UTAH GEOLOGICAL SURVEY

SURVEY NOTES

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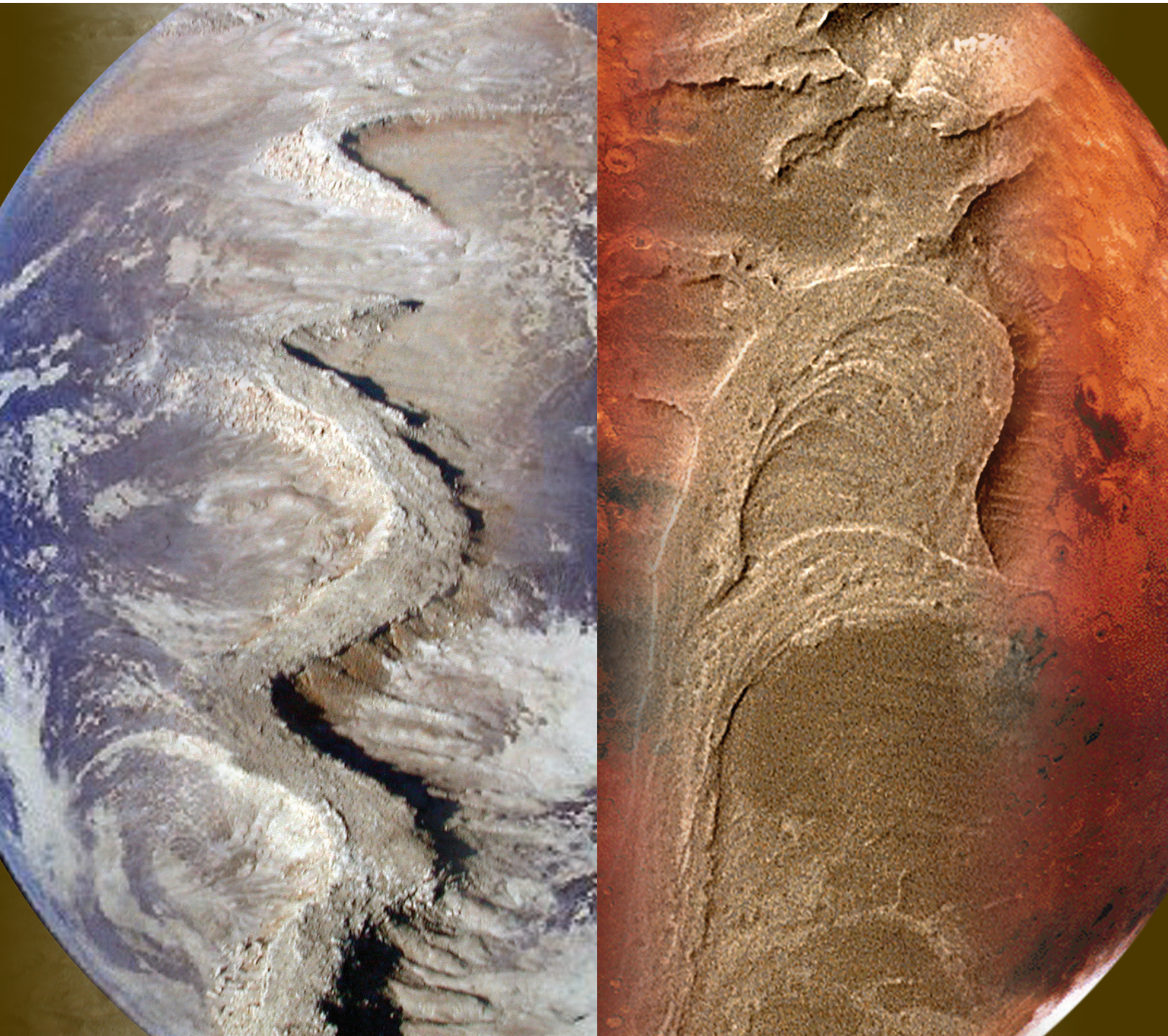

Ancient river channels in Utah provide insight into similar features on Mars

The Director's Perspective

by Richard G. Allis

The Utah Geological Survey (UGS) has an important role in tracking energy and mineral activity in the state (see article on page 8). Over the past five years, the price of many of the geologic commodities that Utah produces has risen dramatically, and this has had a major impact on exploration and development activity in the state. The UGS expects the total value of energy and mineral production in 2008 to exceed $10 billion and set another record. This expected value would be three times the average annual production value between 1960 and 2002 (using inflation-adjusted figures). The five leading commodities are natural gas, oil, copper, molybdenum, and coal.

The UGS often becomes aware of changing trends early in the exploration cycle through an increase in inquiries about the occurrence of a particular resource in the state. During 2006 and 2007, uranium was the hot topic, coinciding with a rise in its price from around $10/lb to $130/lb, and resulting in a boom in claims filed with the Bureau of Land Management. More recently three uranium mines have reopened, and the White Mesa mill near Monticello is once again processing Utah ore. However, uranium inquiries to the UGS have declined this year, as has the price (now around $65/lb). This year's hot topic for our minerals section has been fertilizer minerals such as potash, phosphate, and sulfur as a result of increasing global demand for fertilizers. Utah is already the nation's second largest producer of potash and fourth largest producer of phosphate, and has the potential to significantly increase production of both minerals. The price of potash has tripled since 2003, and that of phosphate has doubled since 2005.

Geologic resources contribute to three staples underpinning the drive toward an overall increase in the global standard of living: energy, materials, and the food supply. The trends in commodity prices highlight the complex interplay between all three staples. Limitations in the growth in future oil production have stimulated initiatives in biofuel production such as ethanol, which have stressed not only food supplies, but also the fertilizer demand. With the exception of natural materials such as wood, most materials require both minerals and energy in their processing. Although supply-and-demand fluctuations for geologic commodities will cause short-term volatility in their prices, it seems likely that the global trend of increasing demand will sustain generally high prices. The need for geological surveys to continue providing information about geologic resource potential is greater than ever.

Contents

Design: *Stevie Emerson*

Cover: *Composite images of Martian and terrestrial river-channel features superimposed (at greatly enlarged scale) on images of Mars and Earth, respectively.* ***Left:*** *Oblique aerial photograph of an ancient sinuous river channel in the Early Cretaceous Cedar Mountain Formation, east-central Utah. Features like this in Utah are providing insight into the origin of similar features on Mars.* ***Right:*** *Feature interpreted as a meander loop suggests persistent river activity in the past on Mars. Image obtained by the Mars Orbiter Camera; NASA/JPL/Malin Space Science Systems.*

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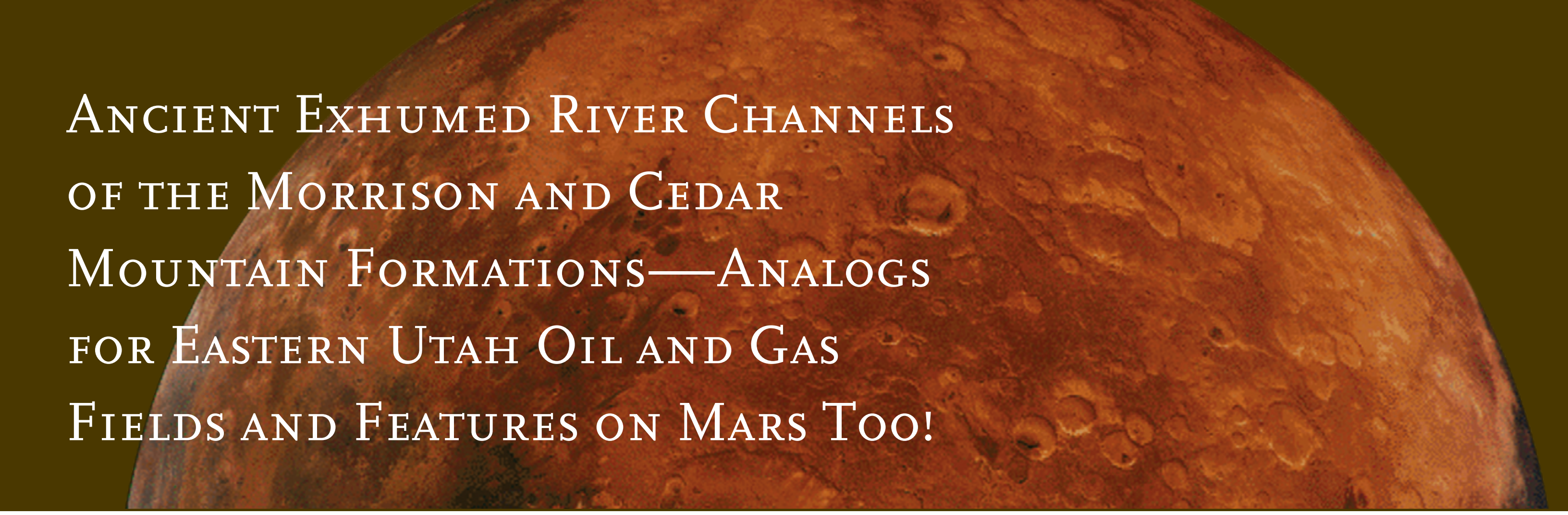
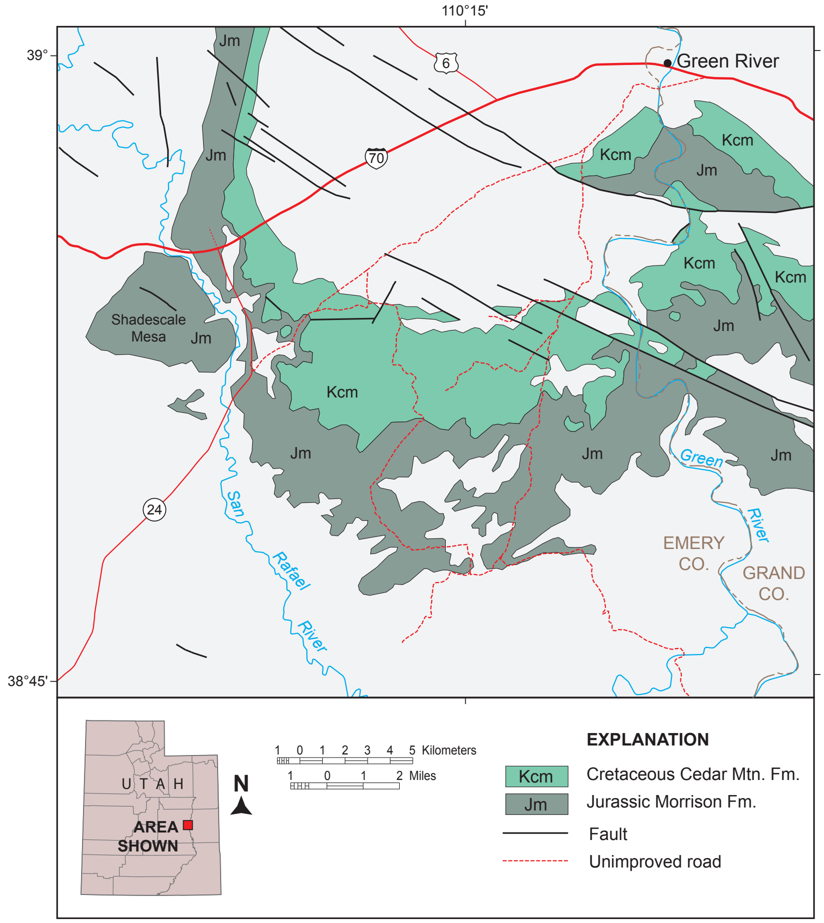


Ancient Exhumed River Channels of the Morrison and Cedar Mountain Formations—Analogs for Eastern Utah Oil and Gas Fields and Features on Mars Too!

by Thomas C. Chidsey, Jr., Utah Geological Survey
Rebecca M.E. Williams, Planetary Science Institute
David E. Eby, Eby Petrography & Consulting, Inc.



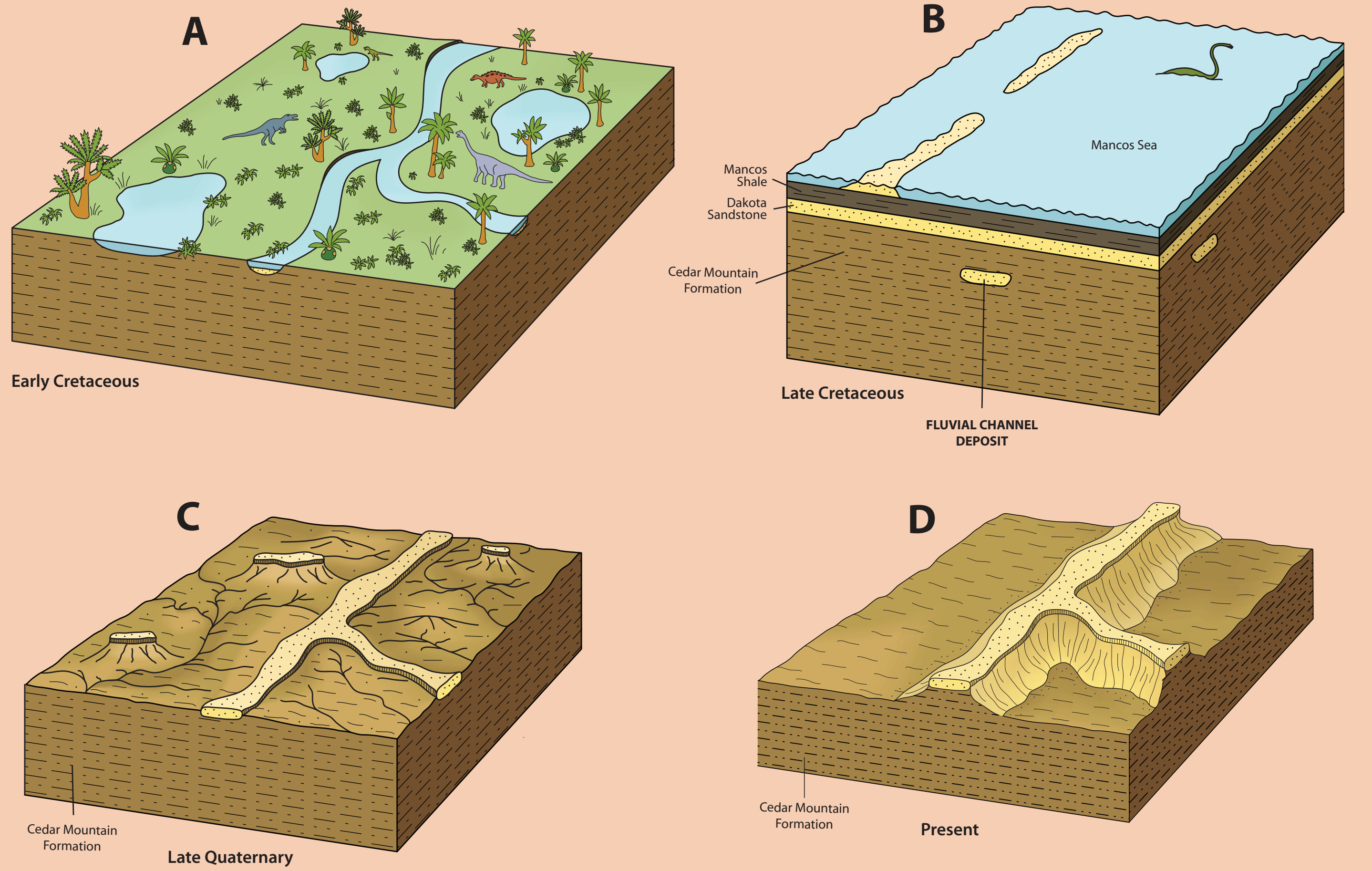
Geologic map showing location of Morrison and Cedar Mountain Formations exhibiting paleochannels and inverted topography in east-central Utah.

Along Interstate 70 (I-70) in eastern Utah, near the junction with Highway 24, sandstone- and pebble-rich ridges and small buttes top the variegated shale and mudstone of the Late Jurassic Morrison Formation. As one travels east on I-70 toward the town of Green River, several similar elongate ridges can be seen in the distance to the south; these ridges belong to the Early Cretaceous Cedar Mountain Formation. Both the Cedar Mountain and Morrison are famous for dinosaur fossils. However, in this region these outcrops also provide clues for finding oil and gas resources in Utah **and** understanding geologic features on Mars. This statement may sound unusual, but it is true.

Geologic Background

The sediments comprising the Morrison and Cedar Mountain ridges and buttes observed along I-70 were deposited in ancient river systems. Although difficult to recognize as such from the highway, when viewed from the air (or even when hiking on the top) they spectacularly display elongate, typically sinuous or crisscrossing features that resemble river-channel patterns. During Late Jurassic and Early Cretaceous time (about 145 million years ago), meandering streams and rivers flowed east across broad plains from highlands to the west. These rivers deposited sand and gravel as point bars along channel bends and as channel fills in the flood plain, which was composed of mud and silt. Over millions of years these deposits were buried by about 8000 feet of Late Cretaceous marine shale of the Mancos Sea and younger sediments. They remained "entombed" for more than 75 million years until regional uplift of the Colorado Plateau began 37 million years ago, deposition ceased, and extensive erosion began. Eventually, the thick section of rock above the Morrison and

Sandstone ridge (about 25 feet high) representing a paleochannel in the Jurassic Morrison Formation near the junction of Highway 24 and I-70 in east-central Utah.



Block diagrams illustrating phases of development of inverted paleochannels in the Cedar Mountain Formation. (A) Sediment was deposited during the Early Cretaceous in fluvial channels (sand and gravel) and flood plains (silt and clay) of an alluvial-plain environment. (B) In the Late Cretaceous, the area was beneath a shallow sea. Ultimately, the Early Cretaceous deposits were buried by about 8000 feet of sediments and remained buried for more than 75 million years. (C) By late Quaternary time (about 130,000 years ago), uplift and erosion had stripped away the overburden, revealing the paleochannel deposits at the surface once again. (D) Present-day expression of the paleochannels is that of a topographic ridge as high as 130 feet above the surrounding plains (inverted topography).

Cedar Mountain Formations eroded away, mainly by the action of flowing water in the Colorado River drainage network, and the ancient river channels were once again exposed at the surface, or "exhumed."

The now compacted and well-cemented sandstone and conglomerate that filled the ancient river channels ("paleochannels") are more resistant to erosion than the surrounding mudstone and shale of the ancient flood plain. Consequently, erosion of the surrounding flood-plain deposits was more rapid than that of the river-channel deposits. The exhumed paleochannels are expressed today as the ridges and buttes topographically above the surrounding landscape. This type of geomorphic phenomenon is referred to as inverted topography—what was previously the lowest part of the ancient landscape is now the highest (for a discussion of inverted topography formed by lava flows in southwest Utah, see the "Geosights" article in the September 2002 issue of *Survey Notes*). Individual paleochannels can be traced for distances of over 5 miles, have widths between 30 and 100 feet, and relief as much as 130 feet above the surrounding terrain.

Oil and Gas Resources

Elsewhere, Morrison and Cedar Mountain channel deposits have produced nearly 3 million barrels of oil and 300 billion cubic feet of natural gas from fields in the southeast Uinta Basin of eastern Utah. In these fields the paleochannels are still encased by the surrounding mudstone and shale deep in the subsurface. The channel sandstones contain enough pore space (which is also interconnected) between the sand grains to store gas and oil (or water), and thus serve as hydrocarbon reservoirs. The shale and mudstone act to seal the paleochannels, forming a stratigraphic hydrocarbon trap (no folding or faulting of the rocks is involved in the trap). The exhumed Morrison and Cedar Mountain paleochannels of the inverted topography region are exposed analogs of the buried reservoir rocks of these oil and gas fields. Petroleum geologists use the outcrops to better predict reservoir-sandstone channel depositional trends, distribution, channel length and width, sand thickness, reservoir quality (such as the amount of pore space), and other critical information in the search for new stratigraphic hydrocarbon traps. These studies also help reduce the chances of drilling "dry" holes when targeting ancient river channels as fields are developed, versus a sometimes "hit or miss" drilling approach.

Similar Features on Mars

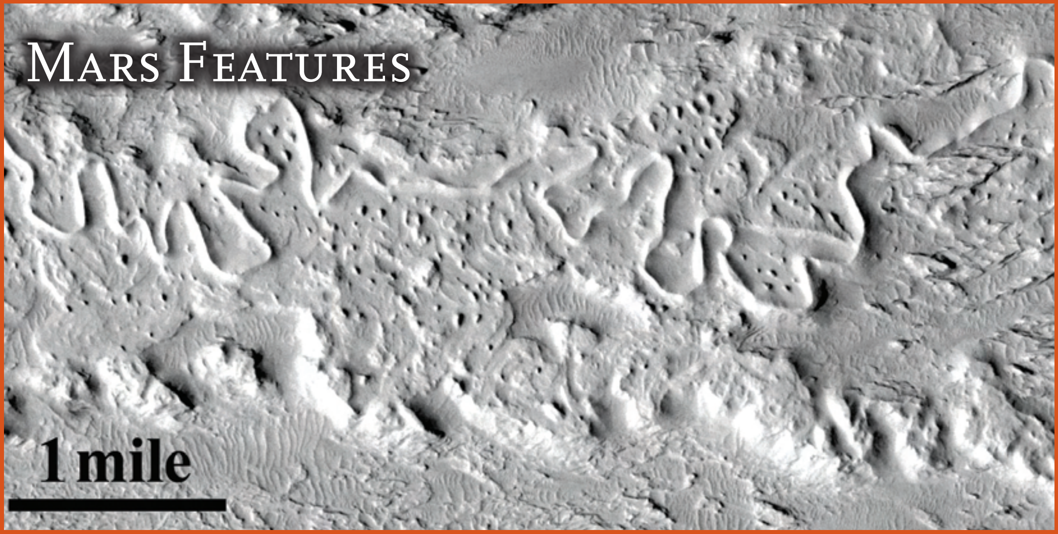
The inverted topography of the Morrison and Cedar Mountain exhumed paleochannels is strikingly similar to the form and size of curvilinear features found on Mars. Valley networks observed in low-resolution images generated from spacecraft orbiting Mars (Mariner 9 in 1971 and the Viking orbiters between 1976 and 1980)

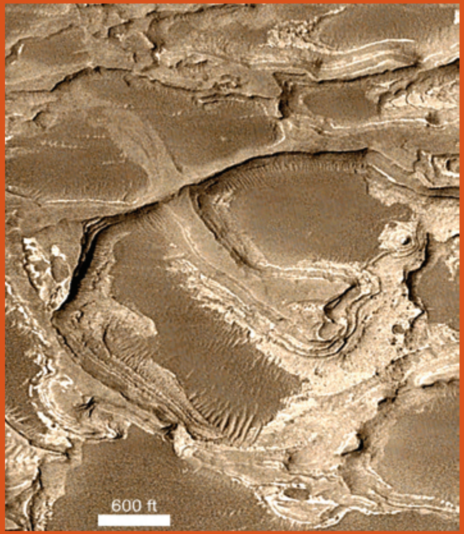
Utah Features

Left: Oblique aerial photograph of a sinuous Cedar Mountain paleochannel having a total length of about 2700 feet. Illumination is from the lower left.

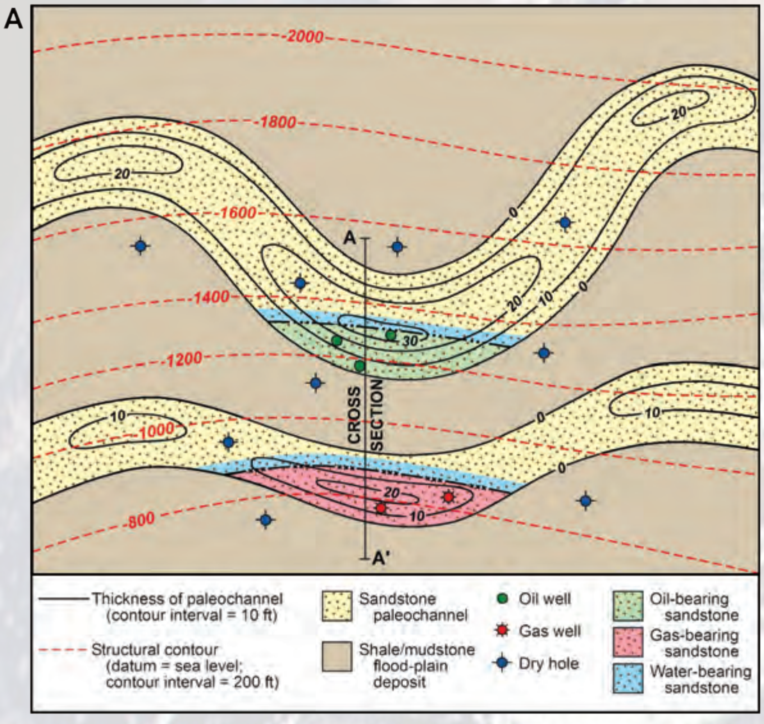
Right: Oblique aerial photograph of crisscrossing inverted paleochannels of the Morrison Formation. Illumination is from left.

Mars Features





Above left: High-resolution image illustrates a meandering Martian valley landform with inverted topography in the Aeolis Mensae region, Mars (image taken by the Context Camera). Note numerous, parallel, elongate dunes perpendicular to the valley landforms. Illumination is from the left. Above right: Crisscrossing ridges formed as a result of topographic inversion, likely due to wind erosion, Eberswalde Crater, Mars (image taken by the Mars Orbiter Camera). Illumination is from the left; north is up in all images. Image credits: NASA/JPL/Malin Space Science Systems.



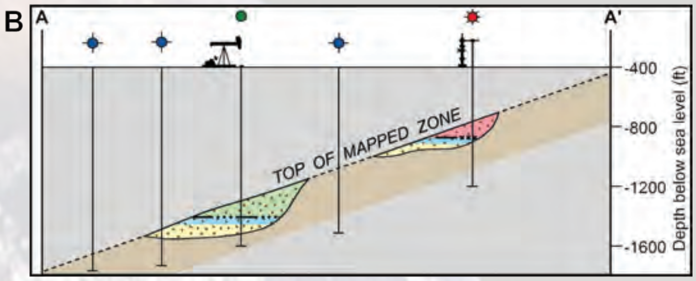


Diagram showing hypothetically how oil and gas can be trapped in deeply buried river channels like those that produce hydrocarbons from the Morrison and Cedar Mountain Formations in eastern Utah. Hypothetical productive oil, gas, and "dry" wells are also shown. (A) Combined structure and thickness map (surface view) of gas- and oil-productive paleochannels. Solid contours represent ancient channel sand thickness (in feet). Dashed contours represent depth below sea level (in feet) of the channel-bearing zone like a topographic map shows the elevation of the land surface. Note the similarity between the mapped channels and those observed in outcrop. (B) Cross section showing oil and gas trapped in paleochannels encased in shale. Hydrocarbons are lighter than water within the pore spaces of sandstone and therefore migrate to the structurally highest part of the sandstone body.

are interpreted as having formed during an earlier warmer and wetter climate. New high-resolution images from the Mars Orbiter Camera (MOC) aboard the Mars Global Surveyor (1997–2006) and the Thermal Emission Imaging System aboard the Mars Odyssey (2002–present) show well-defined preservation of raised, often branching, ridge landforms. These features are 600 feet to 45 miles in length, have widths between 30 feet and 2.5 miles, and relief as much as 170 feet above the surrounding terrain. Like the Morrison and Cedar Mountain examples, these Martian features are also interpreted as paleochannels expressed as inverted topography resulting from deposition, burial, compaction and cementation, erosion, and exhumation. Unlike the Utah paleochannels, however, the Martian features likely were exhumed by wind erosion rather than flowing water. Study of Utah's Morrison and Cedar Mountain inverted paleochannels is helping scientists understand the geologic history that led to development and preservation of the similar Martian paleochannels, as well as the environmental conditions of channel-forming events on Mars.

Related Research

Dr. Brian Currie (University of Miami, Ohio) and his colleagues have evaluated the Cedar Mountain Formation both in the subsurface and in outcrops of eastern Utah under the Utah Geological Survey's (UGS) Characterization of Utah Hydrocarbon Reservoirs and Potential New Reserves program. Their findings and conclusions were recently published in UGS Open-File Report 516 titled *Reservoir Characterization of the Cretaceous Cedar Mountain and Dakota Formations, Southern Uinta Basin: Year-Two Report (2008)*.

About the Authors

Thomas C. Chidsey

Tom Chidsey is the Petroleum Section Chief for the Utah Geological Survey (UGS). His responsibilities comprise managing the petroleum program and conducting research in Utah's petroleum geology. A native of the Washington, D.C., metropolitan area, Tom received his Bachelor of Science degree in 1974 and a Master of Science degree in 1977, both in geology from Brigham Young University. During his 30-year career, Tom has worked as a production geologist for Exxon in South Texas and an exploration geologist in the Rocky Mountains for Celsius Energy Company (Questar Corp.) before joining the UGS in 1989. He has served as Rocky Mountain Section President of the American Association of Petroleum Geologists (AAPG), President of the Utah Geological Association, and General Chairman for the 2003 AAPG Annual Convention in Salt Lake City. He has been an editor/co-editor of five guidebooks on Utah geology and has numerous publications on Utah petroleum geology, carbon dioxide resources and sequestration, hydrogeology, oil and gas reservoir outcrop analogs, and the general geology of Utah's parks and monuments.

Rebecca M.E. Williams

Dr. Rebecca M.E. Williams, a research scientist with the Planetary Science Institute, is a planetary geologist specializing in fluvial geomorphology. Through a combination of qualitative and quantitative characterization of landforms using image and topographic datasets as well as fieldwork at terrestrial analog sites, she investigates the history of water on Mars. Dr. Williams received her bachelor's degree in 1995 from Franklin & Marshall College (Lancaster, Pennsylvania) with a joint major in physics and geology and minor in astronomy, and pursued doctoral studies in planetary geology at Washington University in St. Louis, graduating in 2000. Dr. Williams targeted the high-resolution Mars Orbiter Camera (MOC) on Mars Global Surveyor for over three years at Malin Space Science Systems. She is a participating scientist with the THEMIS instrument aboard Mars Odyssey and the Context Camera (CTX) aboard the Mars Reconnaissance Orbiter. Dr. Williams is the recipient of a 2006 NASA Carl Sagan Fellowship for Early Career Researchers.

Editor's note: If Drs. Williams and Eby look like they could be related, it's because they are! Dave is Rebecca's father.

David E. Eby

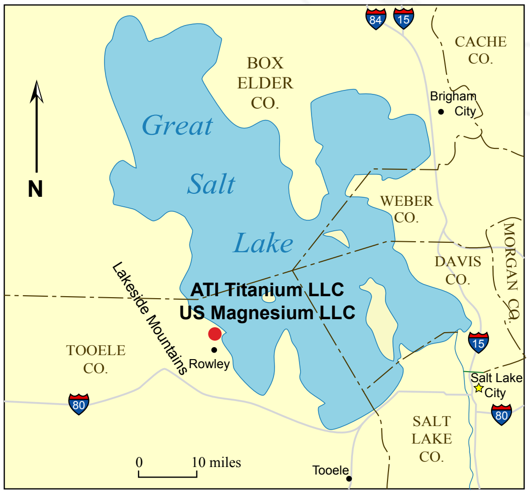
Dave Eby is the owner of Eby Petrography & Consulting, Inc., a consulting firm based in Denver, Colorado, that assists clients in evaluating opportunities for oil, gas, and mineral exploration/production. He also performs projects in sedimentary petrography, mineralogy, core and cuttings studies, as well as training activities emphasizing carbonate and sandstone reservoirs. Clients include large and small energy and mining companies as well as state geological surveys. He previously worked for Marathon Oil Petroleum Technology Center, Union Pacific Resources (now Anadarko Petroleum; and its predecessor Champlin Petroleum), and Mobil Oil R&D Corp. during earlier portions of his 40 years of industry experience. He also held teaching positions in Sedimentology and Paleontology over a 10-year period at the University of Texas (Dallas and Arlington), Franklin & Marshall College (Lancaster, Pennsylvania), and Southampton College (now part of SUNY at Stony Brook). Dave received his A.B. degree from Franklin & Marshall College, M.S. degree from Brown University, and Ph.D. degree from State University of New York at Stony Brook, all in geology.

Great Salt Lake

The Titanium Connection

by Bryce T. Tripp

How is Great Salt Lake involved in stopping bullets, refining oil, making jet aircraft, and fabricating artificial hips? The answer is that magnesium recovered from lake brine is used to refine titanium, and the west shore of Great Salt Lake is the site of a new titanium plant. Titanium is used in the manufacture of military armor, oil refinery equipment, jet engines and airframes, and medical prostheses like artificial hips.

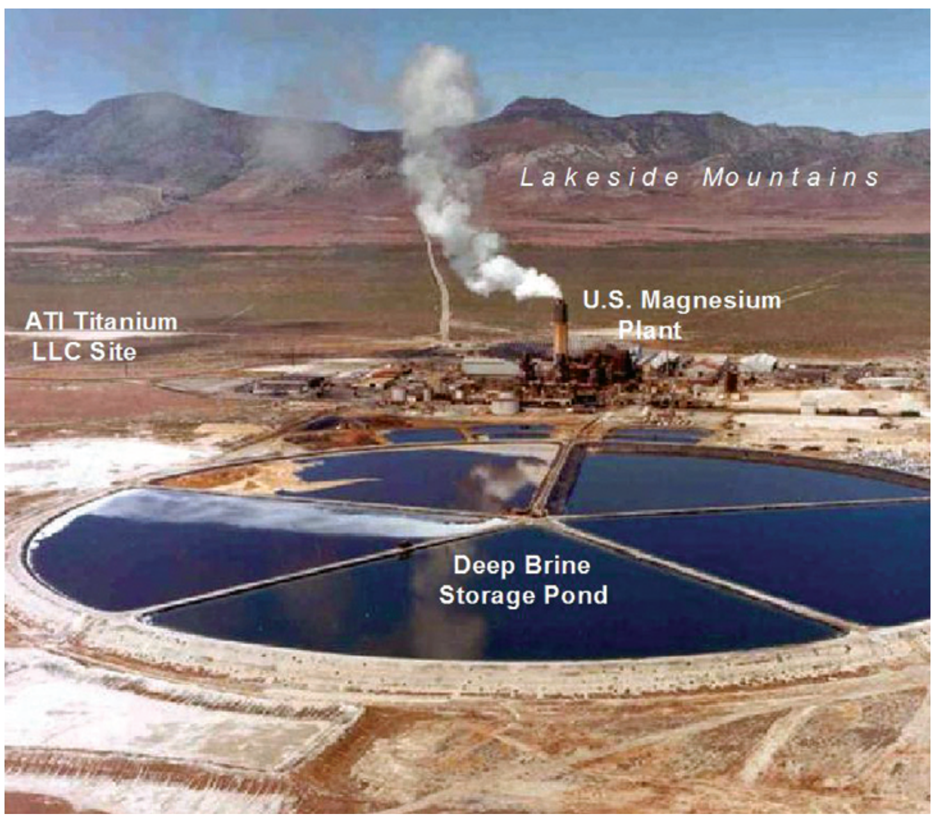


ATI Titanium LLC (a subsidiary of Allegheny Technologies Incorporated) is finishing construction of one of the largest titanium sponge plants in the United States, at Rowley, Utah, adjacent to the U.S. Magnesium plant. Titanium sponge is titanium metal that is porous and sponge-like because of the manufacturing process. High-purity titanium tetrachloride (in liquid form) is chemically reduced to yield metallic sponge, which is then further refined. Magnesium metal is used as the reductant in the Kroll process, which is the chemical process that will be used at the Allegheny plant. The Allegheny titanium plant is the first new titanium sponge plant built in the U.S. in more than 30 years that is not just an expansion of an existing facility. In the United States, titanium sponge is produced only in Nevada, Oregon, and Utah.

Locating the Allegheny plant adjacent to the U.S. Magnesium plant undoubtedly saved time and effort in the regulatory approval process, but the main advantage is the saving of money and energy because of the compatibility of the two plants. Allegheny reacts magnesium metal with titanium tetrachloride in a furnace and produces magnesium chloride as a by-product. U.S. Magnesium separates magnesium chloride in a furnace into magnesium metal and chlorine. Because of the proximity of the two plants, molten magnesium and molten magnesium chloride can be cycled between plants without cooling and without trucking or rail transport, saving energy.

Allegheny started building the $460 million plant in the first half of 2007. It will begin production in late 2008 and achieve its full annual capacity of 24 million pounds of sponge by the second half of 2009. The plant is designed to accommodate future capacity expansion of up to an additional 18 million pounds of sponge.

Strong international demand for titanium products and rapid price increases made construction of the Allegheny plant attractive. Allegheny's 2007 Annual Report projected international demand for titanium mill products to increase from 120 million pounds in 2006 to 350 million pounds in 2011. Allegheny's production of titanium mill products was 32 million pounds in 2005, but is estimated to be 50 million pounds in 2008 and more than 60 million pounds by 2011. To meet this additional demand, Allegheny is also expanding production capacity at its Albany, Oregon, sponge plant, and has been buying sponge from Kazakhstan and Japan and recycling titanium scrap. The price for titanium mill products increased from $11.50 per pound in 2003 to about $30.14 per pound in 2007.



Location of the ATI Titanium LLC titanium sponge plant on the west side of Great Salt Lake, adjacent to the U.S. Magnesium plant. The large, circular feature in the foreground is U.S. Magnesium's magnesuim chloride brine storage pond. Photo courtesy of U.S. Magnesium.

Increased demand for titanium results from its superior characteristics that make it desirable in many growing industries. Titanium is strong and light, heat and corrosion resistant, and has low thermal expansion compared to competing materials; these characteristics often make it the material of choice despite its generally higher cost. Aerospace applications account for 76 percent of the titanium used worldwide. A good example of the trend toward increased use of titanium is in the construction of aircraft. The Boeing 787 "Dreamliner," for example, is designed to achieve improved fuel economy by using a titanium frame covered by a composite skin. One Dreamliner requires 250,000 pounds of titanium, exclusive of the engines, which also contain large amounts of titanium. The energy efficiency of the Dreamliner helped The Boeing Company to sell 900 of the planes to 58 customers from 2004 to May 2008—the most successful introduction of a commercial airplane in aviation history. Allegheny has a long-term supply agreement with The Boeing Company for titanium mill products that extends from 2007 to 2015.

Final assembly begins on fifth Boeing 787 Dreamliner. Each Dreamliner will contain more than 250,000 pounds of titanium. Photo courtesy: The Boeing Company

Additional information on titanium can be found at the following Web sites:

Allegheny Technologies, Inc.
http://www.alleghenytechnologies.com

International Titanium Association,
http://www.titanium.org/index.cfm

Titanium Information Group, 2008
http://www.titaniuminfogroup.co.uk

U.S. Geological Survey
http://minerals.usgs.gov/minerals/pubs/mcs

Another indication of the growing demand for titanium is that the Alta Group (a subsidiary of Honeywell International, Inc.) has increased capacity at its Salt Lake City titanium sponge plant to 1.13 million pounds. This plant, opened in 1996 by Johnson Matthey, Plc. (Public Limited Company), produces titanium sponge by the Hunter process, using sodium as a reductant. About 10 percent of the sponge is sold and the other 90 percent is for Honeywell's internal use. It is refined in Fombell, Pennsylvania, into ultrapure titanium for semiconductors.

Construction of Allegheny's new plant reinforces the economic importance of Great Salt Lake to the state of Utah. As much as 24 million pounds of titanium will join the existing list of mineral products from the lake: salt, potash, magnesium metal, chlorine, and other potassium and magnesium salts. The Allegheny plant will also add about 150 high-paying jobs to Utah's economy.

Teacher's Corner

Earth Science Week Activities at the Utah Geological Survey Cancelled This Year.

The bad news:

The Utah Geological Survey (UGS) cancelled this year's Earth Science Week activities due to building construction at the Utah Core Research Center.

The good news:

The UGS conducted "Rocks of the Wasatch Range" presentations at the Utah State Fair that several school groups were able to attend.

In 2009, Earth Science Week will be celebrated nation-wide October 11–17. The UGS will announce details of the planned activities in Utah at a later date.

GLAD YOU ASKED:

GLACIAL STRIATIONS AND SLICKENSIDES

What are those groovy rocks and how did they get that way?

By Carole McCalla

On a hike around Lake Blanche below Sundial Peak in Big Cottonwood Canyon, a group of hikers came across long, straight, parallel grooves on a smooth, polished rock surface. Recalling another location where they had seen similar features at the foot of the mountains north of downtown Salt Lake City, they wondered if these markings were formed in the same way. Indeed, what exactly are they and how were they formed?

Although the smooth, grooved surfaces at these two locations are similar, they were actually formed in very different ways. The polished surfaces with parallel lines and grooves seen at Lake Blanche were formed by ice movement; the lines and grooves are known as glacial striations. The similar surfaces visible at the base of the mountains resulted from movement of the Wasatch fault; the surfaces are called slickensides, and the lines on these rocks are known as slickenlines.

Glacial striations are a series of long, straight, parallel lines or grooves scratched onto a bedrock surface by rock fragments lodged in the base of a moving glacier. They typically form on hard rock, such as quartzite, that is relatively resistant to erosion. Other types of softer rock do not preserve striations and polished surfaces as well. The orientation of the scratches is parallel to the direction of ice movement. Approximately 30,000 to 10,000 years ago, during the last Ice Age, the area around Lake Blanche was covered by a glacier. In fact, glaciers were present in most of Utah's high mountains at that time. As the glaciers moved, they scoured the rocks beneath, leaving behind the polished surfaces and striations that can be seen today.

Slickensides are smooth rock surfaces with parallel grooves or scratches commonly formed by frictional wear during sliding and movement along a fault. The rock surfaces recalled by the hikers are slickensides formed by the Wasatch fault and are located at Beck Street and 1300 North in northern Salt Lake County. The parallel grooves and scratches (slickenlines) typically align parallel to the direction of slip along the fault.

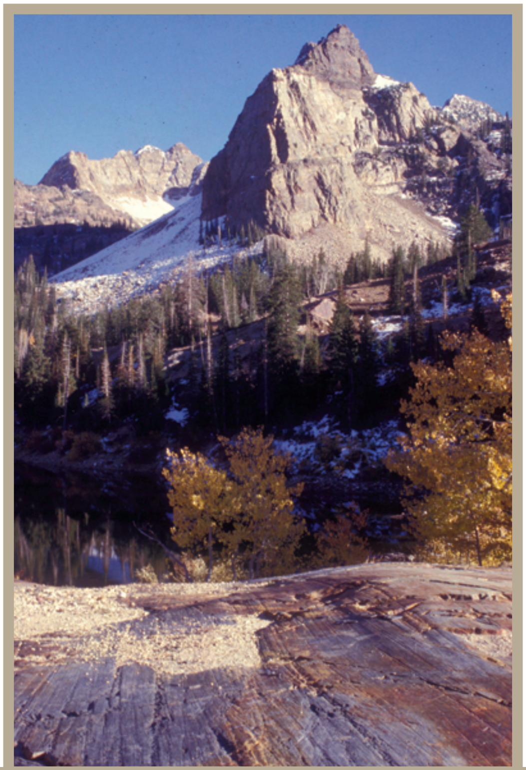
Where else can glacial striations and slickensides be found in Utah?

Glacial striations can also be seen around Secret (Cecret) Lake in Albion Basin at the top of Little Cottonwood Canyon, as well as in the Uinta Mountains of northeastern Utah. Both areas were covered by glaciers during the last Ice Age.

Slickensides are visible at several locations along the Wasatch fault, which extends from north of the Utah-Idaho border south to Fayette, Utah. At select locations along the Wasatch Front, the Wasatch fault has exposed rock outcrops of several feet to hundreds of feet high. Polished surfaces, parallel groove marks, and rough scratches may be present on these rock surfaces. These marks are a result of movement along the fault as the valley floor moves downward and the mountains move upward during large earthquakes.

In Utah County, a large exposure of slickensides on the Wasatch fault can be seen behind the Seven Peaks Resort near Brigham Young University. The slickensides have been raised from thousands of feet below the surface by fault movement and were exposed after site excavation for the Seven Peaks Resort.

Slickensides can be seen on other faults in Utah besides the Wasatch fault. In southern Utah, notable slickensides can be seen on the Hurricane fault in road cuts along U.S. Highway 9 in Washington County. In Grand County, slickensides can be seen on the Moab fault near Arches National Park.



Ice-polished rock and glacial striations (foreground) near Lake Blanche and Sundial Peak in Big Cottonwood Canyon, Salt Lake County.

Slickensides on the Hurricane fault along U.S. Highway 9 between La Verkin and Virgin, Utah. Note large grooves in close-up.

Utah Energy and Mineral Statistics Web Site—Utah's Comprehensive Source for Historical Energy and Mineral Data

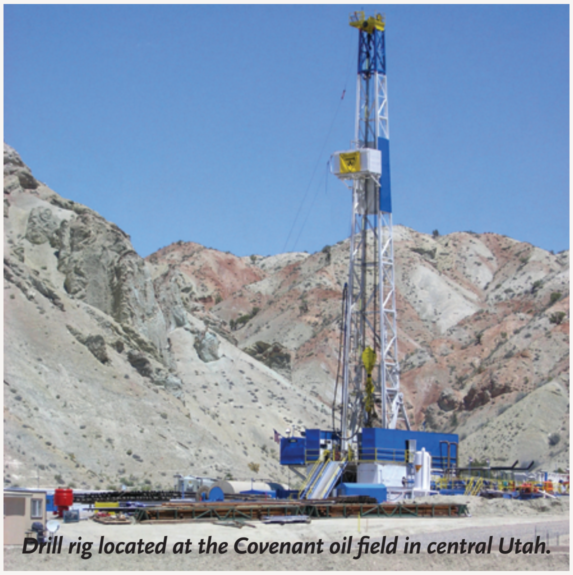
By Michael Vanden Berg

Have you ever wondered how much crude oil, natural gas, and coal is produced in Utah? How does Utah's residential price of natural gas compare to other states? How much of Utah's electricity is from renewable resources? The answers to these questions and more can be found in the tables of the Utah Geological Survey's *Utah Energy and Mineral Statistics* Web site (geology.utah.gov/sep/energydata).

Utah Energy and Mineral Statistics is a Web-based repository for energy and mineral data for the state of Utah. It contains over 130 tables and 50 figures in nine different chapters. Each chapter is separated into several categories including reserves, production, consumption, and prices. Most tables contain historical numbers dating back to 1960, and the tables are regularly updated as new data become available. These data have been used by government offices, research institutes, and private industry to calculate everything from state budgets to greenhouse gas emissions. Chapters include:

- Chapter 1: Overview of U.S. and Utah Energy Trends
- Chapter 2: Coal
- Chapter 3: Crude Oil and Petroleum Products
- Chapter 4: Natural Gas
- Chapter 5: Electricity
- Chapter 6: Renewable Resources
- Chapter 7: Heating/Cooling Degree Days
- Chapter 8: Greenhouse Gas Emissions
- Chapter 9: Industrial Minerals and Metals

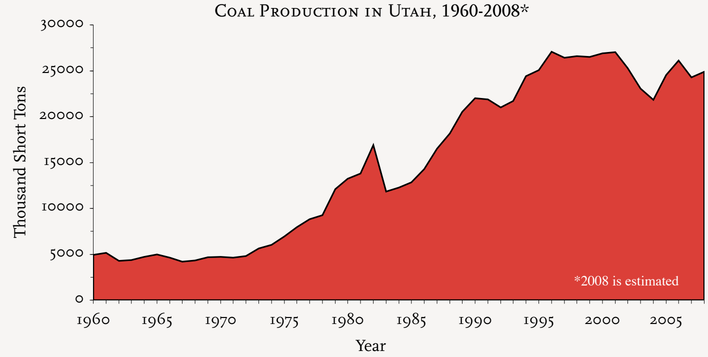

Longwall machine used to mine coal.


Drill rig located at the Covenant oil field in central Utah.

HIGHLIGHTS

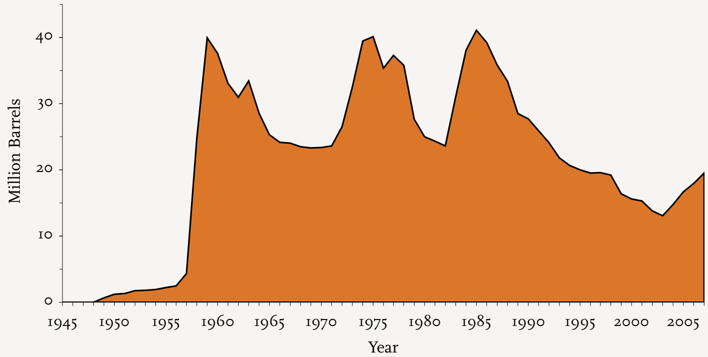
In 2008, Utah will produce its 1 billionth ton of coal (Chapter 2, table 2.10).

Coal Production in Utah, 1960-2008*

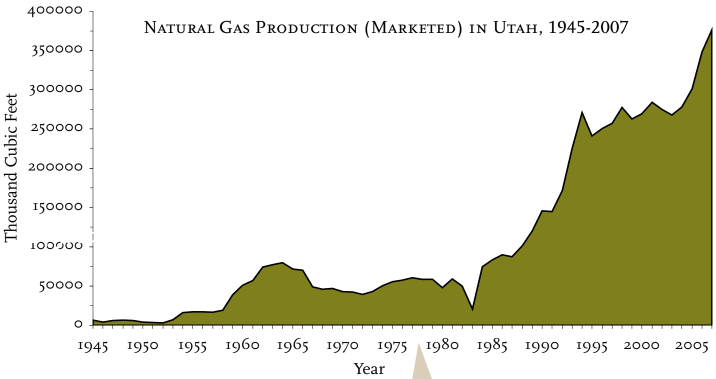


Utah has experienced three oil booms in the past 60 years and appears to be heading into a fourth (Chapter 3, table 3.7).

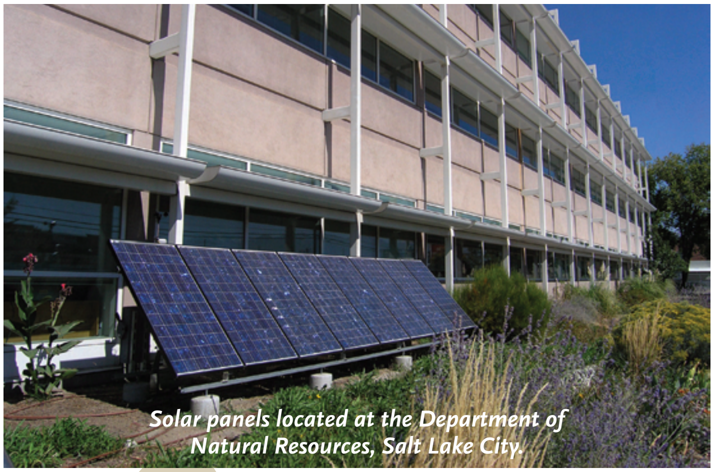
Crude Oil Production in Utah, 1945-2007



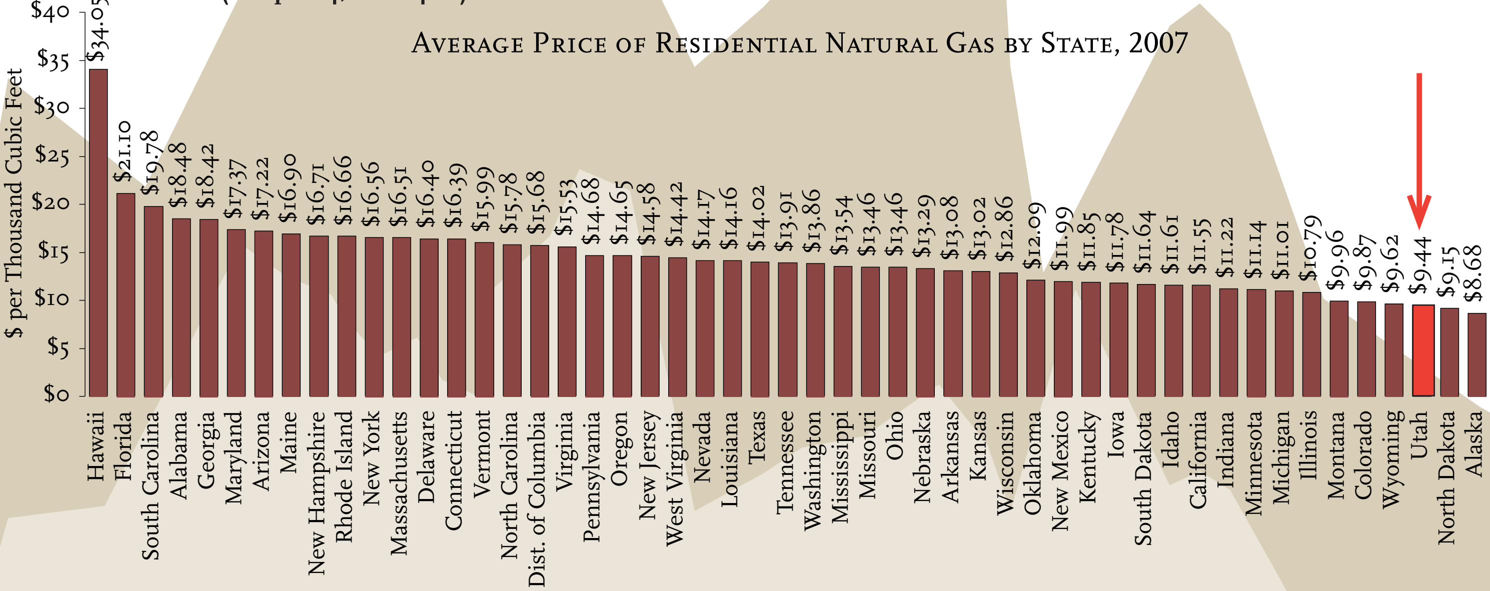
Marketed production natural gas in Utah reached an all-time high of 376 million cubic feet in 2007 (Chapter 4, table 4.5).



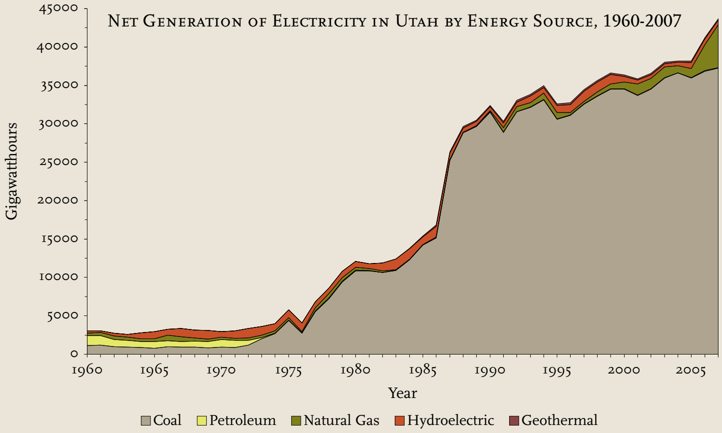
Renewable energy sources makeup 2.3 percent of Utah's electricity generation (Chapter 6, table 6.1).


Solar panels located at the Department of Natural Resources, Salt Lake City.

Utah's average price of residential natural gas in 2007 was only $9.44 per thousand cubic feet, the third lowest in the nation (Chapter 4, table 4.18).

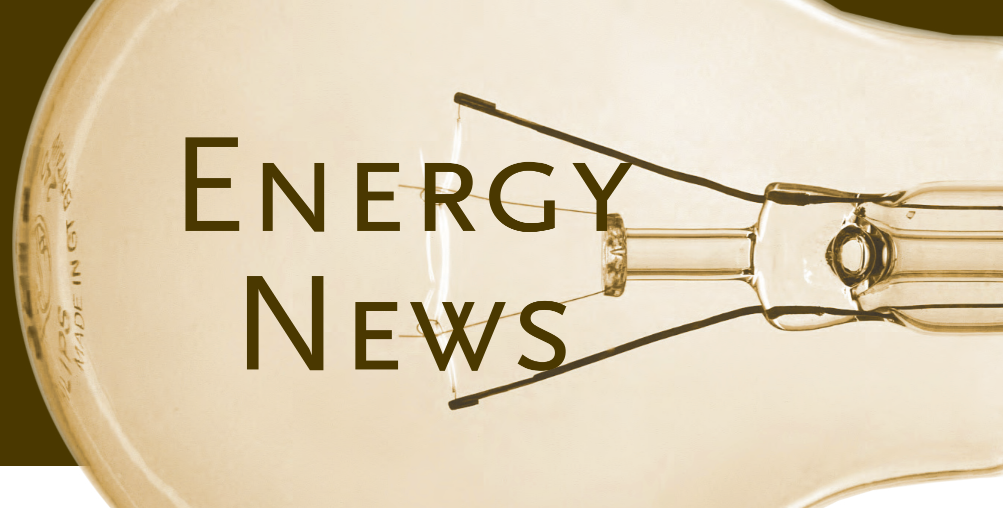


In 2007, 85 percent of the electricity generated in Utah was from coal-burning power plants, down from 95 percent in 2005 as more natural gas-fired power plants were built (Chapter 5, table 5.10).



Utah's first wind farm, located at the mouth of Spanish Fork Canyon, began generating electricity in the fall of 2008 (Chapter 6, table 6.7).


Spanish Fork wind farm.



Energy News

Utah's Energy Renaissance: Geothermal Energy Development in Utah

by Jason Berry

Images of geothermal energy in the West typically conjure up visions of the famous geysers and bubbling mudpots of Yellowstone National Park; but, like most states in the western United States, Utah has its own geothermal resources. In fact, Utah's geothermal potential for electricity production is one of the best in the nation, ranking behind only California, Nevada, and Oregon. A study by the Western Governors Association estimates Utah's 20-year geothermal energy development potential at 620 megawatts (MW) of generating capacity, which would be approximately 12 percent of Utah's estimated electrical energy consumption in 2026.

Even before Europeans explored the area, Utah's geothermal resources had been in use for centuries. Native Americans used geothermal hot springs for washing and bathing and as a heat source during the winter months. When Mormon pioneers settled in Utah in the mid-1800s, among the first proprietorships established were geothermal bath houses, which were located throughout Utah. Wasatch Warm Springs in Salt Lake City, Castilla Hot Springs in Spanish Fork Canyon, and Pah Tempe Hot Springs in La Verkin are but a few examples of hot springs used throughout Utah by Native Americans, European explorers, and Mormon pioneers alike. Many hot springs are still being used today.

Decades later, a renaissance is occurring in the development of Utah's geothermal resources. Drilling and energy-generating technologies have advanced and developed to allow us to drill deep—often miles—into the state's geothermal hot spots to explore their potential for extracting the heat resource (200–500 degrees Fahrenheit) and to convert that heat to useful electrical energy.

Utah's First Geothermal Power Plant

Utah's first geothermal power plant was developed at Roosevelt Hot Springs, in Beaver County, approximately 10 miles northeast of Milford. Phillips Petroleum and Utah Power & Light (now owned by PacifiCorp) explored the area and built the Blundell Geothermal Power Plant in 1984. What was once a small hot spring used by cattlemen and miners for bathing, laundry, and swimming started to generate enough electricity (24 MW) to power approximately 23,000 homes.

In 2007 PacifiCorp, with the help of new technology, added a new generating unit that extracts additional power out of the geothermal resource for an additional 10 MW (approximately 10,000 homes) of clean and renewable electrical energy. PacifiCorp is currently drilling additional exploratory holes with the intent to double the generating capacity of Blundell to 72 MW within the next three to four years.

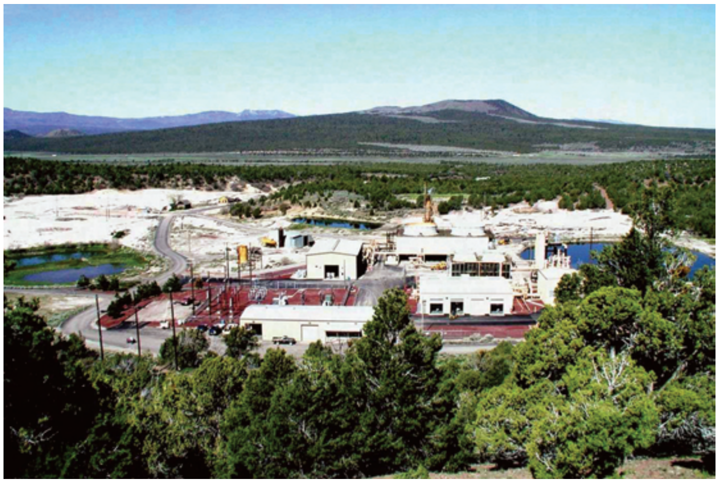
Birth, Death, and Revival

Surrounding historical Cove Fort and Sulphurdale, Utah, is the Cove Fort–Sulphurdale Known Geothermal Resource Area (KGRA), located in Millard and Beaver Counties in south-central Utah. Geothermal exploration in the Cove Fort–Sulphurdale KGRA started in 1974 and continued through 1985 when Mother Earth Industries, Inc., developed a small 1.5 MW power plant. Named the Bonnett Power Plant, second and third phase development raised its capacity to 10 MW by 1990. In 1992 the plant was sold to the City of Provo and Utah Municipal Power Authority (UMPA), which provided power to five Utah cities. In 2003, due to operation and maintenance issues, the Bonnett plant was shut down. Since then, plant ownership changed hands several times, but the plant remained inoperative. Most recently, Enel North America, Inc., purchased the Bonnett plant and leased several thousand acres of U.S. Forest Service property. Enel plans to develop approximately 26 MW of capacity that will be operational by 2011.

Old Exploration and New Developments

In the fall of 1776, Fathers Escalante and Dominguez rode west out of an encampment near present-day Cedar City in search of a route to Monterey, California. They unfortunately encountered fierce, cold, and blowing winds that forced them to turn south back to Mexico. But along the way, the expedition discovered what is now called Thermo Hot Springs in Escalante Valley. More than two centuries later, geothermal developers have drilled a 7,000-foot hole in the heart of Escalante Valley. Due to

The Blundell Power Plant, owned by PacifiCorp Energy, has a 34 megawatt generating capacity. The plant is located approximately 10 miles northeast of Milford, Utah.



The Bonnett Power Plant was one of two geothermal power plants operating in Utah. The Bonnett plant has been dismantled and the new owner, Enel, Inc., will be developing a new power plant, proposed to be on-line by 2011.

Raser Technologies Inc. broke ground at the Thermo Hot Springs site in early spring. The plant should be generating electricity by fall 2008.

its remoteness, the area had not been developed until this year. A geothermal developer, Raser Technologies, Inc., has been drilling production and resource injection holes and plans to have a power plant on-line by October 2008. This 10 MW power plant will use new generating technology that is basically a plug-and-play system. Instead of one big generator, the power plant will consist of 35 smaller generators. This smaller, more modular design will allow development of the plant at a faster rate than a traditional geothermal power plant. Raser has plans for two other power plants in Utah that are similar in size. To carry out their business model, Raser has obtained over 100,000 acres of Bureau of Land Management and private land leases in Utah for current and future developments.

While the development of Utah's geothermal resources is indeed growing, the geothermal renaissance in Utah is not unique to the state; geothermal energy has risen in popularity worldwide for its constant generating potential (other renewables such as solar and wind are intermittent resources) and for being a clean and renewable energy resource. With growing domestic power needs and increased demand for clean and renewable energy in the western United States, Utah is bound to be a leader in geothermal development for decades to come. The potential is right under our feet.

The following Web site provides additional information on geothermal resources in Utah: http://geology.utah.gov/emp/geothermal/index.htm.

SURVEY NEWS

2008 CRAWFORD AWARD

Greg McDonald, Rich Giraud, Ashley Elliott, Lucas Shaw, Francis Ashland, and Gary Christenson.

The 2008 Crawford Award was presented to the Geologic Hazards Program landslide team of Francis Ashland, Greg McDonald, Ashley Elliott, Rich Giraud, Lucas Shaw, and Gary Christenson (retired) for their combined work on landslides and landslide hazards throughout Utah over the past two years. This team has published several landslide reports for both technical and general audiences, used innovative methods to create a landslide susceptibility map of Utah, maintained an informative and up-to-date Web page on landslide hazards in Utah, and helped the Governor's Geologic Hazards Working Group create recommendations to address a variety of geologic hazards in Utah. Collectively, this team is at the forefront of landslide investigations and is deserving of praise for their efforts to disseminate information to consultants, local officials, and homeowners in Utah.

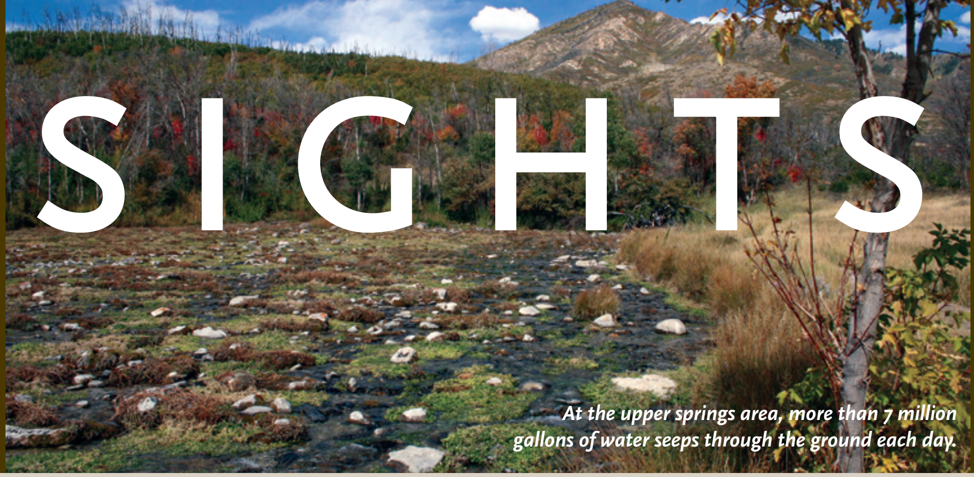
The Crawford Award was established in 1999 to commemorate the 50-year anniversary of the Utah Geological Survey. The award recognizes outstanding achievement, accomplishments, or contributions by current UGS scientists to the understanding of some aspect of Utah geology or earth science. The award is named in honor of Arthur L. Crawford, first director of the UGS.

more Survey News on page 13

GEO SIGHTS

Cascade Springs, Wasatch County

By Christine Wilkerson



At the upper springs area, more than 7 million gallons of water seeps through the ground each day.

Springs Information:

Cascade Springs is a refreshing oasis of lush vegetation, inviting pools, and cascading waterfalls located within the Uinta National Forest in the Wasatch Range, east of American Fork Canyon and west of Wasatch Mountain State Park. Water from the springs flows over a series of travertine terraces and pools and eventually continues on its way to nearby Provo Deer Creek. A variety of mammals and birds make their way here, including otters, beavers, deer, moose, elk, wild turkeys, hawks, hummingbirds, and numerous songbirds.

A trail system of paved paths, raised boardwalks, and wooden bridges consists of three interconnecting loops, permitting visitors a choice of walking only a short distance or completing all three loops for a longer walk. Benches are provided along the walkways, allowing for rest and taking in the beauty of the surroundings. Interpretive signs present educational information about Cascade Springs' geology, water cycle, wildlife, and plant life.

The lower pools loop is the most popular section with its easily accessible pathways and soothingly cool woods. It is very relaxing to walk along the maze-like configuration of boardwalks raised over shallow, crystal clear pools and waterfalls, surrounded by a variety of trees and flowering plants. These pools contain abundant brown trout (no fishing allowed) believed to have originally migrated from the Provo River.

The middle cascade loop begins at a wooden bridge situated over a waterfall with trails continuing up the slope on either side of the cascading falls. The rushing streams along these trails feed the lower pools.

The spring water flows out of the ground within the center of the upper springs loop. This pathway is also the best place to see new plant growth and the recovery of the landscape from a 2003 prescribed burn in the area that escaped containment lines. Thankfully the structures and most of the signs at Cascade Springs were not damaged by the fire.

Geologic Information:

The area around Cascade Springs is underlain by coarse-grained glacial sediment deposited when glaciers covered high elevations of the Wasatch Range approximately 30,000 to 10,000 years ago. Beneath the glacial deposits, bedrock consists of Cambrian-age (about 500 million years old) quartzite, shale, sandstone, and limestone. These rocks were transported eastward 30 to 50 miles during low-angle faulting on the Charleston-Nebo thrust fault around 80 million years ago. As a result of the faulting, the bedrock in the vicinity of the springs is tilted and highly fractured.

Spring water cascading toward the lower pools.

How to get there:

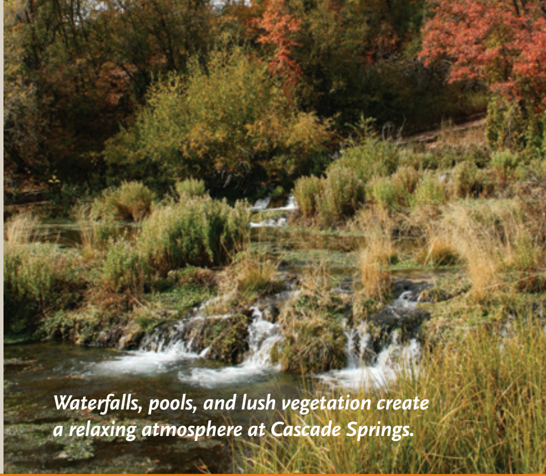
From I-15 in Utah Valley, take the Highland/Alpine exit (Exit 284). Travel east for about 8 miles on State Route 92 to the Forest Service entrance station ($6.00 fee). Continue up American Fork Canyon on SR-92 (Alpine Loop Scenic Byway) for about 17 miles until you reach Cascade Scenic Drive. Turn to the northeast (left) and travel about 6 1/2 miles to the Cascade Springs lower parking lot.

Alternative route from the east through Wasatch Mountain State Park: In the town of Midway, travel west on Main Street. Turn south (left) on Center Street/State Route 113 and drive about 1 mile to 970 South Street. Turn west (right) on 970 South for 1/2 mile to Stringtown Road. Turn south (left) and travel another 1/2 mile; turn west (right) onto Cascade Springs Drive. Continue for about 8 miles to the Cascade Springs lower parking lot.

Note: Cascade Springs may be seasonally closed.

More than 7 million gallons of water flows through Cascade Springs each day. The original source of this water is rain and snow falling on the Wasatch Range. Precipitation that does not end up in streams, evaporate, or get used by plants infiltrates slowly downward along bedrock fractures to become ground water. Ground water passes through the tilted rock layers until it encounters an impermeable layer, which redirects the water upward toward the surface where it seeps through the thin layer of glacial deposits.

As the water moves underground, it dissolves calcium carbonate from rocks such as limestone and dolomite. After reaching the surface, the water cascades over the terraces and releases carbon dioxide gas, which changes the water chemistry and allows calcium carbonate to be precipitated forming travertine, a finely crystalline limestone. The terraces around the pools are slowly but continually changing shape as new travertine is formed.



Waterfalls, pools, and lush vegetation create a relaxing atmosphere at Cascade Springs.

New Publications

Geologic map of the Kanab 30'x60' quadrangle, Kane and Washington Counties, Utah, and Coconino and Mohave Counties, Arizona, compiled by H.H. Doelling, CD (2 pl., scale 1:100,000 [contains GIS data]), ISBN 1-55791-795-7, **MP-08-2DM . $24.95**

Geographic Information System database showing geologic-hazard special-study areas, Wasatch Front, Utah, by Gary E. Christenson and Lucas M. Shaw, CD (7 p. [contains GIS data]), ISBN 55791-800-7, **C-106 .... $24.95**

Annual review and forecast of Utah coal production and distribution—2007, prepared by Michael D. Vanden Berg, 42 p., ISBN 1-55791-801-5, **C-107 .... $12.95**

Interim geologic map of the southwest (Utah Valley) part of the Springville quadrangle, Utah County, Utah, by Barry J. Solomon and Michael N. Machette, 1 pl., 33 p., **OFR-524 .... $8.00**

Interim geologic map of the Lincoln Point quadrangle, Utah County, Utah, by Barry J. Solomon and Robert F. Biek, 1 pl., 31 p., **OFR-526 .... $8.00**

Interim geologic map of the Provo 7.5' quadrangle, Utah County, Utah, by Barry J. Solomon and Michael N. Machette, 1 pl., 31 p., **OFR-525....................................... $8.00**

Geologic map of the Smoky Mountain 30' x 60' quadrangle, Kane and San Juan Counties, Utah, and Coconino County, Arizona, by Hellmut H. Doelling and Grant C. Willis, 2 pl., 1:100,000 (contains GIS data), ISBN 1-55791-766-3 **M-213DM.. $24.95**

Paleoseismology of Utah, Volume 17: Paleoseismic investigation of the northern strand of the Nephi segment of the Wasatch fault zone at Santaquin, Utah, by Christopher B. DuRoss, Greg N. McDonald, and William R. Lund, CD (30 p. + 3 p. appendix, 1 pl.), ISBN 1-55791-789-2, **SS-124 .... $14.95**

Geologic map of the Tickville Spring quadrangle, Salt Lake and Utah Counties, Utah, by Robert F. Biek, Barry J. Solomon, Jeffrey D. Keith, and Tracy W. Smith, CD (2 pl., scale 1:24,000 [contains GIS data]), ISBN 1-55791-794-9, **M-214DM..... $24.95**

Geologic map of the Virgin quadrangle, Washington County, Utah, by Janice M. Hayden and Edward G. Sable, CD (2 pl., 1:24,000), ISBN 1-55791-796-5, **M-231 .... $19.95**

Geologic map of the Richfield 30' x 60' quadrangle, southeast Millard County and parts of Beaver, Piute, and Sevier Counties, Utah, by L.F. Hintze, F.D. Davis, P.D. Rowley, C.G. Cunningham, T.A. Steven, and G.C. Willis, CD (1 pl., 1:100,000 [contains GIS data]), ISBN 1-55791-785-X, **M-195DM....................................... $24.95**

Reservoir characterization of the Cretaceous Cedar Mountain and Dakota Formations, southern Uinta Basin: Year-two report, by Mary L. McPherson, Brian S. Currie, Joshua P. Dark, and Justin S. Pierson, CD (67 p. + 39 p. appendices, 4 pl.), **OFR-516 ... $19.95**

Geologic and hydrologic characterization of the Dakota-Burro Canyon aquifer near Blanding, San Juan County, Utah, by Stephan Kirby, CD (48 p., 4 pl.), ISBN 1-55791-788-4, **SS-123...................... $19.95**

Reconnaissance of the Little Valley landslide, Draper, Utah: Evidence for possible late Holocene, earthquake-induced reactivation of a large, pre-existing landslide, by Francis X. Ashland, 17 p., **OFR-520 .... $7.95**

Reconnaissance of the Draper Heights landslide and other possible earthquake-induced, shallow, disrupted soil and rock slides in Draper, Utah, by Francis X. Ashland, 11 p., **OFR-519.................... $7.95**

Reconnaissance of the Grandview peak rock slide, Salt Lake County, Utah: A possible earthquake-induced landslide?, by Francis X. Ashland and Greg N. McDonald, 13 p., **OFR-518 .... $7.95**

Survey News, continued

Utah Core Research Center Improvements

Major construction is underway at the Utah Core Research Center in response to increasing industry and university demand for workshops and research access to the oil-well core and mineral collection. Improvements include a larger classroom space for meetings and workshops, a digital imaging lab, a microscope examination room, and new office space for visiting scientists and researchers. Other upgrades are radiant heaters in the core examination area, a water-well cuttings lab, new storage space and sinks, and a much-needed second restroom!

Employee News

Elise Brown has joined the State Energy Program as the Renewable Energy Coordinator. Elise received her M.S. in Natural Resource Management from James Cook University, Townsville, Australia.

Ashley Elliott and **Jessica Castleton** have accepted positions with the Geologic Hazards Program and will be working on the new Geologic Hazards Mapping Initiative. Ashley has a B.S. in geology from Utah Valley University, and Jessica received a B.S. in Applied Environmental Sciences from Weber State University.

Scott Madsen has joined the Ground Water and Paleontology Program. He comes to us from Dinosaur National Monument where he worked as a geologist/preparer for 23 years. Scott previously worked at the Museum of Northern Arizona and the American Museum of Natural History in New York City, and is one of the nation's top fossil preparers.

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Survey Notes

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