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Bingham Canyon Open-Pit Copper Mine

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Cover: Bingham Canyon open-pit copper mine in 2003, view looking to the southwest. Photograph courtesy of Kennecott Utah Copper Corporation, all rights reserved.

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THE DIRECTOR'S PERSPECTIVE

by Richard G. Allis

The feature article in this issue highlights the century of copper mining at Bingham Canyon. Prior to about 1905, porphyry copper ore was regarded as worthless by engineers because of its low grade (less than 40 pounds of copper per ton of ore). However, partly as a result of the vision of Daniel Jackling, a metallurgical engineer, the development of large-scale open-pit mining, ore crushing, concentration (by flotation), and smelting facilities began near Bingham Canyon in 1905. By June 1907, the world's first copper produced from a porphyry copper deposit was shipped from the facility. One hundred years later, the mine has produced 19 million tons of copper along with significant molybdenum, gold, and silver. The total gross value of that production is estimated to be more than $100 billion in today's dollars, and Bingham Canyon has become the richest mine in U.S. history. The important role of Daniel Jackling was recognized by the state in 1954 when his statue was unveiled in the rotunda of the Capitol, and it still resides there today. Substantial metal resources remain at Bingham Canyon. Kennecott reports reserves of another 3.2 million tons of copper, 0.2 million tons of molybdenum, and 4 million ounces of gold, which at today's prices could mean an additional $30 billion in production value in future decades.

Another article discusses the UGS role in a Department of Energy-funded project studying the fate of carbon dioxide injection in Aneth oil field, southeast Utah. Although the primary goal of the operator (Resolute Energy Company in partnership with Navajo Oil and Gas Company) is to enhance oil recovery from this mature field, our role is to help determine the fate of the injected CO_2. Will most of the CO_2 remain trapped within the reservoir, and how effective are the low-permeability sealing rocks over the top of the reservoir?

The interest in geologic sequestration of carbon dioxide is growing in importance both nationally and internationally as scientific opinion hardens on the link between human-related increases in greenhouse gas concentrations in the atmosphere and global warming. The layer-cake stratigraphy, structural simplicity, and lack of faults within the Colorado Plateau make this province an ideal region for sequestering large volumes of CO_2. However, the volumes of CO_2 that need to be captured and injected to make a major impact on total emissions in the U.S. are immense, and beyond the scope of one region to handle. A recent study on the future of coal as an energy source[1] points out that if 60% of the CO_2 produced from coal-fired electricity in this country were to be captured and compressed into a liquid for geologic sequestration, the volume would be equal to the national rate of oil consumption (20 million barrels per day). Although the U.S. is the world's largest emitter of CO_2 today, within the next decade it will be surpassed by China, which is currently constructing the equivalent of one 1000 MW coal-fired power plant each week[1]. Stabilizing atmospheric CO_2 concentrations will require global solutions. These issues are important for Utah because 95% of our electricity is coal-fired, and our electricity demand is growing at one of the highest rates in the country (2.5% per year). The trend is for future coal-fired generation to be Integrated Gasification and Combined Cycle (IGCC) plants[2], which make it feasible to capture most of the CO_2. Local geologic sequestration of that CO_2 is therefore important, and the UGS is helping address some of the challenges associated with this new technology.

[1]*Massachusetts Institute of Technology, 2007, The future of coal – an interdisciplinary MIT study: Online, http://web.mit.edu/coal*
[2]*Metz, B., Davidson, O., deConinck, H., Loos, M., and Meyer, L., editors, 2005, Carbon dioxide capture and storage: Online, IPCC Special Report, http://www.ipcc.ch/pub/online.htm*

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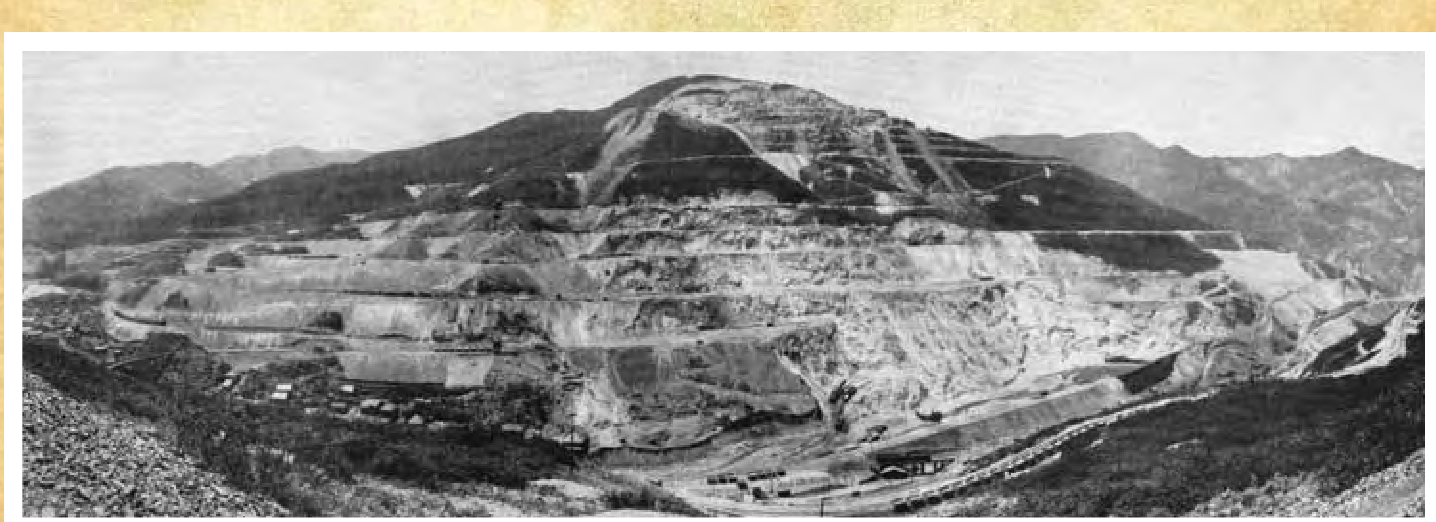
RACE TO ORE: THE BEGINNINGS OF OPEN-PIT COPPER MINING
A CENTURY OF OPEN-PIT MINING AT BINGHAM CANYON

by Ken Krahulec

This year the Bingham copper mine will mark 100 years since its beginnings as the first open-pit copper mine. Today, the mine at Bingham Canyon, located southwest of Salt Lake City on the east flank of the Oquirrh Mountains, is one of the largest and most efficient mines in the world. During the late 1800s, however, metal mining was an entirely different industry. Back then, high-grade ores were mined on a small scale by underground methods. Mining was labor intensive, often hazardous, and back-breaking work. The underground workings were dark, and lighting was by candles or small oil lamps whose weak flames were hampered by the smoke and gas from the black-powder explosions. Many of the deeper mines were wet, and safety was entirely the responsibility of the worker. Transportation of ore was by small mule-powered trams underground and then by six-horse team wagons on the surface to the nearest railhead or smelter.



Top: Underground miners at work with an early machine drill, probably in the early 1900s. Photograph courtesy of Kennecott Utah Copper Corporation, all rights reserved. Bottom: View of the "Hill," site of the early Bingham Canyon open-pit copper mine operations, in 1908. The view is to the southwest with the Utah Copper mine in the foreground at the base of the "Hill" and the Boston Consolidated mine workings at the top of the "Hill." Photograph from U.S. Geological Survey Professional Paper 111, Plate XXXVI.

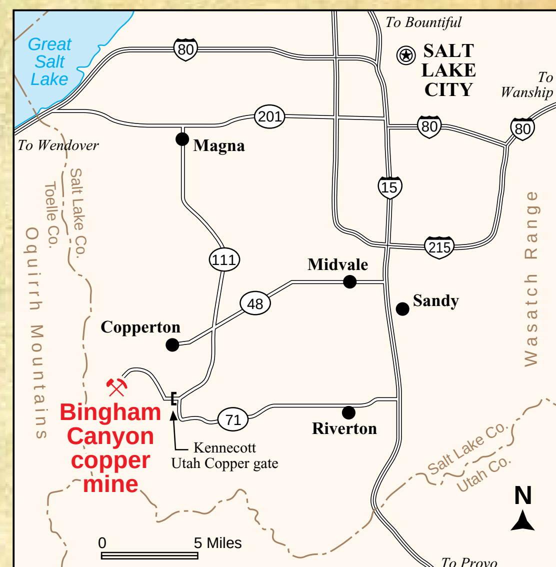
Early open-pit copper ore mining operations at the Utah Copper mine about 1910. Photograph used with permission of the Utah State Historical Society, all rights reserved.

Bingham Canyon's lasting fame in mining history is a result of being the first district to apply large-scale open-pit mining and economical mechanical processing to low-grade copper ores. In the early 1900s, two adjoining mines at Bingham Canyon—Utah Copper and Boston Consolidated—initiated the use of mechanization in the mines, mills, and smelters to achieve economies of scale.

The Boston Consolidated Copper & Gold Mining Company, Ltd., was organized in London in 1898 by Samuel Newhouse to develop a high-grade, copper-gold ore body up the Carr Fork of Bingham Canyon. The property lay near the Highland Boy mine which Newhouse had successfully developed in the late 1890s and then sold to eastern capitalists. Newhouse acquired a couple of claims known as the Steward mine in an attempt to repeat his earlier success, but was informed by his Boston associates that the 27-acre property was too small to support a substantial stock promotion. Newhouse cabled associates in Utah to acquire all the available open, unclaimed ground between the Stewart claims and Enos Wall's ground to the northeast. This added over 300 acres, much of it covering a hill of barren-looking leached monzonite (granitic rock), but adding plenty of property for the planned stock promotion. In a stunning stroke of luck, this ground turned out to cover much of the Bingham Canyon copper ore body.

Enos Wall, another successful mine developer, had been acquiring ground up the main fork of Bingham Canyon since 1887. He had recognized the low-grade, copper oxide mineralization streaking the leached monzonite in the canyon walls and had gradually built up a 220-acre block of mining claims covering the weakly mineralized ground. Wall had offered his property to many of the prominent mine developers of the day and had seen some interest, but no important development work had been done on the prospect. Finally, in 1903, Daniel Jackling acquired the Wall property for mining financiers Spencer Penrose and Charles MacNeill. Jackling, a young metallurgist, was rewarded with a job as general manager and a five percent interest in the promotion that became the Utah Copper Company.

The adjoining Utah Copper and Boston Consolidated claim blocks covered literally a mountain of low-grade copper ore. Boston Consolidated initially started development on a small, high-grade underground operation at the Stewart mine. Utah Copper started bulk mining the low-grade copper ore from the monzonite in the bottom of the canyon in 1904 by underground block caving methods. However, both companies soon began plans for large-scale, open-pit operations using rail-mounted steam shovels to mine the ore and trains to ship it 20 miles to huge concentrating mills at the north end of the Oquirrh Mountains.



The new Bingham Canyon Mine Visitors Center is open from April through October, 8:00 a.m. to 8:00 p.m., seven days a week. The visitor entrance is at about 12800 South on Utah Highway 111 (approximately 8100 West). Entrance fees are $5 per vehicle and Visitors Center information and directions are available at (801) 252-3234.

The enormous capital requirements of the massive Utah Copper development envisioned by Jackling exceeded the wherewithal of Penrose and MacNeill, who were forced to look for additional financing. Ultimately they contacted Guggenheim Exploration Company and, after an unprecedentedly extensive and detailed study of the project, Guggenheim Exploration became its new principal financial backer. Guggenheim Exploration installed a new managing director and three of the Guggenheim brothers became directors, but MacNeill remained as president, Penrose as secretary and treasurer, and Daniel Jackling as general manager.

The two companies each built huge new concentrators on adjoining property at the north end of the range. In addition, Utah Copper built the Bingham & Garfield Railway from the mine to the mills and constructed a power plant nearby. American Smelting & Refining Company, another Guggenheim-backed company, agreed to build a large smelter to process the copper concentrate from the two mills. Moreover, the three companies joined together to build the company town of Garfield near the mills and smelter.

The steam shovel stripping operations began in June 1906 at Boston Consolidated and in August 1906 at Utah Copper. However, due to a thinner leached cap in the bottom of the canyon and problems with an excessively high pyrite content on top of the mountain, Utah Copper began shipping copper ore from the open-pit first in June 1907, followed by Boston Consolidated in January 1908.

Consolidation of the adjoining Utah Copper and Boston Consolidated properties was inevitable. A national financial crisis in the fall of 1907 followed by decreased copper demand put a severe fiscal strain on Boston Consolidated. In 1910, Utah Copper was recapitalized and merged with Newhouse's Boston Consolidated. Today, a century after the initial open-pit copper ore was shipped, Bingham Canyon remains one of the world's largest producers of copper along with by-product gold, molybdenum, and silver.

Ken Krahulec is a geologist in the UGS Energy and Minerals Program, principally concerned with the metallic mineral resources of Utah. He earned a Master's degree in geology and had over two decades of minerals industry experience across North America before joining the UGS in early 2005. His primary responsibilities at the UGS include surveying, cataloging, and publishing information on Utah's metal occurrences, prospects, mines, and districts. He is creating an ArcGIS geographic information system-based geodatabase focused on the exploration potential of Utah's metallic resources. In the past year and a half Ken has written papers or given presentations on gold, uranium, metal prices, Iron County, Piute County, Utah's mining industry, Ashbrook mining district, Bingham district, Stockton district, and Tintic district.

View (2005) of the Bingham Canyon open-pit copper mine from the crest of the Oquirrh Mountains, looking northeast.

GEOLOGICAL SEQUESTRATION OF CARBON DIOXIDE AND ENHANCED OIL RECOVERY

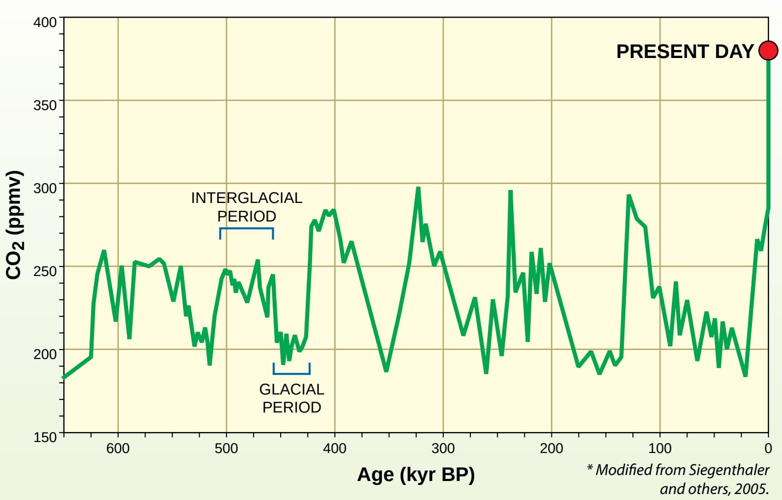
The Utah Geological Survey's Efforts To Reduce Global Warming While Increasing Oil Production

by Thomas C. Chidsey, Jr.

Global warming! It's in the news almost every day. Growing international scientific consensus highlights the need to understand and curtail global warming, and to mitigate potentially disastrous environmental change. The causes of global warming, whether natural or the result of human activity, are topics of considerable debate among scientists. Of current concern are the "greenhouse" gases in the atmosphere that prevent heat from escaping into space—the "greenhouse effect." Without it the Earth's surface would be too cool to support most life forms. The major greenhouse gas is carbon dioxide (CO_2). Carbon dioxide is not a hazardous substance but a naturally occurring component of the atmosphere (about 0.04%). Carbon dioxide is part of the carbon cycle—a natural balance between the carbon in the atmosphere, oceans, and the surface rocks and minerals. The carbon cycle has included natural variations in CO_2 and climate (for example, CO_2 in ice cores has varied with glacial periods over the past 600,000 years). However, unnatural buildup of CO_2 increases the greenhouse effect and threatens the equilibrium of the carbon cycle that has operated for millions of years. This ultimately leads to a rise in the average temperature of both the atmosphere and the Earth's land and sea surfaces—global warming and dramatic climate change.

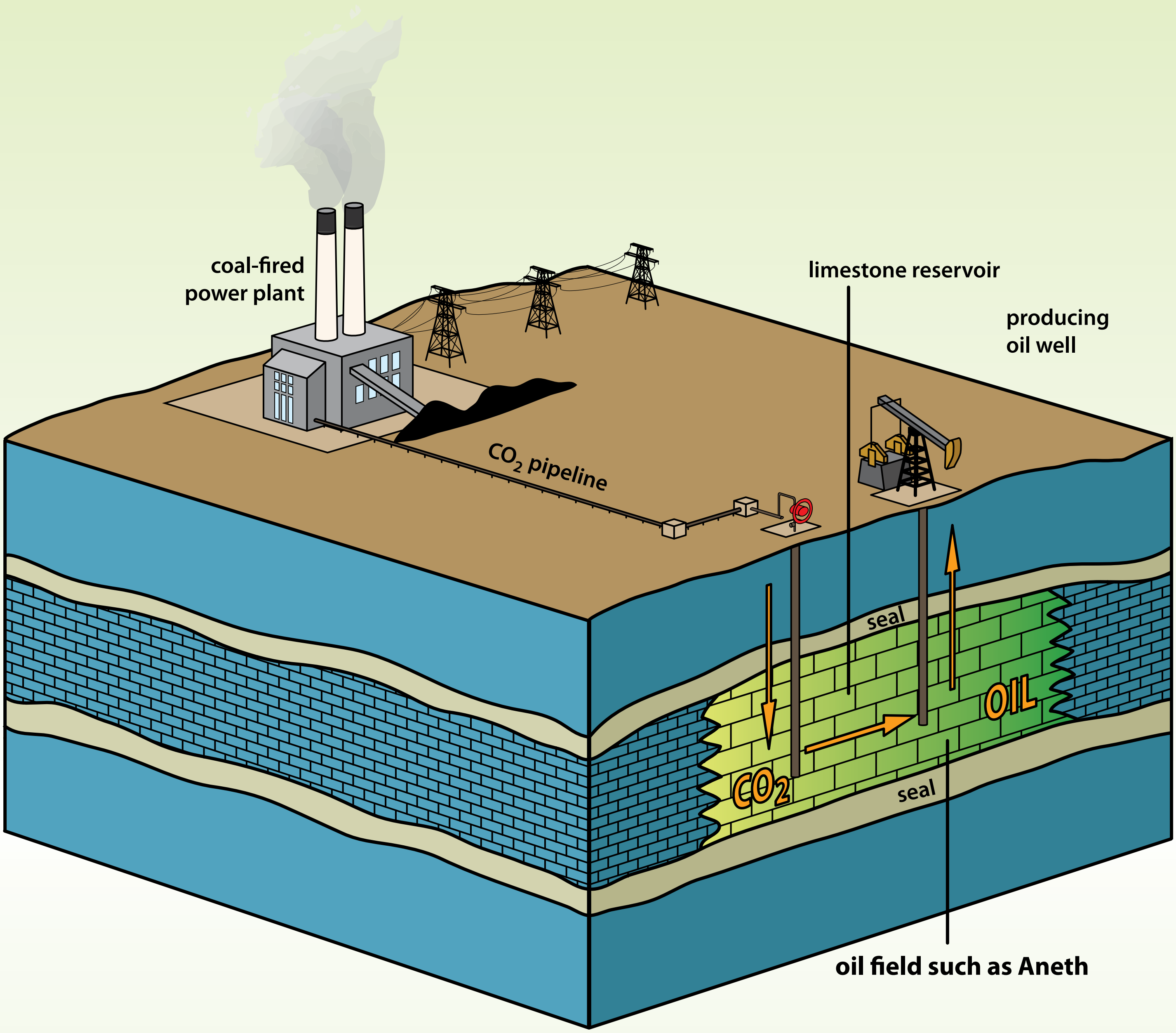
There is little argument that human activities (burning fossil fuels such as coal, oil, and gas) since the industrial revolution began in the 1700s have contributed at least somewhat to increased levels of CO_2 in the atmosphere. A major source of CO_2 emissions is coal-fired power plants. Those in Utah emit 33 to 45 million tons of CO_2 per year. Engineers are developing economic methods to remove and capture the CO_2 from the combustion exhaust at these sites. But what to do with all that CO_2 once it is captured? That is a problem the Utah Geological Survey (UGS) has been addressing through various studies over the past six years. These studies investigate how to permanently and safely store (sequester) CO_2 geologically. Our studies show CO_2 can be sequestered in (1) large folds of rock (anticlines like the San Rafael Swell), (2) coal beds, and (3) deep saline (salty) aquifers, especially near power plants.

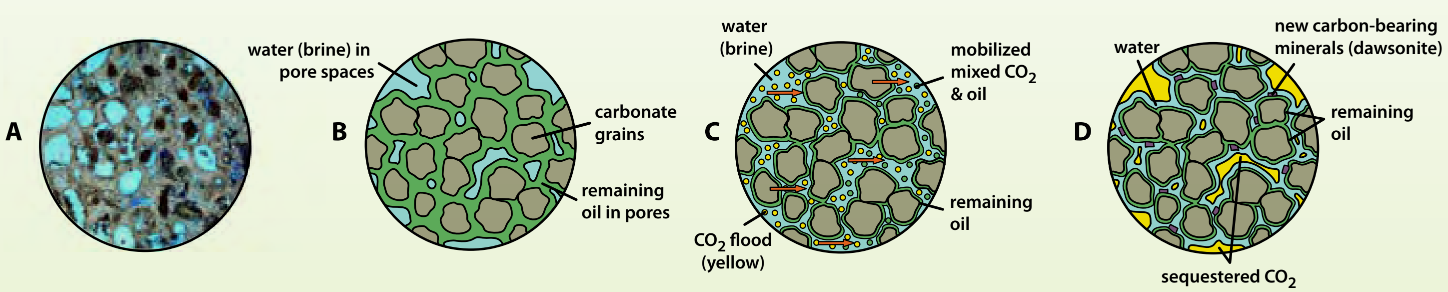
Carbon dioxide may also be sequestered in Utah's many matur-



CO_2 concentrations measured from Antarctic ice cores reflect the natural, varying levels of CO_2 in the atmosphere as the Earth has gone from glacial periods (low CO_2 concentration, ~180 ppm CO_2) to interglacial periods (~280 ppm CO_2) over the past 600,000 years. However, during the past 150 years, CO_2 has increased by 35 percent (100 ppm) above the typical levels for past interglacial periods.

Siegenthaler, U., Stocker, T., Monnin, E., Lüthi, D., Schwander, J., Stauffer, B., Raynaud, D., Barnola, J., Fischer, H., Masson-Delmotte, V., and Jouzel, J., 2005, Stable carbon cycle climate relationship during the late Pleistocene: Science, v. 310, p. 1313-1317.

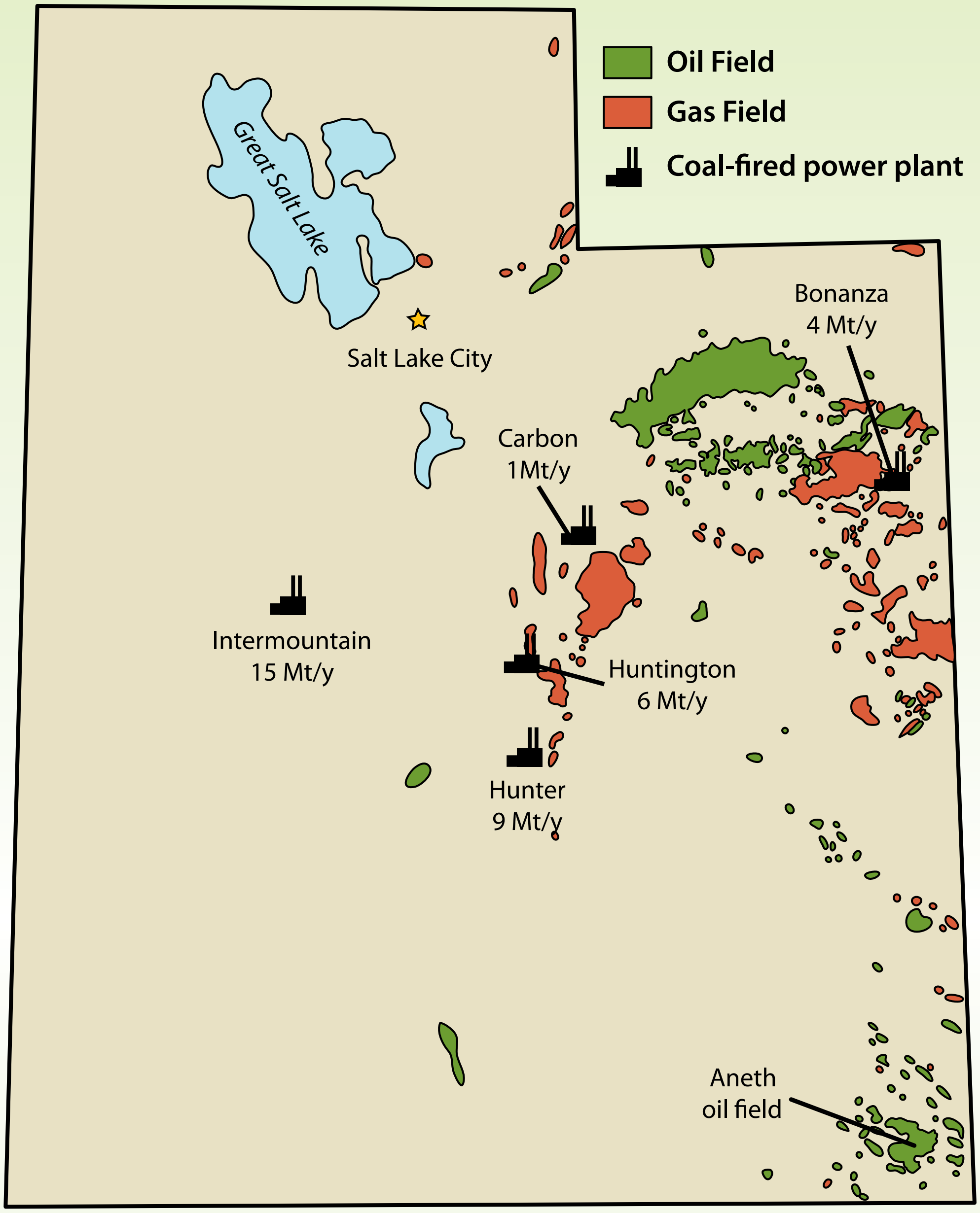




Schematic diagram showing possible future system of capturing and transporting CO_2 from a coal-fired power plant for use in enhanced oil recovery and ultimate permanent storage in a mature oil field like Aneth. (A) Microscopic view of pores (blue areas) from the limestone reservoir rock (black and brown areas=limestone grains and matrix) from Aneth field. (B) Schematic microscopic view of pores containing water (brine) and unproduced oil. (C) Same diagram as B showing injected CO_2 and now-mobile oil mixed with CO_2. (D) Carbon dioxide stored (sequestered) as a gaseous state and dissolved in brine, with minor amounts in some mineral forms.

ing oil and gas fields. Hydrocarbons occupy the pore spaces (like holes in a sponge) of limestone and sandstone (reservoirs), and accumulate over millions of years in traps (such as anticlines or ancient sandbars and reefs). A key component of a hydrocarbon trap is the seal—a layer of rock (salt or shale, for example) that prevents the oil and gas in the reservoir from escaping to the surface or out of the trap. Once the hydrocarbons have been produced, the depleted or "empty" reservoir rock and trap may be an ideal place to sequester CO_2 captured at power plants and shipped via pipeline to the field. One UGS study indicates as much as 1.8 billion tons of CO_2 could be sequestered in Utah's oil and gas fields.

An additional benefit of sequestering CO_2 in oil reservoirs is that CO_2 can be used to enhance oil recovery from old fields before they are abandoned. When oil is produced, a significant portion (often 60 to 80 percent) remains "stuck" to the rock surrounding the pores. Injecting and "flooding" CO_2 into depleted reservoirs allows the CO_2 to mix with the remaining oil, loosening it up as it were (becoming what is termed miscible), thereby becoming less viscous and flowing more easily so twice as much oil can be produced. The CO_2 is later separated from the oil/CO_2 mixture and ultimately re-injected and permanently stored in the reservoirs. This technique has been used for over 30 years but applied, thus far, to only one field



Locations of major oil and gas fields of Utah, and coal-fired power plants. Mt/y = million tons of CO_2 per year; 2001 data.

MORE INFO

To learn more about carbon sequestration or the UGS studies visit any of the following Web sites.

http://geology.utah.gov/emp/co2sequest/index.htm
http://www.southwestcarbonpartnership.org/
http://www.fossil.energy.gov/programs/sequestration/publications/programplans/2005/sequestration_roadmap_2005.pdf
http://www.netl.doe.gov/publications/carbon_seq/subscribe.html
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http://www.fossil.energy.gov/news/techlines/2007/07016-Carbon_Sequestration_Atlas_Publish.html

in Utah—Aneth, the state's largest oil field. Located in southeastern San Juan County, Aneth has produced over 425 million barrels of oil. The CO_2 used for enhanced oil recovery at Aneth is supplied via a specialized pipeline from a naturally occurring source in Colorado (the lack of pipelines has prevented use of this method in other Utah fields). An additional 15,000 barrels of oil per day may be recovered using the CO_2-flood method in this field (about a 140 percent increase in the production rate).

What ultimately will be the fate of the CO_2 used at the Aneth or other fields over time? Again, the UGS, in partnerships with industry, university, and state and federal agencies (the Southwest Regional Partnership on Carbon Sequestration), is conducting a demonstration project (funded by the U.S. Department of Energy) to clarify just that. Will the CO_2 possibly leak through the seal rocks along unknown faults or natural fracture systems into important ground-water aquifers or to the surface? Will it leak through the cement behind the casing of old oil wells (the field is over 50 years old)? What are the long-term effects of CO_2 in contact with the seal rocks? Much of the CO_2 will mix and dissolve in the brine (salty water) remaining in the reservoir; the pore spaces of the reservoir rocks are filled will oil, brine, and gas. When this occurs, the brine becomes acidic (carbonic acid). This acid could dissolve both rocks and casing cement. Conversely, some of the CO_2 could react with the reservoir rock to create new carbonate minerals such as calcite and dawsonite, a sodium aluminum carbonate, making storage more permanent. Sequestering CO_2 in the form of minerals is ideal for long-term storage, but lab studies suggest this is a slow process. These are questions the UGS and its partners hope to answer.

The expansion of a CO_2–enhanced oil recovery program by the Aneth operator to parts of the field that have never experienced CO_2 injection presents a unique opportunity to monitor the fate of CO_2 from the start. The UGS is mapping the surface geology in detail to identify faults and fracture zones. Our partners are analyzing soil gas over the area to note any possible changes in background CO_2 levels. We are also mapping the subsurface geology, especially the ground-water aquifers that supply water for the needs of the local communities (Montezuma Creek and Aneth), livestock, and agriculture. Another element of our study is determining the nature of possible CO_2 effects on the reservoir seals by analyzing cores from wells in the field and stored at the Utah Core Research Center (see sidebar). Evaluating the reservoir rock observed in these cores and our subsurface interpretations of the field geology will be done by our project partners to model the movement and storage of the injected CO_2 over time.

Hydrocarbons have been stored in naturally occurring traps like those at Aneth for millions of years. With this demonstration project, we hope to show that CO_2 can also be permanently stored, safely, in a mature field like Aneth, while increasing oil production and therefore revenues to the citizens of Utah. The CO_2 produced when the oil is burned will of course go into the atmosphere, but the amount of CO_2 ultimately stored in the field will be significantly higher. The project results can then be applied to other fields in Utah and elsewhere to increase domestic oil production and recovery, and simultaneously take a step toward reducing global warming.

Utah Core Research Center: Aiding Utah's Petroleum Development

by Michael Laine

The Utah Geological Survey's Utah Core Research Center (UCRC) offers researchers and scientists access to Utah's most comprehensive collection of geologic specimens for petroleum-industry research, workshops, and short courses; thesis and academic research; and a variety of UGS/industry cooperative projects. Current holdings include core from more than 750 wells and subsurface samples from 3600 wells. Other sample collections include tar sands, oil shale, and type oils from all the producing formations in the state. The UCRC also maintains high-resolution digital imaging workstations, microscopes, and sample preparation equipment. In 2006, the UCRC hosted 20 industry workshops, five university classes, and handled over 100 requests for well information or geologic samples. Assistance was also given to industry and academic research projects of scientists from Utah, 18 other states, and six foreign countries.

As a regional repository for irreplaceable geologic samples, the UCRC collection is ideally suited to supply and prepare samples for projects investigating the characteristics and economic potential of Utah's oil and gas reservoirs. For example, the UCRC has a vital role in the current CO_2 sequestration and enhanced oil recovery investigations in southeastern Utah. Core from Aneth field is being used to supply specimens for detailed reservoir studies, seal analysis and microscopic examination, and specially extracted core plugs are being used to determine the engineering and mechanical properties of the Aneth field oil-producing rocks.

The UCRC is also participating in hydrocarbon investigations of the productive Leadville Limestone of southeastern Utah, the expanded development of deep and tight gas fields in the Uinta Basin, and the economic potential of the Navajo Sandstone from the recent Covenant oil field discovery in central Utah. From an underground core storage facility in Colorado, the UCRC recently acquired 3318 feet of core from six strategic Uinta Basin wells, that will give researchers a better understanding of the nature, distribution, and value of the Green River oil shale deposit.

Geologists examine Ferron Sandstone core during a workshop at the Utah Core Research Center.

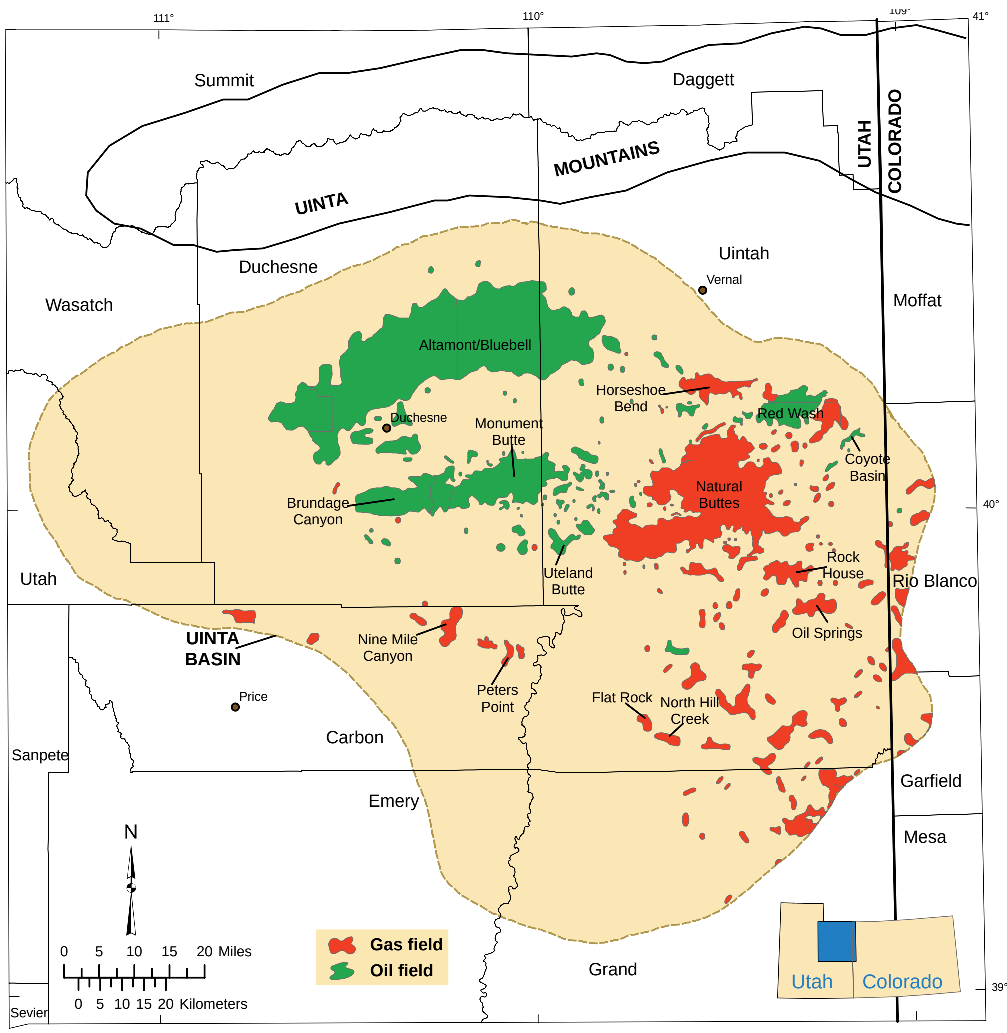
EXPANDED DEVELOPMENT OF DEEP, TIGHT GAS RESERVOIRS IN THE UINTA BASIN

By Stephanie Carney

Introduction

There has been a lot of talk and media coverage about the recent frenzy of drilling activity in eastern Utah's Uinta Basin, and you may be wondering what all the hubbub is about. It has been a very exciting couple of years for oil and gas exploration companies with interests in the Uinta Basin, mainly due to large and profitable reserves of natural gas in deep reservoirs (rocks capable of storing oil and gas). Oil and gas prices have been increasing over the past few years, and this increase has spurred a drilling boom in Utah and other western states.

Utah is the 10th largest producer of natural gas in the United States, with most of the production coming from the Uinta Basin. The Utah Division of Oil, Gas and Mining recently reported that more than 19 billion cubic feet (Bcf) of gas was produced from the Uinta Basin during November 2006. Most of that gas (14.1 Bcf) was produced from the Natural Buttes field, the largest natural gas field in Utah. This field is located in the eastern part of the basin and has produced an impressive total of 1.3 trillion cubic feet (Tcf) of gas since production began in the 1950s. Production of natural gas from this field, and most other gas fields in the Uinta Basin, largely comes from tight gas sandstone reservoirs of the Upper Cretaceous (83 to 71 million years ago) Mesaverde Group and the Paleocene-Eocene (57 to 49 million years ago) Wasatch Formation.



Location of the Uinta Basin and oil and gas fields within the basin.

The U.S. Geological Survey estimates that the tight gas sandstone reservoirs of the deeper Mesaverde Group alone have 7.4 Tcf of undiscovered, technically recoverable gas. The potential for future exploration, drilling, and production in the Uinta Basin certainly looks bright!

What is a tight gas reservoir?

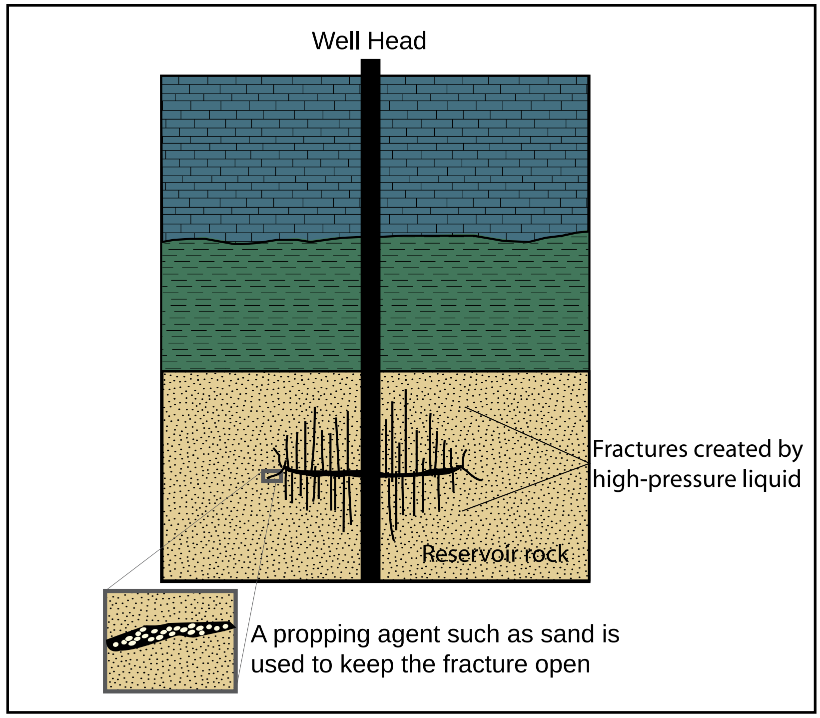
Tight gas reservoirs are often called unconventional reservoirs because "tight" refers to the fact that the permeability of the reservoir rock is very low. Permeability is a measure of the connectivity of pores, which are the spaces between individual grains, in sandstone or other rock types. The more connected the pores, the higher the permeability and the easier it is for liquid or gas to flow through a rock (for example, to a well). Unlike conventional reservoirs, unconventional reservoirs cannot produce economic volumes of gas without first being stimulated by using special processes such as hydraulic fracturing. Tight gas reservoirs include sandstones, carbonates (such as limestone), shales, and coal beds. Almost all of the natural gas currently produced from the Uinta Basin comes from unconventional reservoirs, especially tight gas sandstones.

Because tight gas reservoirs are nearly impermeable, artificial fractures, or hydraulic fractures, need to be created before the gas will flow at economic rates. The fractures are formed when a liquid is pumped down the well at very high pressure. This high-pressure liquid, made up of water and a more viscous (thicker) liquid, exceeds the strength of the rock and opens a fracture. To keep the fractures open after the pumping pressure is released, a propping agent such as sand is usually added and carried into the fractures by the fluid. Hydraulic fracturing connects many pre-existing fractures and flow pathways in the reservoir rock with a larger fracture. This fracture system starts at the well and extends out into the reservoir rock as much as several hundred feet. Deep wells may have as many as 20 separate hydraulic fracture zones. Enhancing the fracture system in the reservoir increases the permeability, or the number of pathways, through which gas can flow to reach a well.

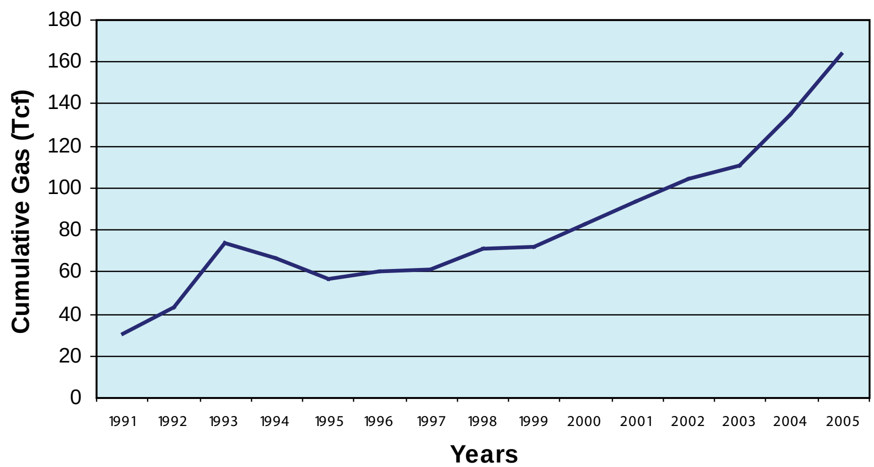
Tight Gas Reservoirs in the Uinta Basin: Past, Present, and Future

In the early 1970s, exploration pointed to the presence of gas locked inside tight gas reservoirs in the Uinta Basin. However, the cost to produce or "unlock" the gas was vastly greater than the revenue of selling the gas on the open market. Conventional reservoirs were far more economic to produce. But in recent years, increased consumer demand has caused an increase in gas prices. That, along with new exploration and production technologies and a decline in production from conventional reservoirs, has increased exploration and production of natural gas from unconventional sources such as tight gas sandstones. The number of permits to drill exploration and production wells in the basin has steadily increased over the past decade and will likely continue to rise.

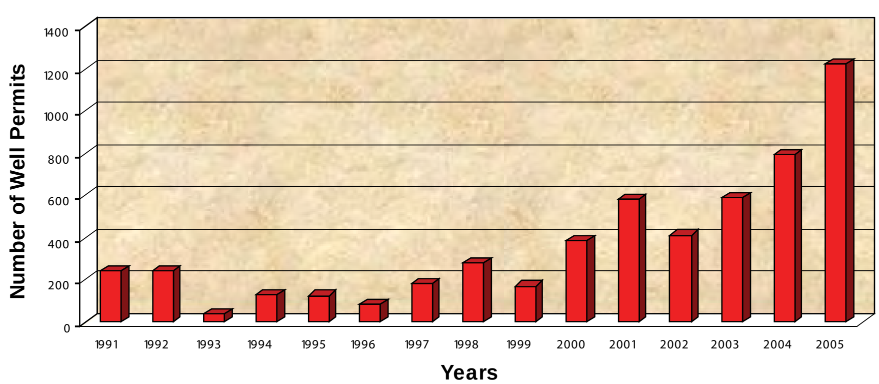
The Uinta Basin has produced a total of 2.6 Tcf of natural gas. According to the U.S. Geological Survey, the basin still has a reserve of over 16 Tcf of undiscovered, technically recoverable resources. As gas prices continue to rise and advances in technology continue, exploration will continue to grow and move from shallow conventional reservoirs to deeper, unconventional reservoirs like those found in the Uinta Basin. Natural gas exploration will likely continue to "barrel" forward by hundreds of wells in the coming years, and the Uinta Basin will likely become an even bigger player in contributing to national natural gas production.



Schematic diagram of hydraulic fracturing in tight gas sandstone.



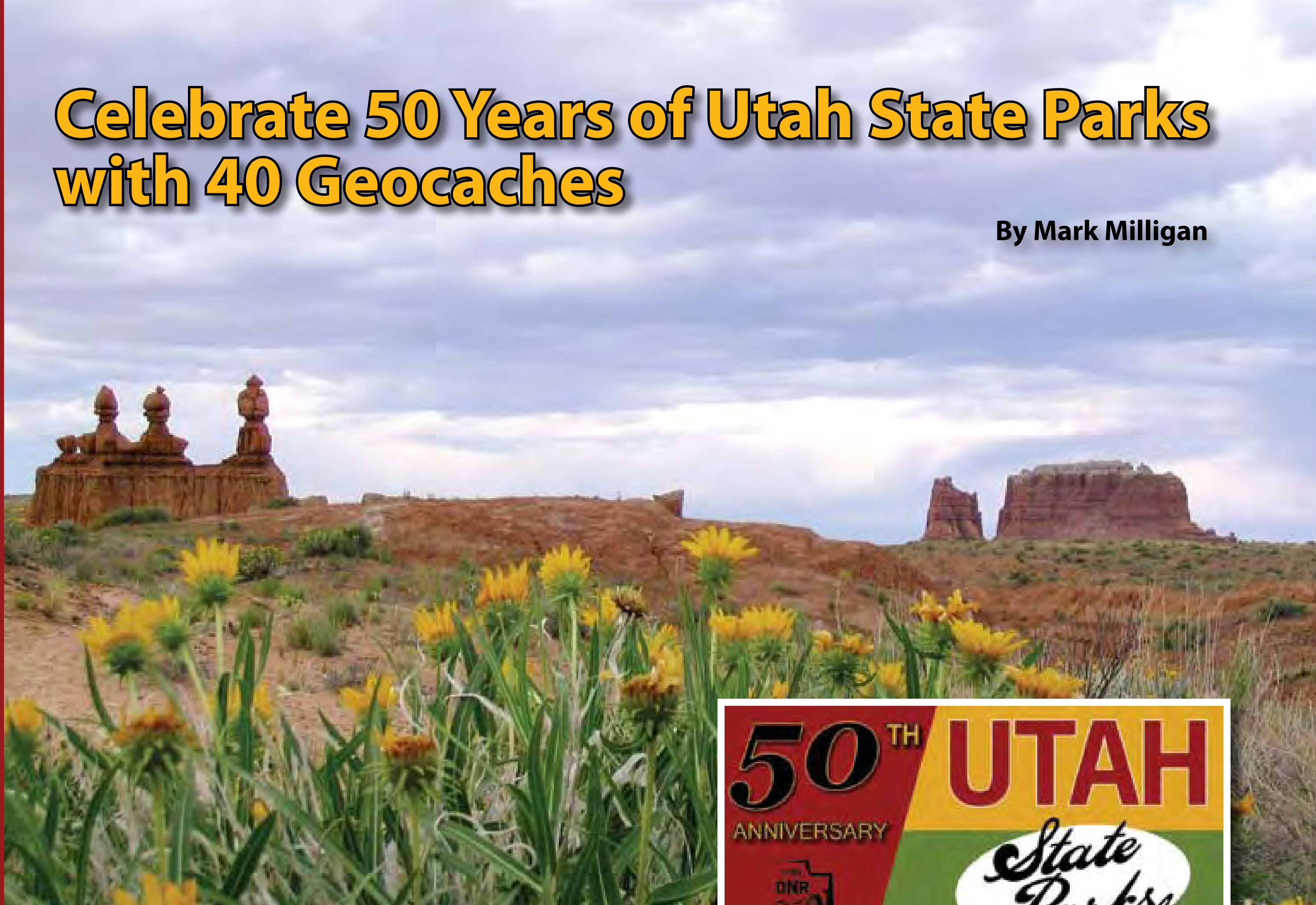
Cummulative gas production curve for the eastern Uinta Basin from 1991 through 2005. Source: Utah Division of Oil, Gas and Mining.



Number of well permits in the eastern Uinta Basin from 1991 through 2005. Source: Utah Division of Oil, Gas and Mining.

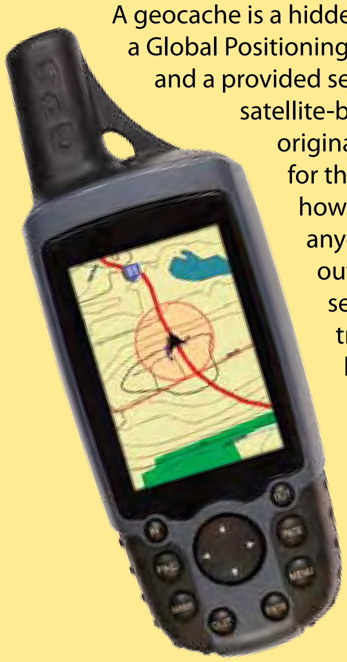
Celebrate 50 Years of Utah State Parks with 40 Geocaches

By Mark Milligan



Goblin Valley State Park: Explore the landscape covered with sandstone goblins. Photo by John Good, Utah State Parks.

This GeoSights issue features not a single sight but 40 sites across the state. To celebrate 50 years of parks, the Utah Division of State Parks and Recreation has placed geocaches at approximately 40 of their 42 parks.



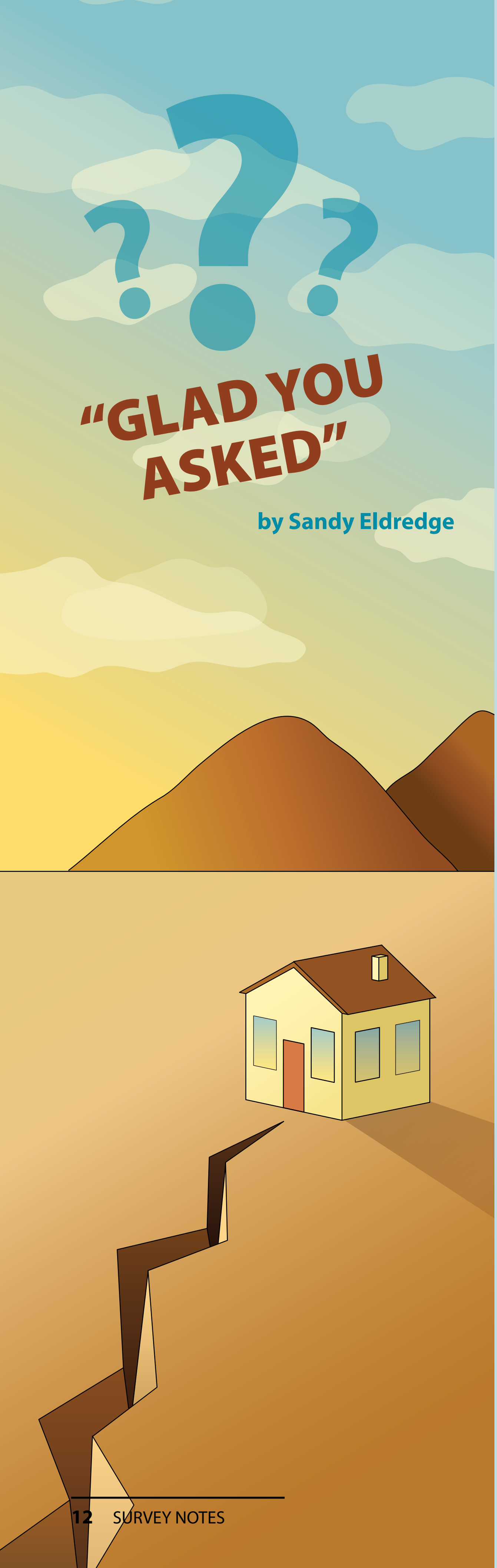
A geocache is a hidden "treasure" found using a Global Positioning System (GPS) receiver and a provided set of coordinates. GPS is a satellite-based navigation system originally intended and designed for the U.S. Military. Now, however, GPS can be used by anyone who works or plays outside, from geologists to sea captains to modern-day treasure hunters. Don't have a GPS receiver? Many of the state parks have GPS units available for check out free of charge (normal park entrance fees must be paid). Contact individual parks for details and availability. Individual geocache locations highlight features of the park they are in. The geocaches are placed in small (11.5"x7"x6") ammo cans with "50th Anniversary" stickers on one side and "Official Geocache" stickers on the other. The "treasure" contained in these ammo cans includes 50th Anniversary key chains, carabiners, erasers, rubber bracelets, and other assorted goodies. Additionally, a specially minted collectible coin will be randomly placed in State Park geocaches across the state.

Visit www.geocaching.com for more information about geocaching and a listing of all State Parks' geocaches (and thousands of other geocaches located around the globe). The State Parks' Web site, www.stateparks.utah.gov, also lists their geocaches on an interactive map. Unlike with other geocaches, park geocachers are not encouraged or expected to place items in these caches. However, visitors are encouraged to post a log of their visit and digital photographs on www.geocaching.com.

So what are you waiting for? Log on, then head out the door, see some sights, and find some treasure in Utah's State Parks. Oh, and check out the geology while you're there!

Sand Hollow State Park: With its warm, blue waters and red sandstone landscape, Utah's newest state park is also one of its most popular. Photo by John Good, Utah State Parks.

A geocache is a hidden "treasure" found using a Global Positioning System (GPS) receiver and a provided set of coordinates.



"GLAD YOU ASKED"

by Sandy Eldredge

I AM THINKING OF BUYING A HOUSE AT "X" ADDRESS... IS IT NEAR A FAULT?

We receive this inquiry often and are glad that these inquiries have been on the rise, as they reflect increased awareness of the earthquake threat in Utah. Many people associate main earthquake damage with nearness to a fault. Although fault proximity is a major concern, strong ground shaking and other earthquake hazards are more widespread and can cause damage over large areas many miles from the fault. In addition, fault rupture at the ground surface is expected only in large (magnitude 6.5 and greater) earthquakes, which are less frequent than moderate earthquakes that may still cause extensive damage from ground shaking.

Therefore, we often surprise the inquirer with more information than they probably expected. Earthquake risk to any particular home depends on what and where the earthquake hazards are, as well as when and how the house was constructed.

What are the main earthquake hazards?

Ground shaking:

- is the most damaging and widespread earthquake hazard,
- can occur almost anywhere and is difficult to avoid (but house retrofits can minimize damage),
- induces most of the other earthquake hazards, and
- can cause damage to houses in earthquakes as small as magnitude 5.0, which on average occur once every four years somewhere in Utah and once every 10 years in the Wasatch Front region (most recent event was the 1992 magnitude 5.8 St. George earthquake).

Ground shaking from the 1934 magnitude 6.6 Hansel Valley (north end of Great Salt Lake) earthquake damaged structures 80 miles away in Salt Lake City.

Soil liquefaction :

- is caused by ground shaking in areas with sandy soil and shallow ground water,
- means that the soil liquefies and acts more like a fluid than a solid,
- can cause a house to settle, crack, or tip,
- is most likely to occur near streams and other bodies of water, and
- can occur in earthquakes of about magnitude 5.0 and greater.

Slope failure (landslides and rock falls):

- can occur on unstable slopes within a few miles of a magnitude 4.0 earthquake, which on average occur once every year in Utah,
- can occur more than 100 miles from a magnitude 7.5 earthquake, and
- is expected in mountain and canyon areas and valley slopes having susceptible rock/soil types.

Liquefaction caused these apartment buildings to tip over during the 1964 magnitude 7.4 Niigata, Japan, earthquake (Earthquake Engineering Research Institute.)

Newly formed fault scarp from the 1954, magnitude 6.8 Dixie Valley, Nevada, earthquake. Note the tilting and deformation of the ground surface on the downdropped side of the fault.

Surface fault rupture:

- occurs during large earthquakes of about magnitude 6.5 and greater, which on average occur once every 50-120 years somewhere in Utah and once every 300-400 years on the Wasatch fault in the urban Wasatch Front area (last large earthquake in Utah was in 1934, magnitude 6.6, at the north end of Great Salt Lake; last large earthquake on the Wasatch fault in the urban area was approximately 500 years ago),
- typically offsets the ground surface vertically on each side of the fault, forming fault scarps (steep breaks in slope) that can be over 10 feet high,
- causes the mountain side of the fault to rise and the valley side to drop,
- may deform the ground surface for hundreds of feet from the fault, chiefly on the valley side of the fault, and
- causes tectonic subsidence, which is the broad, permanent tilting of the valley floor down toward the fault scarp.

Flooding:

- from dam failure would cause the greatest damage,
- from stream or canal blockage or diversion could cause major damage, and
- from tectonic subsidence could happen in several ways. A large earthquake on the Wasatch fault could cause subsidence as far as 10 miles from the fault, and Great Salt Lake or Utah Lake may flood eastern shoreline areas. Subsidence could also cause the ponding of water in areas with a shallow ground-water table. In addition, tilting of the ground surface could compromise gravity-flow structures such as canals or sewer lines.

What should I consider before buying a house?

- What earthquake hazards are present (hazard maps are available for inspection at most Wasatch Front county planning departments and at the UGS).
- How frequently each type of hazard occurs.
- What effects each hazard may have on a house.
- House construction—for example, year built and type of material. Houses constructed before 1975 are not built to today's earthquake building codes, but they can be retrofitted to make them more resistant to ground shaking. In general, unreinforced brick or masonry houses are more susceptible to damage than wood-frame houses.
- What options are available for minimizing damage. Many retrofit procedures are relatively inexpensive and often can be performed by the experienced do-it-yourself homeowner (see the Utah Division of State History Web page listed below).

For more information, visit the following Web addresses:

http://geology.utah.gov/online/pdf/pi-38.pdf for more information about earthquake hazards for the homebuyer (UGS).

http://history.utah.gov/historic_preservation/rehabilitation_information/bracingforthebigone.html for seismic retrofitting of historic houses (Utah Division of State History).

http://homelandsecurity.utah.gov/hazards/earthquake.htm for preparedness information (Utah Division of Homeland Security).

http://www.seis.utah.edu/ for earthquake events in Utah (University of Utah Seismograph Stations).

THE STATUS OF WIND ENERGY DEVELOPMENT IN UTAH

by Philip Powlick

Electricity, my friend, is blowing in the wind.

For many people, the iconic image of renewable energy is the modern wind farm—tall white towers with long, sleek blades gracefully rolling across the sky. Commuters between Salt Lake and Utah Counties are used to seeing the two turbines at Camp Williams, but to-date these are Utah's only large wind turbines. Many Utahns who have traveled elsewhere in the West have seen large wind farms in states such as Wyoming or Oregon and wondered why, with its wide-open spaces and growing electricity demand, are there not such sights in Utah?

The siting of a wind farm represents a grand compromise of many, sometimes contradictory, factors. The importance of wind speed is a given. Wind speeds tend to be greater at high altitude, but air density—which is greatest at low altitude and with low temperatures—is also important. Smooth air flow is also desirable, so wide-open spaces with little vegetation are also useful. There are few places where one can find all of these in the same place, except perhaps Antarctica—where there is little demand for electricity. And this raises yet another issue—load and transmission. To be commercially viable, a wind farm must be close enough to electricity consumers, or to large transmission lines, to take the power to them. Southern Wyoming—high, cold plains with wind speeds that can knock you over—is fairly well suited for wind power production. Limited local demand and transmission capacity, however, keep Wyoming from having even more wind farms. For the most part, though Utah has greater demand for power, we lack large areas of sustained high winds. However, there are local wind phenomena that are conducive to wind power development, and wind farms will soon be coming to Utah, albeit on a smaller scale than in some neighboring states.

The intersection of mountains, valleys, and canyons can sometimes create the conditions for commercial production of wind power. Long canyons descending from high mountains can create significant nighttime wind flows as cold air drops and is channeled toward a canyon mouth. Residents at the mouths of Spanish Fork and Weber Canyons are familiar with this phenomenon, and it is at Spanish Fork that Utah's first commercial wind farm may well be built. Currently planned to be in service by the end of 2007, Wasatch Wind's Spanish Fork project involves nine turbines, each rated at 2,100 kilowatts (kW) of peak output. These will be large turbines. For comparison purposes, the larger of the two machines at Camp Williams has a capacity of 665 kW, less than one-third that of each planned Spanish Fork turbine.

The Stockton Bar—a preserved section of ancient Lake Bonneville shoreline in Tooele County spanning the valley between South Mountain and the Oquirrh Mountains—is another example of a local feature that can create commercially viable wind power. Near Stockton, two mountain ranges come together, creating a funnel that channels the predominant southerly winds. The bar itself, rising 30 meters (100 feet) above the valley floor, sees high winds as air is further channeled up and over. Two of the UGS' 50-meter (160 ft) anemometer towers are currently deployed at Stockton Bar in support of the Pioneer Wind project, a 70,000 kW project planned by Tasco Engineering. An additional two UGS towers are in place just north of the bar as well, where the U.S. Army is planning to install one or two turbines at the Tooele Army Depot.

As exciting as these projects are, one recently proposed project dwarfs them all. The Escalante Valley is a northeast-trending valley that runs for over 160 kilometers (100 miles) from Iron, through Beaver, and into Millard Counties. With predominant winds out of the southwest (parallel to the mountain ranges that bound it both east and west) and a wide, flat, and tree-less floor, the section of the valley along the Beaver/Millard border is one of the few places in Utah where truly large-scale wind development may be possible. After quietly collecting data for several years in the area north of Milford, UPC Wind, a wind development firm based in Massachusetts, unveiled plans in November 2006 for a 400,000 kW project. Phase One of the UPC project calls for 80 2,500 kW turbines to be built in Beaver County in early 2008. An additional 80 turbines are to be built a year later in Beaver and Millard Counties. Each turbine will sit on an 80-meter-tall (260 ft) tower and the length of each of the turbine's three blades will be over 50 meters (160 ft). A 145-kilometer (90 mi) transmission line is to be built to the Intermountain Power Plant near Delta to bring the electricity to market. All told, this project is expected to cost between $700 and $800 million!

Utah is not blessed with the best wind resources in the West, but with growing demand for renewable energy and local wind resources, Utah is on the verge of significant wind energy resource development. And likely more will follow. UGS anemometer towers are measuring the wind in many parts of Utah (see *Survey Notes*, September 2006). Just as it does with characterizing Utah's fossil fuel resources, the UGS is seeking to build our understanding of Utah's resources and, hopefully, will play a major role in allowing more Utahns to enjoy the graceful dancing of turbine blades, not to mention the benefits of renewable energy.

NEW PUBLICATIONS

The 2005 Sage Vista Lane Landslide, Cedar Hills, Utah County, Utah, by Ashley Elliott, 2 p., PI-89 ....FREE

The 2001 Heather Drive Landslide, Layton, Davis County, Utah, by Ashley Elliott, 2 p., PI-88 ....FREE

Surficial geologic map of part of the Kaysville quadrangle, Davis County, Utah, by Barry J. Solomon, 2 pl., 1:24,000, ISBN 1-55791-758-2, M-224 ....$11.95

Geologic map of the Magna quadrangle, Salt Lake County, Utah, by Barry J. Solomon, Robert F. Biek, and Tracy W. Smith, 2 pl., scale 1:24,000, ISBN 1-55791-748-5, M-216 .....$11.95

Temperature-depth monitoring in the Newcastle geothermal system, by Robert E. Blackett, 23 p., ISBN 1-55791-772-8, CD, RI-258 ....$6.75

Ground-water sensitivity and vulnerability to pesticides, Sanpete Valley, Sanpete County, Utah, by Mike Lowe, Janae Wallace, J. Scott Horn, Anne Johnson, and Rich Riding, 24 p., 2 pl., scale 1: 140,000, ISBN 1-55791-765-5, CD, RI-255 ....$19.95

Great Salt Lake brine chemistry database and reports – 1966 to 2006, by J. Wallace Gwynn, 7 p. + 11 p. appendices, additional 14 databases and 14 reports, CD, OFR-485 ...$14.95

Fluvial facies and architecture of the Poison Strip Sandstone, Lower Cretaceous Cedar Mountain Formation, Grand County, Utah, by Mathew W. Stikes, 84 p. + 27 p. appendices, ISBN 1-55791-751-5, CD, MP-06-2 ....$11.90

Surficial-geologic reconnaissance and scarp profiling on the Collinston and Clarkston Mountain segments of the Wasatch fault zone, Box Elder County, Utah – Paleoseismic inferences, implications for adjacent segments, and issues for diffusion-equation scarp-age modeling, by Michael D. Hylland, ISBN 1-55791-763-9, 18 p, CD, SS-121 ....$9.95

Geologic map of the Manti 30' x 60' quadrangle, Carbon, Emery, Juab, Sanpete, and Sevier Counties, Utah, by Irving J. Witkind, Malcolm P. Weiss, and Terrence L. Brown, digitized from U.S. Geological Survey Miscellaneous Investigations Series Map I-1631 (1987), scale 1:100,000 (contains GIS data), ISBN 1-55791-755-8, CD, M- 212DM $19.95

Interim geologic map of the St. George 30' x 60' quadrangle and the east part of the Clover Mountains 30' x 60' quadrangle, Washington and Iron Counties, Utah, by Robert F. Biek, Peter D. Rowley, David B. Hacker, Janice M. Hayden, Grant C. Willis, Lehi F. Hintze, R. Ernest Anderson, and Kent D. Brown, 70 p., 2 pl., scale 1:100,000, OFR-478 ....$11.95

(continued on page 16)

SURVEY NEWS

NEW BOARD MEMBERS

The UGS Board has three new members who were appointed by Governor Huntsman and confirmed by the Senate during this year's legislative session. They began serving their terms in March 2007.

Mark Bunnell, our new minerals (coal) representative, is employed by Arch Coal and has been a coal and mining geologist in east-central Utah for 25 years. **Kenneth Puchlik**, our new minerals (industrial) representative, is a mining consultant for Puchski GeoConsultants, Inc., in St. George, Utah, and has over 30 years experience in the mineral industry. **Alisa Schofield**, our new public-at-large representative, is a professional career science teacher with the Salt Lake School District. We are pleased to welcome them on board.

Terms have expired for **Chuck Semborski**, **Robert Robison**, and **Kathleen Ochsenbein**. They have served us well as members of the UGS Board and we thank them for their efforts.

UGS EMPLOYEE OF THE YEAR

Congratulations to **Tom Dempster** who was named the 2006 UGS Employee of the Year. Tom has a great attitude, consistently performs quality work, and is always willing to go out of his way to help others. He is especially valued by the UGS during Earth Science Week, when he works enthusiastically with the many school children and teachers who visit the facility. Tom's efficient work at the Utah Core Research Center contributes greatly to the many classes held for academic and professional geoscience groups. Tom is a geological technician and has been with the UGS for seven years.

Tom Dempster, 2006 UGS Employee of the Year.

EMPLOYEE NEWS

The Ground Water and Paleontology Program bid farewell to **Scott Horn** who accepted a position at Washington University in St. Louis, Missouri.

NEW PUBLICATIONS

(continued from page 15)

Paleoseismic investigation and long-term slip history of the Hurricane fault in southwestern Utah, by William R. Lund, Michael J. Hozik, and Stanley C. Hatfield, 43 p. + 38 p. appendices, ISBN 1-55791-760-4, CD, SS-119 ....$11.00

Shale gas resources of Utah: Assessment of previously undeveloped gas discoveries, by Steven Schamel, 60 p. + 25 p. appendices, CD, OFR-499 ....$14.95

Interim geologic map of the Durst Mountain quadrangle, Morgan and Weber Counties, Utah, by James C. Coogan and Jon K. King, 30 p., 1 pl., scale 1:24,000, OFR-498 ....$7.25

Interpretation of the Jurassic Entrada Sandstone play using 3D seismic attribute analysis, Uinta Basin, Utah, by R. William Keach II, Thomas H. Morris, John H. McBride, Mike Mullen, Hannes E. Leetaru, and Ryan O'Neal, 22 p., 4 pl., CD, OFR-493 ....$14.95

Interim geologic map of the Dutch John 30' x 60' quadrangle, Daggett and Uintah Counties, Utah, Moffat County, Colorado, and Sweetwater County, Wyoming, by Douglas A. Sprinkel, 3 pl., scale 1:100,000 (contains GIS data), CD, OFR-491DM $19.95

Land subsidence in southwest Utah from 1993 to 1996 measured with Interferometric Synthetic Aperture Radar (InSAR), by Richard R. Forster, 30 p., ISBN 1-55791-754-X, CD, MP-06-5 ....$11.95

Reservoir characterization of the Cretaceous Cedar Mountain and Dakota Formations, southern Uinta Basin: Year-one report, by Mary L. McPherson, Brian S. Currie, and Justin S. Pierson, 139 p., CD, OFR-492 ....$14.95

Integrated sequence stratigraphic and geochemical resource characterization of the lower Mancos Shale, Uinta Basin, Utah, by Donna S. Anderson and Nicholas B. Harris, 130 p., CD, OFR-483 ....$14.95

These and other publications are available from:

Natural Resources Map & Bookstore
1594 W. North Temple , Salt Lake City, UT 84116
801-537-3320 or 1-888-UTAHMAP
http://mapstore.utah.gov

Teacher's Corner

Integrating *Survey Notes* Articles in the Classroom

by Nancy Carruthers

The Great Energy Debate

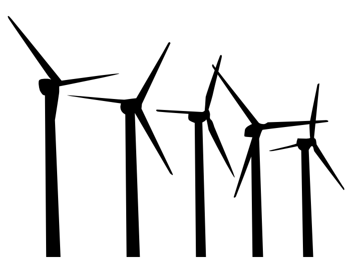
We now live in a world where increasing energy demands brought on by industrial and economic development, as well as population growth, are challenging us to think differently about energy production. Global warming, increasing gas and oil prices, and alternative energy are all topics of considerable debate. Utah boasts of substantial energy resources from non-renewable resources like coal, natural gas, and petroleum to renewable resources like wind power, solar energy, and geothermal energy. How will we meet the challenge of our future energy needs and find a balance between energy conservation, energy efficiency, and environmental considerations? To see what steps Utah research scientists are taking read the three articles in this issue of *Survey Notes* that discuss the future development of energy in our state.

Wind power is now growing at a faster rate for generating electricity than any other source in the world. Interest in alternative energy like wind power is growing because of public interest in clean fuels, environmental pollution awareness, and the increasing cost of fossil fuels. The article "The Status of Wind Energy Development in Utah" discusses Utah's wind potential and how scientists are currently identifying areas that have good wind resources. Learn about the Spanish Fork Wind Project and how it could be Utah's first wind farm developed for generating electricity.

With an increased demand for cleaner fuel along with new exploration and production technologies, there has been a decline in conventional production of gas resources from shallow reservoirs to a rise in production from deeper unconventional "tight gas reservoirs." In the article "Expanded Development of Deep, Tight Gas Reservoirs in the Uinta Basin," learn about Utah's natural gas reserves and future potential in the Uinta Basin.

Growing concern about global climate change has stimulated research in finding ways to reduce greenhouse gas emissions. In 2002, the President announced a "Global Climate Change Initiative" goal of reducing the nation's greenhouse gas intensity by 18% between 2002 and 2012. In the article "Geologic Sequestration of Carbon Dioxide and Enhanced Oil Recovery—The Utah Geological Survey's Efforts to Reduce Global Warming While Increasing Oil Production," learn how the Utah Geological Survey is investigating how to permanently and safely store (sequester) carbon dioxide (CO_2) underground in Utah.

This issue of *Survey Notes* provides a variety of discussion topics that align with the 9th–12th grades Social Studies curricula.



GEOGRAPHY FOR LIFE

Standard 5, Objective 2
c. Compare and contrast the use of renewable and nonrenewable resources.

POSSIBLE DISCUSSION POINTS

- Are wind farms practical for Utah? What areas in Utah might make good locations for wind farms?
- How does Utah measure the wind to determine where to set up wind turbines to generate renewable electricity? Name some important considerations for the establishment of wind farms in Utah.
- What is a "tight" gas reservoir? How is the exploration and production of gas changing in Utah?
- What is CO_2 sequestration and why is geologic sequestration such an attractive option? What are some potential problems that these studies might address?
- In the bigger picture of the great energy debate, what are the pros and cons of renewable vs. nonrenewable energy? Give your ideas on which energy resource you think is the best.

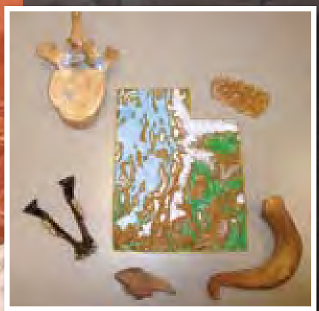
To learn more about the Utah Geological Survey's role in energy-resource development as well as details about Utah's State Energy Program, visit geology.utah.gov. You can also read about the Utah Anemometer Loan Program in the September 2006 *Survey Notes* (v. 38, no. 3) at http://geology.utah.gov/surveynotes/snt38-3.pdf.

TEACHERS!

We would like to know how you use *Survey Notes*.

1. Do you use *Survey Notes* in the classroom?
2. If so, which articles do you use (Teacher's Corner, Glad You Asked, GeoSights, Energy News, and/or other geologic articles)?
3. Do you have any suggestions for improving Teacher's Corner?
4. What grade do you teach?
5. Do you prefer a hard copy or the Web version of *Survey Notes*?

To send your responses, please fill out the short questionnaire on our Web site at geology.utah.gov/teacher_survey.htm. Current and past issues of *Survey Notes* can be viewed at geology.utah.gov/surveynotes/index.htm.

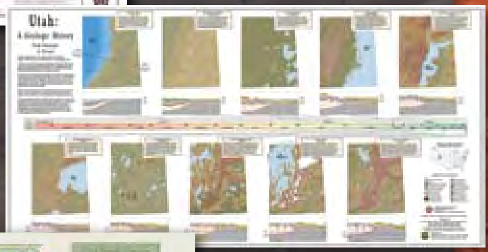


Did you know that the Utah Geological Survey loans out four educational teaching kits?

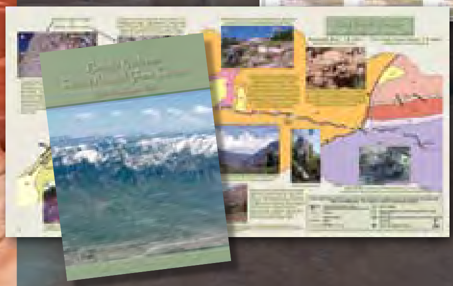
For more information visit http://geology.utah.gov/teacher/teachkits.htm. Call 537-3300 to reserve the dinosaur, ice age, landforms, or rocks, minerals and fossils kit.

Did you know our bookstore has maps, posters, and publications that can enhance your curriculum?

Geologic Cross Section of the Central Wasatch Front $8.00



Utah: A Geologic History PI-54...........$2.00



Geologic Guide to the Central Wasatch Front Canyons PI-87 ....$3.95

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