UTAH GEOLOGICAL SURVEY

SURVEY NOTES

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TAPPING INTO UTAH'S UNCONVENTIONAL OIL AND GAS RESOURCES

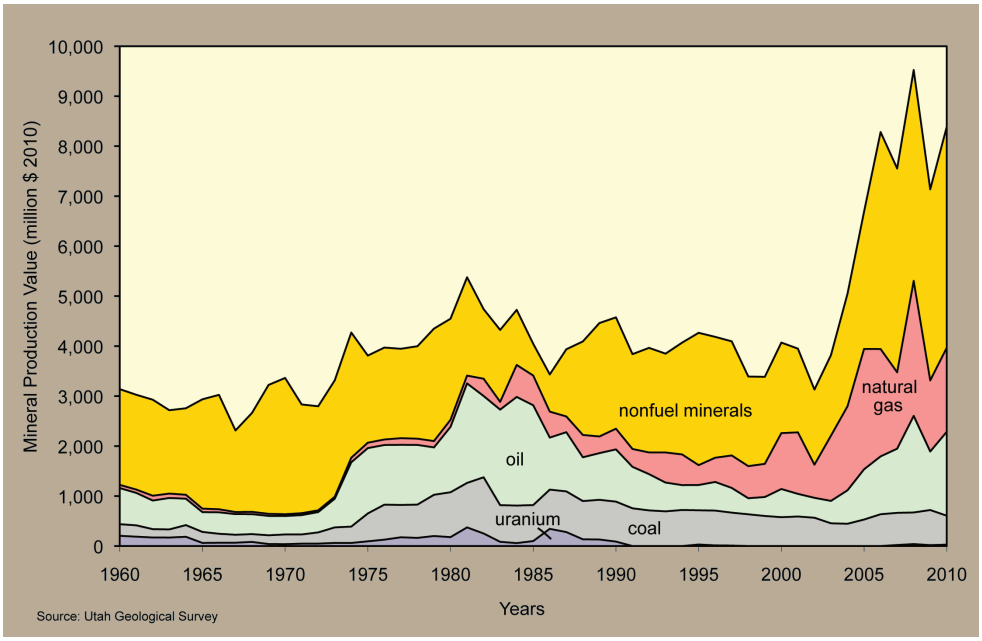
THE DIRECTOR'S PERSPECTIVE



Every year the Utah Geological Survey (UGS) provides information on the production trends of Utah's energy and minerals commodities to the Governor's Office of Planning and Budget (GOPB) *Economic Outlook* report (see www.governor.utah.gov/dea/ERG/2011EconomicOutlook.pdf for the 2011 report). We also provide price and production estimates of critical geologic commodities to quarterly meetings of GOPB's Revenue Assumption Committee. The role of this committee is to monitor and predict key indicators of Utah's economic activity. Inclusion of information provided by the UGS underscores the growing importance of geologic commodities to Utah's economy (see graph).

During the second half of the 20th century the annual production value of Utah's geologic commodities averaged about $4 billion (inflation-adjusted to 2010 dollars). However, the production value has doubled since about 2005, with the 2010 figure being $8.4 billion. The $4.4 billion figure for nonfuel production in 2010 comprises base metals (66 percent; e.g., copper, molybdenum, magnesium, beryllium), industrial minerals (22 percent; e.g., saline minerals, sand, gravel, limestone, phosphate), and precious metals (15 percent; e.g., gold, silver). The dominant factor influencing most of the trends is the commodity price, which is influenced by complex factors such as supply, demand, and economic activity. During the past year most geologic commodities showed upward trends in value. The only sector that showed a significant decrease was industrial minerals (down 3 percent). Natural gas revenue remained

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Design: *Stevie Emerson*
Cover: *Outcrop of the upper Green River Formation lacustrine deposits along Evacuation Creek, Uintah County, Utah. See article on page 1. Photo by Michael Vanden Berg.*

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Exploring Utah's Other Great Lake

Michael Vanden Berg

Great Salt Lake and its Ice Age predecessor, Lake Bonneville, are well known to many, but long before these lakes existed, another large lake played an important role in Utah's geologic history. About 50 million years ago, northeastern Utah's Uinta Basin and northwestern Colorado's Piceance Basin were covered by a large body of water called Lake Uinta. A similar ancient lake, named Lake Gosiute, existed to the north in the Green River and Washakie Basins of Wyoming. The rocks of the Eocene Green River Formation preserve a record of these ancient lakes, including world famous fish and leaf fossils. Additionally, Utah's much-talked-about oil shale resources, as well as significant conventional oil and gas reserves, are within the strata that accumulated in ancient Lake Uinta.

In May 2010, the Utah Geological Survey (UGS) and the University of Utah's Institute for Clean and Secure Energy (ICSE) teamed up to recover 1000 feet of 4-inch-diameter core from the upper Green River Formation, about 60 miles southeast of Vernal in Uintah County. ICSE's purpose for this coring program was to recover "fresh" oil shale samples for a variety of geochemical and geomechanical testing to facilitate possible future oil shale development. The UGS has additional goals for drilling the core which include (1) reconstructing the climatic changes in ancient Lake Uinta's environment, (2) correlating changes in Utah's lake sediments with changes in the adjacent Piceance Basin of Colorado, and (3) providing an educational tool to teach others about ancient lake systems and their petroleum potential.

The borehole, named Skyline 16, was spudded (start of drilling) on May 18, 2010, on land owned by the Oil Shale Exploration Company. The drillers recovered 20 feet of rock per coring run and typically recovered between 100 and 200 feet of core a day. After a 20-foot section of core was brought to the surface, UGS geologists ferried it into the back of a large truck and laid it out in trays. The core was then accurately measured, marked with footage depths, striped to indicate proper orientation, described to note changes in rock



Ancient Eocene lake basins and the location of the new Skyline 16 core.



Drill rig used to recover the Skyline 16 core in the eastern Uinta Basin.



UGS geologist Andrew Rupke "catching" core as it is brought to the surface.

type, and placed in protective wrapping within storage boxes for transport to the Utah Core Research Center in Salt Lake City. After transport, the core was cut lengthwise with about one-third placed in display boxes for easier physical examination, and the remaining two-thirds placed back in the original box and stored for future sampling and testing.

Researchers at the University of Utah have taken samples from the core to analyze several physical and chemical properties of the rich oil shale layers. ICSE engineers are hoping to determine the most efficient methods for heating oil shale to turn its organic matter, called kerogen, into useful petroleum products. In addition, researchers will investigate how the changes in the non-organic components of the rock might affect successful heating and kerogen conversion.

Geologists at the UGS, along with collaborators from the University of Utah's Energy and Geoscience Institute, are using the record preserved in the Skyline 16 core to help reconstruct the ancient landscape of Eocene Lake Uinta. Different sediment layers in the core record changes in lake level and can be related to changes in ancient regional climate. The geological team's inch-by-inch description of the core, notation of preserved fossils, and geochemical analyses will be used in combination with descriptions from other nearby cores and natural outcrop exposures to develop a regional lake and climate history. Because rocks from these ancient lake systems are major oil and gas sources and reservoirs, this research will help geologists to better predict the petroleum development potential of ancient lake deposits in Utah and around the world.

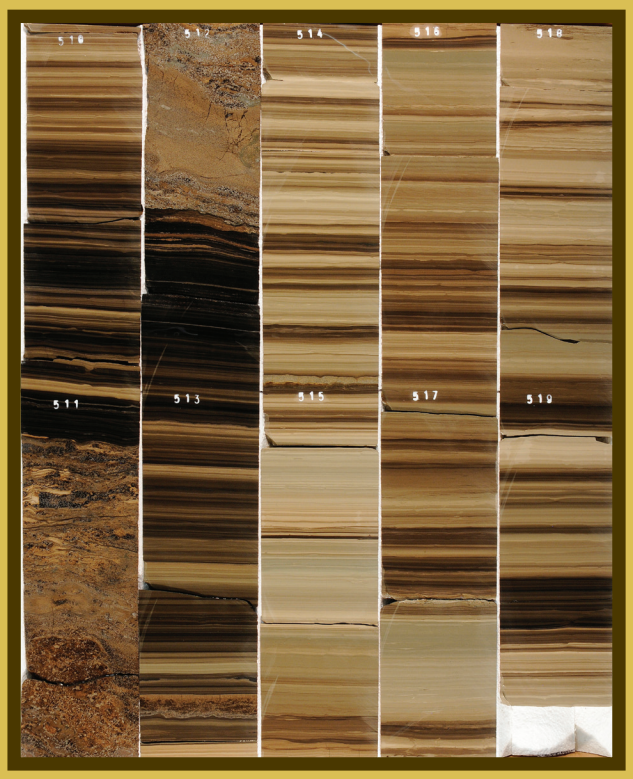
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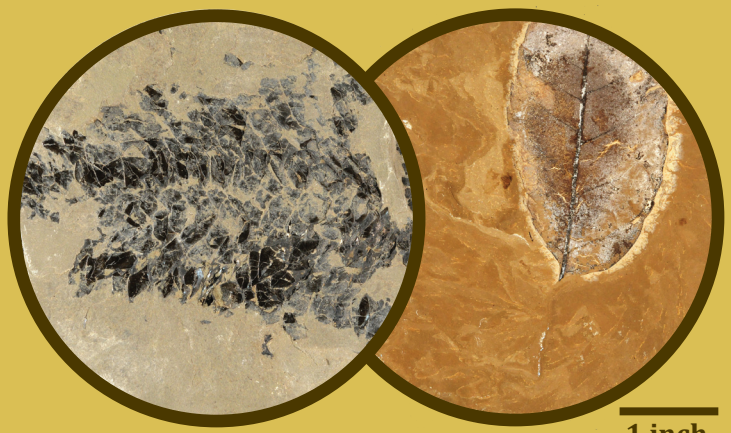
Michael Vanden Berg has been a geologist with the UGS's Energy and Minerals Program for eight years. His research focuses on conventional and unconventional petroleum resources and ground-water aquifers in the Uinta Basin. Mike also manages extensive Utah energy databases, providing reports and information to the public, legislature, and Governor's Office.



The author labeling a 20-foot section of the Skyline 16 core.



Slabbed Skyline 16 core (4-inch diameter) displaying organic-rich (dark layers) and organic-lean (light layers) oil shale. The mottled zone on the left is volcanic ash.



Fossil fish (Gar) and fossil leaf captured in the Skyline 16 core.

Utah Shales May Contain The "Right Stuff" Natural Gas

Thomas C. Chidsey, Jr.



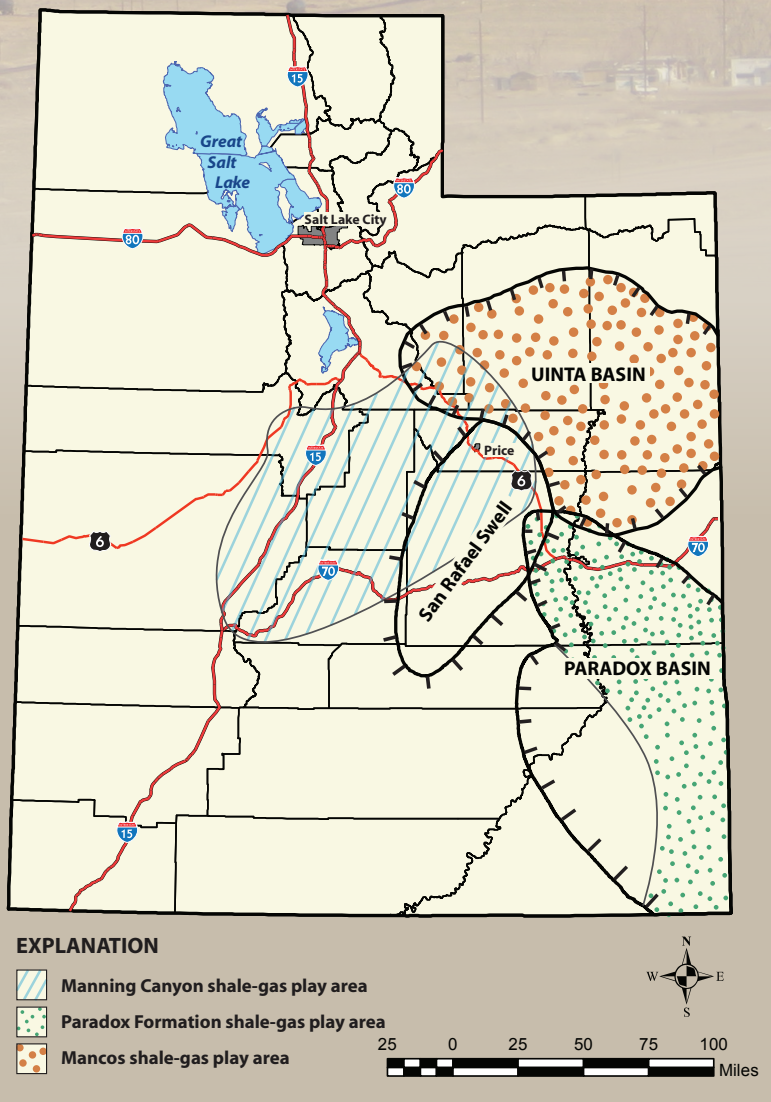
Typical exposure of the Mancos Shale as viewed looking north from I-70 near Green River, Utah.

Are They Just Really Ugly Rocks?

Driving south from Price along Highway 6 and then east toward Grand Junction along Interstate 70, one observes a desolate, drab gray landscape of gullies, small buttes, low rounded hills, and slopes leading up to the massive Book Cliffs to the east and north, respectively. This is the Mancos Shale, a thick geologic formation composed primarily of mud and clay deposited in the bottom of an ancient seaway that extended from Canada to the Gulf of Mexico about 80 to 100 million years ago during the Cretaceous Period. To look at these sediments, one might wonder what interest or value they could possibly have to anyone. When wet, they become a muddy quagmire and when dry, a desert wasteland. However, the Mancos and other Utah shales may contain the right stuff to generate, store, and produce natural gas. These shale beds are widespread, thick, organic rich, and buried deep enough in many areas to create and hold significant recoverable gas reserves.

New Techniques and the "Hottest" Gas Plays in the U.S.

Shale-gas plays in Texas, Arkansas, Louisiana, Oklahoma, and the northern Appalachia states are the sites of extensive drilling programs. Not too long ago the U.S. was anticipating huge increases in natural gas imports. Although shale was known to contain natural gas, the numerous pores (open spaces) within the rock are very small and the permeability (the connectivity of those pores that allows gas or liquids to flow) is extremely low. However, new techniques were developed that changed many shales from only being a source of hydrocarbons (oil and natural gas) to major producers today, and thus the need for future gas imports has vanished. Once the target shale is reached, wells are now drilled horizontally to encounter multiple natural fractures. Shales that contain sand and silt are usually brittle and therefore more susceptible to fracturing. Hydraulic fracturing techniques (see "Energy News" on page 8) further increase the number of fractures and the amount of permeability. The result of these new techniques and drilling activity is that the major U.S. shale-gas plays have 1400 trillion cubic feet of commercial, recoverable gas. But what about the shale-gas potential in Utah?



Potential shale-gas play areas for the Manning Canyon, Paradox, and Mancos Formations in Utah.

We're On It!

Utah Geological Survey Shale-Gas Studies

The Utah Geological Survey (UGS) is presently conducting major studies of Utah's shale-gas resources in the Manning Canyon, Paradox, and Mancos Formations. Although the organic content of some of these shales is partially known, the reservoir quality and the basic rock-mechanics data so important to successful well completions are virtually unknown. Also, the regional distribution and thickness of these rocks are poorly mapped and the extent of the gas plays has not been defined. The burial history of these shales, critical to understanding gas generation, appears complex and probably varies widely from deep to shallow. There are no published studies of the best completion practices (horizontal drilling and hydraulic fracturing techniques). The UGS studies address all of these issues.

Manning Canyon Shale

The Mississippian (around 320 million years ago) Manning Canyon Shale in central Utah has long been known for its potential as a hydrocarbon source rock, but has not been considered as a potential gas producer. The Manning Canyon is mainly shale with interbeds of limestone, sandstone, siltstone, and mudstone, and has a maximum thickness of 2000 feet. These interbedded brittle rock types are ideal for hydraulic fracture stimulation. The Manning Canyon may have been deposited in a shallow restricted marine, brackish, and freshwater setting like the modern Everglades and Florida Bay. Total organic carbon that can create hydrocarbons in shale varies from 1 to 15 percent. Over time, the Manning Canyon was buried deeply enough to generate natural gas. The greatest Manning Canyon potential is a 600-square-mile area at the north end of the San Rafael Swell, south and southeast of Price. Several recent wells have had significant shows of gas from the Manning Canyon and additional drilling is planned.

Paradox Formation

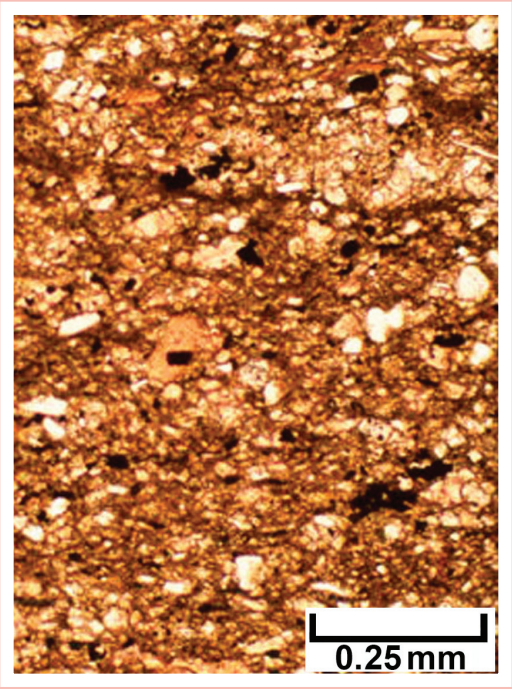
In the Paradox Basin of southeastern Utah and southwestern Colorado, the Pennsylvanian (around 310 million years ago) Paradox Formation consists of thinly interbedded, black, organic-rich marine shale, siltstone, dolomite, and anhydrite (an evaporitic rock). The shales generally range between 25 and 50 feet thick and are the source rocks for the oil in Utah's largest oil field—the 450-million-barrel Greater Aneth field. In Utah, exploratory efforts are just beginning to target some of these shales for gas. The Colorado part of the basin has seen considerable success using horizontal drilling. Our study has revealed two very important features of these shales: (1) most contain significant amounts of silt and are therefore brittle, and (2) bounding and interbedded carbonates (limestone or dolomite) possess modest amounts of previously unrecognized pore space that may contain gas. These carbonates, as well as some shales, also possess numerous fractures. Therefore, new gas discoveries are highly probable not only from the shales themselves, but also from the associated carbonates.



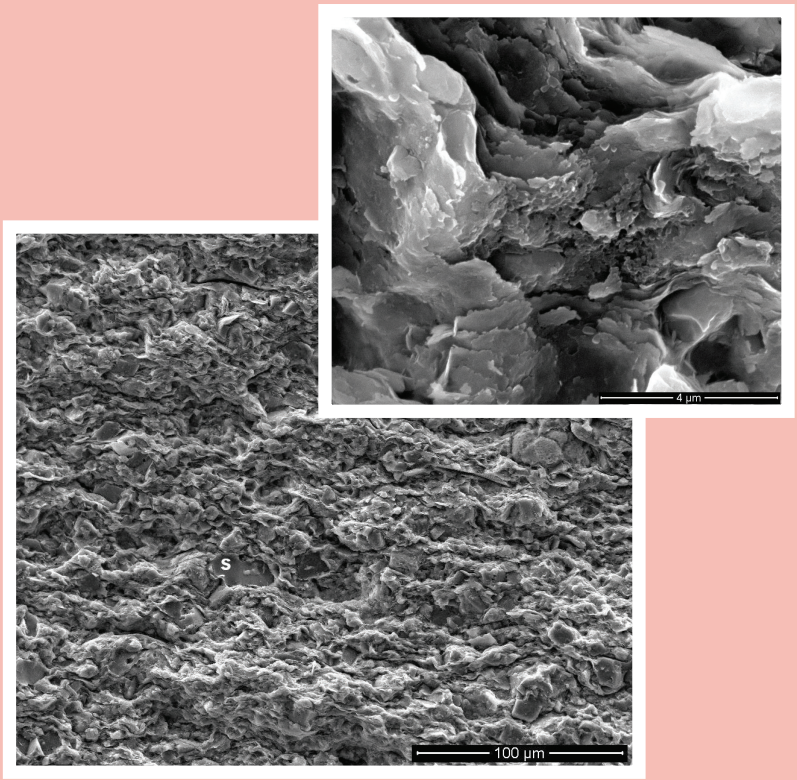
UGS geologists describing and measuring an outcrop of the Manning Canyon Shale in Soldier Canyon, Oquirrh Mountains, southwest of Salt Lake City.



Well core of typical Gothic shale (Paradox Formation). Slabbed core (inset) shows vertical fractures. Effective gas production depends on interconnected fracture networks.



Microscopic view (thin section) of the Hovenweep shale (Paradox Formation) showing quartz silt (numerous white angular grains), which creates brittleness and fractures, within a muddy matrix.



Scanning electron microscope images of the Gothic shale. Wavy clay flakes with silt grains (s) appear to lack pore spaces. Inset of a high-magnification image of the same sample reveals numerous micropores between clay layers capable of storing gas.

Mancos Shale

The Mancos Shale is an emerging shale-gas play in the Uinta Basin of northeastern Utah. Existing gas production from more conventional sandstone reservoirs in the basin could be greatly enhanced by the addition of recoverable gas in the Mancos from new wells or bypassed gas zones in existing wells. The Mancos is an extremely thick (as much as 3500 feet) package of rock consisting of different types of shale, siltstone, and very fine grained sandstone. Unlike the Manning Canyon Shale and Paradox Formation, production from the Mancos Shale is proven within the Uinta Basin. The Mancos has more than 50 producing wells scattered over the basin and most of these also produce gas from overlying and underlying sandstone reservoirs. Estimated ultimate gas production from the Mancos ranges from 3 to 6 billion cubic feet per well.

So What?

Upon completion, the UGS studies will identify premium target zones, determine the resource potential, and potentially lower the economic risk of exploration and development of Utah's shale-gas plays, especially in environmentally sensitive areas, thus encouraging larger-scale, commercial production. For more information, visit our Web page at geology.utah.gov/emp/shalegas/index.htm.

So the next time you are traveling through those gray, muddy rocks in east-central Utah, remember that although they may be "ugly," they contain the right stuff —natural gas!

continued from "Director's Perspective"

flat due to relatively depressed prices caused by the dramatic increase in reserves (and oversupply) both in Utah and nationally over the past five years.

The state of Utah is rich in geologic resources (3rd in mineral production value, 8th in natural gas production, 13th in oil and coal production). The world is becoming increasingly constrained in energy and mineral supplies, as evidenced by current concerns over Middle East oil and rare-earth-element supplies. The state faces important, complex questions concerning the supply of and future access to strategic commodities, related environmental impact concerns, and the potential for energy efficiency gains, conservation, and recycling to mitigate future demand. Currently the value of natural gas energy ($4/million BTU) is one-quarter that of oil energy ($17/ million BTU). Should Utah be trying to increase its use of natural gas in transport fuels and electricity generation? Important questions such as these will require ongoing input from the UGS.

Historical Maps
More Than Meets The Eye

Stephanie Earls

As luck would have it, the Utah Department of Natural Resources Library recently received a very interesting donation—a world atlas from 1826, titled ***Morse's New Universal Atlas of the World on an Improved Plan of Alphabetical Indexes, Designed for Academies and Higher Schools***, by Sidney E. Morse. The atlas conveys more than just world geography—it visually illustrates what was happening in the early 1800s.

In 1826, as indicated by the map of the United States, Utah was not a state, the Mormon Pioneers had not arrived, Great Salt Lake was not yet named, and the area now known as Salt Lake City was inhabited by the Shoshone, Ute, and Paiute Indian Tribes. However, there is an area on the map designated ***Valle Salado***, which translates from Spanish as Salt Valley, that sits just east of an unnamed lake that most likely represents Great Salt Lake. On the map, the lake is fed by the Buenaventura River to the north, which is now known as the Bear River. The presumed outflow of the lake was represented as a dotted line labeled "Supposed river between the Buenaventura and the Bay of Francisco, which will probably be the communication between the Atlantic and the Pacific." Around this time, rumors from the Native Americans claimed that the lake did indeed have an outflow, but the entire shoreline had not yet been explored. Jim Bridger, in 1825, was the first white man to reach the shores of Great Salt Lake. In the same year, Jedediah Smith investigated the northern and western edges of the lake, with no success of finding the outflow. The lake was not circumnavigated until 1849 when Howard Stansbury completed the route and officially declared that no river flowed from Great Salt Lake.



Inset of "Unexplored Country" from the United States map. This region, which at the time was Mexican territory, included the areas now known as Salt Lake City, Great Salt Lake, and California.

Although in 1826 Utah was still 70 years away from statehood, the United States was rapidly expanding its borders from the thirteen original colonies that had gained independence from the British Empire in 1776. As a result of agreements such as the Treaty of Paris in 1783 and the Louisiana Purchase in 1803, the continental United States already included roughly three-fourths of the land area that it does today. However, the western-border states were not yet developed and were known as the Missouri and Arkansaw [sic] Territories, as shown on the map of the United States. The area that would eventually become Utah was considered to be part of Mexico and did not become part of the United States until 1848, when the Treaty of Guadalupe Hidalgo was signed, ending the Mexican-American War.

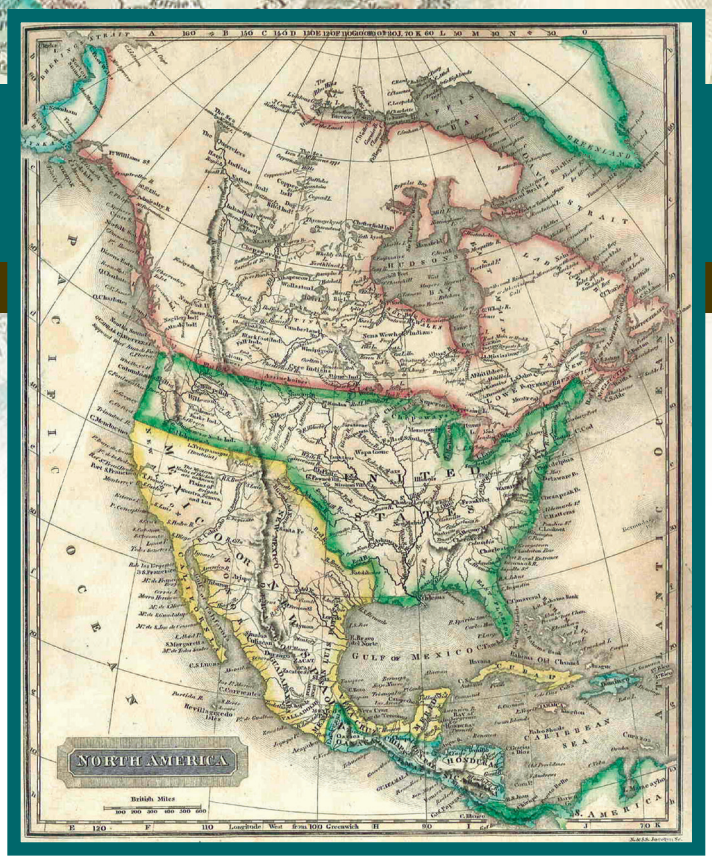
An example of a better explored area is demonstrated by the map of South America. The map is fascinating because it contains a lot of detail since this area was well explored in the sixteenth and seventeenth centuries. However, the entire continent was composed of only seven individual countries (mostly European colonies), and countries like Brazil and Ecuador had only recently become independent from Portugal and Spain, respectively. Changes in Central America, evident from the map of North America, include California joining Mexico, and Costa Rica, Guatemala, Honduras, Nicaragua, and San Salvador gaining independence from Mexico as the United Provinces of Central America.

During the time in which the atlas was compiled, land was rapidly changing hands as a result of fluctuating European colonial rule. This is reflected in the atlas not only in the level of detail of each individual map, but also by which maps the author chose to include, and the order in which they are presented. For example,

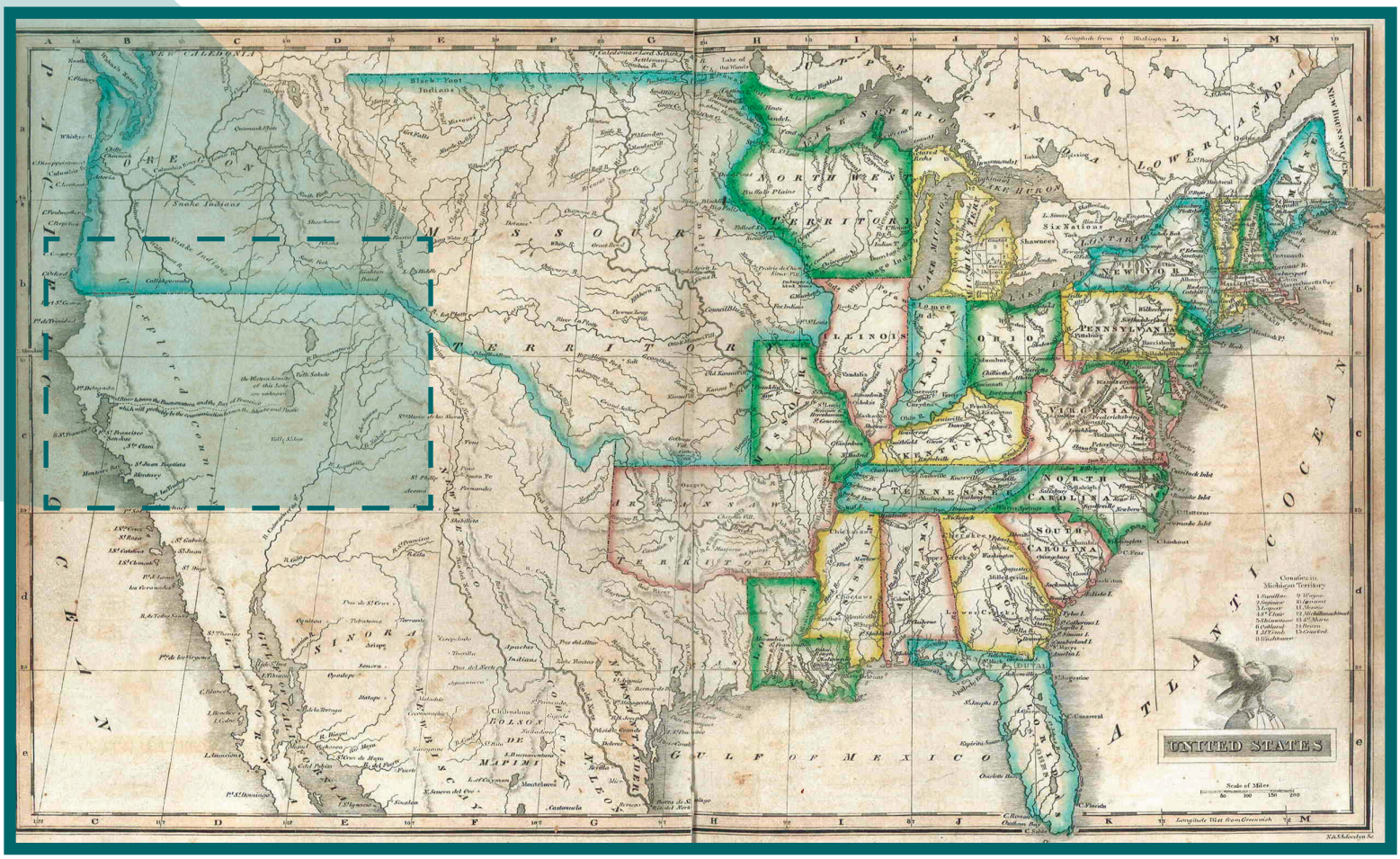
continued on page 11



Map of South America, which in 1826 was composed of only seven countries.



North American map showing California as part of Mexico, and the United Provinces of Central America (Costa Rica, Guatemala, Honduras, Nicaragua, and San Salvador), which had recently gained independence from Mexico.



Map of the United States, which in 1826 already included three-fourths of the land area of the present continental U.S.

Energy News

Natural Buttes Field—Utah's "Tight"

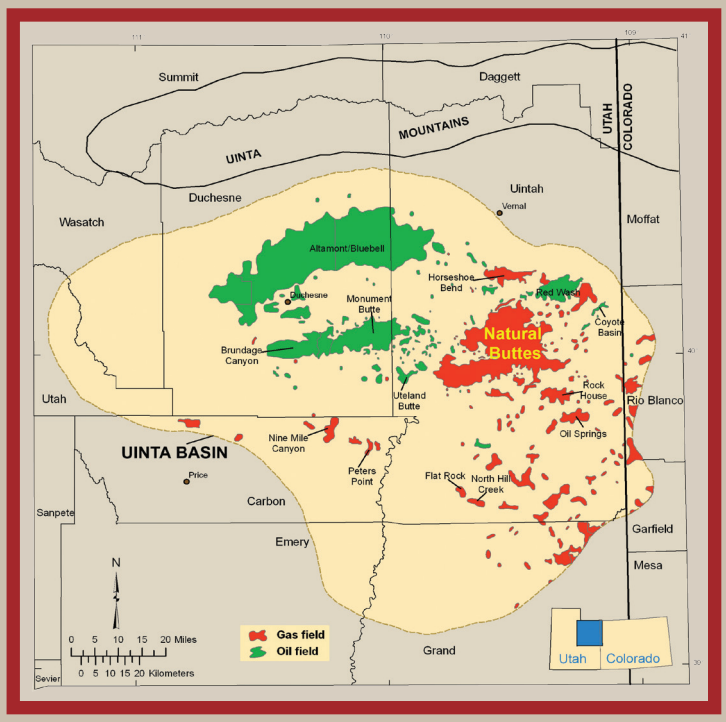
Thomas C. Chidsey, Jr.

Where is nearly all of the drilling action in Utah taking place? The answer is Natural Buttes field in the eastern Uinta Basin south of Vernal where over a hundred new wells are drilled each year. Natural Buttes field, the largest gas field in Utah, has produced over 2.1 trillion cubic feet of gas from about 4000 wells. Why is Natural Buttes field so large? It covers a huge area underlain by many layers of gas-bearing rock (gas reservoirs) where all the right conditions existed for large deposits of natural gas to accumulate. Why are so many wells being drilled there? The size of the field area and the unusual nature of the reservoir rocks require many closely spaced wells, using state-of-the-art drilling and completion technology to economically produce the gas. Is the Utah Geological Survey (UGS) conducting any research in the area? In fact, the UGS is assisting with a major project on Natural Buttes, with and under the direction of reservoir engineers and modelers at the University of Utah. The study is funded by the Research Partnership to Secure Energy for America (RPSEA) and also involves Utah State University, software companies, and industry participants.

Natural Buttes, and other fields in the eastern Uinta Basin, produce natural gas primarily from sandstone in the Cretaceous Mesaverde Group (70–80 million years old) and the Tertiary Wasatch Formation (52–56 million years old). Gas is stored in pores within very fine grained sandstone (the reservoir rock). The connectivity of the pores (permeability), which allows gas or liquids to flow, is very low. This hinders the ability of the rocks to release the stored gas, and thus the reservoir rock is referred to as "tight" sandstone.

During much of Cretaceous time, a warm, shallow, inland sea extended from Canada to the Gulf of Mexico across the North American continent, including eastern Utah. Most of the gas production from Natural Buttes field is from highly compartmentalized, discontinuous, lens-shaped sandstone bodies deposited in channels and as sandbars along rivers flowing eastward across a coastal plain from ancient mountains (the Sevier orogenic belt) in western Utah toward the inland sea during Late Cretaceous time. Other sandstone beds represent a nearshore marine setting. The gas was generated and expelled from older Cretaceous coal beds (originally swamps and marshes) after deep burial in the basin.

Rocks of the Mesaverde Group and Wasatch Formation are exposed at the surface in the cliffs and deep canyons along the southern rim of the Uinta Basin, and are inclined gently northward such that in the basin center they are deeply buried. In Natural Buttes and other gas fields within the basin, individual wells typically penetrate multiple, vertically stacked, tight sandstone beds, each capable of producing gas. These beds may be in direct contact with each other or be separated by very thin to thick, extremely low-permeability siltstone and



Location of Natural Buttes and other fields in the Uinta Basin.



Castle Gate in Price River Canyon (view looking east) is composed of the Castlegate Sandstone of the Cretaceous Mesaverde Group. The Castlegate Sandstone was deposited in an ancient braided stream system and produces gas at Natural Buttes field in the eastern Uinta Basin. Photo courtesy of Robert Ressetar.

Sandstone Gas Storehouse

shale that act as either barriers or baffles to fluid flow. Natural fractures in the reservoir rocks increase both their porosity and permeability.

The discontinuous nature of these tight sandstone bodies is seen in outcrop and in seismic profiles from Natural Buttes field. The sandstone beds that produce in one well are often completely different and separate from sandstone beds in another well, even if the distance between the two wells is only a few thousand feet. Thus, field development at Natural Buttes requires drilling dozens of closely spaced wells each year. Four to six wells are often completed from the same surface location by directionally drilling to the targeted intervals at depth. This practice saves drill-site construction costs and reduces the environmental footprint of development.

The lateral and vertical reservoir characteristics such as thickness, degree of porosity and permeability, fractures, and internal barriers and baffles to fluid flow, determine where a well is drilled and the plan as to how it will best produce. Gas production from tight sandstone reservoirs requires mechanically increasing the number of fractures for the wells to produce at commercial rates and amounts of gas. This is accomplished by hydraulic fracturing techniques (also used to develop shale-gas reservoirs described on p. 3) that have become significantly more effective over the past 10 years. Water and minor amounts of chemical compounds are pumped down the well under pressures high enough to locally fracture the sandstone, thereby increasing both the porosity and permeability and allowing the trapped gas to flow to the well. Hydraulic fracturing is usually conducted in several stages, moving from sandstone bed to sandstone bed up the well. To keep the natural and new open fractures from closing due to the pressure of the overlying rock layers, sand or other porous materials of various sizes (called proppant) is also pumped into the fractured zones.

Understanding the natural fracture systems and reservoir characteristics created by various depositional environments can aid in optimizing hydraulic fracturing and lead to more effective drilling and completion strategies. Cores in the Castlegate, Sego, and Price River Formations of the Mesaverde Group, for example, display classic tight sandstone characteristics including porosity, permeability, and natural fractures that the UGS is evaluating to assist with the creation of new reservoir models and simulations for hydraulic fracturing. For more information, visit our Web page at geology.utah.gov/emp/tightgas/index.htm.

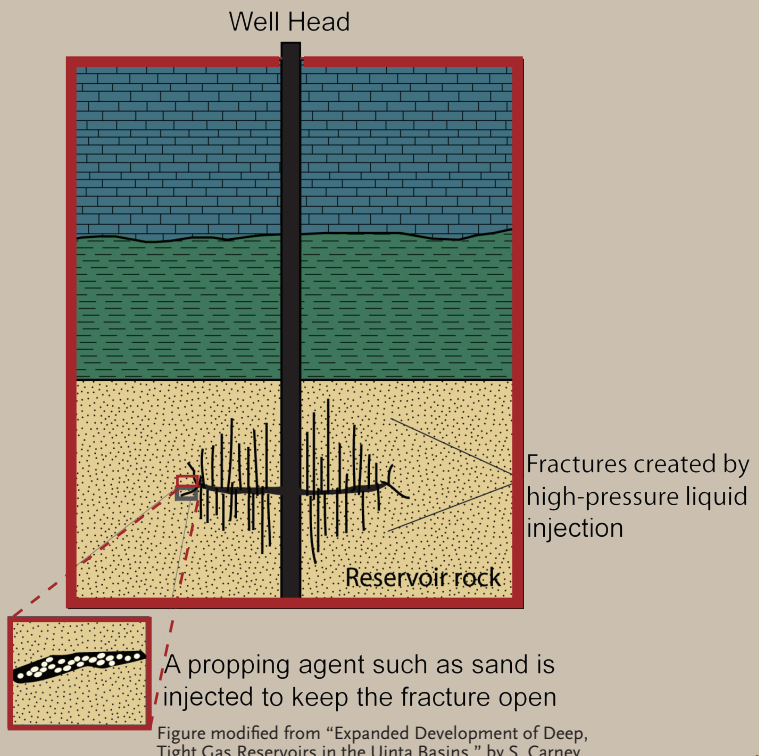
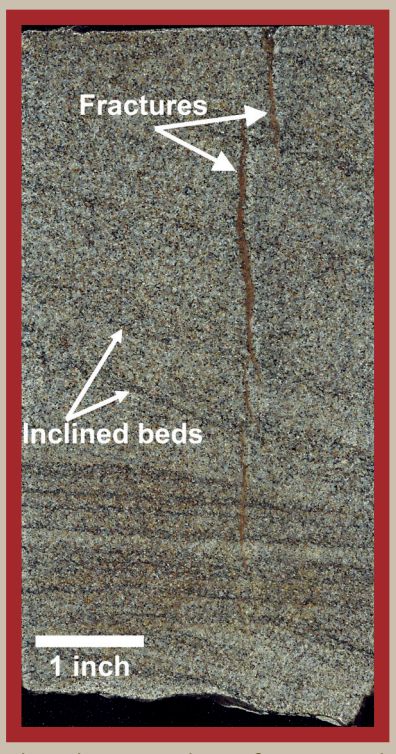


Figure modified from "Expanded Development of Deep, Tight Gas Reservoirs in the Uinta Basins," by S. Carney, 2007, *Survey Notes*, v. 39, no. 2.

Schematic diagram of hydraulic fracturing in tight gas sandstone.



Well core of typical Castlegate Sandstone from Natural Buttes field showing inclined beds representing deposition in a lower coastal plain to nearshore marine environment, and open vertical fractures.

Glad You Asked

What is the correct name of...?

Mark Milligan

Among the more commonly asked questions we receive at the Utah Geological Survey (UGS) are those dealing with the correct names of Utah's geographic features. Perhaps the best tool for answering these questions is a searchable database established and maintained by the U.S. Board on Geographic Names, which is part of the U.S. Geological Survey (USGS). This database, called the Geographic Names Information System (GNIS), is available online at geonames.usgs.gov. Following the American Civil War, a surge of exploration, mining, and settlement of western territories created many inconsistencies and contradictions in geographic names, which became a serious problem for surveyors, map makers, and scientists. To address this problem, President Benjamin Harrison signed an executive order that created the U.S. Board on Geographic Names in 1890 (the current form of the board was established by a 1947 law).

Technology, such as geographic information systems, global positioning systems, and the Internet increases the need for standardized data on geographic names, but it also makes accessing that data quick and easy through the GNIS. The database includes current and historical information for over 2 million physical (e.g., mountain ranges, summits, lakes, arches, and streams) and cultural (e.g., populated places, churches, airports, and cemeteries) geographic features in the United States, associated areas, and Antarctica. However, it does not include roads and highways. Named features are located by state, county, USGS topographic quadrangle map, and geographic coordinates. Other attributes include elevation (another commonly asked question at the UGS), alternative and unofficial (variant) names and spellings, feature class/type, historical and descriptive information, and citations.

In addition to finding official names, elevations, citations, and such, all sorts of name curiosities can be investigated using the GNIS. The following list illustrates some of the more entertaining results of our GNIS name queries.

- The ***San Rafael Swell***, in Utah, has the company of 12 other ***Swell*** places across the U.S.
- Based on "feature names," Utah has more ***Bars*** (29) than Arizona (1), Nevada (3), and Wyoming (3). Also based on "feature names," the density of ***Bars*** is apparently not directly related to how dry a state is; Florida has 10, while Idaho has 115. But based on "feature class," Florida, Idaho, and Utah have 211, 116, and 40 bars, respectively. Note: a bar is an elongated ridge of sand, gravel, or other sediment that forms in a river, lake, or ocean.
- Of the 99 U.S. ***Nipples***, nearly one-third (29) are in Utah; ***Mollies/Mollys*** is most common (8).
- The U.S. has 365 ***Eggs***, but only Utah, Virginia, and Texas have ***Eggnog***.
- Utah has only two wives (***Wife***), but this is one more than any other state in the nation.
- ***Devil*** (U.S.–1,853 and Utah–69) is more common than ***Hell***, but ***God*** and ***Jesus*** are omnipresent. Each has "more than 2,000" matches in the U.S. In Utah ***God*** has only 37 matches, while ***Jesus*** has 1,126. This is due to the inclusion of church names in the database (the devil is in the detail).
- ***Hell*** on earth (or at least in the U.S.–983 matches, and Utah–55 matches) is much more common than ***Heaven*** (U.S.–327 and Utah–13).
- Utah has a ***Mitten Canyon*** in Uintah County, but the famous Mittens (***East*** and ***West Mitten Buttes***) of the Navajo Nation's Monument Valley are on the Arizona side of the border.
- ***Shite Creek*** is in Idaho. ***Shitten Creek*** is in Oregon. ***Shitamaring Creek*** is in Utah. None of these states contain one of the nation's 28 ***Paddles***.
- ***Scape Ore Swamp*** in South Carolina has not always been named such. Feature names can be and are changed for political correctness and other reasons, but the original name is maintained in the database. (You will have to look up the original name yourself.)
- Curiously, Utah contains none of the 104 ***Strange*** U.S. names and not one of the truly ***Odd*** (311) U.S. names.
- While 23 names across the U.S. include ***Goblin***, Utah's "***Goblin Valley***" is unique.
- ***Unique*** is not unique (12 in the U.S.), but nothing is ***Unique*** in Utah.



"The Great Bar at Stockton, Utah" as illustrated in Lake Bonneville, U.S. Geological Survey Monograph 1, by G.K. Gilbert (1890). The name has subsequently been shortened to Stockton Bar.



Devils Kitchen, Juab County.

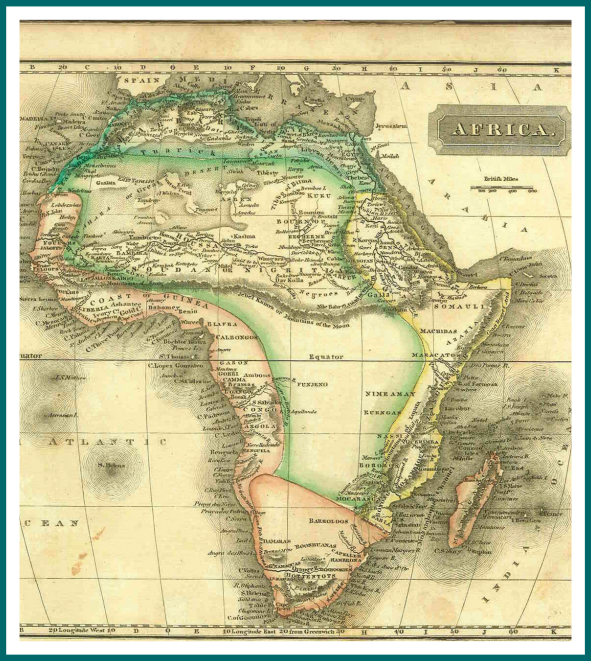


Devils Playground, Box Elder County.



Goblin Valley, Emery County.

continued from page 7



Map of Africa, with little detail and vast unmapped areas.

there are separate maps of each European country, and each of those contains a high level of detail. In contrast to the European maps, Africa is represented only as a continent, composed of roughly five ambiguous countries, vast blank areas, and terra incognito—parts unknown.

Another interesting fact about the atlas is that the author had some rather famous relatives. Sidney Morse's father, Jedidiah Morse, both a clergyman and geographer, was given the title "Father of American Geography" for his important role in early American cartography. Sidney's brother, Samuel F.B. Morse, an artist and inventor, is probably the most well known Morse as a result of his significant contributions in developing the single-wire telegraph and Morse Code. Sidney Morse followed in his father's footsteps as a geographer as well as an inventor, and ***The New Universal Atlas*** is only one of many attributed to him.

Come and see the atlas for yourself! ***The New Universal Atlas*** will be on display at the Utah Department of Natural Resources Library until December 2011. The Utah Geological Survey thanks William L. Chenoweth, who has worked with UGS staff as a consultant after retiring from the U.S. Atomic Energy Commission, for the donation. Contact Stephanie Earls, Utah DNR Librarian, if you have any questions at stephanieearls@utah.gov or 801-537-3333.

GeoSights

The Witches near Echo, Summit County, Utah

Christine Wilkerson

Near the town of Echo in northern Utah is a cluster of reddish-brown natural monuments called The Witches (also known as Witch Rocks, Witches Rocks, Witch Bluffs, or Witches Bluffs), composed of the Henefer Formation. In 1858, army Captain Albert Tracy described them in his journal as "witch-like" and "so singularly like figures in kirtles [long skirts] and steeple-hats, or bonnets that they have received the appellation [Witch Rocks]". By using your imagination (and perhaps squint-ing a bit), you can picture a coven of witches in long robes and witches' hats standing on the hillside.

Nearby Echo Canyon has long been used as a main thoroughfare between southern Wyoming and northern Utah, first by Native Americans, fur trappers, and explorers, then by wagon trains on their way to Salt Lake City or other points west. Before the interstate highway, passengers on the Overland Stage and then the Union Pacific Railroad also made their way through the canyon. At the town of Echo, the canyon opens into the Henefer Valley where most of these travelers rested and marveled at the unusual rock formations, some even drawing sketches or taking photographs of The Witches.

Geologic Information: Between 170 and 40 million years ago, western North America experienced a mountain-building period called the Sevier orogeny. Dense oceanic crust beneath the Pacific Ocean collided with and moved under the lighter continental crust of North America. This convergence generated compressional forces that produced low-angle thrust faults within the crust. Transported tens of miles eastward along these thrust faults, rock formations were pushed up and over adjacent rock layers, forming the Sevier mountain belt.

The conglomerate of the Henefer Formation was deposited about 90 to 85 million years ago when Sevier thrust faulting in Utah had reached its peak. The conglomerate is composed of sandstone and quartzite pebbles, cobbles, and boulders eroded from the mountainous areas to the west and northwest. Streams then carried these sediments off of the highlands, eventually deposit-ing the heavier material in large alluvial fans (fan-shaped stream and debris-flow deposits).

In more recent times, the elements have eroded areas of the conglomerate near Echo and within Echo Canyon into the fantastic shapes we see today; in addition to The Witches, there are rock structures named Pulpit Rock, Castle Rock, Devils War Club, Sphinx, and Sentinel Rock, to name a few. The upper "caps," or witches' hats, are formed of a lighter-colored conglomerate layer cemented into a harder mass than the softer, underlying conglomerate layer that forms the witches' "robes." The harder cap rock erodes more slowly and helps protect the rock underneath. But as a witch becomes more and more slender, her hat eventually falls off and can no longer protect her, and thus, like the infamous Wicked Witch of the West, she succumbs to the effects of water and gradually melts to the level of the surrounding landscape.



How to get there: From the south and west, travel along I-80 East to exit 169 (Echo) at the entrance to Echo Canyon. At the bottom of the off-ramp, turn left (north) to go under the interstate. Take a left (west) onto Echo Canyon Road heading towards the town of Echo. Continue on Echo Canyon Road/Echo Road/Old Highway 30 for approximately 2 miles (passing Echo). A landmark sign for The Witches will be on the right (east) side of the road.

From the north, travel along I-84 East to exit 115 (Utah State Highway 65/Henefer/Echo). Turn left (east) onto Main Street, cross over I-84, and as you curve to the right (south) towards the town of Echo, the road becomes Echo Road/Old Highway 30. Continue for approximately 2 miles until you reach The Witches landmark sign on the left (east) side of the road.



The more resistant, light-colored cap rock slows down the erosion of the underlying reddish-brown conglomerate layer.



The Henefer Formation is composed of pebble-, cobble-, and in some places even 9-foot-diameter boulder-size clasts of mostly sandstone and quartzite. Photos courtesy of Amanda Wilkerson.





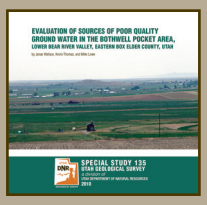
Employee News

Bruce Miya has joined the Utah State Energy Program as the Energy Project Coordinator. Bruce received his Masters in Architecture from the University of Utah and has worked as a project manager in the private sector for the past 20 years. He replaces **Jim Levy** who accepted a position with Quantum Lighting.

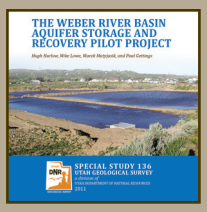
Barry Solomon retired in January after 22 years of service with the UGS. Barry's work in the Geologic Hazards Program involved research and mapping of a wide variety of geologic hazards, in particular earthquakes and radon. He completed geologic-hazard map folios of the Tooele Valley, Cache Valley, and Springdale areas as well as detailed surficial-geologic maps of the Oquirrh and West Cache fault zones. He was involved in several suitability studies for hazardous-waste disposal, and characterized geologic conditions as they relate to indoor-radon hazards in numerous areas throughout Utah. Barry worked closely with the Geologic Mapping Program, authoring or co-authoring nearly two dozen geologic quadrangle maps. Barry's expertise and breadth of knowledge will be missed, and we wish him well in his retirement.

News Flash: This past March, the 2011 State Legislature created an Office of Energy Development, which will consolidate some state energy and policy functions including those of the Utah State Energy Program (USEP). Housed at the UGS since 2005, USEP will be moving shortly to new offices at the Department of Environmental Quality.

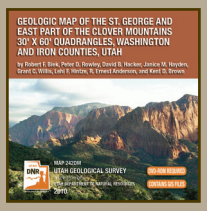
New Publications



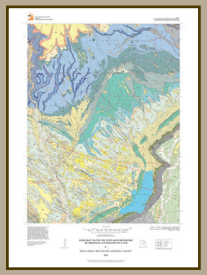
Evaluation of sources of poor quality ground water in the Bothwell Pocket area, lower Bear River Valley, eastern Box Elder County, Utah, by Janae Wallace, Kevin Thomas, and Mike Lowe, CD (38 p. + 12 p. appendices, 1 pl.), ISBN 978-1-55791-839-0,
SS-135 ..... $14.95



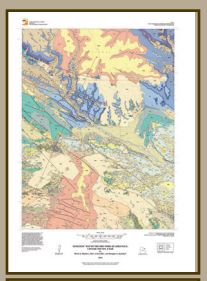
The Weber River Basin Aquifer Storage and Recovery pilot project, by Hugh Hurlow, Mike Lowe, Marek Matyjasik, and Paul Gettings, CD (79 p. + 48 p. appendices, 2 pl.), ISBN 978-1-55791-840-6,
SS-136 ..... $19.95



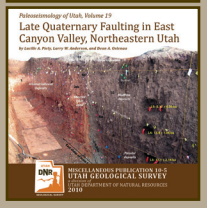
Geologic map of the St. George and east part of the Clover Mountains 30' x 60' quadrangles, Washington and Iron Counties, Utah, by Robert F. Biek, Peter D. Rowley, Janice M. Hayden, David B. Hacker, Grant C. Willis, Lehi F. Hintze, R. Ernest Anderson, and Kent D. Brown, DVD (108 p., 2 pl., scale 1:100,000 [contains GIS data]), ISBN 978-1-55791-843-7,
M-242DM $24.95



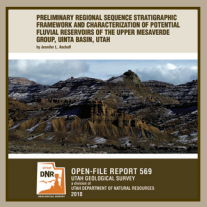
Geologic map of the Steinaker Reservior quadrangle, Uintah County, Utah, by David A. Haddox, Bart J. Kowallis, and Douglas A. Sprinkel, 2 pl., scale 1:24,000, ISBN 978-1-55791-831-4,
MP-10-3 ..... $13.95



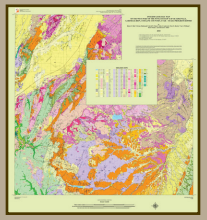
Geologic map of the Dry Fork quadrangle, Uintah County, Utah, by David A. Haddox, Bart J. Kowallis, and Douglas A. Sprinkel, 2 pl., scale 1:24,000, ISBN 978-1-55791-832-1,
MP-10-4 ..... $13.95



Paleoseismology of Utah, Volume 19: Late Quaternary faulting in East Canyon valley, northern Utah, by Lucille A. Piety, Larry W. Anderson, and Dean A. Ostenaa, CD (38 p.), ISBN 978-1-55791-841-3,
MP-10-5 ..... $14.95



Preliminary regional sequence stratigraphic framework and characterization of potential fluvial reservoirs of the upper Mesaverde Group, Uinta Basin, Utah, by Jennifer L. Ashcroft, CD (40 p., 6 pl.),
OFR-569 ..... $14.95



Interim geologic map of the west part of the Panguitch 30' x 60' quadrangle, Garfield, Iron, and Kane Counties, Utah—Year 2 progPhado, David W. Moore, John J. Anderson, Peter D. Rowley, Van S. Williams, L. David Nealey, and Edward G. Sable, 94 p., 1 pl., scale 1:65,000,
OFR-577 ..... $17.95

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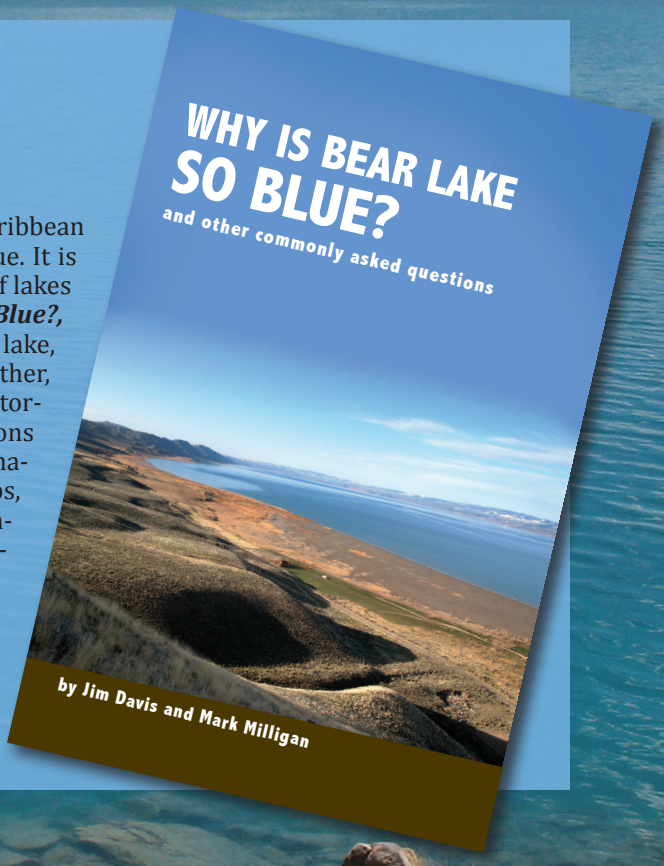
WHY IS BEAR LAKE SO BLUE?
And Other Commonly Asked Questions

by Jim Davis and Mark Milligan

Beautiful Bear Lake, in northern Utah, is called "the Caribbean of the Rockies" because of its vivid turquoise blue hue. It is Utah's deepest natural lake and is among the oldest of lakes in North America. This booklet, ***Why is Bear Lake So Blue?,*** answers 17 commonly asked questions about the lake, including topics 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. This colorful and informative publication contains dozens of photographs, maps, and figures to help answer the questions. It also highlights new information and discoveries from a collaborative and intensive scientific study of Bear Lake that was published in 2009.

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