as much as 20 miles.

tion system. Hopefully a simplified classification system will foster greater communication and collaboration between the many agencies that work in these complex environments.

We reclassified the 210 unique wetland classes for Great Salt Lake provided by the NWI by grouping classes having similar characteristics into seven new classes. The new classes consider geomorphic features, water sources, and directional movement of water through wetland areas. Auxiliary information from the NWI dataset was retained, such as excavated areas (canals) or impounded water (waterfowl ponds), and we added other information and features such as evaporation ponds from the current water-related land-use coverage provided by the Utah Division of Water Resources.

Through field checking the results at Bear River Bay, we determined that the new classes are approximately 76 percent accurate. We attribute most of the error to change in the wetlands as they responded to a lowering of Great Salt Lake water levels since the 1980s. The seven classes are intended to be clearly determined in the field or from aerial photos and elevation data so that corrections to a wetland study area are quick and repeatable.

We anticipate that this



Wetland reclassification scheme of Bear River Bay, Great Salt Lake, Utah. We reduced the 210 wetland classes for Great Salt Lake in the National Wetland Inventory to seven new classes.

Wetland Class	Description
Open water	Perennial water body
Emergent	Wetland dominated by emergent vegetation. This wetland type is commonly associated with ground-water discharge (seeps and springs) or areas with shallow surface interflow over the land surface
High fringe	Largely non-vegetated wetlands near the historical lake margin, where water supply is primarily controlled by water level. At lower lake levels, fringe wetlands represent large areas of mudflats adjacent to Great Salt Lake
Low fringe	Fringe wetland from the perennial shoreline to the ephemeral high water level
Playa	Ephemeral ponds or depressional features with mineral soils; primary water sources include precipitation and ephemeral surface flow inputs
Riverine	Perennial streams (including canals and ditches) and associated riparian areas that are regularly flooded by overbank flow
Forest or shrub	Wetlands associated with woody plants such as willow or iodine bush

new wetland classification method will be useful to agencies that need Great Salt Lake wetland GIS data. The data are expected to be released soon and made available through the Utah Automated Geographic Reference Center (AGRC). We expect to continually revise the dataset as high-resolution elevation data and aerial imagery become increasingly available to aid mapping efforts of Great Salt Lake wetlands.

ABOUT THE AUTHORS

Richard L. Emerson is a geologist in the UGS Groundwater and Paleontology Program, where he has worked since 2007. His duties include geographic information system (GIS) analysis and mapping of wetland, shallow-groundwater, and aquifer data throughout the state. He is currently working on wetland projects in Snake Valley and Great Salt Lake.

Toby Hooker has been a Wetland Scientist with the UGS's Groundwater and Paleontology Program since 2010. His work focuses on developing methods to assess the health of wetlands around Great Salt Lake and correlating ecosystem health with wetland hydrologic monitoring in Utah's west desert.

(continued from Director's Perspective)

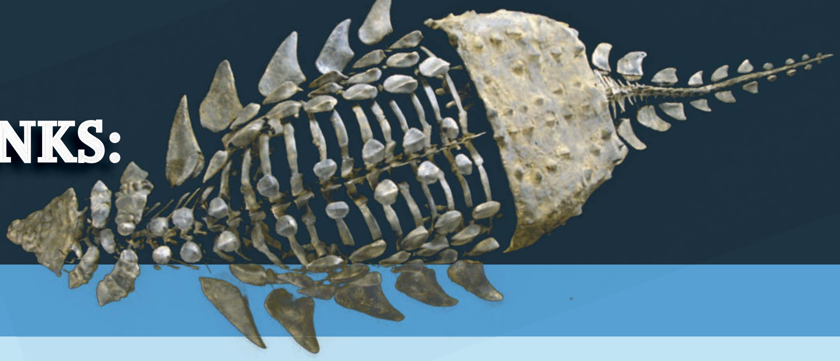
space. Today, only a few of our high-demand publications, such as the recent booklet *Why is Bear Lake so Blue?*, our annual geology calendar, and geologic maps near major urban areas, are still printed commercially. Otherwise, most of our publications are now digital, and our bookstore supplies either CDs or print-on-demand hard copies to customers. Our publications are also available for free download on the web six months after their release.

The UGS website has become our primary avenue for providing information about the geology of Utah. Over the past year, visits to our website increased by more than 25 percent, to about 500,000 visits. The most popular pages are typically our less technical material that has broad appeal to those interested in rock/mineral collecting and earth-science education. Our six most popular web pages are "Rock and Mineral Collecting Sites," "Volcanoes [in Utah]," "How do Geologists Know How Old a Rock Is?," "What are Fulgurites and Where Can They be Found?," "Utah Gold," and "What are Minerals Used For?".

The UGS recognizes the new constituency of potential customers who use Internet sites such as blogs, Facebook, and Twitter for accessing information. The UGS blog began in September 2008—we have made 252 posts under four categories ("New on the Web," "New Publications," "News Releases," and "UGS in the Media") and the blog has been viewed 24,000 times. People can sign up to receive email notifications from the blog whenever a new post is added. These posts are also sent to the UGS Facebook page (792 followers) and UGS Twitter page (125 followers). We also recognize that smartphone capabilities are rapidly evolving and becoming increasingly popular, and earlier this year we released a free, downloadable application for Android phones. This "app" gives information and directions to 29 "GeoSights" previously described in *Survey Notes*. The application has been downloaded 857 times and is presently active on 430 phones.

The days of interfacing with the public only by phone or from behind a counter are long gone—for every one inquiry by phone, email, or walk-in, we get about 100 website visits. Although we still enjoy face-to-face interaction with our customers, the widespread and common use of technology dictates that our primary interface is now the Internet, and our ability to provide information and data has increased tremendously. Information technology continues to evolve, so agencies like the UGS must continually adapt to meet the expectations of modern society.

UTAH'S PREHISTORIC TANKS: THE ANKYLOSAURS



James I. Kirkland
Utah Geological Survey

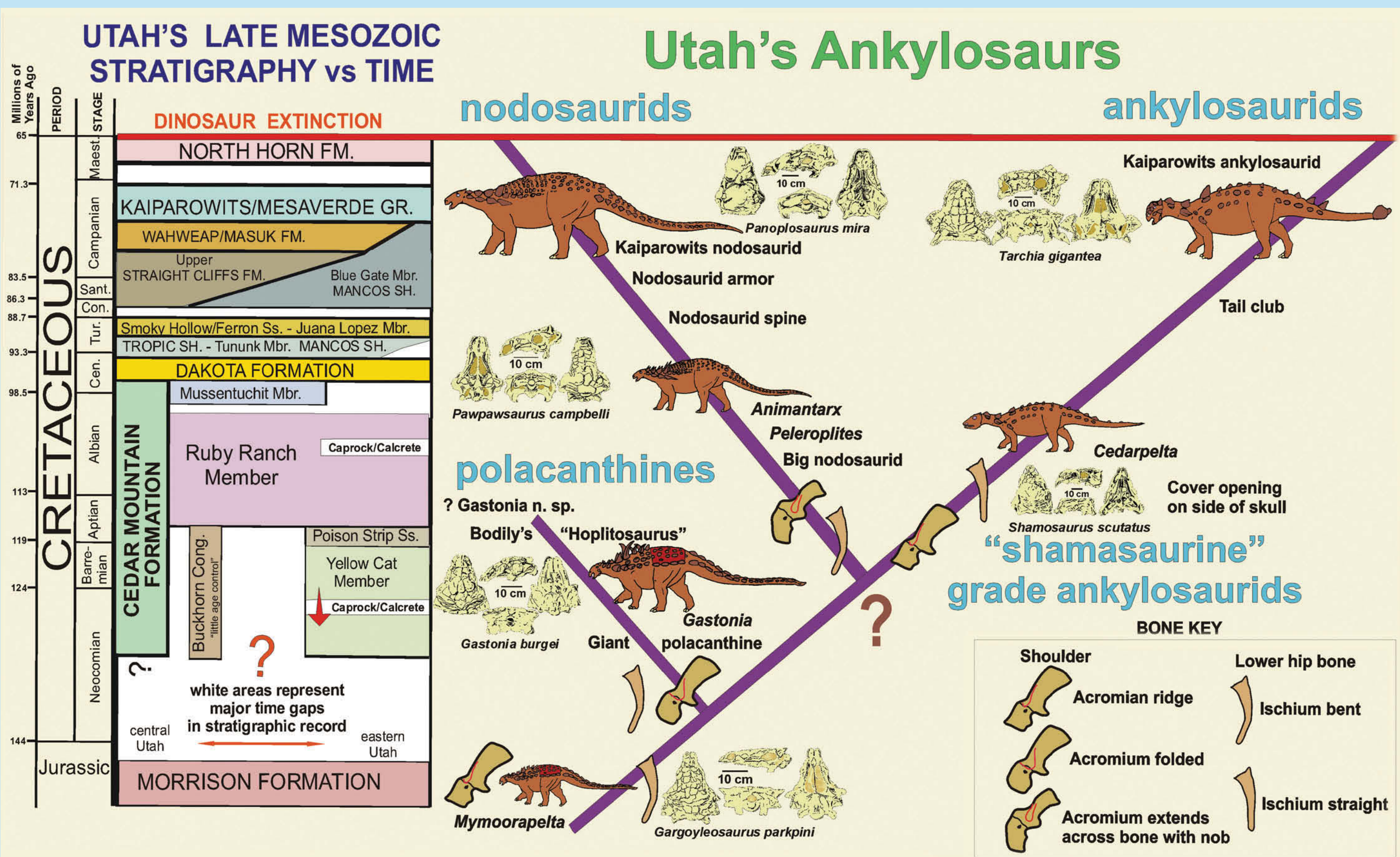
Mark A. Loewen
Utah Museum of Natural History

Utah is famous for its many dinosaur localities spanning the Mesozoic Era (the Age of Dinosaurs). However, of all Utah's dinosaur species, one group is truly unappreciated: the Ankylosauria. These were heavily armored, tank-like, plant-eating dinosaurs characteristic of the Cretaceous Period (65–145 million years ago). Ankylosaurs were so well protected that even their eyelids were armored.

Historically, ankylosaurs are best known from the last 10–15 million years of the Cretaceous and have traditionally been split into two taxonomic families. The family Ankylosauridae is known for having distinctive tail clubs and boxy skulls, where the openings in the sides of the skull characteristic of other dinosaur groups are closed off and the bony armor covering the skulls includes spines at the back of the skull above and below their eyes. The family Nodosauridae never had tail clubs, typically had large shoulder spines, and had more simple, "pear-shaped" skulls lacking spines and retaining the openings in the sides of the skull behind the eyes. These two families also differ in their distinctive shoulder blades (scapula) and lower pelvic bones (ischia). This two-part classification scheme held up well until the discovery of new ankylosaur species in the Upper Jurassic and Lower Cretaceous of eastern Utah and westernmost Colorado, which provided important insights on ankylosaur evolution that complicated this simple story.

Mymoorapelta maysi, *a primitive ankylosaur (about 10 feet long) recovered from the Upper Jurassic Morrison Formation in westernmost Colorado and on exhibit at the Museum of Western Colorado in Fruita. Photo courtesy of Francois Gohier.*

The first ankylosaur to be described from Utah was a large tail with massive triangular spines and massive bone plates. It was discovered by Lin Ottinger of Moab, Utah, in the early 1960s in the Poison Strip Member of the Early Cretaceous-age Cedar Mountain Formation west of Arches National Park. This distinct specimen is known as the Bodily "*Hoplitosaurus*" for Brigham Young University student N.M. Bodily who compared the specimen with the smaller and poorly known *Hoplitosaurus* from the Lower Cretaceous of the Black Hills region of South Dakota.



Simplified ankylosaur family tree, listing species known from Utah opposite the strata they occur in. Note the numerous species of ankylosaur from the Cedar Mountain Formation at the branching points for the families of ankylosaur.

In 1989, J.I. Kirkland discovered the first fairly complete Jurassic ankylosaur, *Mymoorapelta*, just over the state line in the Morrison Formation of westernmost Colorado. Within a week of this discovery, he learned of a similar dinosaur discovered by Robert Gaston, now of Fruita, Colorado, northeast of Arches National Park. As it turned out, this dinosaur was from the basal Yellow Cat Member of the Cedar Mountain Formation. The presence of a shield of fused armor over the hips (sacral shield) and distinctive triangular spines running down each side of its tail revealed that this new species, *Gastonia burgei*, was closely related to *Polacanthus foxi*, from nearly age-equivalent rocks on the Isle of Wight in southern England. *Gastonia* is now the best known member of a subfamily of primitive ankylosaurids known as the Polacanthinae that also includes *Hoplitosaurus*; the Bodily "*Hoplitosaurus*"; the third dinosaur ever named, *Hylaeosaurus*; and a number of other undescribed new species from the lower and middle Cedar Mountain Formation.

Utah's first nodosaurid was discovered by University of Utah radiological technician Ramal Jones in 1994 by mapping low-level radiation across a dinosaur quarry near the top of the Cedar Mountain Formation east of Castle Dale, Utah. *Animantarx ramaljonesi* was the first and is still the only dinosaur discovered solely by technology and not by seeing bone fragments on the ground surface. While the rocks preserving these fossils date from the beginning of the Late Cretaceous, larger nodosaurids are also known in the older Ruby Ranch Member of the Cedar Mountain Formation from near the end of the Early Cretaceous. One of these is the near elephantine-sized *Peleroplites cedrimontanus* described by Ken Carpenter (current director of the Prehistoric Museum, Price, Utah) in 2008 from the Prehistoric Museum's Price River Quarries.

The Price River Quarries have also yielded North America's only Lower Cretaceous ankylosaurid, the elephantine-sized *Cedarpelta bilbyhallorum*. *Cedarpelta* has closed off the opening in the skull behind the eye and has straightened the ischium as in more advanced ankylosaurids from the Upper Cretaceous, as is the case with the similar Lower Cretaceous ankylosaurids *Shamosaurus* and *Gobisaurus* from Asia. Likewise, *Cedarpelta* is primitive in that it had an elongate, weakly ornamented skull, and no evidence of a tail club.

Given that there are fossils indicating several additional, but as yet undescribed, ankylosaur species in the Cedar Mountain Formation, it becomes clear that the Cedar Mountain Formation of Utah preserves more species of ankylosaur than any other geologic formation in the world. However, Utah's other major dinosaurian frontier, the Upper Cretaceous rocks of Grand Staircase–Escalante National Monument (GSENM), is beginning to also yield evidence of a rich ankylosaurian record.

The distinctive armor of nodosaurids has been collected from the Straight Cliffs, Wahweap, and Kaiparowits Formations of GSENM. However, the Utah Museum of Natural History's recent ankylosaurid discoveries in the Kaiparowits Formation are the most significant amkylosaur finds to date. They have found evidence, based primarily on forelimbs and tail clubs, that two species of ankylosaurid coexisted during Kaiparowits time (around 76 million years ago). One site preserves much of a large animal including a well-preserved skull and a complete tail club. Still under study, portions of this important discovery will be exhibited in the new Natural History Museum of Utah in Salt Lake City when it opens in late 2011.

Ankylosaurid tail club newly discovered in the Kaiparowits Formation by the Utah Museum of Natural History (UMNH VP 20202).

Gastonia burgei, *a polacanthine ankylosaur (about 16 feet long) collected at the Lower Cretaceous Gaston Quarry (Yellow Cat Member, Cedar Mountain Formation) northeast of Arches National Park and on exhibit at the Prehistoric Museum in Price, Utah. Photo courtesy of Francois Gohier.*

WHAT DO ENVIRONMENTAL TRACERS TELL US ABOUT GROUNDWATER IN SNAKE VALLEY?

by Stefan M. Kirby

Introduction

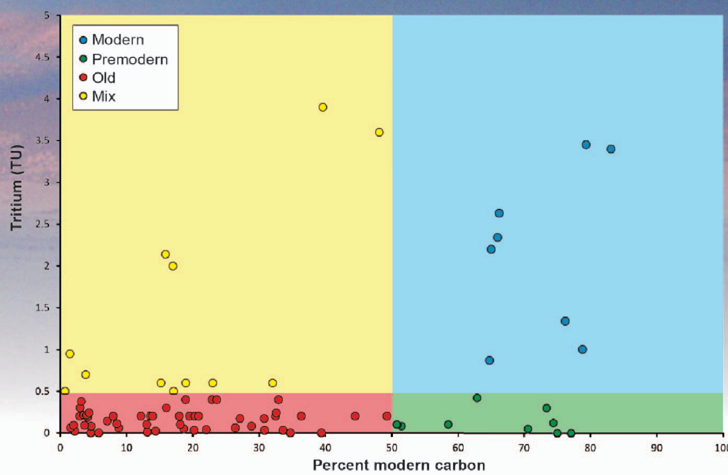
Water is the most basic natural resource. Its availability controls not only the distribution and health of plant and animal communities but also the extent and ultimate longevity of human cultures and economies in a given area. Throughout much of the western United States and particularly in the arid regions of Nevada and Utah, knowledgeable use of water is required for long-term occupation and economic growth as well as the health and productivity of the natural environment. The primary water resource in most arid areas lies below Earth's surface in the form of groundwater, and in the Great Basin significant quantities of groundwater lie beneath most basins. Sustainable development of these resources depends on an accurate understanding of the groundwater system.

Major recent population growth in Las Vegas and elsewhere in the Great Basin will require water in excess of current local supplies. This has caused water suppliers and developers to consider large-scale groundwater extraction and transport schemes to supply future demand. Foremost among these schemes is the now well-known plan by the Southern Nevada Water Authority to pipe significant amounts of groundwater from east-central Nevada southward to the Las Vegas area. In response to this plan and at the request of the Utah State Legislature and water managers, the Utah Geological Survey (UGS) has installed a series of new monitoring wells. A campaign of groundwater sampling for environmental tracers from the new wells and springs is providing insight to the groundwater resource in west-central Utah and its connection with groundwater to the west in Nevada. Analyses ranging from standard dissolved-ion chemistry to measurement of various isotopes and dissolved gases provide a range of environmental-tracer data that place basic constraints on the groundwater flow paths and processes in the Snake Valley area of west-central Utah.

Environmental Tracers

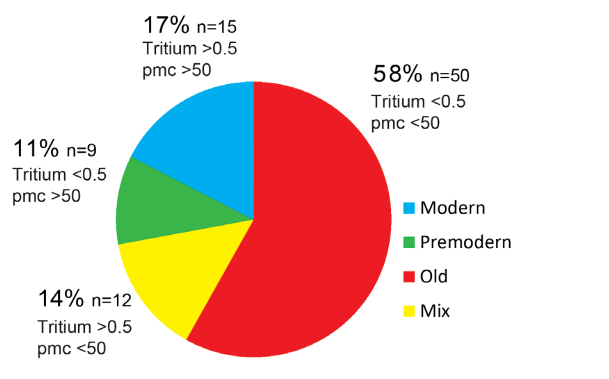
Environmental tracers are any natural or anthropogenic chemical compound or isotope in groundwater that can be measured and used to interpret sources of recharge and discharge, rates of groundwater movement, and groundwater age. Groundwater age may be used to estimate the rates and distribution of recharge along flow paths, and can provide constraints on the potential availability of groundwater for human use. Groundwater age is a relative concept that assumes groundwater begins as recharge and steadily aquires "age" as it moves along a flow path. Under this assumption, groundwater is youngest near areas of recharge, and its relative age increases with distance from the recharge area.

Environmental tracers that include radiogenic isotopes of hydrogen and carbon (tritium and carbon-14, respectively) can provide important information concerning the age of groundwater. These isotopes are created naturally in the upper atmosphere, or in much higher concentrations during above-ground nuclear testing, and exist in predictable concentrations throughout the atmosphere. As precipitation seeps into the ground, it incorporates these isotopes into the groundwater system. Following recharge, concentrations of tritium and carbon-14 in groundwater decrease at rates dictated by their half-lives (12.3 and 5730 years, respectively) and their concentrations may be used to estimate time since recharge. Tritium is directly incorporated into the water molecule and is chemically inert, so its concentration in a sample primarily records the initial concentration and subsequent radioactive decay. The process is more complicated for carbon-14 because this isotope readily undergoes geochemical exchange with various minerals in the aquifer system that can alter its concentration, and calculating groundwater age based on carbon-14 concentration requires a variety of complicated numerical techniques. Fortunately, these tracers may also be used in a qualitative sense to yield more general age ranges that can indicate important trends in a groundwater system.

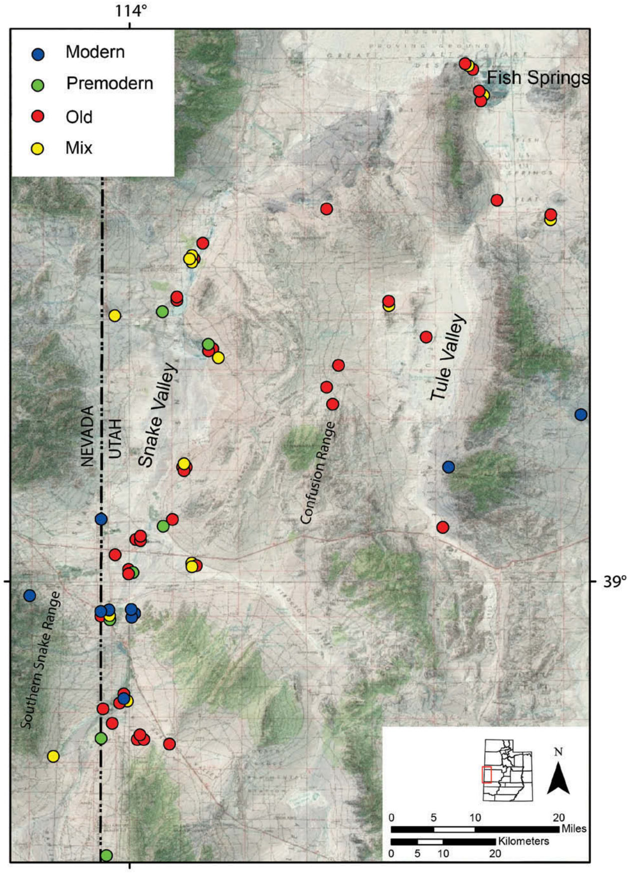


Tritium vs. carbon-14 (as percent modern carbon) for samples in the Snake Valley area. Colored zones correspond to qualitative ages of groundwater.

Previous studies have shown that tritium concentrations greater than 0.5 Tritium Units (TU) and carbon-14 concentrations greater than 50 percent modern carbon (pmc) indicate a water sample is modern, recharged since approximately the 1950s. Tritium concentrations less than 0.5 TU and pmc greater than 50 indicate a sample is premodern and may consist of water recharged prior to the 1950s and up to hundreds of years ago. Samples having tritium less than 0.5 TU and pmc less than 50 are considered old and consist of water recharged more than several hundred years ago and possibly up to tens of thousands of years ago. Samples



Distribution of qualitative groundwater ages in the Snake Valley area. More than two-thirds of all the samples are old or mixed-age groundwater. Only one-third of the samples represent groundwater recharged in the last thousand or several hundred years.



Qualitative groundwater age in the Snake Valley area. Modern recharge is limited to areas in Snake Valley and near isolated uplands elsewhere. Away from these areas most groundwater is old.

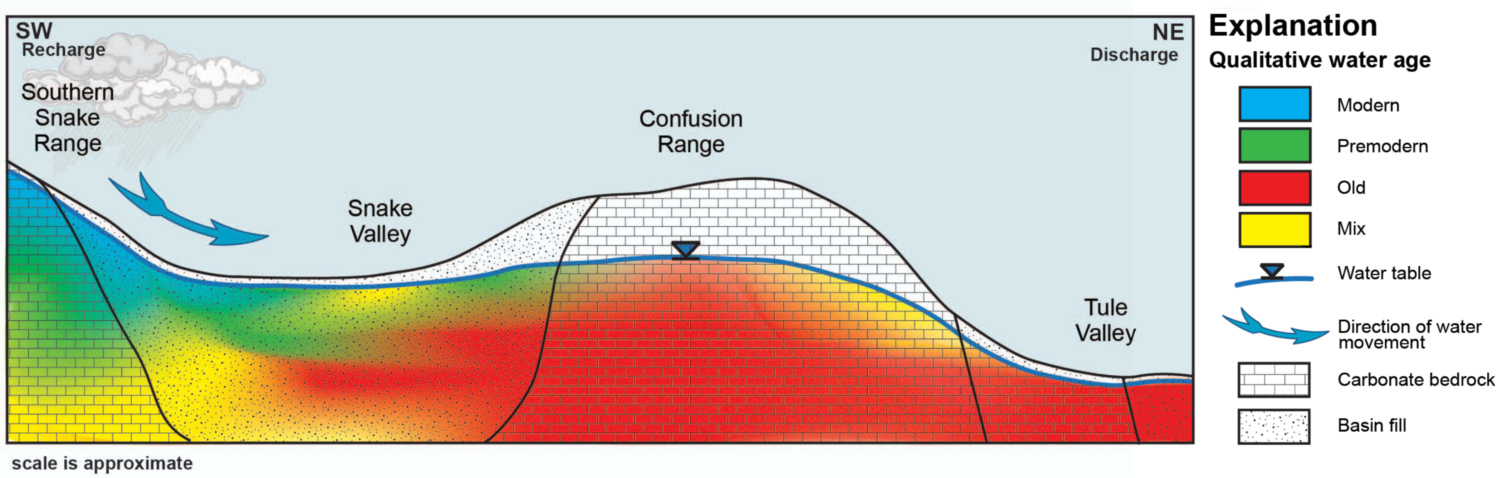
are considered to be a mix of young and old water when their tritium is greater than 0.5 TU and pmc is less than 50.

Results for Snake Valley

Environmental-tracer data indicate that more than half of the groundwater sampled in the Snake Valley area is old, and modern recharge comprises less than a fifth of all the samples. Samples classified as premodern or mixed comprise the remaining 25 percent of the dataset. Modern water is limited to parts of southern Snake Valley and other isolated areas likely supplied by uplands having relatively high precipitation and recharge rates. Apart from these areas, most of the groundwater likely has significant age, implying that low recharge rates and/or long flow paths are typical of much of the Snake Valley groundwater system. The environmental-tracer results suggest that away from localized major sources of recharge in mountain ranges, groundwater is recharged very slowly if at all. This implies that significant groundwater extraction from this system could easily exceed long-term recharge rates and produce permanent declines in groundwater levels and spring flow.

Environmental-tracer data and measured groundwater levels in wells and springs, collected by the UGS, provide the basic data that constrain the Snake Valley groundwater flow system. All other refinements of our understanding of groundwater in Snake Valley, including numeric models and hydrogeologic framework studies, must also explain the distribution of environmental tracers such as carbon-14 and tritium. These data, therefore, provide the fundamental information that allows water managers to make informed decisions concerning water allocation and use.

For more information on the ongoing UGS Snake Valley groundwater monitoring project, see the website **geology.utah.gov/databases/groundwater/map.php?proj_id=1.**



Schematic cross section of groundwater age in the Snake Valley area. Groundwater increases in age as it moves from areas of recharge to areas of discharge.

Snake Valley and Wasatch Front Groundwater Data Now Available Online

The Utah Geological Survey (UGS) has made its groundwater monitoring data available to the public through its new Groundwater Monitoring Data Portal. With just a few simple clicks you can access water levels in UGS monitoring wells and flow rates from springs in Snake Valley and adjacent areas. Or, if your interest is in landslide potential, you can find out what the water levels are in wells in and near landslides along the Wasatch Front. Users can easily find wells and springs using a map interface, view graphs of the data, and download graphic or tabular data in several formats.

The UGS has made the information available, partly due to the large amount of interest in proposed water-development projects in Snake Valley in west-central Utah and east-central Nevada. The groundwater levels, most which have been continuously monitored by the UGS since 2007, have declined in areas of current pumping, suggesting that use is presently at or near the maximum sustainable rate for the region.

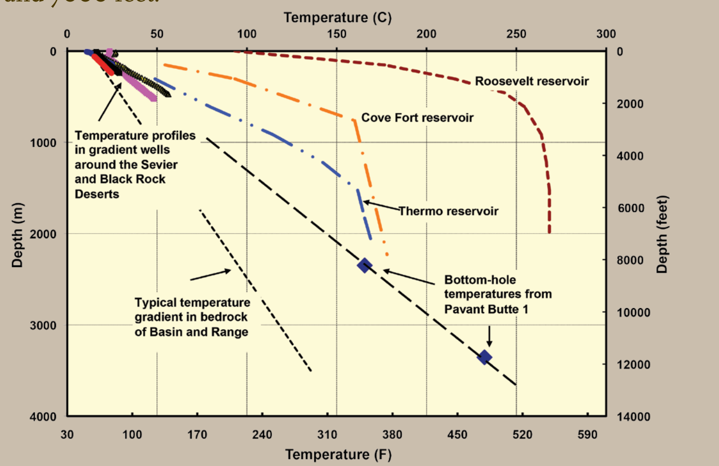
The Groundwater Monitoring Data Portal, which contains over 1 million records, is a collaborative effort between the UGS's Geologic Hazards and Groundwater & Paleontology Programs. To view the data and learn more about the monitoring projects, go to **geology.utah.gov/databases/groundwater/projects.php.**

ENERGY NEWS

UGS Explores for New Geothermal Resources in Utah

Rick Allis and Bob Blackett

This past spring the Utah Geological Survey (UGS) contracted the U.S. Geological Survey research drilling team to drill two thermal gradient wells in the Sevier and Black Rock Deserts to investigate a new type of geothermal resource: Great Basin sedimentary-hosted geothermal reservoirs. Most geothermal power plants around the world tap into plumes of hot water that rise towards the ground surface along near-vertical fault zones. PacifiCorp's Blundell power plant (36 megawatts) near Milford in Beaver County is a good example of this. Here, production wells encounter a reservoir on the Opal Mound fault zone adjacent to the Mineral Mountains where temperatures of 500°F occur between depths of about 2000 and 7000 feet.



Temperature-depth trends observed in selected wells of the Sevier–Black Rock Desert region near Delta and Beaver, Utah. Thermo, Cove Fort, and Roosevelt are geothermal fields with power plants (being developed in the case of Cove Fort); typical temperature profiles shown on the graph. The Pavant Butte 1 (PB-1) well was a deep oil exploration well drilled in 1981. Shallower temperature gradient wells in young sedimentary deposits in the region have high gradients consistent with the bottom-hole temperatures observed in the PB-1 well.

The sedimentary geothermal reservoirs that we seek are deeper, perhaps 8000 to 13,000 feet, with temperatures of more than 300°F (ideally more than 400°F). In contrast to the narrow, near-vertical fault zone reservoirs, we believe these sedimentary reservoirs are sub-horizontal and confined to the more extensive and permeable layers within the bedrock. Because of the extra depth, geothermal companies have been reluctant to risk their exploration dollars on relatively deep wells with an unproven target. However, drilling technologies and costs have been steadily improving over recent years, and drilling to such depths is now common in oil and gas exploration. Since 2007, over 1200 oil and gas wells have been drilled to depths of between 9000 and 19,000 feet in Utah (mostly the Uinta Basin), representing 32 percent of all the oil and gas wells drilled during this time. The UGS hopes that its geothermal investigations will attract geothermal companies to drill for this deeper but more extensive type of reservoir.

Two important factors that control the power potential of a geothermal reservoir are temperature and permeability. The temperature determines the energy content of the water and the permeability determines how much water will flow into the well. Western Utah is part of the Basin and Range physiographic province, an area characterized by young volcanic rocks, range-bounding faults, and naturally high heat flow. Away from fault zones where groundwater movement sometimes disturbs ground temperatures, the temperature gradient in bedrock strata (i.e., beneath the ranges) is typically about 2°F per 100 feet, but beneath unconsolidated sediments in the basins the gradient climbs to 3.3–4.4°F per 100 feet. The higher gradient is due to the insulating properties of the unconsolidated sediment, and it means that the temperatures at about 10,000 feet beneath basins could be around 400°F. If the bedrock that underlies these sediments has zones of high permeability, the geothermal energy potential could be large. Evidence from bedrock exposures in the ranges of western Utah shows that some of the Paleozoic limestone formations, which also underlie the basins, do have characteristically high permeability.

The Sevier and Black Rock Deserts attracted us as a possible location for sedimentary geothermal reservoirs because of the bottom-hole temperatures observed during the drilling of an oil exploration well in 1981—the Pavant Butte 1 (PB-1) well (now abandoned). These temperatures, including a 480°F temperature at the well's total depth of 11,000 feet, indicate a gradient of 4°F per 100 feet. The PB-1 well encountered 9000 feet of relatively unconsolidated sediments before penetrating an unconformity (major time break) and

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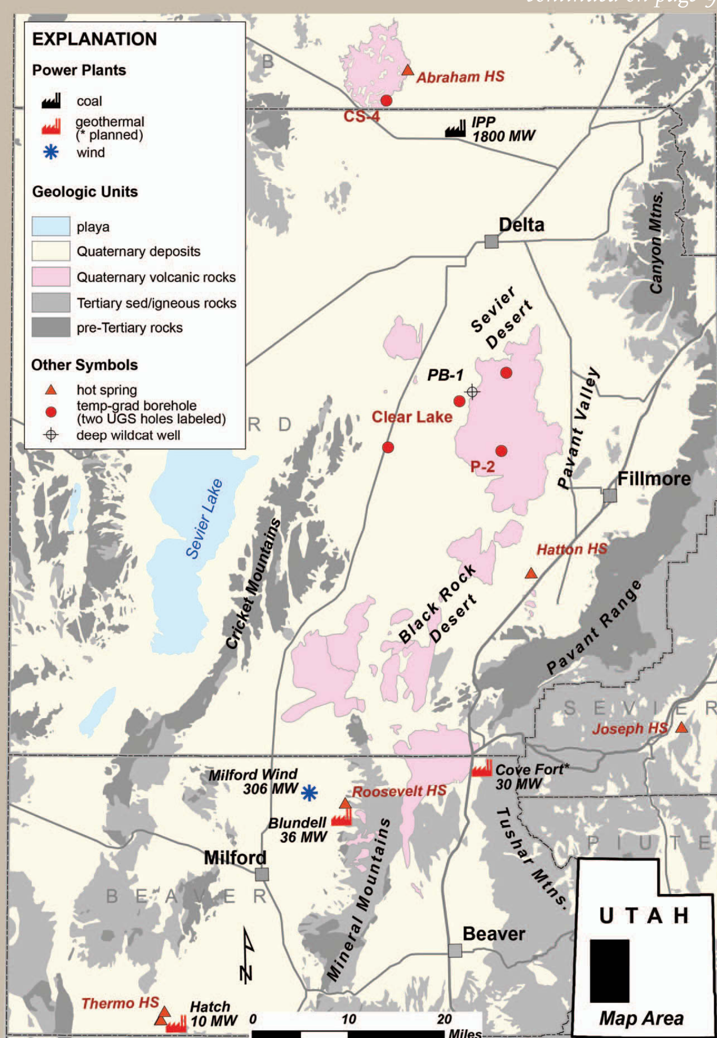


Sevier–Black Rock Desert area wells and springs, simplified geology, and power plants (nominal capacities in megawatts).

GLAD YOU ASKED

How Can I Name a Mountain?

Mark Milligan

The "Glad You Asked" article in the previous issue of *Survey Notes* (May 2011) addressed how to find the correct names of Utah's geographic features using the U.S. Geological Survey's Geographic Names Information System (GNIS). This article addresses how to propose a new name or change an existing geographic feature name.

Policies for naming geographic features have been established by the Domestic Names Committee (DNC) of the U.S. Board on Geographic Names. Want to name a geographic feature after your boss or favorite geologist? First, wait until they have been deceased five years as features cannot be named after the living or recently deceased. Additionally, they need to have had a direct and long-term association with the feature (tragic death at a site does not normally qualify). Exceptions are made for those who have made a significant contribution to the area or state and those "with an outstanding national or international reputation." Think your boss was a *#@*? Sorry, highly offensive or derogatory names are not acceptable. Also, names proposed for features in wilderness areas are not approved, unless needed for purposes of safety, education, or area administration. Names for features on Native American tribal lands must be supported by the tribal government. Submitted names should not duplicate another name in the state or nearby in an adjoining state (however, well-established names are not normally changed to avoid duplication unless there is strong public support). Long names are discouraged but not forbidden. Full names (first and last) are generally not approved unless the full name is short and euphonious or where the surname used alone would be ambiguous.

In Utah the bureaucratic process begins with the Utah Committee on Geographic Names (the Utah Geological Survey holds a permanent position on this board). Name proposals must include a full explanation of the name, a complete description and location of the feature with maps and/or photos, and documentation of local support. Proposals can be submitted directly to the Utah Committee or to the DNC, which will forward the proposal to the Utah Committee. The DNC has an 11-page online application found at **geonames.usgs.gov/pls/gnispublic/f?p=DGNPPUBLIC**. Though extensive, this online form is straightforward and easy to use. Alternatively, paper proposal forms are available from the Executive Secretary, Utah Committee on Geographic Names, Division of State History, 300 Rio Grande, Salt Lake City, UT 84101, phone (801) 533-3500. Whether received in digital or paper form, the Utah Committee will research the proposal and contact state and federal agencies, local officials, and other concerned citizens for comment. If accepted, the Utah Committee will then submit or return the proposal to the DNC for final approval.

For more details see the DNC website listed above, the Utah Committee on Geographic Names website (**www.npl.com/~nomain/ut_gnames/index.html**), or *Principles, Policies, and Procedures: Domestic Geographic Names* by Donald J. Orth and Roger Payne, 1997, available at **geonames.usgs.gov/docs/pro_pol_pro.pdf**. And for anyone reading this at least five years after my death, my name is spelled M-I-L-L-I-G-A-N.

Information required for the U.S. Domestic Names Committee application:

- Proposed feature name and any current or past local names.
- Specific reason for proposal.
- Any GNIS data on the feature.
- Meaning or significance of the proposed name and history of its origin.
- State and county location.
- If proposed name is commemorative, nominee's full name, birth and death dates, other biographical details, and evidence of extensive association with the feature.
- Geographic coordinates.
- Administrative agencies (e.g., Bureau of Land Management, municipality, etc.).
- Maps and other documents showing use of the proposed name.
- Any documents showing feature is not named.
- Any documents showing alternative names and extensive evidence of why such names should be changed.
- Information for local, county, state, or tribal government authorities who can confirm local usage of the proposed name.
- Contact information for those who are submitting or preparing the form.

continued from Energy News

underlying ancient (Cambrian) bedrock.

When choosing locations for the two new thermal gradient wells, we considered where we already had temperature data in the region and where the largest gaps in data were. In 2010, the Utah Division of Wildlife Resources drilled a water investigation well in the Clear Lake wildlife management area near the PB-1 well, and temperatures in this new well were consistent with a high thermal gradient. Two other thermal gradient wells drilled by Phillips Oil Company in the early 1980s southwest and northeast of Pavant Butte also showed high gradients. We therefore decided to site one of our wells adjacent to Crater Bench (Fumarole Butte volcano) northwest of Delta, and the other in the volcanic rocks south of Pavant Butte and west of Fillmore. Abraham hot springs on the east side of Crater Bench has a large outflow of hot water at temperatures up to 190°F, but there has never been a serious investigation of the thermal conditions at depth. Both wells were drilled to 800 feet, and both entered unconsolidated lake sediments below about 150 feet depth. Preliminary measurements indicate gradients between 3.5 and 4°F per 100 feet. These initial results point to relatively high temperatures (around 400°F at 10,000 feet depth) beneath the region.

The UGS has recently received funding from the Department of Energy to drill several more thermal gradient wells to improve understanding of the geothermal power potential of Utah. We intend to site these wells in the same region to confirm and better delineate the extent of high temperatures at depth. The broad basin beneath the Sevier and Black Rock Deserts, containing as much as 10,000 feet of unconsolidated sediments, extends over 70 miles from Milford to north of Delta, so we are excited about the geothermal potential of this entire basin. The region is already the site of the 300-megawatt Milford-Wind wind farm and the Roosevelt geothermal field, and the Thermo geothermal field (Hatch power plant; 10 megawatts) lies about 20 miles to the south. Perhaps the Sevier–Black Rock Desert region could soon become a renewable power hub in the western U.S.

GEOSIGHTS

Little Grand Canyon, Wedge Overlook, and Buckhorn Draw Scenic Backway, San Rafael Swell, Emery County, Utah

Stephanie Earls

Did you know Utah has its very own version of the Grand Canyon? Nicknamed the "Little Grand Canyon," it is the deepest part of the San Rafael River canyon located directly beneath the Wedge Overlook (Overlook) in the San Rafael Swell (Swell). Looking down river from the Overlook, you can see where Buckhorn Draw—a narrow, winding canyon walled in by scenic sandstone cliffs—meets the San Rafael River canyon.

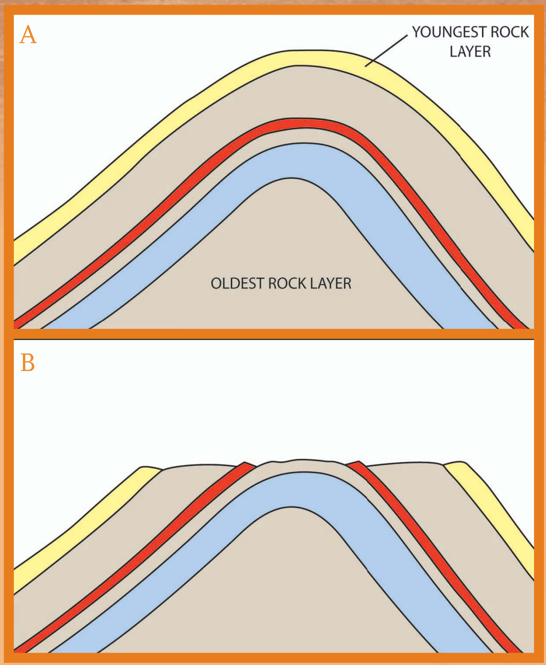
Located in the northern portion of the Swell, numerous viewpoints along the dramatic Overlook provide stunning views of varied landforms sculpted mainly in multi-colored sandstone formations. Directly beneath the Overlook is a shear drop off of 1,200 feet to the San Rafael River's deeply cut Little Grand Canyon. Panoramic vistas reveal the river winding its way through canyons of changing widths, surrounded by multi-layered cliffs, buttes, domes, and spires.

A short distance from the Overlook, you can drive down through scenic Buckhorn Draw. The steep canyon walls, which showcase several different colorful sandstone formations, contain a spectacular Native American rock art panel, as well as a three-toed dinosaur footprint.

The drive from Castle Dale to the Overlook and down through Buckhorn Draw to Interstate 70 is designated a Utah Scenic Backway (Backway), which means the route meets the highest standard of scenic, recreational, and historical criteria, but may not be safe to drive year-round (unlike a designated Scenic Byway) and may require a high-clearance or four-wheel-drive vehicle. Allow approximately one hour and 45 minutes of travel time to drive the 51 miles of this Backway.

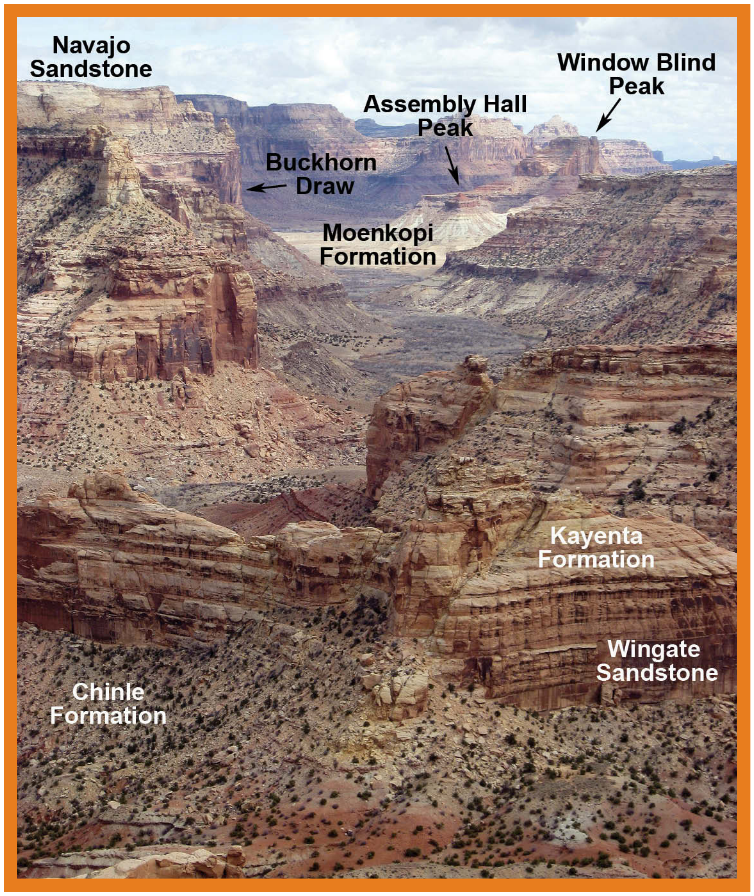
Geologic Information: The Swell is an uplifted area where sedimentary rock layers were arched skyward into an elongate dome-like structure (called an anticline). The upwarp resulted from compressional forces in the Earth's crust about 40–70 million years ago. This mountain-building episode uplifted other areas as well, such as the Rocky Mountains to the east and the Uinta Mountains to the north. Millions of years later, erosion began in force, eventually removing thousands of feet of rock from the Swell's crest, exposing older rocks (about 300 million years old) in the middle region of the Swell surrounded by a ring of younger rocks (ranging in age from 100 to 230 million years old). Numerous canyons were eroded into and through the Swell by rivers and streams. The San Rafael River, the largest river in the north part of the Swell, slices across the Swell, cutting deepest along the 3-mile stretch of the Little Grand Canyon.

As you enter the Swell from the northwest, you follow geologic history back in time. From youngest to oldest, the strata include



A. Horizontal compression arched rock layers upward, creating the San Rafael Swell. B. Erosion stripped off thousands of feet of rock from the crest of the Swell, exposing older rocks in the middle of the uplift and younger rocks on the edges.

mostly sandstones of the Carmel Formation, Navajo Sandstone, Kayenta Formation, Wingate Sandstone, Chinle Formation, and Moenkopi Formation, which were formed in a variety of depositional environments (rivers, deserts, and shallow seas). Driving on Wedge Road to the Overlook you cross the Carmel Formation, which is composed of alternating beds of light-grayish limestone and light-brown fine-grained sandstone. The rock formation exposed at the edge of the Overlook is the Navajo Sandstone, which is probably the most famous rock formation in Utah. It is composed of mostly light-brown to white sandstone, and is sometimes seen as sloped domes or rounded knobs reminiscent of the ancient sand dunes from which it formed. The Navajo Sandstone is also present as you first turn onto Buckhorn Draw Road, where you can see a three-toed dinosaur footprint on a ledge 10 feet up on the left side of the road. The underlying Kayenta Formation consists of reddish-brown sandstone and siltstone that forms slopes and benches. As you continue driving southeast on Buckhorn Draw Road, you see the red and pale orange vertical cliffs of the Wingate Sandstone which are home to the well-known Buckhorn Draw rock art panel. The Chinle Formation is composed of green-gray sandstone, red-brown sandstone, gray-brown



View down canyon from the Wedge Overlook into the Little Grand Canyon shows the colorful cliff- and slope-forming rock layers. Assembly Hall and Window Blind Peaks can be seen in the distance near the mouth of Buckhorn Draw, which enters from the left (north).

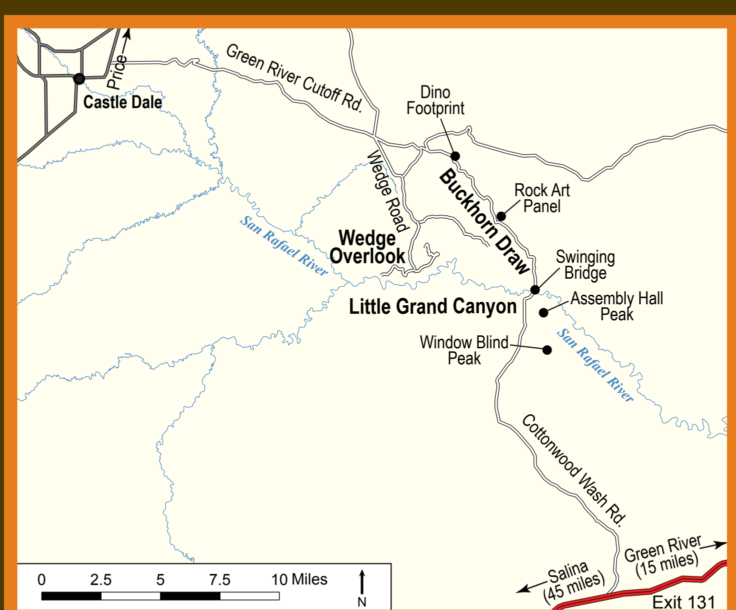
limestone conglomerate, and maroon shale. As you exit Buckhorn Draw and cross over the San Rafael River, you can see Assembly Hall and Window Blind Peaks towering overhead. The formation exposed at the bottom of these peaks is the Moenkopi Formation, which is composed of red-brown fine-grained sandstone and siltstone.

The Swell offers a variety of recreational activities including hiking, mountain biking, camping, and beautiful scenic drives. Campsites are available at the Wedge Overlook and in Buckhorn Draw at Swinging Bridge. All roads between Castle Dale and I-70 are well-maintained gravel roads, but may require a four-wheel-drive vehicle during inclement weather. Visit the Price Bureau of Land Management (BLM) Field Office at 125 South 600 West, Price, UT 84501 (phone: 435-636-3600) for directions, maps, driving conditions, and a list of other must-see sites in the San Rafael Swell.

Useful Maps:

- Utah Atlas & Gazetteer
- San Rafael Motorized Route Designations, put out jointly by the BLM, Emery County, and Utah DNR. Map is available at the Price BLM office or online at the following link: **castlecountry.org/geo/SanRafaelMotorizedRouteDesignations.pdf.**
- National Geographic Trails Unlimited Map – San Rafael Swell

How to get there: From the north, take exit 241 in Price onto State Route 10. Drive 28.5 miles and take a left onto the Green River Cutoff Road (EM401), labeled only as a San Rafael Recreation Access Road just before Castle Dale. At 0.2 mile down the Green River Cutoff Road, you will see a mileage sign for Buckhorn Draw (16 miles) and the Wedge Overlook (20 miles). Continue on this road for 12.6 miles to the intersection with Wedge Road (EM405). Go right onto Wedge Road and drive 6.6 miles to the Wedge Overlook (N39°05.60', W110°45.39'). Short drives along the canyon rim provide additional views of the Little Grand Canyon. To access Buckhorn Draw, drive back the way you came 4.4 miles and take a right onto road EM406. After 1.3 miles, go right on the Green River Cutoff Road, and in 0.2 mile take another right onto Buckhorn Draw Road (EM332). At mile 1.6, the dinosaur footprint is on the left (northeast) side of the road about 10 feet up on a ledge. The rock art panel is on the left side of the road at mile 5.8, and the Swinging Bridge (a now-unused, wooden suspension bridge built by the Civilian Conservation Corps in 1937) is at mile 9.5 as you cross over the San Rafael River and see Assembly Hall and Window Blind Peaks. You can then backtrack north, or continue south for 18.8 miles to I-70 if traveling to points east, south, or west.



The approach from the south is via I-70. Take exit 131 onto Cottonwood Wash Road (EM332). The gravel road reaches the Swinging Bridge and Buckhorn Draw in 18.8 miles.

TEACHER'S CORNER

Earth Science Week 2011

October 11–14, 2011
9:30 a.m.–3:30 p.m.

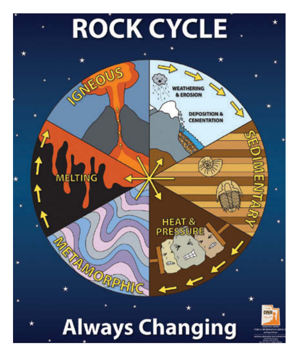
Hands-on activities for school groups

Come celebrate Earth Science Week with your 4th or 5th grade class. The Utah Geological Survey will once again be offering hands-on science activities, including gold panning, observing erosion and deposition on a stream table, identifying rocks and minerals, and learning how Utah's dinosaur discoveries are excavated and prepared. For more information, please visit our website at **geology.utah.gov/teacher/esweek.htm**.

Call 801-537-3300 to make reservations and ask to speak with Jim Davis or Sandy Eldredge. Groups are scheduled for 1 1/2 hour sessions.

New! Rock Cycle Poster

This poster illustrates one of the fundamental concepts of geology—rocks continually cycle from one type to another. Using simple diagrams and vivid color, the poster depicts how heat, pressure, weathering, erosion, deposition, and cementation create igneous, metamorphic, and sedimentary rocks. Posters will be given out at Earth Science Week. They are also available from the Natural Resources Map & Bookstore for $4.95.



SURVEY NEWS

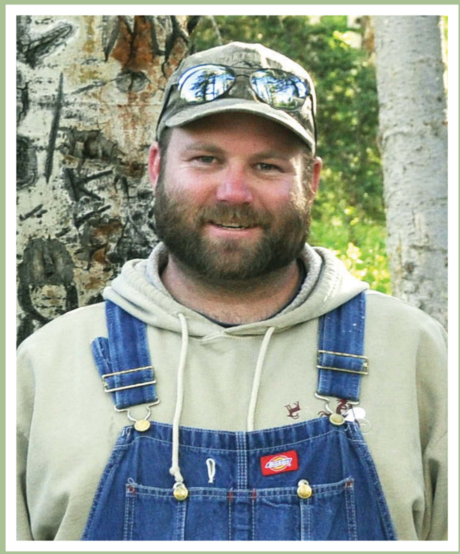
2011 Crawford Award

2011 Crawford Award winners Tyler Knudsen and Bill Lund.

The Utah Geological Survey awarded its prestigious 2011 Crawford Award to UGS geologists **Bill Lund** and **Tyler Knudsen** in recognition of their combined work on the outstanding geologic publication *Geologic Hazards of the Zion National Park Geologic-Hazard Study Area, Washington and Kane Counties, Utah* (UGS Special Study 133). Together with David Sharrow (National Park Service), they created a comprehensive, remarkably detailed, user-friendly guide to the 10 most common geologic hazards in the park area. The report, maps, and accompanying GIS data are important tools that park managers can use to assess geologic hazards that may affect existing infrastructure, future development, and visitor safety.

The Crawford Award recognizes outstanding achievement, accomplishments, or contributions by a current UGS scientist 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.

2010 UGS Employee of the Year



J. Buck Ehler was named the 2010 UGS Employee of the Year for his outstanding contributions and service during this past year. Buck is a GIS Analyst with the Geologic Mapping Program and has worked at the UGS for six years. He developed a GIS template that simplifies and expedites geologic map production and enables consistency between maps to a degree previously unattainable. Buck has organized regular classes and taken on the task of teaching the fundamentals of GIS to all interested employees. He is always available to answer questions and offer support to others learning GIS. He is also active in the statewide GIS community, where he represents UGS interests at annual GIS user conferences. Buck's excellent work, positive attitude, and enthusiasm for his job make him a deserving recipient of this award.

UGS Receives Special Recognition from AAPG

At the recent Rocky Mountain Section meeting of the American Association of Petroleum Geologists (AAPG), the Utah Geological Survey (UGS) received special recognition "for [its] past and ongoing exemplary contributions to the understanding of the geology of Utah and surrounding states." A plaque was presented to David E. Tabet, manager of the UGS Energy and Minerals Program, with the inscription to the UGS stating "With sincere appreciation for your support of the AAPG Rocky Mountain Section, of the AAPG meetings and members, and for your continued timeless contributions to the geoscience knowledge of the West. We are in your debt." The AAPG is the largest professional organization of petroleum geologists in the world with over 30,000 members.

In a letter to Governor Gary Herbert, David H. Hawk (Chair of the AAPG House of Delegates) stated "at each Rocky Mountain Section annual meeting, the Utah Geological Survey can be counted on to have a very stimulating and informative booth, present papers of the highest caliber with obvious application to general geology and energy minerals understanding, and to interface and share research and knowledge with all present. The UGS geologists can be rightfully proud of their scientific acceptance by relationships with the greater scientific community. We believe the great state of Utah can be proud of the work product and deserved reputation of the men and women who constitute the UGS."

Employee News

The Energy and Minerals Program welcomes **Christian Hardwick** as a geophysicist. He is completing his M.S. at the University of Utah on geophysical delineation of geothermal systems in Utah. **Ben Erickson** joined the Geologic Hazards Program as a geologist. He has an M.S. in Geological Engineering from the University of Utah. Welcome to the UGS!

The Museum of Westerm Colorado presented the George Callison Paleontological Award to **James I. Kirkland** for outstanding commitment to the study and promotion of the paleontological heritage of Western Colorado, and for significant contributions to the understanding of the region's biological history. Jim is the Utah State Paleontologist and has been with the UGS since 1999. Congratulations!

In Memoriam

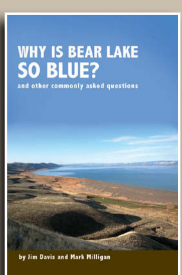
Former UGS employee Martha Smith passed away March 7, 2011, at the age of 90. Martha, who worked for the UGS for 10 years, received her bachelor's degree in Geology from Pomona College, California, and was a University of Utah Ph.D. candidate. Her interests included economic geology and technical writing. Before coming to the UGS, she worked in the economic geology field for the University of Utah, the U.S. Geological Survey, and as a consulting geologist.

Martha started at the UGS as Editor in 1977 and then became the UGS's first Information Specialist, the position she held until her retirement in 1987. As the Information Specialist, Martha was in charge of public inquiries, sales, and the library. The origins of what is now the Geologic Information and Outreach Program began with Martha, who was always enthusiastic about sharing her knowledge of geology.

Utah State Energy Program Relocates

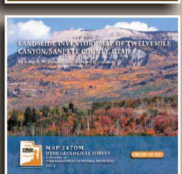
The Utah State Energy Program is now part of the newly created Office of Energy Development and has moved to new offices at the Department of Environmental Quality. For more information, contact Denise Brems, Partner Coordinator, at 801-536-4169.

NEW PUBLICATIONS

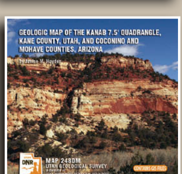


Why is Bear Lake so blue? And other commonly asked questions, by Jim Davis and Mark Milligan, 41 p., ISBN 978-1-55791-842-0, **PI-96**......$2.95

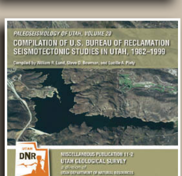
Rock Cycle—always changing, 27" x 32.5" poster, **PI-97** $4.95



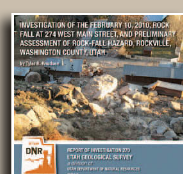
Landslide inventory map of Twelvemile Canyon, Sanpete County, Utah, by Greg N. McDonald and Richard E. Giraud, CD (1 pl. [contains GIS data]), scale 1:24,000, ISBN 978-1-55791-844-4, **M-247DM** $24.95



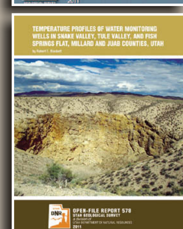
Geologic map of the Kanab 7.5' quadrangle, Kane County, Utah, and Mohave and Coconino Counties, Arizona, by Janice M. Hayden, CD (2 pl. [contains GIS data]), scale 1:24,000, ISBN 978-55791-829-1, **M-248DM** $24.95



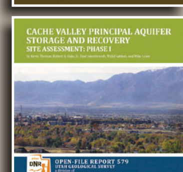
Paleoseismology of Utah, Volume 20—Compilation of U.S. Bureau of Reclamation seismotectonic studies in Utah, 1982–1999, compiled by William R. Lund, Steve D. Bowman, and Lucille A. Piety, CD (808 p., 18 pl.), ISBN 978-55791-846-8, **MP-11-2** $14.95



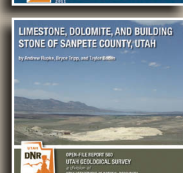
Investigation of the February 10, 2010, rock fall at 274 West Main Street, and preliminary assessment of rock-fall hazard, Rockville, Washington County, Utah, by Tyler R. Knudsen, CD (17 p.), **RI-270** $14.95



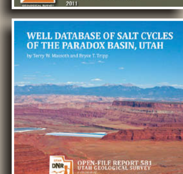
Temperature profiles of water monitoring wells in Snake Valley, Tule Valley, and Fish Springs Flat, Millard and Juab Counties, Utah, by Robert Blackett, 13 p. + 24 p. appendix, **OFR-578** $9.95



Cache Valley Principal Aquifer Storage and Recovery Site Assessment: Phase I, by Kevin Thomas, Robert Q. Oaks, Jr., Paul Inkenbrandt, Walid Sabbah, and Mike Lowe, CD (34 p. + 23 p. appendices), **OFR-579** $14.95



Limestone, Dolomite, and Building Stone of Sanpete County, Utah, by Andrew Rupke, Bryce Tripp, and Taylor Boden, CD (21 p. + 48 p. appendices, 1 pl.), **OFR-580** $14.95



Well database of salt cycles of the Paradox Basin, Utah, by Terry W. Massoth and Bryce T. Tripp, CD (13 p. + 2 pl. appendices), **OFR-581** $14.95

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