

U T A H G E O L O G I C A L S U R V E Y

SURVEY NOTES

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HOW MANY ISLANDS
ARE IN GREAT SALT LAKE?

THE DIRECTOR'S PERSPECTIVE



by *Richard G. Allis*

This issue of *Survey Notes* features projects from the Ground Water and Paleontology Program. One of our largest projects in recent years has been the installation of a ground-water monitoring network in the west desert (Snake Valley) of Utah. This was specially funded by the legislature in 2007 in response to concerns that water on the Utah side of Snake Valley could be extracted by pumping on the Nevada side of the valley by the Southern Nevada Water Authority (SNWA) for use in Las Vegas. The Utah Geological Survey (UGS) spent over \$3 million drilling wells and installing monitors on springs in the region (see page 6 for article by

Hugh Hurlow). The wells were completed in near-surface alluvium and in basement rocks, they are located both far from and near existing irrigation areas, and the sites are spread over a 100-mile distance between Fish Springs in Juab County and northern Hamlin Valley in Millard County.

We continue to make information coming from the project available on the UGS Web site (geology.utah.gov/esp/snake_valley_project/index.htm). The interactive Google Earth map shows the various monitoring sites, and clicking on a site opens up a brief description and provides links to measurements such as the water level history, well logging data, and spring flow history. Although the monitoring history varies from as short as six months to several years, it is already clear that the hydrologic picture is not simple; some wells show declining water level trends, some show annual fluctuations, and some show stable trends. The data from the well drilling and initial monitoring are being compiled and analyzed, and we anticipate releasing the data in a UGS report toward the end of this year.

SNWA has indicated that the need for Snake Valley water has been delayed by about 10 years due to the economic downturn and slowed growth, and their applications for water rights have also been delayed by a recent decision from the Nevada Supreme Court. This delay helps with establishing the hydrologic baseline(s) in the Snake Valley area before significant new extraction of ground water occurs in the region. We believe that it could take at least 5–10 years to better understand the existing patterns of aquifer behavior and establish a scientifically sound baseline. The 2010 Utah legislature also recognized the importance of sound hydrologic data for guiding an agreement with SNWA on the allocation and management of Snake Valley ground water; it established a funding source for the UGS to maintain and monitor the wells and springs between 2010 and 2020. A priority is improving the database and its link to the UGS Web site so that everyone can see the hydrologic trends, and this can inform the decision-making process between Utah and Nevada.

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Cover: *Antelope Island is the largest island in Great Salt Lake. Exposures of a wide variety of rock types and ages make the island a unique outdoor geologic classroom.*

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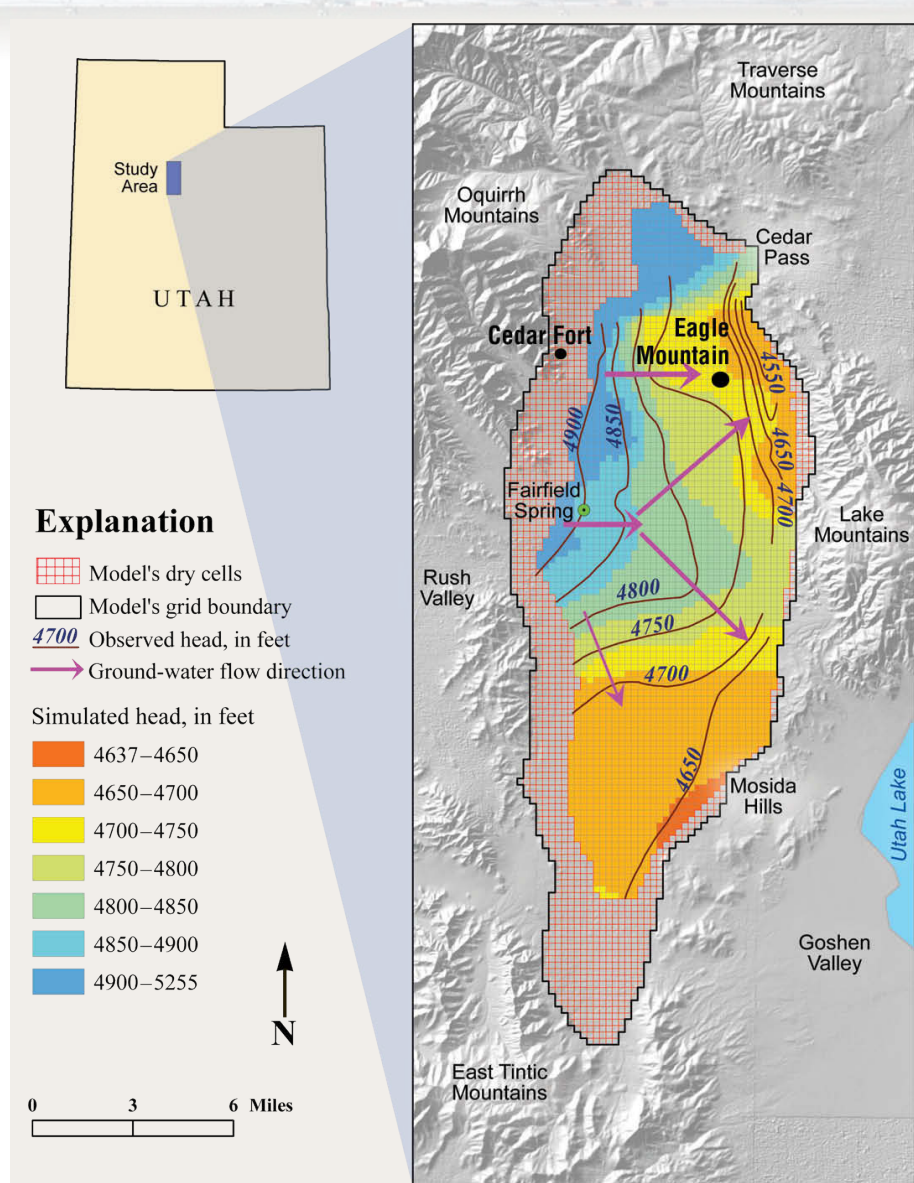
MODELING GROUND-WATER FLOW IN CEDAR VALLEY, UTAH COUNTY

by J. Lucy Jordan and Walid Sabbah

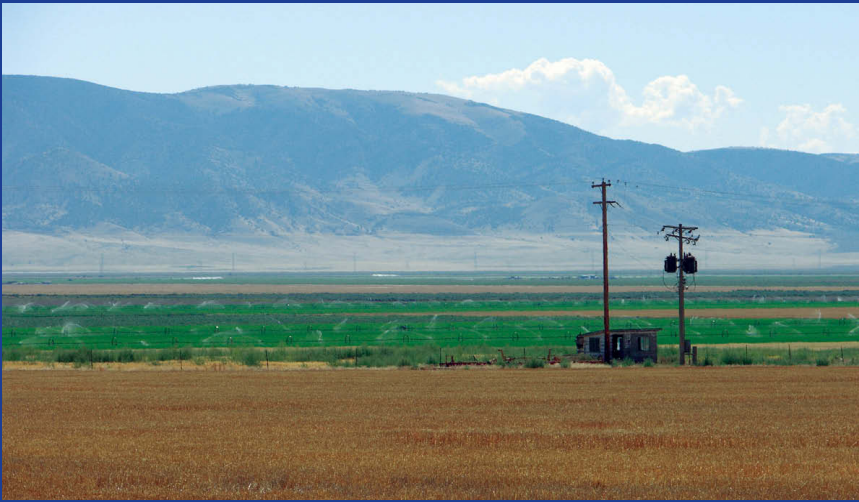
The population of Utah County's Cedar Valley, including the city of Eagle Mountain, has grown from less than 1000 residents in 1990 to over 23,000 today, drastically increasing the need for potable water. This need is being met primarily by installing new wells and converting agricultural supply wells to municipal use, since the few natural streams and springs are fully appropriated. Over the past 5 years, the UGS has performed pumping tests, collected water levels and water-quality samples, and created a three-dimensional (3D) computer ground-water flow model to provide water users and regulators with a better understanding of the ground-water flow system.

Cedar Valley occupies a closed surface-water drainage basin west of Utah Lake and the Provo-Orem metropolitan area. Ground water is present in the unconsolidated sediments that fill the basin and in bedrock that underlies the basin fill and forms the surrounding Oquirrh, Traverse, Lake, and East Tintic Mountains. The unconsolidated sediments are as much as 2100 feet thick and are generally silt and clay mixed with small amounts of gravel, except near the mountains where sand and gravel dominate. A clay unit as much as 240 feet thick covers two-thirds of the surface of the valley and creates confined ground-water flow conditions beneath it. On average, the basin fill is slightly less permeable to ground water than the fractured Paleozoic carbonate bedrock, which is atypical compared to most ground-water basins.

Ground water generally flows from west to east across the valley but then encounters a north-south-trending normal fault on the eastern margin of the valley. The fault is a conduit for ground-water flow parallel to the fault, but acts as a barrier to ground-water flow across the fault. As a result, ground-water flow is directed around the Lake Mountains to exit the valley through the bedrock at Cedar Pass and the Mosida Hills on the north and south ends of the Lake Mountains, respectively.



Area of Cedar Valley ground-water model. Computer-simulated water-level elevation (colored shading) compares favorably to the measured water levels (brown contour lines) and indicates ground-water flow is from the Oquirrh Mountains across the valley to Cedar Pass and the Mosida Hills (pink arrows).



A shed houses a well that provides water for agricultural irrigation. Other irrigation wells have been converted to municipal supply as the population of the valley increases. Lake Mountains in the background.



The community of Cedar Fort sits beneath ridges of Oquirrh Group sedimentary strata, the recharge zone for aquifers underlying Cedar Valley. The population of this small town at the edge of the Oquirrh Mountains is projected to increase from around 400 to 35,000 people in the next 50 years.



Recent residential development in Eagle Mountain flanks the Lake Mountains in northern Cedar Valley.

The primary source of ground-water recharge to the Cedar Valley basin-fill aquifer is mountain precipitation, which enters the basin-fill aquifer as subsurface inflow from the mountain block. We estimate mountain-block recharge ranges from 9700 to 43,800 acre-feet per year and averages 24,000 acre-feet per year (an acre-foot is the volume of water that would cover an acre of land—slightly smaller than a football field—to a depth of 1 foot). The Oquirrh Mountains likely provide about 90 percent of mountain-block recharge and the East Tintic Mountains provide the rest. Recharge through the valley floor includes seepage from one perennial stream, unused irrigation water, seasonal standing water in the center of the closed basin, a sewage treatment plant, septic tanks, and minor precipitation infiltration; these sources combined average about 1600 acre-feet per year. Based on water balance calculations and the results of our computer modeling, we think that little to no subsurface ground-water flow enters Cedar Valley from Rush Valley to the west, contrary to estimates made by other researchers in the 1960s.

Discharge out of the Cedar Valley ground-water system is primarily by subsurface flow through bedrock at the northeast and southeast margins of the valley. We estimate flow through fractured bedrock beneath Cedar Pass into northern Utah Valley is about 10,200 acre-feet per year and beneath the Mosida Hills into Goshen Valley is about 4700 acre-feet per year. Springs discharge an average of 4800 acre-feet per year, and evapotranspiration probably accounts for 3000 acre-feet per year. Discharge from wells increased from around 2500 acre-feet per year in the 1960s and early 1970s to around 5700 acre-feet per year by 2005, and then almost doubled to 10,500 acre-feet in 2007 as several large production wells came on line. Water-level trends indicate that changes in recharge due to wet and dry climatic cycles have historically had more influence on long-term ground-water levels than pumping. However, the significant increase in pumping from wells tapping the bedrock aquifer at Cedar Pass since 2005 has drawn down water levels in some wells more than can be expected as the result

of climate change.

Stable and radioactive isotope analyses indicate that wells and springs along the western margin of the valley probably receive water that has traveled along flow paths a few miles in length and originating in the lower slopes of the Oquirrh Mountains, and that wells in the center of the valley likely receive recharge via long flow paths originating in the higher elevations of the Oquirrh Mountains. Water traveling along these longer flow paths may have taken hundreds or thousands of years to reach its destination. Many new wells have been drilled into bedrock in the Cedar Pass area to provide water for development. Data from these wells suggest there may be a component of modern (less than 50 years old) recharge in an otherwise quite old fractured bedrock flow system that receives its recharge from precipitation in the Oquirrh Mountains. Several bedrock wells throughout the valley produce water that is 9°F to 21°F warmer than the rest of the wells in the valley. The geologic setting of the warm-water wells and their chemical and isotopic signatures suggest deep circulation along long flow paths that end at fracture zones, which provide relatively rapid flow to near-surface wells.

UGS geologists created a 3D computer model using MODFLOW 2000 computer code to simulate ground-water flow in the basin fill during the years 1969 to 2007. The two-layer model includes an upper basin-fill layer and a lower bedrock layer, which acts only as a source of recharge and discharge in the model. The model was calibrated to match measured water levels in wells and measured flow at Fairfield Spring, the valley's largest spring. We modeled a variety of possible scenarios, including drought and increased pumping, 30 years into the future. If 2007 pumping and average climatic conditions persist, the model predicts most areas of the basin-fill aquifer will experience as much as 15 feet of drawdown from 2007 levels. In scenarios that include doubling the 2007 well extraction rates, large areas of the valley are predicted to experience over 100 feet of drawdown, and the northeast corner of the valley, where recent bedrock wells have been developed for municipal use, generally would experience even greater amounts of drawdown.

Our study is providing new insight into the ground-water resources of Cedar Valley. The UGS is preparing a comprehensive report of the findings of this study, which we anticipate will be made available to the public later this year. The ground-water flow model code will be made available to government agencies and consulting scientists as a planning tool. ■

ABOUT THE AUTHORS



J. Lucy Jordan is a hydrogeologist in the UGS Ground Water and Paleontology Program. She has a B.S. degree in Geology from North Dakota State University and an M.S. degree in Geology from the University of Montana. Lucy worked on mining-related ground-water contamination as

a consultant to Kennecott Utah Copper and on water-supply and protection projects for other consulting firms in Utah for a decade prior to joining the UGS in 2004. Lucy's work with the UGS has focused on water-resource assessments in Utah, including water-quality studies, aquifer testing, and computer-based modeling projects. She is currently managing the surface-water monitoring program in Snake Valley in western Utah.



Walid Sabbah is a hydrogeologist/ground-water modeler in the UGS Ground Water and Paleontology Program. Walid has a B.S. degree in Geology from Yarmouk University and an M.S. degree in Hydrogeology from the University of Jordan. He worked for eight

years as a hydrogeologist before returning to school to pursue a doctorate, and in 2004 received his Ph.D. in Civil and Environmental Engineering with emphasis in GIS and hydrological modeling from Brigham Young University. He also worked as an adjunct Assistant Professor at Utah Valley University for a year and a half prior to joining the UGS in 2006.

THE FOSSIL PREPARATION LAB AT THE UTAH GEOLOGICAL SURVEY

BRINGING EARTH'S ANCIENT PAST TO LIFE

by Scott Madsen

The science of paleontology is the study of ancient life. By studying extinct organisms, paleontologists can attempt to reconstruct past ecosystems and understand how animals and plants adapted to the environments in which they lived. Evidence of this ancient world comes from the fossilized remains of life that have been quarried from rocks or excavated from sediment. But before we can fully appreciate or understand these long-extinct organisms, the fossils must first undergo a long and painstaking process of laboratory preparation.

The vast backcountry and badlands of Utah are an especially good place for field paleontologists to make new discoveries. Much of the paleontological research at the Utah Geological Survey (UGS) focuses on the dinosaurs and other life of the Mesozoic Era (about 250 to 65 million years ago). UGS paleontologists, colleagues, and volunteers spend summers

finding and excavating dinosaur bones and then encasing them, rock and all, in protective plaster and burlap "jackets" for transport to the preparation lab at the UGS's Utah Core Research Center. But this is only the beginning of getting the bones ready for study and exhibit. The process of removing the rock from the bones and stabilizing them is known as "preparation," and the people who specialize in this craft are called "preparators."

Although most of the fossil bones you see on display in museums might look strong, most of them were not found in that condition. A typical fossil is riddled with cracks, pieces might have eroded away before it was collected, or it may be porous as a sponge. Some bones are as thin as paper and others might be as small as pinheads. A preparator needs to learn how to deal with all of these problems so that bones can be safely studied, stored, and displayed.



Volunteer preparator Judy Sanders cleans an iguanodont shoulder bone (scapula) that rests in a plaster jacket.



UGS fossil preparator Don DeBlieux removes iguanodont bones from a plaster field jacket.

Fossil preparation has changed a lot since the old days of the hammer and chisel. On a typical day, the “prep lab” at the UGS will be filled with the buzz of aircsribes (small handheld pneumatic jackhammers). These tools gently pulverize the rock around the fossil and allow the preparator to expose the bone a little at a time. The preparators at the UGS also use miniature sandblasters to remove rock. As cracks in bone are encountered, they can be filled with glue, or the bone fragments can be pulled apart, cleaned piece by piece, and glued back together again. Shellac is also a thing of the past. Modern prep labs use special plastic materials dissolved in solvents to reattach and consolidate spongy and shattered bones. Dental tools are still handy for scraping off small bits of rock, although these have mostly been replaced by needles made of carbide and other strong metal alloys.

UGS fossil preparators Don DeBlieux and Scott Madsen, and a small team of dedicated volunteers are currently busy preparing several dinosaurs from Early Cretaceous-age (145 to 100 million years ago) rocks of Utah. These include the skeletons of new species of plant-eating dinosaurs (iguanodonts) and new species of small carnivorous bird-like dinosaurs (similar to the famed sickle-clawed *Utahraptor*), all from quarries near Green River, Utah. Many of these bones are so small and delicate they must be prepared under a microscope using carbide needles.

When new plaster field jackets are opened in the lab, surprises are common. One jacket, known from field observation to contain part of an iguanodont tail, was also hiding three skulls, including those of a juvenile iguanodont and a crocodile; when turned over, the same block of rock revealed yet another tail, that of a small carnivorous dinosaur. A less welcome surprise was a scorpion that had somehow managed to survive being entombed in a plaster jacket for 15 months! It was later returned to the wild.

Fossil preparation is slow, painstaking work. All of these projects will take years of labor to complete, but when finished will reveal new and interesting chapters in the story of life on Earth. ■



UGS fossil preparator Scott Madsen uses a microscope and carbide needle to prepare fragile iguanodont bones.



UGS preparator Don DeBlieux next to a partially excavated dinosaur humerus (upper arm bone) in the field.



The same bone after preparation by volunteer Tom Mellenthin at the UGS prep lab. Sections of bone were glued together with epoxy resin; the blue strap and padding help hold the bone together while the epoxy sets.

UTAH GEOLOGICAL SURVEY'S WEST DESERT GROUND-WATER MONITORING NETWORK

PROGRESS REPORT

by Hugh A. Hurlow

The Utah Geological Survey's west desert ground-water monitoring network is essentially in place and fully operational. Requested by the Utah State Legislature in 2007, the network was established in response to water-development projects in east-central Nevada and west-central Utah. The network includes wells in Snake and Tule Valleys and Fish Springs Flat, and surface-flow gages in Snake Valley.

The monitoring wells include 68 individual PVC wells in 51 boreholes (one to three wells per borehole) at 27 sites (one to three boreholes per site). Sixty of these wells are equipped with pressure transducers that measure water levels hourly. Eleven surface-flow gages are in place at six springs, and the data are streamed continuously to the Utah Division of Water Rights Web site (www.waterrights.utah.gov/distinfo/realtime_info.asp). We are currently constructing a database that links to the project Web site to manage the transducer data. The UGS maintains the project Web site (geology.utah.gov/esp/snake_valley_project/index.htm), which includes all currently available water-level and drilling data from the network, a Google Earth-compatible location file that describes the project sites and includes data links, and photographs from the project.

Work on the project from May through December 2009 focused on sampling ground water from wells, installing surface-flow gages, maintaining the transducer network,

and installing shallow piezometers at wetlands in spring-outflow areas. Well sampling occurred in two main phases. The UGS, U.S. Geological Survey's Utah Water Science Center, and Southern Nevada Water Authority collaborated to collect general-chemistry, stable- and radiogenic-isotope, and dissolved-gas samples from 14 wells in the network during May. Hurlow sampled 17 additional wells during June through September. Lucy Jordan (UGS) and Aaron Hunt (Division of Water Rights) completed installation of the stream gages and radio telemetry system in December, after much hard work from March through December. Fish Springs Wildlife Refuge and the Baker family kindly donated significant labor to assist flume installation at several sites. UGS geologists Stefan Kirby and Matt Affolter continued to download transducer data quarterly and improve the transducer network. In a related effort, the U.S. Environmental Protection Agency funded UGS geologist Richard Emerson to assist with installation of 60 shallow piezometers in five spring-outflow areas as part of a project to establish baseline physical habitat conditions of wetlands in Snake Valley.

Remaining work for the project includes analysis of aquifer-test data, analysis of water-chemistry data, completing the wetlands piezometer network, developing a water-level database that links directly to the Web page, and writing the report. ■

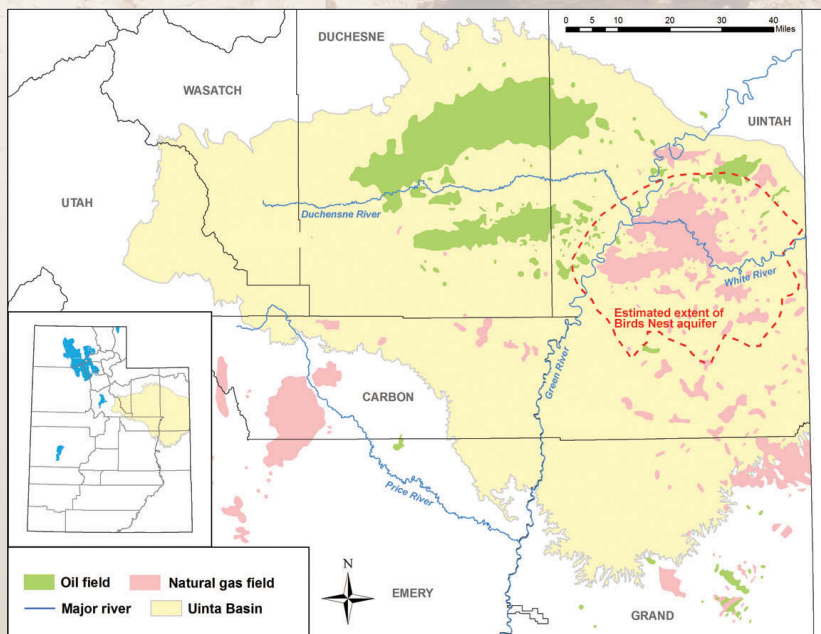


SALINE WATER DISPOSAL IN THE UINTA BASIN, UTAH

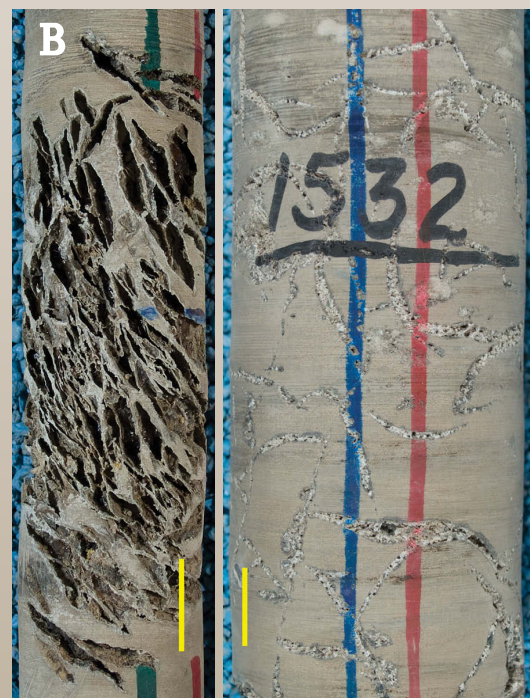
PROTECTING FRESH WATER WHILE ALLOWING FOR INCREASED HYDROCARBON PRODUCTION

by Michael D. Vanden Berg

Saline water disposal is one of the most pressing issues with regard to increasing crude oil and natural gas production in the Uinta Basin of northeastern Utah. Conventional oil fields in the basin provide 67 percent of Utah's total crude oil production and 70 percent of Utah's total natural gas, the latter of which has increased 60 percent in the past 10 years. Along with hydrocarbons, wells in the Uinta Basin produce significant amounts of salty water—nearly 4 million barrels of saline water per month in Uintah County and nearly 2 million barrels per month in Duchesne County. As hydrocarbon production increases, so does saline water production, creating an increased need for economic and environmentally responsible disposal plans. Current water disposal wells—wells specifically used to re-inject saline water underground—are near capacity, and permitting for new wells is being delayed because of a lack of technical data regarding potential disposal aquifers and questions concerning contamination of freshwater sources. Many companies are reluctantly resorting to evaporation ponds as a short-term solution, but these ponds have limited capacity, are prone to leakage, and pose potential risks to birds and other wildlife. Many Uinta Basin operators claim that oil and natural gas production cannot



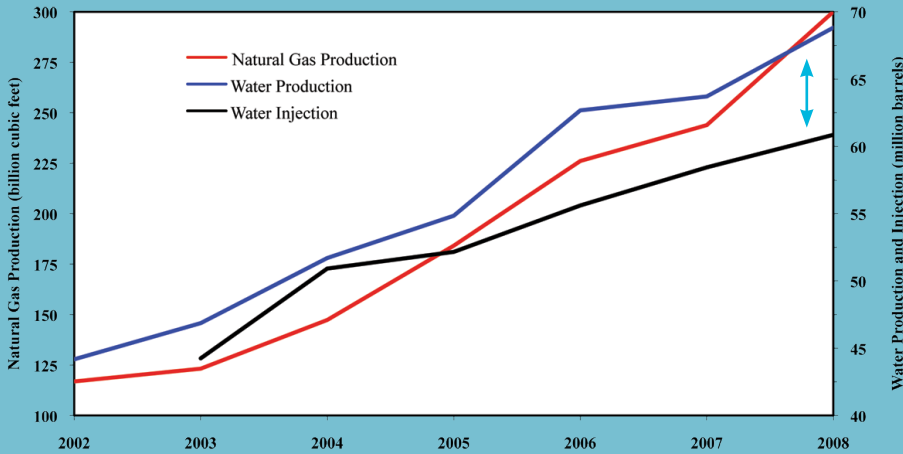
The Birds Nest aquifer in the eastern Uinta Basin is a promising reservoir for the disposal of saline water that accompanies hydrocarbon production.



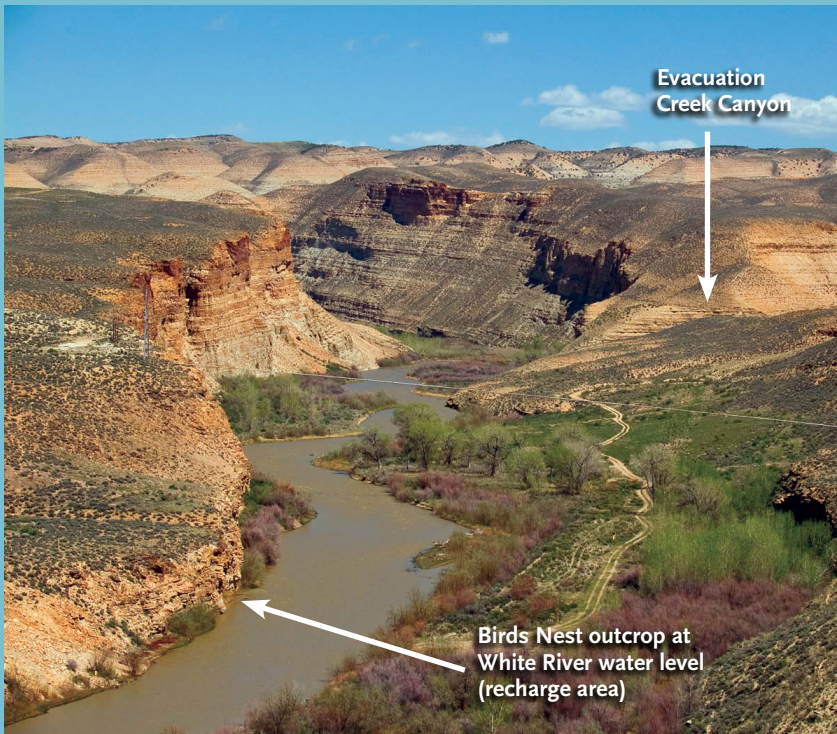
A) Birds Nest aquifer in outcrop along Evacuation Creek, eastern Uinta Basin. The large cavities resulted from the dissolution of saline minerals, creating the aquifer's porosity (percent of pore space) and permeability (a measure of how effectively the pores are connected). B) Dissolution of saline minerals in core from central Uintah County (yellow bars equal 1 inch).

reach its full potential until a suitable, long-term saline water disposal solution is determined.

The Utah Geological Survey (UGS) is currently half-way through a three-year, joint UGS–U.S. Department of Energy-funded study investigating the aquifers in the Uinta Basin to help facilitate the development of prudent saline water disposal plans. The project is divided into three parts: (1) re-mapping the base of the moderately saline aquifer in the Uinta Basin, (2) creating a detailed geologic characterization of the Birds Nest aquifer, a potential reservoir for large-scale saline water disposal, and (3) collecting and analyzing water samples from the eastern Uinta Basin to establish baseline water quality.



Natural gas production, water production, and water injection in the Uinta Basin, Utah, 2002–2008. The gap between water production and water injection (indicated by blue arrow) has widened as natural gas production has increased, leading to a need for the development of mitigation strategies.



Birds Nest aquifer outcrop along the White River, eastern Uinta Basin, Utah.

Part 1: Regulators currently stipulate that saline water must be disposed of into aquifers that already contain moderately saline water (water that averages at least 10,000 parts per million total dissolved solids). These underground zones are currently determined using 25-year-old data compiled on a less-than-useful paper map. The UGS plans to re-map this moderately saline water boundary in the subsurface using a combination of actual water chemistry data collected from various sources and by analyzing geophysical well logs. By re-mapping the base of the moderately saline aquifer using more robust data and more sophisticated computer-based mapping techniques, regulators will have the information needed to more expeditiously grant water disposal permits while still protecting freshwater resources.

Part 2: Eastern Uinta Basin gas producers have identified the Birds Nest aquifer, located in the Parachute Creek Member of the Green River Formation, as the most promising reservoir suitable for large-volume saline water disposal. This aquifer, ranging in thickness from less than 100 feet on the basin margins to greater than 300 feet in the basin’s center, formed from the dissolution of saline minerals which left behind large open cavities and fractured rock. Understanding the aquifer’s areal extent, thickness, water chemistry, and zones of differential dissolution will help determine possible saline water disposal volumes and safe disposal practices, both of which could directly impact the success of increased hydrocarbon production in the region.

Part 3: The UGS has determined a regulatory need for baseline water quality and quantity data for lands identified in the eastern Uinta Basin as having oil shale development potential. Water-quality degradation could result from new oil shale developments via mining and surface retort or in-place processes. The UGS has identified 17 sites in the area, including wells, springs, and streams, that will be sampled and analyzed on a bi-annual basis. This information will provide a baseline water quality profile, which can be used to compare with future data after petroleum development begins.

This multifaceted study will provide a better understanding of the aquifers in the Uinta Basin, giving regulators the tools needed to protect precious freshwater resources while still allowing for increased hydrocarbon production. To find out more about this study or to download quarterly reports and recent presentations, visit the UGS Web site: geology.utah.gov/emp/UBwater_study. ■

GLAD YOU ASKED

HOW MANY ISLANDS ARE IN GREAT SALT LAKE?

by Jim Davis



Black Rock, a steep-sided offshore rock island (or “sea stack”) near Saltair, was the site of Utah’s first recorded community beach excursion in 1851. Sea stacks are created by wave erosion of a headland, in this case the Oquirrh Mountains, which eventually leaves behind isolated rock islands.

Great Salt Lake has islands from small to large, from one corner of the lake to the other. But how many islands are there? The question is not as straightforward as one might think. Although there are 17 officially named islands, answers to the question typically range from zero to 15.

It All Depends. . .

Great Salt Lake is in a closed basin, an area without any drainage outlet. The elevation of the lake’s surface changes continually, reflecting changes in weather and climate; heavy precipitation and low evaporation rates cause the lake level to rise, whereas drought and heat will result in a declining lake level. The lake level can change 2-plus feet a year, and because the basin floor slopes very gently, the shoreline advance or retreat can be a mile or more in certain areas.

Great Salt Lake’s ups and downs have exceeded a 20-foot range in historical times. At high lake levels some islands submerge and new ones are created by the water enclosing higher topography. At low lake levels new islands emerge and some adjacent islands merge with each other or with the mainland. All islands become connected to the mainland during very low lake levels (e.g., 1963), and the maximum number of islands occurs during very high lake levels (e.g., 1873, 1986–87). A few examples illustrate how the number of islands changes with changing lake levels. Badger Island is submerged at historic high levels (4212

feet above sea level), and Goose Island in Farmington Bay is submerged at the average historical lake level of 4200 feet. Strongs Knob and Stansbury Island, technically peninsulas, are tied to the mainland by dry land until the lake level is a few feet higher than average. Some islands divide into multiple islands at higher lake levels. Strongs Knob spawns an islet or two at higher levels, as does Cub Island, splitting into two smaller islets—Greater Cub and Lesser Cub. Antelope Island is a peninsula at lake levels below average. Egg Island and White Rock were connected to Antelope Island during the lowest historical lake level (4191.35 feet). Carrington, Badger, Hat, and Stansbury Islands all combine during low lake levels by way of sand bars.

So, discrepancies in the reported number of islands are to be expected, depending on the level of the lake at the time of counting. The 11 most commonly cited islands are Antelope, Badger, Carrington, Cub, Dolphin, Egg, Fremont, Gunnison, Hat, Stansbury, and Strongs Knob. Islands often left out of the count are Black Rock and White Rock, Browns and Goose in Farmington Bay, and the Bear River Bay islands of Rock and Goose (the other Goose Island). All 17 islands have official names recognized by the U.S. Board on Geographic Names (geonames.usgs.gov/).

Why So Many Islands?

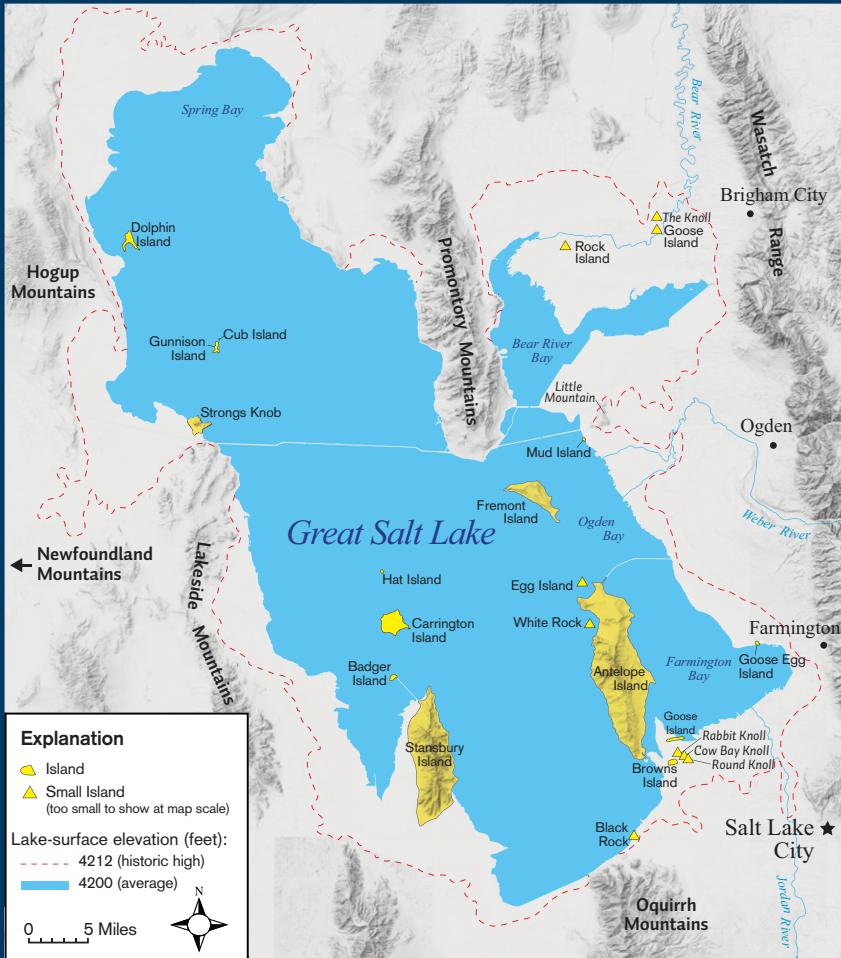
The major islands, such as Antelope, Stansbury, and Fremont Islands, as well as some of the minor islands, are actually moun-



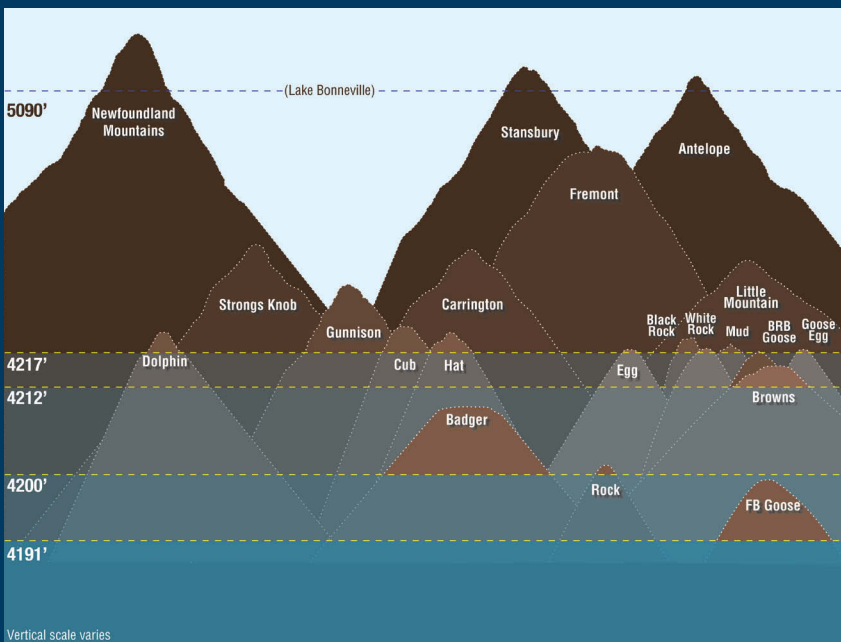
Wide sandy beaches span scalloped coves of the Gunnison Island shoreline, a State Wildlife Management Area closed to the public.



Aerial view (looking north) of Fremont Island and the nearby Promontory Mountains. Fremont Island has also been called Disappointment Island, Castle Island, and Miller’s Island. (Photo source: Don Currey, University of Utah.)



Islands of Great Salt Lake.



Great Salt Lake island family portrait: The number of islands varies depending on lake level. The four elevations of the surface of Great Salt Lake (up to 4217 feet) represent, from bottom to top, the historical lowstand, historical average, historical highstand, and late-prehistoric (ca. 1700) highstand levels. Also shown is the highstand level of Lake Bonneville, Great Salt Lake's Ice Age predecessor. BRB, Bear River Bay; FB, Farmington Bay.

tain ranges that poke up above the lake. Great Salt Lake lies within the eastern part of the Basin and Range Province; because of the characteristic topography of this physiographic province—north-south-trending isolated mountain ranges and adjacent valleys—Great Salt Lake hosts an unusually large number of islands.

In contrast, the low-lying islands of Great Salt Lake's eastern edge were constructed by the Bear, Jordan, and Weber Rivers. As the river channels migrate, erosion and deposition of sediment creates local high points. Additionally, liquefaction from large-magnitude earthquakes roils this soggy landscape, forming bumpy topography. Some of these low-lying islands are termed “knolls” rather than islands—for instance Rabbit, Cow Bay, and Round Knolls in Farmington Bay, and The Knoll by Bear River.

An artificial but nonetheless remarkable island is Goose Egg in the Farmington Bay Waterfowl Management Area (not to be confused with the other two Goose Islands). Goose Egg is an island created from material generated in the May 1983 Rudd Canyon debris flow in northern Farmington in Davis County, which was hauled to and piled up in Farmington Bay. Another island of note is Mud Island, about 5 miles northeast of Fremont Island in Ogden Bay. For nearly a century it could be found labeled on maps, but no longer. Mud Island still makes an appearance between particular lake levels. In 1850, Captain Howard Stansbury and his exploration crew set up a station on Mud Island. He described it as a point of rocks surrounded by a mud plain . . .

“ . . . a belt of soft, black mud, more than knee-deep lay between the water and hard rocky beach, and seemed to be impregnated with all the villainous smells which nature's laboratory was capable of producing.”

More Islands?

Two substantial islands add to the sum if we go back a few hundred years to a period of cool climate known as the Little Ice Age. The Newfoundland Mountains became an island some decades before the year 1700 when the lake rose to approximately 4217 feet, spilling out into the west desert and Bonneville Salt Flats, expanding its surface area by 900 square miles and encompassing “Newfoundland Island.” The State of Utah would recreate this situation in 1987, when the lake's water was pumped into the west desert to control flooding associated with the lake's historical highstand. Also, Little Mountain in Weber County was an island for awhile in the 17th century. This is the place where famed American explorer John C. Frémont summited for his first panoramic view of Great Salt Lake in 1843. ■

GEO SIGHTS

FREMONT INDIAN STATE PARK

SEVIER COUNTY, UTAH

by William F. Case

Fremont Indian petroglyphs pecked into the Joe Lott Tuff. The dark surface was produced by weathering of the lighter colored tuff. (Photo courtesy of Fremont Indian State Park).

Fremont Indian State Park is named after a diverse group of people, the Fremont Indians, who lived in Utah from A.D. 400 to 1350. The park exists because of successful archaeological excavations in Clear Creek Canyon prior to construction of Interstate 70 between Richfield and Cove Fort, Utah. There are at least 10 Fremont sites within the park.

In 1983 local elementary school students told Brigham Young University archaeologists that there were pottery shards and collapsed dwelling depressions on top of Five Finger Ridge. At the time bulldozers were removing the surficial deposits of Five Finger Ridge for use as highway fill. The archaeologists quickly recovered hundreds of artifacts from Five Finger Ridge; these and other Fremont artifacts are housed and displayed in the Fremont Indian State Park museum that opened in 1987.

Clear Creek Canyon has afforded a human connection between the Colorado Plateau and Basin and Range areas since at least 12,000 B.C. The area has provided habitat or layover essentials for Paleoindians, Fremont Indians, more recent Native Americans, and Mormon pioneers. Interstate 70 is the latest human connection between Richfield and Cove Fort.

How has the geology of Clear Creek Canyon contributed to the attraction of so many people over such a length of time? Clear Creek flows east to the Sevier River through the Clear Creek downarp, a geological structure that began forming 27 million years ago. This downarp helped form the passage between the formidable Pahvant Range to the north and Tushar Mountains to the south.



Fremont Indian State Park Museum. Low distant clouds lie over the Mount Belknap caldera. The Sevier River Formation forms the light-colored hills in the middle distance. Photo courtesy of Vandy Moore (Fremont Indian State Park).



An airfall volcanic ash layer is exposed in this outcrop of the pink unit of the Joe Lott Tuff along State Route 4 near I-70 exit 17.

The oldest rock unit at the park is the 19-million-year-old Joe Lott Tuff, named after an early Mormon pioneer who settled in Clear Creek Canyon. The rock is a welded volcanic-ash avalanche deposit containing scattered pieces of rhyolite lava (ash-flow tuff) that was produced by an explosive volcanic eruption. The massive eruption created the Mount Belknap caldera located about 10 miles south of Clear Creek Canyon. The tuff is exposed in the high cliffs in the canyon. The surface of the originally white, pink, and gray tuff has weathered to darker colors and serves as a “blackboard” for Fremont Indian rock art.

Overlying the Joe Lott Tuff, the Sevier River Formation consists of sandstones, siltstones, conglomerates, volcanic ashes, and lava flows that were deposited in lake basins, rivers, and alluvial fans between about 5 and 14 million years ago, when the present topography of the Basin and Range area began forming. The Sevier River Formation was uplifted and tilted around 5 million years ago. Where the Sevier River Formation is not capped by conglomerate, its sandstones and siltstones are easily eroded, and the resulting sediment has provided

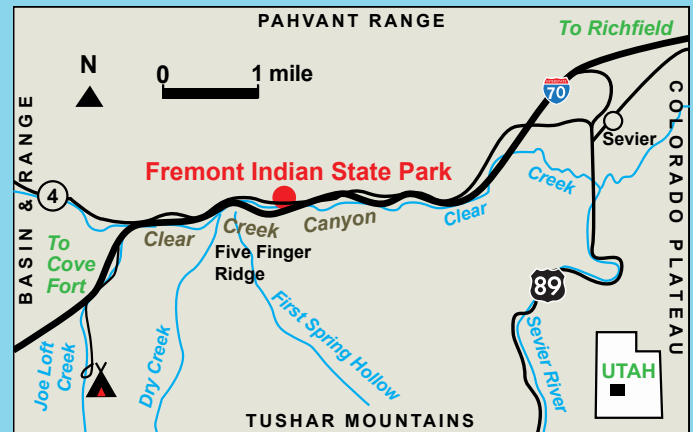
valley fill suitable for construction materials for buildings and for growing crops. Excellent exposures of the Sevier River Formation can be seen at the nearby Castle Rock Campground south of I-70 (see “GeoSights” article in the September 2006 issue of *Survey Notes*).

Several years ago, local-area residents and amateur naturalists Jeff and Denise Roberts found fossils of two previously unknown species of tiny rodents related to modern deer and pocket mice in the Sevier River Formation near the mouth of Clear Creek Canyon. In addition to identifying new species, the finds are significant because mammal fossils dating to the time of the Sevier River Formation are exceedingly rare in Utah.

Clear Creek tributary drainages, particularly Dry Creek and First Spring Hollow, provide sand and silt eroded from the Sevier River Formation and landslides in the Joe Lott Tuff for alluvial fans that extend into the canyon. The fan surfaces are good agricultural locations, and the tributary stream flow supplements the water supply in the canyon. ■



Tilted strata of the Sevier River Formation capped by resistant conglomerate near the mouth of Clear Creek Canyon.



How to get there: Fremont Indian State Park is on the north side of I-70. From the I-15/I-70 interchange south of Cove Fort in Millard County, head east on I-70 to exit 17. Exit 17 is about 20 miles southwest of Richfield in Sevier County. Follow the signs to Fremont Indian State Park. For more information, visit stateparks.utah.gov/parks/fremont.

SURVEY NEWS

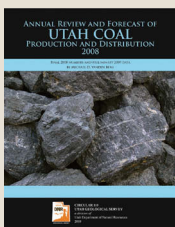
EMPLOYEE NEWS

The Energy and Minerals Program welcomes **Andrew Rupke** as the new industrial minerals geologist. Andrew has an M.S. in Geology from the University of Utah and has worked for Graymont Lime for the past five years.

Toby Hooker recently joined the Ground Water and Paleontology Program as a wetlands specialist and will be working on EPA-supported projects at Snake Valley and near the Bear River Bay. Toby has a Ph.D. in Soil Microbiology and Biogeochemistry from Utah State University.

Jim Levy has joined the ever-growing Utah State Energy Program (USEP). He will be working as a project specialist under the American Recovery and Reinvestment Act programs. Jim comes to the USEP with over 20 years experience in the building lighting industry. Most of his career has been in California working for international firms, and most recently he was Vice President of Up-Light Electric Engineering, Inc. Jim is the first DNR employee to own a 100 percent electric car. **Megan Golden** left the USEP in March to pursue other interests.

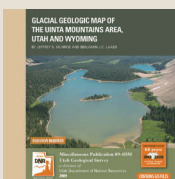
NEW PUBLICATIONS



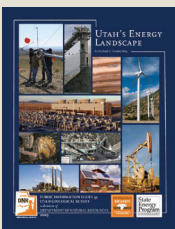
Annual review and forecast of Utah coal production and distribution—2008, prepared by Michael D. Vanden Berg, 37 p., ISBN 978-1-55791-824-7, **C-110** \$12.95



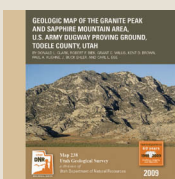
Geologic map of the St. George and east part of the Clover Mountains 30' x 60' quadrangles, Washington and Iron Counties, Utah, by Robert F. Biek, Peter D. Rowley, Janice M. Hayden, David B. Hacker, Grant C. Willis, Lehi F. Hintze, R. Ernest Anderson, and Kent D. Brown, 108 p., 2 pl., scale 1:100,000, ISBN 1-55791-816-3, **M-242** \$19.95



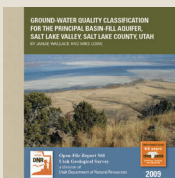
Glacial geologic map of the Uinta Mountains area, Utah and Wyoming, by Jeffrey S. Munroe and Benjamin J.C. Laabs, DVD (1 pl., scale 1:100,000 [contains GIS data]), ISBN 1-55791-825-2, **MP-09-4DM** \$24.95



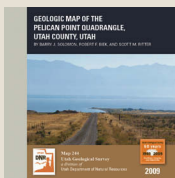
Utah's Energy Landscape, by Michael D. Vanden Berg, 41 p., ISBN 1-55791-823-6, **PI-95** \$14.95



Geologic map of the Granite Peak and Sapphire Mountain area, U.S. Army Dugway Proving Ground, Tooele County, Utah, by Donald L. Clark, Robert F. Biek, Grant C. Willis, Kent D. Brown, Paul A. Kuehne, J. Buck Ehler, and Carl L. Ege, CD (2 pl., scale 1:24,000), ISBN 1-55791-810-4, **M-238** \$14.95



Ground-water quality classification for the principal basin-fill aquifer, Salt Lake Valley, Salt Lake County, Utah, by Janae Wallace and Mike Lowe, CD (15 p. + 64 p. appendices, 3 pl.), **OFR-560** \$19.95



Geologic map of the Pelican Point quadrangle, Utah County, Utah, by Barry J. Solomon, Robert F. Biek, and Scott M. Ritter, CD (2 pl.), scale 1:24,000, ISBN 1-55791-820-1, **M-244** \$14.95

2009 UGS EMPLOYEE OF THE YEAR

Congratulations to **Mike Hylland** who was named the



2009 UGS Employee of the Year. Mike has worked for the UGS for 16 years and does an extraordinary job balancing duties as technical editor and geologic researcher. Mike is quite knowledgeable and professional, and his work ethic and demeanor are exemplary. As a patient, positive, and well-rounded reviewer, he strives for consistency and thoroughness, but is also flexible and willing to look at an author's particular viewpoint. His ongoing

contributions to fault studies in northern Utah and maintenance of the Quaternary fault database are long-lasting. Overall, Mike's excellent technical skills and great temperament make him the perfect UGS role model.

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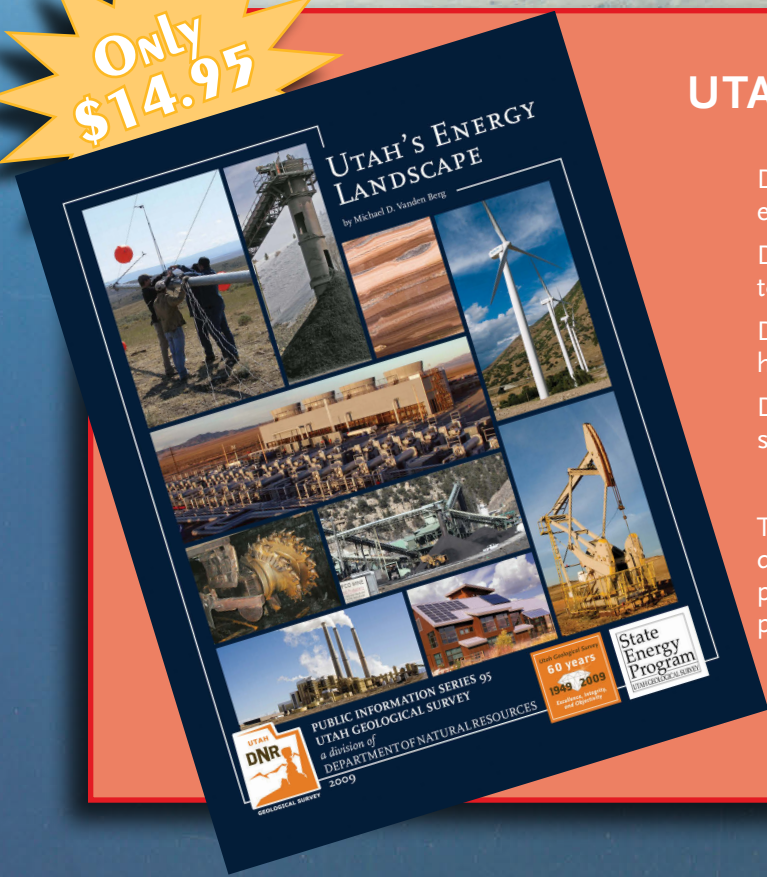
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UTAH'S ENERGY LANDSCAPE

- Did you know that Utah is one of only six states that generate electricity from geothermal sources?
- Did you know that Utah recently produced its one billionth ton of coal?
- Did you know that Utah has the second lowest price for home-heating natural gas in the nation?
- Did you know that Utah has been a net exporter of energy since 1980?

These little-known facts, along with many more interesting details, can be found in the Utah Geological Survey's new publication *Utah's Energy Landscape*—a visual-based comprehensive description of Utah's entire energy portfolio.

Available at the Natural Resources Map & Bookstore
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