UTAH GEOLOGICAL SURVEY

# SURVEY NOTES

Volume 44, Number 3 September 2012

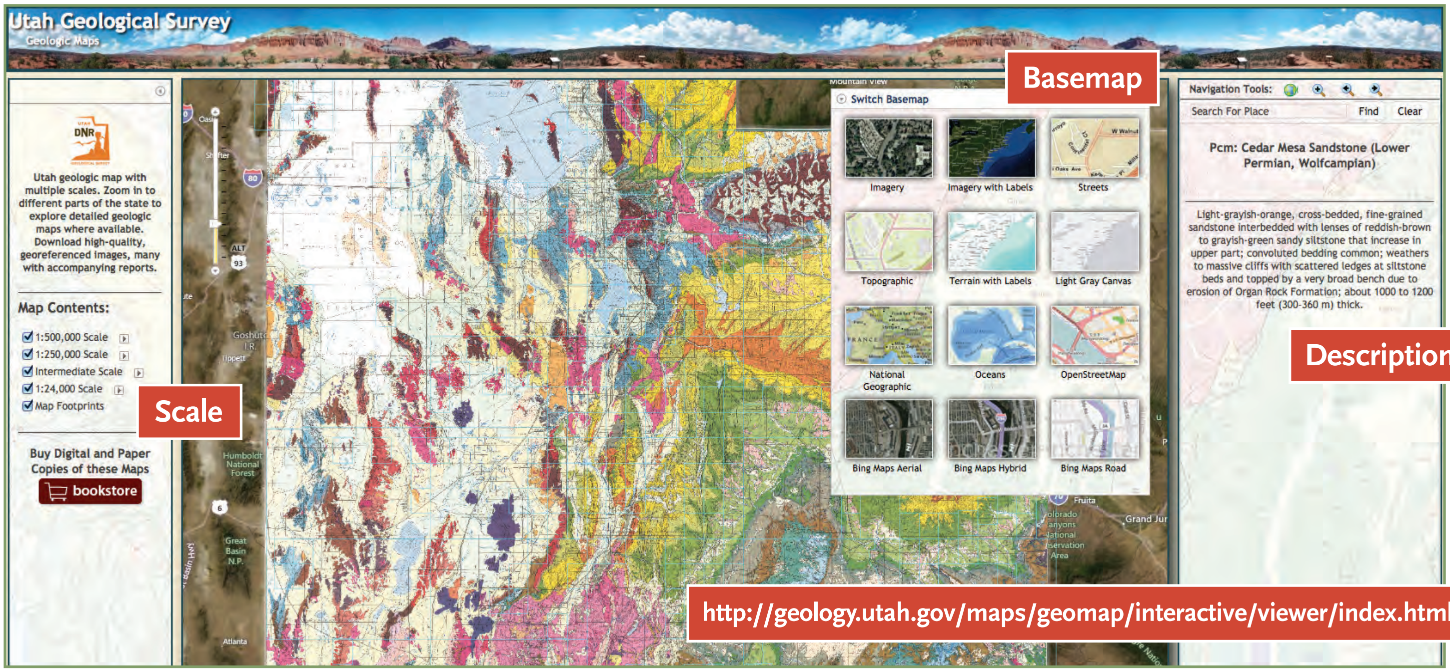
# POTASH IN UTAH

# The Director's Perspective

*by Richard G. Allis*

One of the newest additions to the Utah Geologic Survey website that we are very proud of is the interactive geologic map of the state. Within a month it became one of our most visited pages. The map has been a collaborative effort between the Geologic Mapping Program and staff from the Geologic Information and Outreach Program who worked on the application of the GIS technology. Over 400 geologic maps at scales from 1:24,000 to 1:500,000 were scanned and georeferenced so that the user can seamlessly zoom from a statewide view down to an urban geology scale, where those maps are available. A useful feature is a selection of basemaps that underlie the geologic map. A slider allows the user to choose the transparency, anywhere between 100 percent geologic layer and 100 percent basemap layer. Basemap choices include various airphoto, topographic, and street map layers, which also zoom so that the user can easily switch between the layers. Another feature is a sidebar that contains a geologic description when the user clicks on a particular map unit anywhere on the map. There is also an option for downloading GIS map information or any associated report.

Take a look at the map and zoom into your favorite area in Utah! The link to access the interactive map is on the front page of our website. Please give us feedback on the map and ideas on how to make it even more user-friendly. Send comments to Sandy Eldredge at sandyeldredge@utah.gov.

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***Design:** Jeremy Gleason*

***Cover:** Solar evaporation ponds at Intrepid's Moab facility. Photograph by Andrew Rupke.*





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# UTAH'S POTASH RESOURCES AND ACTIVITY

*by Andrew Rupke*

*Processing plant at Intrepid's Moab operation.*

## Introduction

Potash refers to natural or manufactured, water-soluble potassium salts, most commonly in the form of potassium chloride (KCl). Potash minerals are primarily used as fertilizer and are vitally important because they provide plants with potassium, one of three essential plant nutrients along with nitrogen and phosphorous. The chemical industry also consumes potash for production of or use in a number of products, including soap, glass, ceramics, and batteries. The U.S. Geological Survey (USGS) estimates that 37 million metric tons (mt) of potash (reported as $K_2O$ equivalent) were produced in the world in 2011, and 1.1 million mt were produced in the U.S. Consumption in the U.S. was about 6.5 million mt, so the U.S. is currently a net importer of potash. The largest producer of potash in the world is Canada, but Russia, Belarus, Germany, and China also produce significant amounts.

Until 2008 potash prices were relatively stable for a number of years at less than $200 per mt of potassium chloride, but in early 2008 prices rose sharply to about $900 per mt. However, during and following the economic recession of late 2008 and 2009, prices dropped significantly to slightly above $300 per mt. As the economy improved, potash prices increased, bringing current prices back up to over $500 per mt—so prices are not at peak levels, but are moving in that direction.

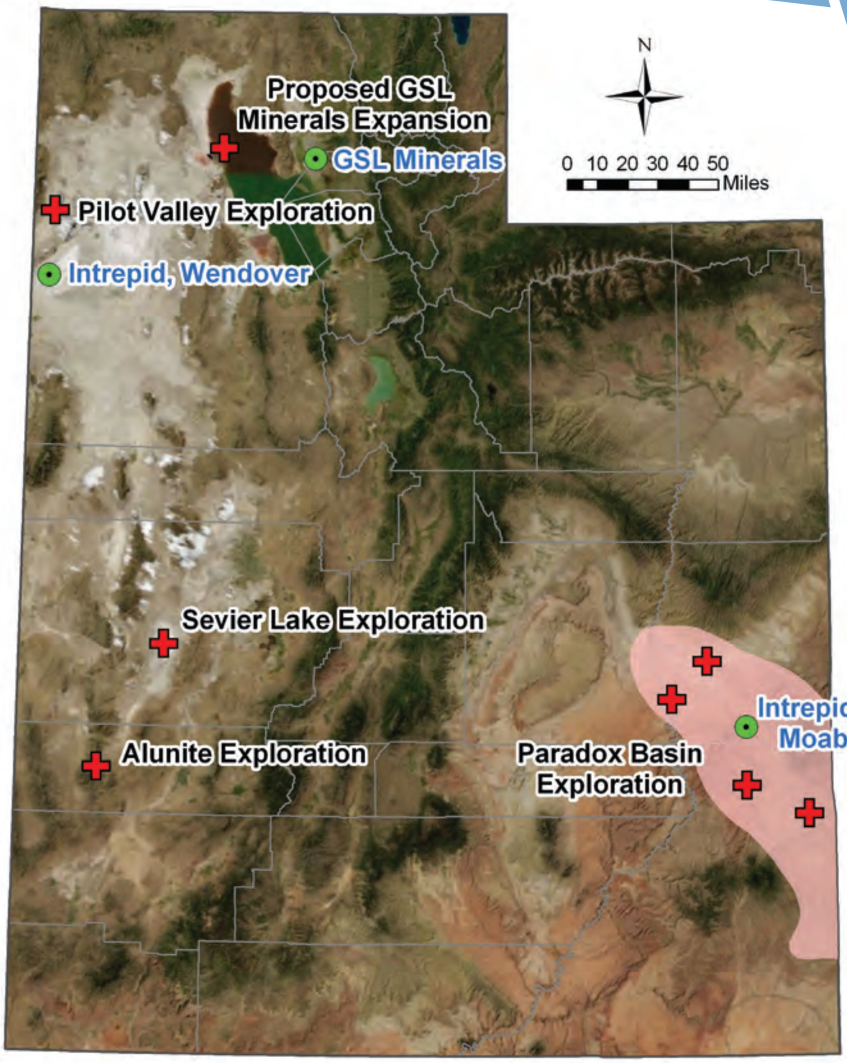
## Utah's Potash Production and Resources

Utah is one of only three states in the U.S. that produces potash. Two companies, Intrepid Potash, Inc. (Intrepid) and Great Salt Lake Minerals (GSLM), produce potash at three locations in Utah: Great Salt Lake, Wendover, and Moab. At all locations, Utah's producers use solar evaporation ponds in which brine enriched with potassium is evaporated and concentrated, which leads to precipitation of potash minerals. Those minerals can then be collected, purified, and processed. Utah's warm, dry climate is well-suited for this efficient use of solar energy.

Utah is unique in that its potash resources occur in a number of geological settings, including surface brines, subsurface brines, bedded evaporites, and alunite—all but alunite are currently exploited for potash production. Surface brines of Great Salt Lake are harvested by GSLM, which has evaporation pond capacity to produce over 360,000 mt of potassium sulfate ($K_2SO_4$) per year. Worldwide, potassium sulfate, which is also used as fertilizer, is much less commonly produced than potassium chloride, but sells for a higher price. GSLM is able to produce potassium sulfate due to relatively high sulfate content in Great Salt Lake brine, and they are the largest producer of potassium sulfate in North America.

Intrepid produces potash in the form of potassium chloride from subsurface brines of the Great Salt Lake Desert near Wendover. The Great Salt Lake Desert contains salts precipitated during the late stages of ancient Lake Bonneville, and the precipitated salts (also known as evaporites) enrich the groundwater with potassium. Intrepid extracts the groundwater using trenches and wells and then pumps the water into evaporation ponds. Near Moab, Intrepid produces potash from deeply-buried evaporites found in the Paradox Basin of southeast Utah. In the Paradox Basin, evaporites formed during the Pennsylvanian Period (~300 million years ago) in a restricted marine basin where seawater was concentrated, precipitated salt, and was subsequently diluted multiple times, producing bedded evaporite cycles. Several thousand feet of evaporites precipitated in the basin, and, during the times when the seawater was most concentrated, potash minerals formed and were deposited. At least 29 evaporite cycles have been identified in the Paradox Basin, and 18 of those cycles are known to have potash mineralization—although only a few of the cycles likely have economic significance. Intrepid solution mines two of the potash cycles by pumping water down a well, dissolving the potash minerals at depth, and pumping the potassium-enriched fluid back up another well. The potash is then re-precipitated in surface evaporation ponds and harvested for processing (see cover photo).

*Solar evaporation pond at Intrepid's Wendover operation. Photo by Mark Gwynn.*




*Potash activity in Utah. The green circles represent existing producers, and the red crosses represent proposed expansions and exploration areas. The pink shaded area shows the estimated extent of potash deposition in the Paradox Basin. Orthophoto base is provided by Bing maps.*

# ABOUT THE AUTHOR

**Andrew Rupke** joined the UGS as an industrial minerals geologist in 2010. Prior to that, he worked as a geologist in the lime industry for over 6 years. His work and research at the UGS focus on Utah's diverse industrial mineral resources, including potash, salt, high-calcium limestone, aggregate, gypsum, and others.

*Blawn Wash alunite deposit in the Wah Wah Mountains of Beaver County.*

Alunite is another potential source of potash in Utah, but it is not currently being exploited. Alunite is a potassium aluminum sulfate mineral ($KAl_3[SO_4]_2[OH]_6$) that can be processed into potassium sulfate and alumina. Although not currently mined in Utah, alunite was historically mined near Marysvale during World War I as a source of potash, and during World War II as a source of alumina. Alunite forms from alteration of volcanic rocks, and a number of deposits can be found in southwest Utah, including the Blawn Wash deposit, which is the largest known alunite deposit in the country. Recently, only Azerbaijan has mined and processed alunite—although primarily for alumina rather than potash.

## Potash Activity in Utah

Due to high potash prices and Utah's diverse potash resources, expansion of the state's existing potash production and renewed exploration of the state's unexploited potash resources are occurring. GSLM has proposed an expansion of its evaporation ponds, primarily in the North Arm of Great Salt Lake, by 69,000 acres which would significantly increase potash production. Currently, GSLM is working through the permitting process for the expansion.

Two companies are currently evaluating Utah's subsurface brines for potash potential. Mesa Exploration Corp. has acquired 104 square miles of leases and is in the preliminary stages of evaluating the subsurface brine of Pilot Valley, which is just north of Intrepid's Wendover operation. Also, Peak Minerals Inc. has drilled over 400 mostly shallow exploration holes to evaluate the subsurface brine of Sevier Lake, a playa in Millard County, where it holds leases on over 190 square miles of the lake bed. If sufficient grade and resource are present, both Pilot Valley and Sevier Lake could be amenable to extraction operations similar to the Intrepid Wendover operation. Throughout the Paradox Basin, a number of companies have applied for or obtained resource rights to the bedded evaporites. At least four companies have recently drilled or are planning to drill exploration holes: K2O Utah LLC in the Hatch Point area; Potash Green Utah LLC in Lisbon Valley; Pinnacle Potash International, Ltd. near Crescent Junction; and American Potash LLC south of the town of Green River. Any new mines in the Paradox Basin would likely be solution mines similar to Intrepid's Moab operation.

Even Utah's alunite resources are drawing interest; Potash Ridge is evaluating the alunite resource at Blawn Wash in the Wah Wah Mountains of Beaver County. In the 1970s the alunite in Blawn Wash was discovered and defined by Earth Sciences,

# Energy News

by David Tabet

## A Longer Term View of the Results of U.S. Energy Policy

Sometimes it is helpful to step back from current policy discussions to take a longer term view of issues. Interestingly, a little over 35 years ago, on April 18, 1977, President Jimmy Carter delivered a televised speech to the U.S. public declaring the "moral equivalent of war" on the energy crisis facing our country. President Carter framed the crisis in terms of a U.S. dependence on oil and gas for 75% of the nation's energy, dwindling U.S. petroleum production and reserves, and the economic threat of supply disruptions or embargos from petroleum suppliers in the Middle East. Carter's answers to the energy challenge he saw were to advocate energy conservation to reduce our nation's consumption and need for outside energy, establishing a strategic petroleum reserve as a supply cushion, creation of a new Department of Energy (DOE) to consolidate national efforts to tackle the energy crisis, application of stricter safety standards for nuclear energy, increasing coal production and consumption to more than a billion tons a year to lessen the U.S. use and reliance on petroleum, and starting research and development of new unconventional sources of energy.

How has the U.S. done on meeting the energy goals set out 35 years ago?

1. Energy conservation has been a goal of various administrations since President Carter left office; therefore, numerous American homes have been insulated as a result of federal and state tax credit incentives, more energy efficient building standards have been established for new homes and buildings, and the energy efficiency of appliances and lighting has greatly improved, all of which have reduced U.S. per capita energy consumption.

2. The U.S. Petroleum Reserve has been established and as of June 22, 2012, held 695.9 million barrels of oil, somewhat below the 1 billion barrels envisioned by Carter.

3. The DOE was created, and although there were some thoughts to disband it in the past 35 years, it still promotes research on unconventional fuels and manages U.S. energy policy.

4. The U.S. has implemented stricter nuclear energy safety standards in light of the 1979 accident at the Three Mile Island plant in Pennsylvania. At present, a fleet of 104 commercial nuclear reactors generates approximately 20% of the U.S.'s total electric energy for consumption. Of those reactors, ground was broken on all of them in 1974 or earlier, so for many years, no new nuclear plants have been built here, although there is some renewed interest.

5. From coal production of 697 million tons in 1977, annual U.S. coal production rose to about 1 billion tons in 1990 and remained at that level through 2010, fulfilling Carter's wish to rely more on our most abundant domestic energy source. However, according to the U.S. Energy Information Administration (EIA), the average share of electricity generated from coal in the U.S. has dropped from 52.8% in 1997 to just over 45% in 2010, and has been even lower this year. Natural-gas-generated electricity has shown a corresponding increase in that same period. The percentage of U.S. electricity generated by coal is projected to drop further to 39% by 2035 as utility companies shut down and retire a significant number of older coal-fired power plants in response to the Environmental Protection Agency's plans to regulate greenhouse gas emissions.

6. Although it is unlikely President Carter considered oil and gas from shale reservoirs when he proposed development of new unconventional energy sources, refinement of new exploration and development technologies in the past 35 years have made petroleum from shale reservoirs a "game changing" market development in producing new energy supplies. While 35 years ago Carter thought we were running out of domestic petroleum, the U.S. EIA's "Annual Energy Outlook 2012" now includes projections envisioning that the U.S. might be independent from imports of oil and gas by 2035 because of the new ability to tap oil and gas economically from shale reservoirs.

Shale reservoirs have become economic to find and produce due to technology improvements for petroleum exploration, from improved seismic imaging and down-hole logging methods, to petroleum production from more efficient horizontal drilling and reservoir fracturing methods (see Chidsey, this issue). Many of these technology developments are the results of research partnerships between industry and government sponsored by DOE in the past 35 years. Looking at the developments of the past 35 years indicates that research for new sources of energy should continue to take place on many fronts in future years. It is difficult to foresee now which technologies will be future changers, much as President Carter was unable to see the future of oil and gas produced from shale reservoirs, and, as with shale reservoir technologies, the amount of time needed to bring new technologies to the market on a large economic scale can take tens of years.

*(continued from page 2)*

Inc., and Potash Ridge has recently completed drilling in the area to confirm the previously defined resource.

### Utah's Potash Outlook

Potash-related activity is clearly at a high point in Utah's history. Considering Utah's current potash production and the diverse nature of Utah's potential potash resources, Utah is well-situated to play an important role in U.S. production of this important fertilizer. However, as with many industrial minerals, price and demand for potash will need to remain high for new projects to reach production. Production costs for proposed operations will also need to be competitive, as potash may need to be shipped over long distances.

# UGS Uses Geophysics to Explore for New Geothermal Resources

*by Richard G. Allis*

A year ago we reported that the UGS had begun an investigation of the geothermal potential beneath the Black Rock Desert south of Delta (September 2011 *Survey Notes*). This region has experienced episodes of volcanism over the last few million years, the most recent dated at 600 years ago, indicating the possibility of unusually high temperatures deeper within the crust. In the 1970s and early 1980s several companies explored for geothermal energy and for oil and gas, drilling shallow and deep wells, but they all abandoned their exploration efforts. However, an oil exploration well near Pavant Butte found temperatures of over 200°C at more than 3000 m depth (400°F below about 10,000 feet). Although these results point to potential geothermal reservoirs below about 3 km depth, the geothermal exploration industry was then looking for shallower targets, so further investigation in the region was neglected for the next 30 years. Last year the UGS began reassessing the potential of this area using federal funding allocated to promote geothermal development. The results look very interesting and indicate a major geothermal resource.

## Preliminary Results

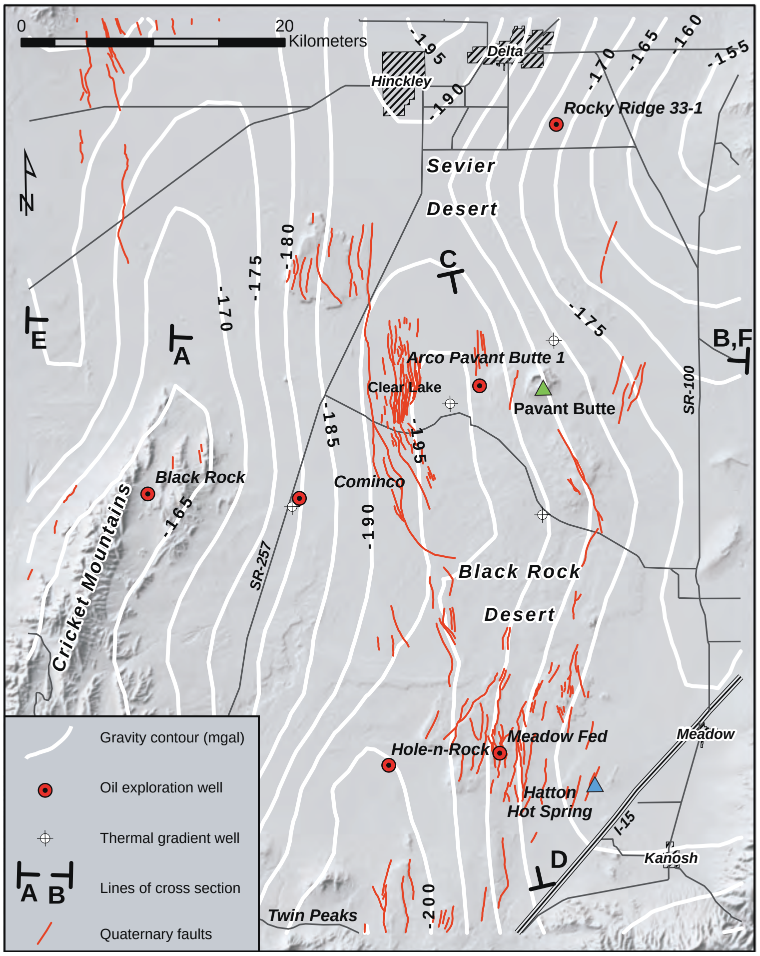
A geothermal power development requires at least two critical characteristics for a reservoir: adequate temperature (ideally at least 200°C) and rocks with good permeability (so the hot water flows easily through the reservoir between injection and production wells). Because the likely reservoirs beneath Black Rock Desert will be between 3 and 4 km depth, we are using geophysical techniques to detect conditions at these depths. In addition to drilling several wells for temperature gradient measurements, we are applying gravity, magnetotelluric, and reprocessed seismic reflection technologies. Gravity measurements enable the thickness of the unconsolidated sediments filling the basin beneath the desert to be calculated. Magnetotelluric measurements allow the electrical resistivity at depth to be mapped. This can be very useful because geothermal reservoirs are often associated with low resistivity due to the presence of high temperature, saline pore fluids, and clay minerals. Seismic reflection techniques are commonly used by the oil exploration industry to image the underlying basin structure and stratigraphy. Here we had a Cocorp seismic reflection line that had been recorded in the 1980s reprocessed and reinterpreted based on formation tops from abandoned oil exploration wells (such as the Pavant Butte well).

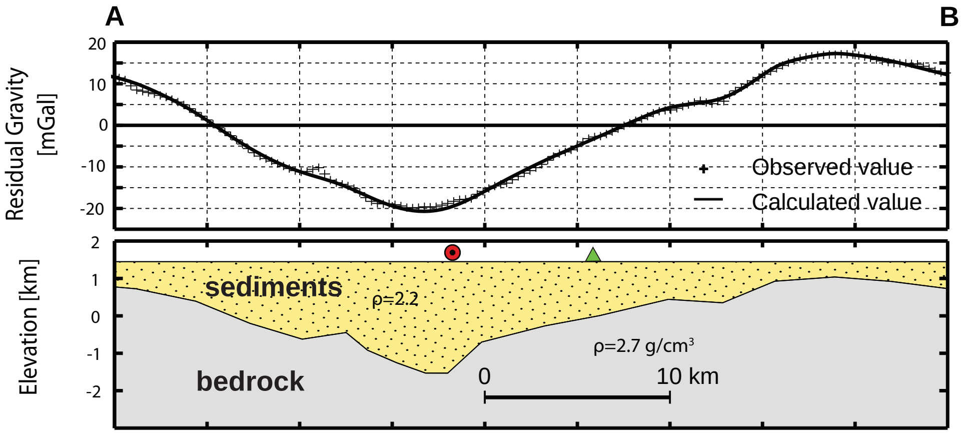
## Temperatures

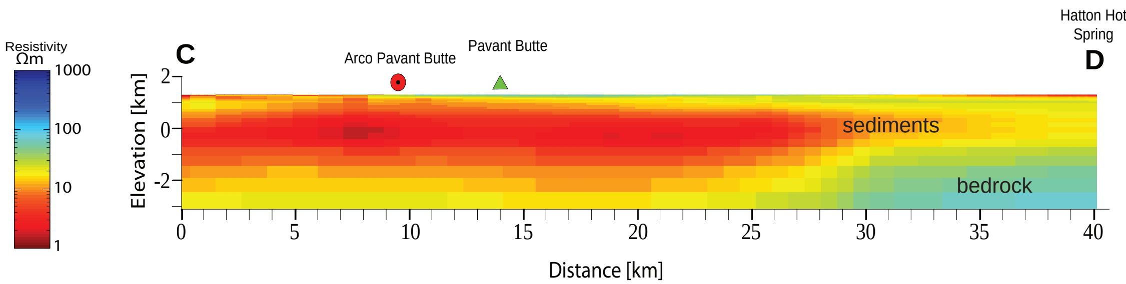
The available temperature information at the moment suggests the highest temperatures are around Pavant Butte and Clear Lake where near-surface temperature gradients are between 60 and 100°C/km (33 to 55°F/1000 feet). The highest temperatures appear to exist in the central Black Rock Desert where the unconsolidated Quaternary and Tertiary sediments are the thickest (e.g., Arco Pavant Butte well). This is to be expected because of the thermal insulating properties of these sediments. Six additional thermal gradient wells are currently being drilled, so later this summer we will have a better idea of the extent of the high temperature area.

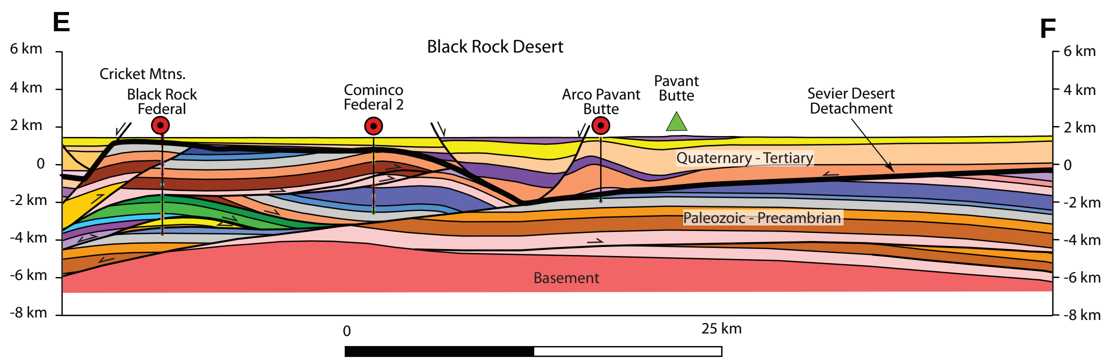
## Low Density Sediments

The same property (porosity) that causes the sediments to be thermal insulators also causes them to have a relatively low density. This means that thick sediments cause a gravity low anomaly, which can easily be mapped with gravity measurements (white contours on map). During 2011, 168 new measurements were made to improve resolution of the gravity low beneath the Black Rock Desert. Modeling of the 30 mgal low gravity anomaly (relative to the gravity over the bedrock of Cricket Mountains) that extends northwards from the Twin Peaks area in the southern Black Rock Desert towards Delta shows it is due to about 3 km of sediments filling an elongate, north-trending basin.






*Three geophysical cross-sections of the Black Rock Desert. The upper section shows the thickness of unconsolidated sediments interpreted from gravity measurements[1], the middle section shows resistivity variations derived from magnetotelluric measurements[1], and the lower section is the structure and stratigraphy from seismic reflection surveys[2].*
*[1] modified from paper by Christian Hardwick and David Chapman*
*[2] modified from report to UGS by Daniel Schelling*

### Resistivity Contrasts

The magnetotelluric measurements indicate very low resistivity at 1–3 km depth along the axis of the basin (red color, 1–3 ohm-meters). These are surprisingly low values, and a preliminary interpretation is that they are due to hot saline water with clay-rich sediments. Towards the south end of the profile, near Hatton hot springs, higher resistivity (green colors) that is associated with more resistive bedrock beneath the sediments is being detected below about 2 km depth.

### Seismic Reflectors

The reinterpreted seismic reflection line reveals complicated stacks of bedrock units beneath the Cricket Mountains as a result of Late Cretaceous Sevier shortening, and a major detachment beneath the Black Rock Desert that forms the base of the unconsolidated sediments. The shape of the bedrock-sediment interface is very similar to that inferred from the gravity modeling. An important feature of the seismic reflection results is the variety of bedrock units beneath the Black Rock Desert. These present targets for finding some high permeability, and therefore geothermal reservoirs, at 3–4 km depth beneath the Black Rock Desert.

### Ongoing Work

The UGS is also reviewing permeability characteristics of likely bedrock units beneath the desert based on outcrop observations and their well log properties when they have been encountered in deep oil exploration wells. Later this year, the project will be integrating these new geophysical findings with other geological characteristics of the basin. In addition to the six UGS staff contributing to the project, the UGS is working with other team members, many of whom are at the University of Utah. The Black Rock Desert study is part of a much larger project investigating the geothermal power potential of sedimentary basins in the U.S. Other components involve economic modeling of the resource potential and reservoir simulation of development scenarios. We hope that the new results discussed here will confirm a major new geothermal resource south of Delta, adding to the existing geothermal and wind developments in Millard and Beaver Counties.

# OIL SHALE VS. SHALE OIL:

*by Thomas C. Chidsey, Jr.*

The Utah Geological Survey (UGS) has conducted resource studies of oil shale and shale oil for over 20 years. The two topics sound like the same thing, but they are actually very different in terms of oil exploration and development.

## Oil Shale

Utah's oil-shale deposits are located in the Uinta Basin of northeastern Utah. The estimated in-ground resources are over 300 billion barrels of oil—some of the largest oil-shale resources in the world. For decades many politicians and scientists have touted Utah's oil shale as the energy of the future. However, fluctuating oil prices, technical challenges, and major environmental issues have precluded any commercial oil-shale production in Utah.

Utah oil shale was deposited as organic-rich sediments in a freshwater lake (Lake Uinta) about 50 million years ago (see related article by Michael Vanden Berg, *Survey Notes*, May, 2011, v. 43, no. 12). These deposits are found exposed around the Uinta Basin's rim in the Green River Formation—also a major oil and gas producer in the subsurface of the basin.

Shale is a fine-grained sedimentary rock composed of mud containing clays and silt-size particles of other minerals. Some shale can also contain significant amounts (5% or more) of organic matter—the fossil remains of protozoans, microscopic animals, or plants—called kerogen. When kerogen-bearing shale is buried deeply enough and for millions of years, the natural heat and pressure of the Earth can convert the kerogen to oil (and/or gas). However, in Utah's oil-shale deposits, much of the kerogen-bearing rock is close to the surface and therefore has not yet generated hydrocarbons. The oil industry has for years attempted to develop economic techniques to artificially "cook" the kerogen, thus speeding up the process from millions of years to days. (Estonia and China produce significant amounts of oil from their oil-shale deposits that are organically richer than those in the Green River Formation; environmental regulations are also much less stringent in these countries.) Potential Green River Formation oil shale reserves based on 30 gallons per ton of rock are almost 20 billion barrels of oil.

*Outcrop of the Mahogany bed oil shale in the Green River Formation, Evacuation Creek, Uinta Basin, Utah. Photo by Michael Vanden Berg.*


## Shale Oil

So what is shale oil? It's just that—ready-to-be refined oil produced from shale. When organic-rich shale (which can be deposited in marine or lacustrine [lake] environments) is buried for millions of years (or is now "mature") and the kerogen has been naturally "cooked," pressure can force the newly generated oil and gas to migrate from the shale beds (also referred to as hydrocarbon source rocks) to traps in porous sandstone or limestone reservoirs where it can be produced from typical conventional vertical wells. Any remaining oil in the shale is—you guessed it—shale oil.

Shale, like sandstone, contains pores capable of storing hydrocarbons. However, these pores can be extremely small and poorly connected to each other (permeability is the measurement of how well-connected the pores are and, thus, the ability of fluids to flow through a rock), making it difficult for fluids to flow through the shale. The word "tight" is often used to describe this characteristic. Sometimes the shale beds are naturally fractured by hydrocarbon expulsion or the same tectonic forces that create folds, faults, and other geologic structures. Fractures provide additional pore space and increase the permeability of the shale. Thus, shale that is organic-rich, and mature in terms of burial history and oil generation, may be a potential shale-oil drilling target.

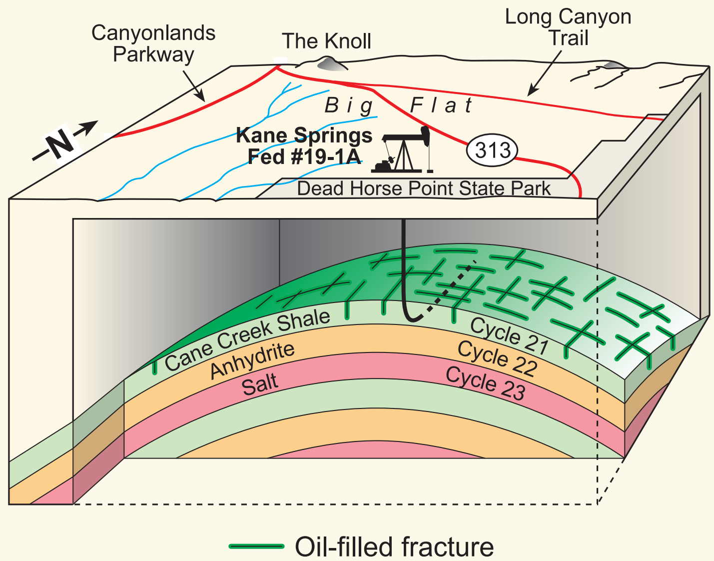
Prior to 1990, finding shale oil was a hit or miss undertaking. A vertical well needed to encounter numerous natural fractures in the oil-bearing shale just right to make a commercial discover. One such successful discovery well is the Long Canyon No. 1, located about 1 mile north of Dead Horse Point State Park. Drilled in 1962, the well encountered the Cane Creek shale, as a fractured, overpressured zone in the Pennsylvanian Paradox Formation, which was deposited 306 million years ago in a warm, shallow inland sea. The Long Canyon well has produced over 1 million barrels of shale oil! However, this well is an exception rather than the rule.

Two technologic achievements regarding shale oil have come into play since about 1990—horizontal drilling and improved hydraulic fracturing (fracking). Wells can now be drilled and steered horizontally in a targeted layer of rock (even if it is relatively thin) for thousands of feet, and thereby dramatically increase the number of natural fractures encountered. Additional fractures are created through fracking (see article by Robert Ressetar, *Survey Notes*, May 2012, v. 44, no. 2). Water is pumped down the well under pressures high enough to locally fracture the shale, significantly adding to the natural fracture system and thereby allowing the trapped shale oil to flow to the well. To keep the natural and new artificial open fractures from closing due to the pressure of the overlying rock layers, sand or other materials of various sizes (called proppant) is also pumped into the fracture zones to provide porous pathways for fluid flow. With the advent of horizontal drilling, several new Cane Creek shale oil fields were discovered near the Long Canyon well in the 1990s. Pump jacks can be seen along Utah Highway 313 near Dead Horse Point State Park. These and nearby wells have produced nearly 3 million barrels of shale oil.

*Shale oil (right) from the Cane Creek shale, Paradox Formation, Long Canyon No. 1 well, Grand County.*

# WHAT'S THE DIFFERENCE?

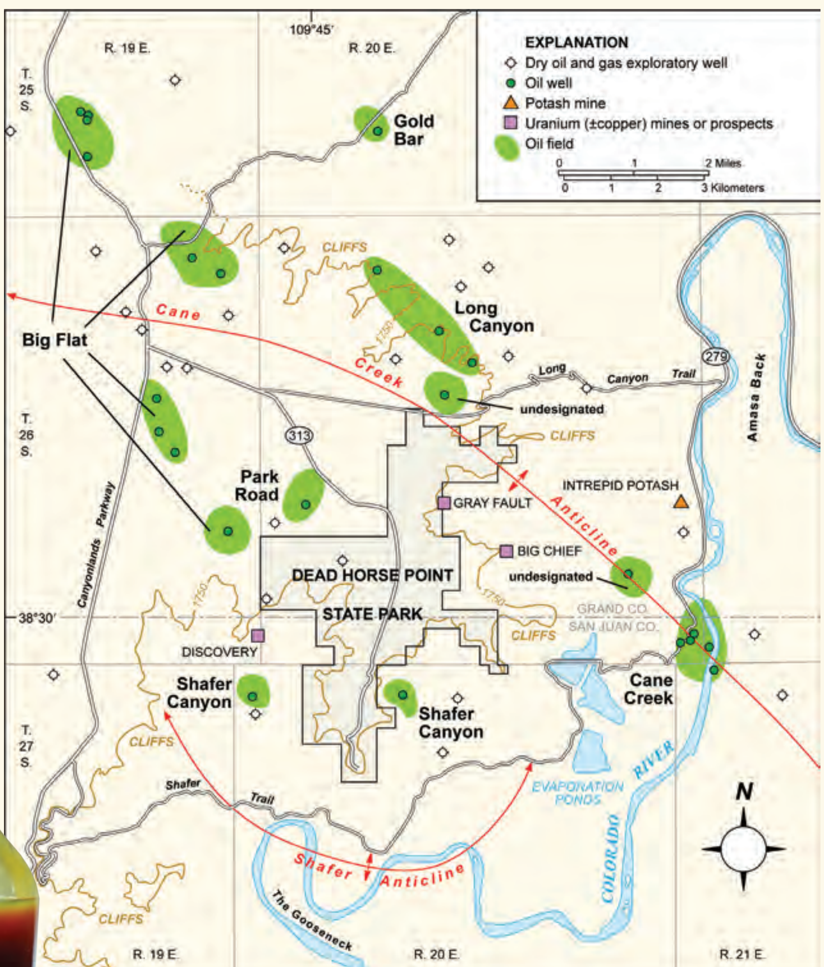
*Oil-shale sample (left) from the Green River Formation showing dark bands of kerogen.*




*Schematic block diagram (above) showing a horizontal well encountering oil-filled fractures in the Cane Creek shale, Park Road oil field near Dead Horse Point State Park. From Doelling and others, 2010.*

## Where the Action Is

Since the series of new Cane Creek shale oil discoveries in the 1990s, drilling in that area has been sporadic. On the bright side, two new Cane Creek shale oil discoveries have been announced in 2012 by Fidelity E & P Company and Stone Energy Corporation. But these pale in comparison to the drilling activity for shale oil in the Late Devonian-Early Mississippian (370 to 345 million years old) Bakken Formation in the Williston Basin of western North Dakota and eastern Montana. There are three principle layers or formation members in the Bakken. Although oil was first discovered in the Bakken in 1951, only recently was the potential of the middle member recognized. The U.S. Geological Survey (USGS) issued a report in 2008 estimating 3.65 billion barrels of oil is recoverable from the middle Bakken, based on the use of horizontal drilling and new fracking techniques. Drilling activity for the Bakken shale oil play has exploded with hundreds of wells being drilled and hundreds planned for years to come. The town of Williston, North Dakota, is booming with the creation of thousands of new energy-related jobs.




*Location of fields producing shale oil from the Cane Creek shale in the Dead Horse Point area, Grand and San Juan Counties (above). From Doelling and others, 2010.*

## What's Next for Utah

Recent studies by the UGS and the USGS indicate additional shale oil potential in the Cane Creek as well as other organic-rich shale zones in the Paradox Formation (Chimney Rock, Gothic, and Hovenweep shales). The USGS (March 2012) published a report estimating the total undiscovered, recoverable oil resources in these shales of the Paradox Basin, southeast Utah and southwest Colorado, could now be as much as 471 million barrels of shale oil, an increase from the 1996 estimate of 190 million barrels.

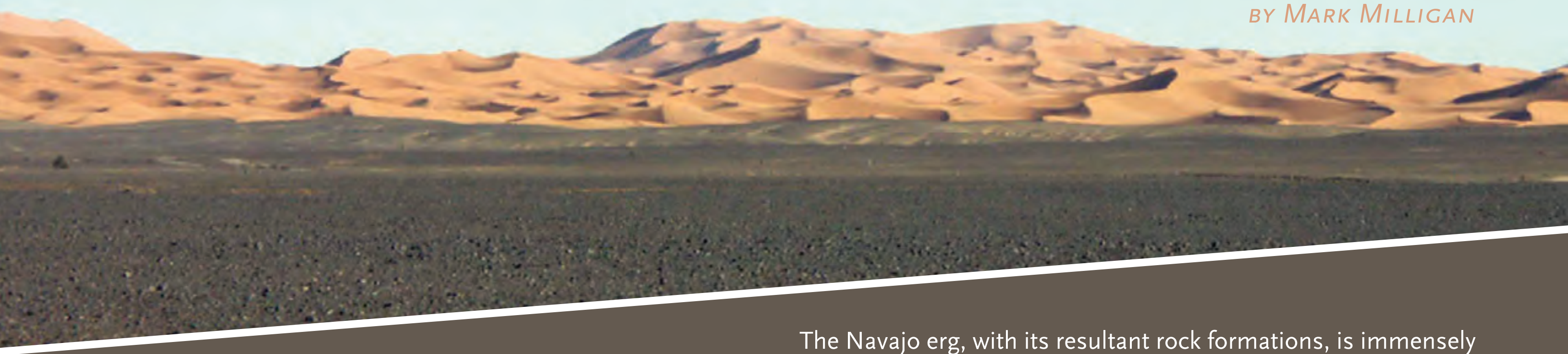
In Utah's Uinta Basin, operators are targeting the deep Uteland Butte zone in the lower Green River Formation—a highly fractured, 30- to 40-foot thick unit similar in rock characteristics to the middle Bakken Formation. Recent wells using horizontal drilling and fracking have been very encouraging, with estimated recovery from 150,000 to 275,000 barrels of oil per well.

Whether the Uteland Butte, Cane Creek, or other potential shale-oil zone becomes the next Bakken play remains to be seen. The UGS is actively evaluating these potential oil plays. One thing seems certain: while oil shale remains the energy of the future, the future for shale oil may be now.

# Glad You Asked

## Sizing Up Titans—Navajo Erg vs. Sahara Ergs
## Which was the larger sand box?

by Mark Milligan



Some 185 million years ago, during the Early Jurassic, an enormous "sea" of dune fields called the Navajo erg covered most of eastern and southern Utah as well as parts of Idaho, Wyoming, Colorado, New Mexico, Arizona, Nevada, and California. This vast and ancient sand sea is now exposed as the Navajo, Nugget, Aztec, and Glen Canyon Sandstones (the name varies with location). These formations tend to form colorful and massive cliff faces that play leading, supporting, or cameo roles in the spectacular scenery at the following parks:

**Utah**

- Arches National Park
- Bryce Canyon National Park
- Canyonlands National Park
- Capitol Reef National Park
- Zion National Park
- Dinosaur National Monument
- Grand Staircase–Escalante National Monument
- Rainbow Bridge National Monument
- Flaming Gorge National Recreation Area
- Glen Canyon National Recreation Area
- Coral Pink Sand Dunes State Park
- Red Fleet State Park
- Snow Canyon State Park
- Wasatch Mountain State Park

**Nevada**

- Red Rock Canyon National Conservation Area
- Valley of Fire State Park

**Wyoming**

- Grand Teton National Park

The Navajo erg, with its resultant rock formations, is immensely impressive! But how does its vastness compare to modern analogs? Multiple authors, myself included, have described it as "bigger than the dune fields of the modern Sahara" (see the May 2012 issue of *Survey Notes*) or some variant of that claim. I recently had an inquiry questioning the validity of the claim. Was the Navajo erg bigger than the dune fields of the modern Sahara or is that claim just oft repeated dogma?

The answer is dependent upon the specific phrasing of the claim and the extent of the ancient Navajo erg versus its modern rock remnant. First consider the modern Sahara. The Navajo erg was not bigger than the entirety of the modern Sahara Desert. Estimates vary but the Sahara Desert is roughly 3.3 million square miles. By comparison, the contiguous United States is 3.1 million square miles. However, like the modern deserts of Utah, the modern Sahara is composed of many environments in addition to sand dunes. Contrary to Hollywood portrayals of one endless sand sea, the Sahara has several ergs that are isolated by vast expanses of dry valleys (*wadis*), gravel plains (*regs*), rocky plateaus (*hamadas*), salt pans (*chotts*), and mountains (*tassilis*). Again, estimates vary but dune fields only cover 15 to 20% of the Sahara Desert, which equals roughly 495,000 to 660,000 square miles. Size estimates for individual ergs of the Sahara are difficult to find but perhaps the biggest Sahara erg is the Grand Erg Oriental which covers about 119,000 square miles. Note that this estimate of the Grand Erg Oriental includes small non-dune areas within the erg. Of these estimated 119,000 square miles, roughly 70% is sand-covered (for more details see U.S. Geological Survey Professional Paper 1052, *A Study of Global Sand Seas*, 1979). So, was the Navajo erg bigger than the individual dune fields or the combined dune fields of the Sahara? This brings us to the second consideration—how big was the Navajo erg?

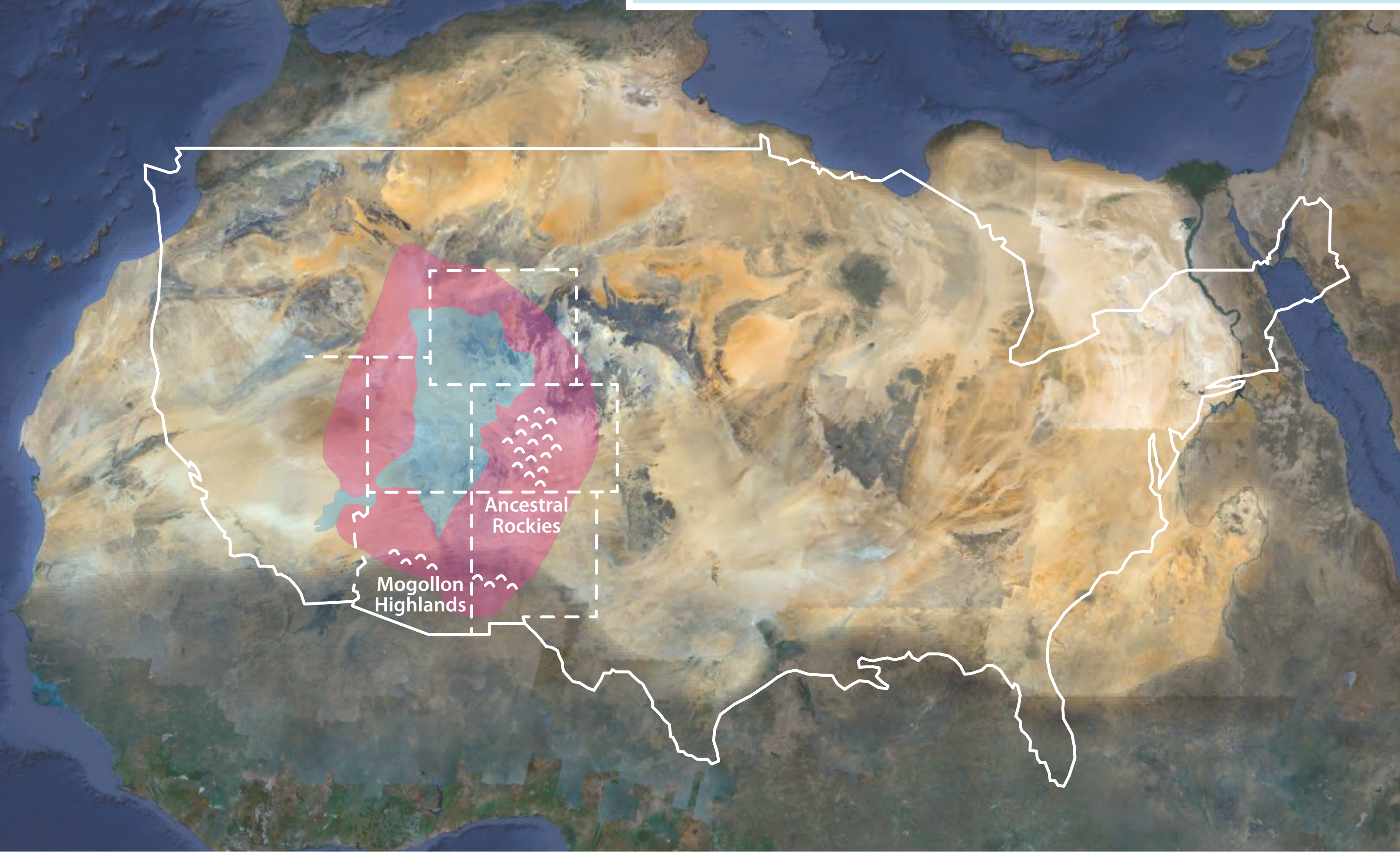
Though outcrops of Navajo, Nugget, Aztec, and the Glen Canyon Sandstones are found over a vast area of some 230,000 square miles, they certainly do not show the full extent of the Navajo erg. Much of the original erg was removed by erosion. Many maps and figures that depict the extent of the Navajo erg refer to a 1983 paper by geologists Kocurek and Dott (see Jurassic Paleogeography and Paleoclimate of the Central and Southern Rocky Mountain Region in *Symposium on Mesozoic Paleogeography of West-Central U.S.: Society for Sedimentary Geology, Rocky Moun-*

*As exemplified by Checkerboard Mesa in Zion National Park, the petrified dune fields of the Navajo Sandstone produce many picturesque outcrops.*

*The modern Sahara Desert is composed of multiple environments in addition to dune fields. This scene in Morocco shows a gravel plain (called a reg) and the Erg Chebbi in the background. Photo courtesy of Richard A. Muller.*

*tain Section*). Kocurek and Dott approximate the full extent of the Navajo erg by using various lines of evidence, such as nearby equivalent age rock formations that contain sand dune deposits (eolian sandstones) inter-bedded with non-dune deposits. Furthermore, they suggest that at its full extent the erg included only local sand-free regions, notably at the Ancestral Rockies in central Colorado and Mogollon Highlands in central Arizona. The maximum area of the Navajo erg as depicted by Kocurek and Dott covers approximately 850,000 square miles. Thus, the Navajo erg is likely to have been larger than the combined dune fields of the modern Sahara.

The dune fields of the modern Sahara are compared to the Navajo erg because they are the most famous modern dune fields. However, they are not the largest modern dune fields. That distinction goes to the Rub' al Khali erg, which covers between 200,000 and 300,000 square miles, most of the southern Arabian Peninsula.




*Lightened area of background image shows the Sahara Desert with its varied environments, only 15 to 20% of which are large dune fields called ergs. The extent of the outcrops of the Navajo, Nugget, Aztec, and Glen Canyon Sandstones (zero-isopach line) are shown in blue. The probable full extent of the Navajo erg, including areas presumably removed by erosion, is shown in pink. Modified from Kocurek and Dott, 1983.*

# GeoSights
## Bonneville Salt Flats, Utah

*by Christine Wilkerson*

Often called the flattest place on earth, the Bonneville Salt Flats is a favorite surface for high-speed automobile racing. Racing began on the salt flats in 1914 and numerous land-speed records for various vehicle classes have been set here. The Bonneville Salt Flats also hosts rocket club launches and marathons and acts as a backdrop for movies, commercials, and photographs. This landscape is a place of expansive views, distinctive scenery, and sharp contrasts.

The Bonneville Salt Flats is located in northwestern Utah within the western part of the Great Salt Lake Desert near the Utah-Nevada border and is mostly managed by the U.S. Bureau of Land Management (BLM). Interstate 80 (I-80) divides it into northern and southern halves with the north side including the motor-sport racetracks and sightseeing areas and the south side containing commercial potash operations.

### Geologic Information

The Bonneville Salt Flats lies on what was once part of the floor of the ancient, freshwater Lake Bonneville that occupied western Utah during the last ice age. Lake Bonneville shorelines can be seen as flat wave-cut benches or terraces on the sides of the Silver Island Mountains to the north-northwest of the salt flats. The salt crust began to form as Lake Bonneville dried up to become Great Salt Lake.

Because the Bonneville Salt Flats is within a closed basin (no drainage outlet), water can only escape by evaporation or seepage into the ground. The area's shallow groundwater transports

*The Bonneville Salt Flats is a dazzling white, salt-covered area in northwestern Utah; Silver Island Mountains with Lake Bonneville shorelines viewed to the north.*

*Occasional flooding leaves thin sheets of salty water on the surface, which, in addition to the wind, help smooth out the salt flats by dissolving the high points and filling in the low spots.*

*Close up of salt crust precipitated on top of the Bonneville Salt Flats.*

*Travel across the salt flats is at your risk. Steer clear of the light brown mud and stay on the white salty surface to avoid becoming stuck.*

salts in the subsurface—the salty water is then wicked to the surface, dries, and leaves behind a salty crust. Surface water runoff and precipitation also add small amounts of salt onto the flats. Flooding in the winter can dissolve the salt crust, and as temperatures rise in the summer, salt re-precipitates on the flats as the water vaporizes.

Potash, a mixture of potassium-bearing salts mostly used in fertilizers, was first mined from the shallow-brine aquifer beneath this area in 1917 with continuous production since 1939. The brine (a combination of dissolved salts and water) is collected in open ditches on both halves of the salt flats and directed to a series of solar evaporation ponds on the south side. The potash is then separated out, processed, and loaded into railcars or trucks for shipment.

## How to get there

From Salt Lake City, travel on I-80 West toward Wendover, Nevada. Rest areas at about mile marker 10 on both sides of the interstate have great views of the Bonneville Salt Flats. To get a closer look, continue traveling on I-80 West and take exit 4 (Bonneville Speedway). Turn right (north) onto Leppy Pass Road, continue about 1.2 miles, turning right (east) onto the Bonneville Speedway access road. Drive almost 4 miles to the cul-de-sac at the end of the pavement where there is parking.

The BLM Bonneville Salt Flats travel advisory warns that if you decide to leave the access road and drive onto the salt flats, travel is at your own risk. The BLM recommends avoiding the mud flats (light brown) that surround and underlie the salt flats (white) and staying on the clean, white salt surface as much as possible as vehicles can easily sink and become stuck in the soft, wet mud. More than one tow truck has become stuck trying to pull vehicles out of the muck. If you do have an emergency on the salt flats, contact the Tooele County Sheriff Dispatch office at 435-882-5600.

# SURVEY NEWS

## Employee News

**John Kingsley** retired in June this year after 13 years as Associate Director (Finance) for the UGS. John had worked for the State of Utah for 35 years, coming to the UGS from Utah's Energy Office. He was responsible for overseeing all of our financial management systems. One of his first tasks when he joined the UGS was to institute a new project management system that allowed more systematic monitoring of the numerous research contracts. We wish John many happy years of retirement.

Congratulations to **Peter Nielsen** who accepted the position of Curator for the Utah Core Research Center, and to **Kathi Galusha** who was promoted to Financial Manager for the UGS. The Natural Resources Map & Bookstore welcomes **Bryan Butler** as an accounting technician. Bryan replaced **Emily Chapman** who returned to Ohio to be close to family.

## 2012 Crawford Award

*Mark Milligan and Jim Davis.*

The prestigious 2012 Crawford Award was presented to UGS geologists **Jim Davis** and **Mark Milligan** in recognition of their combined work on the outstanding geologic publication *Why Is Bear Lake So Blue?—and other commonly asked questions* (UGS Public Information Series 96).

This 41-page full-color booklet is filled with dozens of photographs, maps, and figures. It contains information on geology, biology, hydrology, weather, recreation, history, the Ice Age, the modern and prehistoric connection to the Bear River, and laws and regulations governing the use of the lake. It now serves as the most comprehensive source of scientific information for the general public on Bear Lake. Since its release in March 2011, the booklet has been highly sought after in the region by bookstores, tourist shops, and local information agencies, and was the top-selling UGS publication for 2011.

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.

# TEACHERS CORNER

## Earth Science Week 2012

**October 9–12, 2012 9:20 a.m.–2:10 p.m.** ***Hands-on activities for school groups***

Come celebrate Earth Science Week with the Utah Geological Survey this year. We will be offering hands-on science activities (especially relevant to 4th- and 5th-grade classes) including panning for "gold," 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 http://geology.utah.gov/teacher/esweek.htm.

To make reservations, contact Jim Davis or Sandy Eldredge at 801-537-3300. Groups are scheduled for 1½ - hour sessions.

## Utah Earth Science Teacher of the Year for *Excellence in the Teaching of Natural Resources in the Earth Sciences* receives $1,500 Award

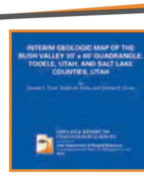
Annually, the Utah Geological Association (UGA) holds a statewide competition for the Utah Earth Science Teacher of the Year Award. The purpose of the award is to (1) recognize and support an outstanding K-12 Utah earth science/natural resources teacher, and (2) provide a Utah candidate for the regional competition sponsored by the Rocky Mountain Section of the American Association of Petroleum Geologists (AAPG). Ultimately, the Utah candidate could then qualify for the annual AAPG nationwide competition.

The 2012 winning teacher — **Patti White**, 6th-grade teacher at Morningside Elementary School in the Granite School District — received $1,500 and the school was presented with a gift certificate. Patti weaves the teaching of natural resources into other areas of the 6th-grade curriculum. Among several natural resource projects this year, Patti and her students created several teaching kits, including a geothermal energy kit and a solar energy kit.

# NEW PUBLICATIONS

**Geologic map of the Thistle quadrangle, Utah County, Utah—Insight into the structural-stratigraphic development of the southern Provo salient of the Sevier fold-thrust belt,** Parker M. Valora and Jennifer L. Aschoff, CD (21 p., 3 pl.), scale 1:24,000, ISBN 978-1-55791-857-4, **MP-12-1 ............$19.95**

**Groundwater quality classification for the principal basin-fill aquifer, east shore area, Davis County, Utah,** by Janae Wallace, Paul Inkenbrandt, and Mike Lowe, CD (15 p. + 79 p. appendices, 3 pl.), **OFR-592..........................................$19.95**



**Interim geologic map of the Rush Valley 30' x 60' quadrangle. Tooele, Utah, and Salt Lake Counties, Utah,** by Donald L. Clark, Stefan M. Kirby, and Charles G. Oviatt, CD (65 p., 2 pl.), scale 1:62,500, **OFR-593..........................$19.95**

**Moderately saline groundwater in the Uinta Basin, Utah,** by Paul B. Anderson, Michael D. Vanden Berg, Stephanie Carney, Craig Morgan, and Sonja Heuscher, CD (30 p., 9 pl., [contains GIS data]), ISBN 978-1-55791-8564-2, **SS-144 ............$24.95**

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## 2013 CALENDAR OF UTAH GEOLOGY

Featuring scenic photographs highlighting Utah's geologic diversity. The photographs were taken by UGS employees who are often on assignment in some of the state's most interesting and unique locations. Pictures are accompanied by geologic descriptions and location information. The calendar will be available in October, so order now and don't miss out!


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