UTAH GEOLOGICAL SURVEY

SURVEY NOTES

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MINING FOR GILSONITE

Black Dragon Mine, circa 1905

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Design by Vicky Clarke

***Cover**: Gilsonite mining at the Black Dragon Mine, circa 1905 (from Kretchman, 1957; copyrighted photo used with permission from American Gilsonite Company.)*

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The Director's Perspective

by Richard G. Allis

This issue of Survey Notes has a strong energy theme, which is timely because of the present high prices and energy issues being in the news almost every day. Increasing demand for information from the Utah Geological Survey about the location of Utah's oil and gas fields has led to the production of a new map (see article on the map). This is one of three maps we are producing to replace the popular 1983 Energy Resources Map of Utah. The other two maps are on Utah's coal resources, and its uranium and vanadium occurrences. All three maps will be available in hard copy and digital format, and will also be available on our Web site.

The high price for oil (locally between \$35 - \$40/barrel) and natural gas (more than \$5/thousand cubic feet at Opal hub in southern Wyoming) is stimulating exploration throughout the Rocky Mountain region, and in particular Utah. Drilling permit applications to Utah's Division of Oil, Gas and Mining for the first half of 2004 are at record levels (close to 500 in six months), and drilling activity has also sustained a high level (close to 20 rigs presently active, compared to between 9 and 17 rigs active in the spring during the previous two years). One interesting new trend is for recent wells to be deeper, particularly in the Uinta Basin. In past years, the total depth for many wells was between 5000 and 7000 feet. Drilling results from the first six months of 2004 show 46% of all wells having a total depth of between 8000 and 10,000 feet, with 38% having a total depth of 5000 to 7000 feet. The reason is the targeting of deeper gas plays, in particular the Mesaverde Group. A brief surge in drilling activity during 2001 resulted in Utah's gas reserves increasing by 15%. The chances are good that the present level of increased drilling activity will also significantly increase Utah's natural gas reserves.

Additional exciting energy news from central Utah concerns the probable oil discovery in an exploration well drilled by Wolverine Gas and Oil near Richfield in Sevier County. Although no information has been released by Wolverine about the status of this well, the "Rocky Mountain Oil and Gas Journal" (May 21-27, 2004 issue) reports that this well flowed at up to 40 barrels of oil per hour from the Lower Jurassic Navajo Sandstone at depths near 9500 feet. A June 2004 lease sale by the Utah office of the Bureau of Land Management drew record interest, and land parcels offered in this area attracted high prices. BLM reports that Wolverine successfully bid \$3.9 million for almost 70,000 acres in this region. Wolverine has proposed an expanded program of seismic exploration and additional drilling. If the probable discovery is confirmed, this will open up a new exploration play along the Sevier thrust belt (often referred to as the "Hingeline") in central Utah, and it could be a significant boost to both the local economy of the region and to the state as a whole.

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GILSONITE

AN UNUSUAL UTAH RESOURCE

by Bryce T. Tripp

Definition and Description

Gilsonite is a naturally occurring, solid, black, lightweight organic material that originates from the solidification of petroleum. The dull, black appearance of weathered gilsonite resembles coal, whereas the surface of freshly broken gilsonite is shiny and resembles obsidian. Gilsonite is distinguished by its solubility in organic solvents, low density, and brown streak when rubbed on paper. Solid hydrocarbons like gilsonite are called asphaltites and are found in oil-bearing sedimentary basins, commonly as veins associated with oil shale. There are dozens of asphaltite deposits around the world and many of them have been mined; however, the gilsonite variety is relatively rare and the large size of the Utah deposits makes them unique.

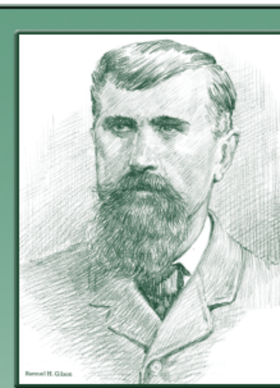
Uses

Gilsonite has hundreds of industrial applications and is used by companies all over the world. Gilsonite is added to oil- and gas-well drilling mud to stabilize the borehole and decrease friction; it is also used in oil-well cements. Gilsonite and gilsonite-derived resin wet and disperse carbon black pigment in printer's ink and bind pigment to the newsprint so it does not rub off. Addition of powdered gilsonite to asphalt paving mixes produces a more durable road surface. Paint-like mixtures of gilsonite, solvents, and other additives are used to coat and seal asphalt pavements like driveways and parking lots. Gilsonite is also used as an adhesive and waterproofing agent in the manufacture of roofing felt. Addition of gilsonite makes some paint and wood stain formulations more durable. Gilsonite is added to iron foundry molding-sand mixtures to produce a smoother finish on the cast item and make it easier to unmold. Small amounts of gilsonite are used in fireworks and to manufacture high-purity carbon electrodes.

Prices of gilsonite vary from about $250 to $1800 per ton depending on whether it is pulverized, how it is packaged, its melting temperature, or if additives and special processing are involved.

Location and Extent

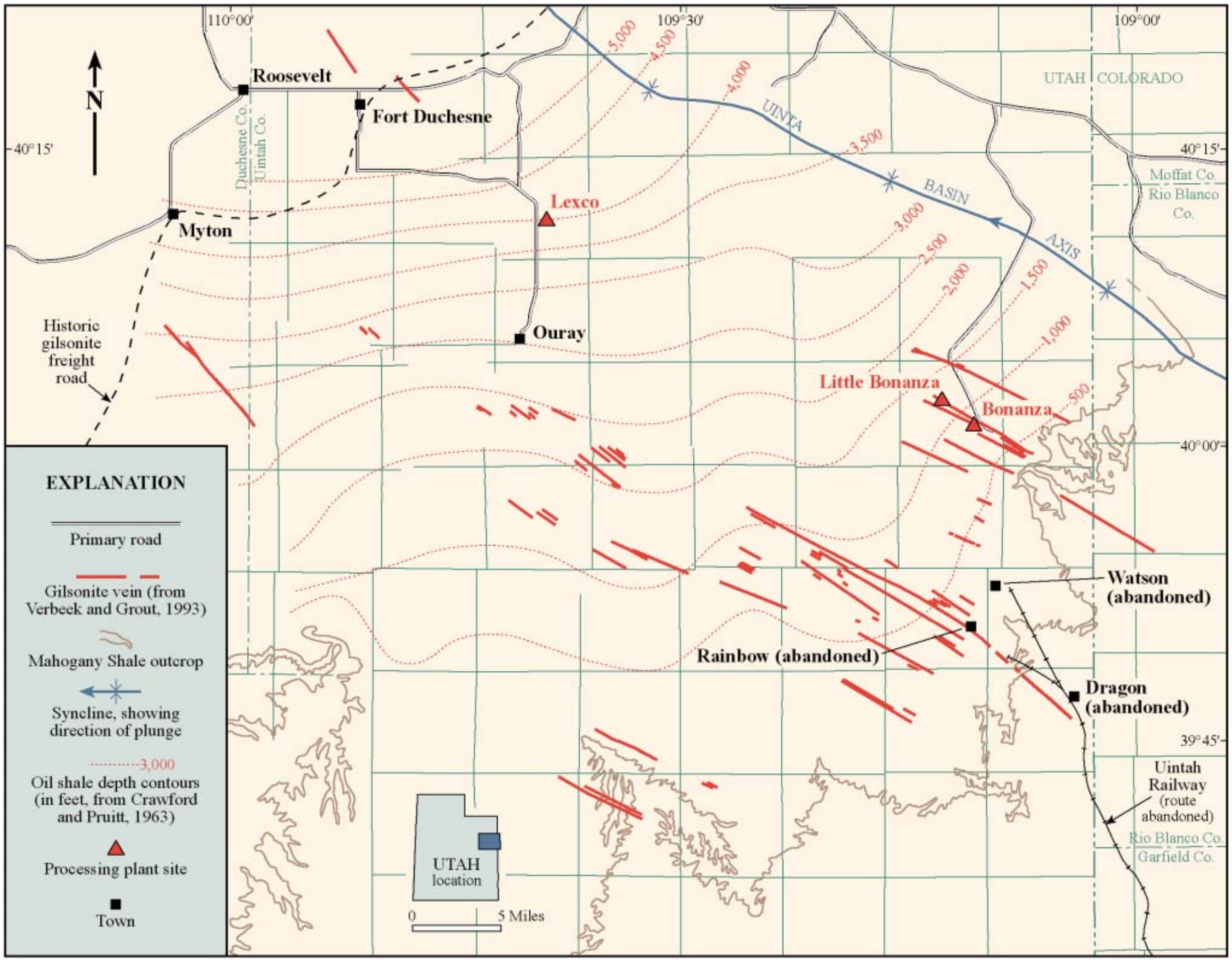
Gilsonite is found in dozens of long, vertical, northwest-trending veins in a 60-mile by 30-mile area of the Uinta Basin (see figure). The veins vary in width from fractions of an inch to almost 18 feet, but average about 3 to 6 feet. The continuity of the veins is impressive; they stretch in long, straight ribbons across the hills of the Uinta Basin. These veins are commonly several miles long and the longest vein system in the basin extends 24 miles. The gilsonite veins are also vertically continuous for hundreds to as much as 2,000 feet or more, commonly with only small



It Could Have Been Seyboldtite

Samuel Henry Gilson's flamboyant, enthusiastic personality overshadowed all other early gilsonite developers, most of whom are only briefly mentioned in obscure historical references. Sam Gilson had a wide range of interests and occupations. At various times he: raised horses for the Pony Express, was a cattle rancher, was a metals prospector and miner, invented a successful ore concentrating machine and an unsuccessful flying machine, experimented with an oven to convert coal to coke, and was the U.S. Marshall who supervised the execution of John D. Lee at Mountain Meadows. Gilson also obtained gilsonite samples in 1885 and began to experiment with uses (including chewing gum).

Bert Seaboldt, Manager for Construction for the Denver and Rio Grande Western Railroad, shared Gilson's interest in gilsonite - the two became partners, procured financing, and developed gilsonite mines and markets. They had many other partners in the early days; one set named their company the Gilson Asphaltum Company and adopted "gilsonite" as their trademark, ensuring Sam Gilson's place in mining history. Other industry founders to be remembered (besides Bert Seaboldt) are T.J. Almy, R.C. Chambers, Richard McIntosh, George Goss, Walter Almy, Abraham Hanover, and C.O. Baxter.



Gilsonite vein locations, industry facilities, and some geologic information for the gilsonite field, Uinta Basin, Utah.

variations in vein width. The veins are usually rooted in the Green River oil shale, so they are more vertically extensive to the northwest where they are not as deeply eroded. The oil-shale depth contours on the accompanying figure indicate potential depth of the veins.

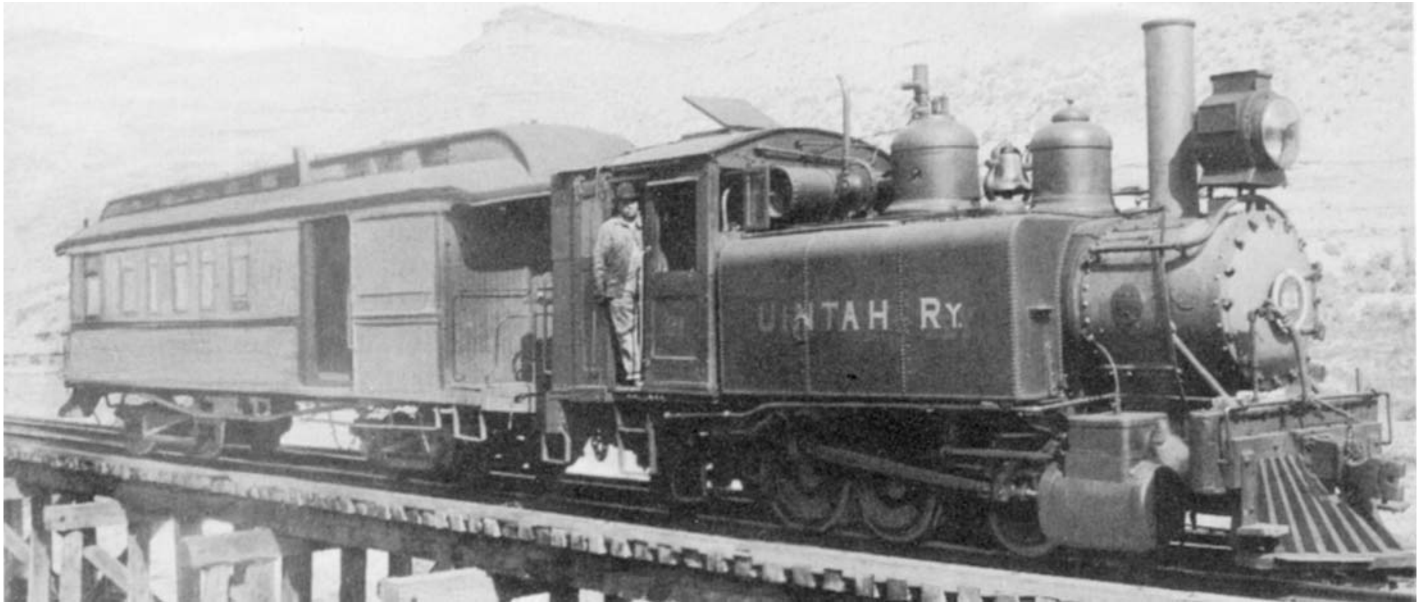
Geologic Setting and Origin

Gilsonite veins are found in Tertiary-aged (about 57 to 36 million years old) sedimentary formations in the Uinta Basin. These formations, in order from oldest to youngest, are the Wasatch, Green River, Uinta, and Duchesne River Formations. The veins are best developed in the thick sandstones of the upper Green River and lower Uinta Formations and tend to split and be less continuous in mudstone, marl, and discontinuous channel sandstones. In the Wasatch Formation (below the oil shale), gilsonite is exposed only in veins at the easternmost edge of the gilsonite field where the strata are most deeply eroded.

Deformation (thrust faulting and downwarping) associated with the Sevier/Laramide mountain-building episode formed the Uinta Basin. This topographic basin was occupied by lakes of various sizes over millions of years. Large amounts of organic material accumulated on the lake bottom, particularly during one period when Lake Uinta reached its maximum areal extent in the basin. Later, heat and pressure of burial changed the organic-rich sediment into the thick oil shales of the middle to upper Green River Formation. Burial of the oil shale generated water and hydrocarbons that were expelled, fracturing the surrounding rock. The escaping water deposited minerals on the walls of the fractures. Viscous petroleum was later extruded into the fractures, forcing them open, filling associated sills, and in some areas saturating wall rock. The viscous hydrocarbons later solidified into gilsonite.

Development History

The first documented mining of gilsonite was in 1868, when a blacksmith asked local Native Americans to find coal for his forge. The gilsonite that they (mistakenly) brought him reportedly melted, caught fire, flowed out of the forge, and almost burned down the blacksmith shop. This unusual material also caught the attention of many of the new immigrants in the area who staked claims on the veins even before it was clear what the material was, or how it might be used. Two



Uintah Railway Company locomotive. The Uintah Railway was constructed for transporting gilsonite but also was a major transporter, in the Uinta Basin, of other freight and passengers from 1904 to 1938 (photograph from Kretchman, 1957, copyright American Gilsonite Company).

early prospectors, Bert Seaboldt and Samuel Gilson, experimented with the gilsonite, developed uses for it, and secured financing for development. Gilson's enthusiasm and promotional ability resulted in the newly discovered material being named after him (its formal mineralogical name is uintaite).

The first regular shipments of gilsonite began in 1888, from veins in the western part of the gilsonite field. The gilsonite was shipped 60 miles south by wagon from Myton to the railroad at Wellington. Early development was an intense period marked by exploration, mining property consolidation, negotiation and conflict with Native Americans and government agents, and lobbying in the U.S. Congress for changes to Native American Reservation boundaries. By 1903, the Gilson Asphaltum Company (predecessor of the American Gilsonite Company) controlled most of the gilsonite resource, including large veins that had been discovered in the eastern part of the basin. In 1904, Gilson Asphaltum constructed the now defunct, narrow-gage Uintah Railway from the eastern part of the field (near Rainbow, Utah) to the Denver and Rio Grand Western railroad in Colorado. The improved transportation helped the industry expand and develop new markets. In 1935, Gilson Asphaltum moved its operation north from the Rainbow area to a new mine and processing plant at Bonanza and switched to truck transportation.

The Gilson Asphaltum Company reorganized, and in 1948 became the American Gilsonite Company that was jointly owned by the Barber Oil Company and Standard Oil of California (now ChevronTexaco Corporation). The company's research led to the use of gilsonite as a refinery feedstock to produce gasoline, high-purity electrode carbon, and other products. By 1957, American Gilsonite had constructed a refinery in Gilsonite, Colorado, that was connected to their Bonanza plant by a 72-mile-long slurry pipeline laid along the abandoned Uintah Railway route. Gilsonite production rose to about 470,000 tons in 1961 as a result of the pipeline and refinery. The gasoline was marketed under the trade name Gilsoline. Cars fueled with Gilsoline were reportedly easy to identify because their exhaust had a characteristic odor. The company sold the refinery in 1973 and redirected their marketing efforts to nonfuel uses of gilsonite. In 1981, Chevron purchased Barber Oil's share of American, and in 1991, Chevron sold their interest. Today, the American Gilsonite Company remains the world's largest gilsonite producer.

Small independent companies have long competed with the American Gilsonite Company and its predecessors. Between 1952 and 1962, G.S. Ziegler and Company, originally a gilsonite customer, purchased and operated the properties of many of the small independents and changed its name to the Ziegler Chemical & Mineral Corporation. They have long maintained a plant and office at Little Bonanza and have been a substantial gilsonite producer for more than 40 years.

Lexco, Inc. began operations in 1988 and constructed a plant and office southeast of Fort Duchesne. They have mined and shipped ore from veins in the south-central part of the gilsonite field.

The original in-place gilsonite resource was estimated at 45 million tons. Most of that ore has been extracted; since 1907 gilsonite production has typically varied between 20,000 and 60,000 tons per year with a spike to 470,000 tons per year in 1961 when American Gilsonite Company's refinery was operating. Additionally, some of the remaining in-place resource cannot be mined due to geo-

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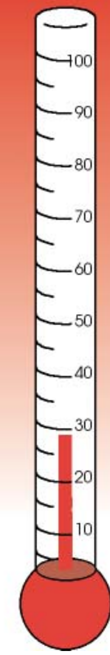
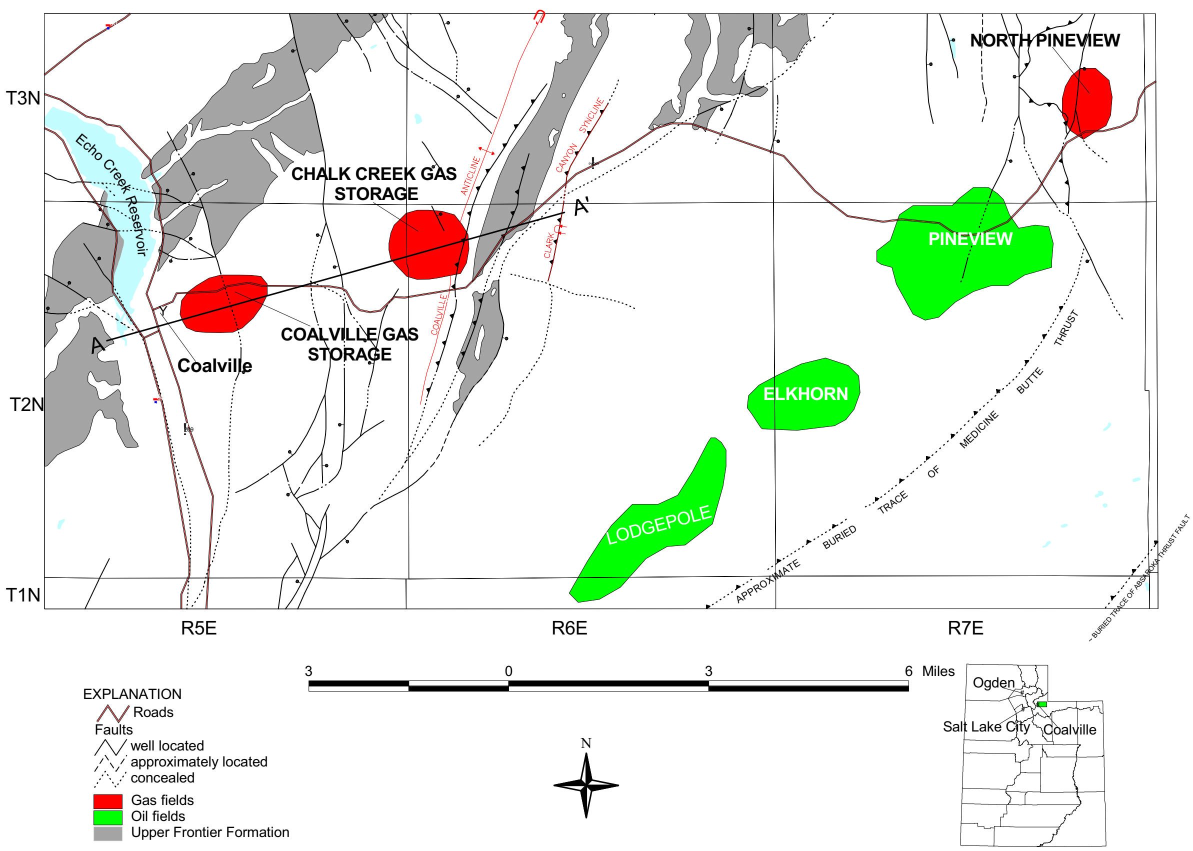
Turn up the thermostat and turn on the shower... What if we all do it at the same time?

by Craig D. Morgan

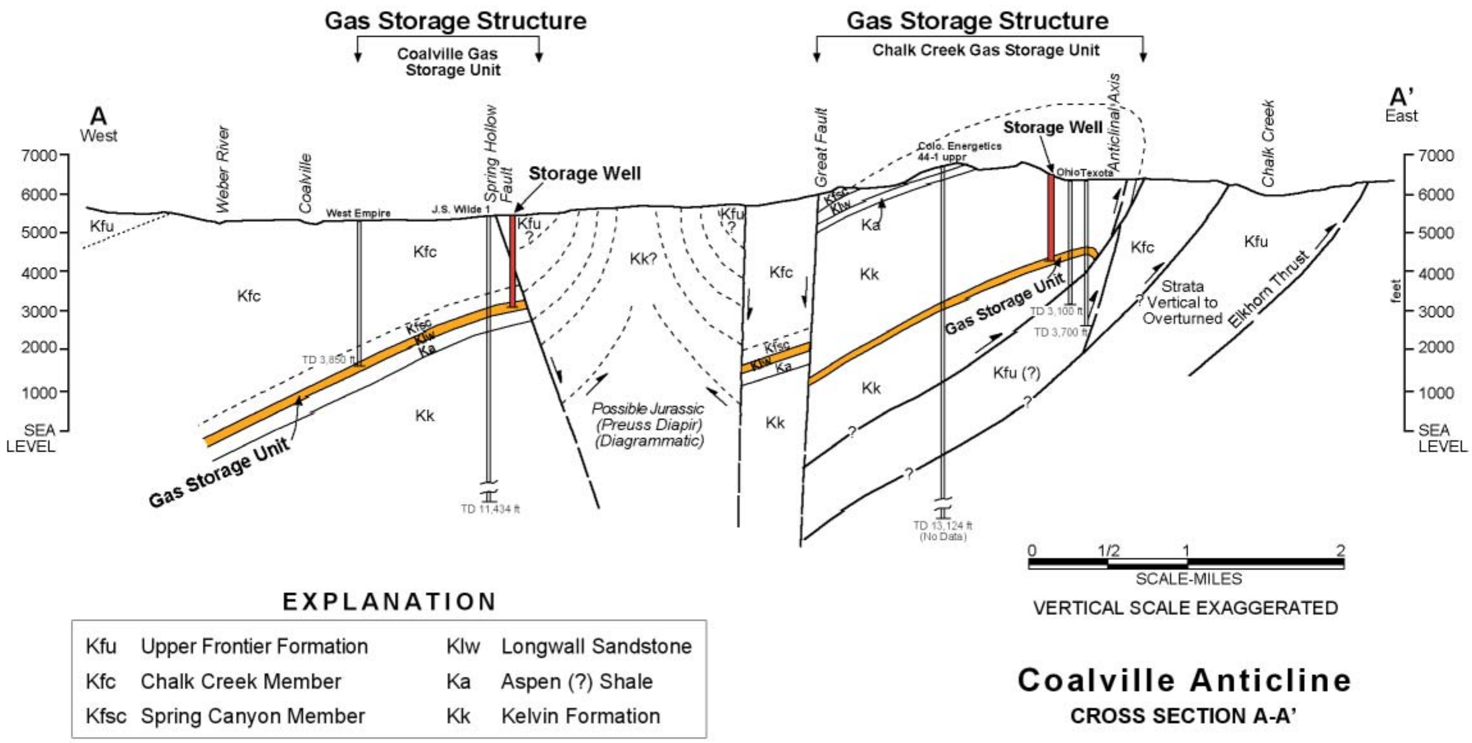


It's the middle of winter, there's snow on the ground and the skies were clear last night. As a result, the temperature has dropped into the sub-zero range. You climb from beneath those warm covers, turn up the thermostat to your gas furnace, and step into the shower for a spray of hot water heated by natural gas, hoping it will wake you up for the day ahead.

You probably won't be surprised to hear that you're not the only one doing that. In fact, more than 700,000 households in Utah use natural gas and most of them are probably doing the same thing at about the same time. This often results in an increase in gas demand statewide at 8:00 to 9:00 a.m. of 15 to 30 percent from the nighttime low. Also, there is a large seasonal variation in gas usage. The typical Utah household uses up to 610 cubic feet (CF) of gas per day during January and as little as 80 CF per day during August. Statewide, Utahns will use as much as 900 million CF of gas per day during some of the coldest winter days. How large is a million cubic feet? As an example, the interior of the new six-story Salt Lake City



Location of the Chalk Creek and Coalville gas storage units east of the town of Coalville, and location of cross section A – A'. Outcrops of the upper Frontier Formation define the Coalville anticline.



library is about 2.4 million cubic feet.

Most of the natural gas we use in Utah is supplied by Questar Gas Company from wells in southwest Wyoming and the Uinta Basin in eastern Utah. How do they handle such a large increase in demand so quickly when the wells are so far away? The sudden demand known as "peak load" is met, in part, by extracting gas from sandstone beds that are used as underground storage units near the town of Coalville just east of the Wasatch Front, the major population center in Utah.

A pipeline transports gas from Wyoming down Chalk Creek Canyon to the Coalville compressor station. From Coalville, a gas line goes northwest down the Weber Valley to Ogden, and two parallel lines go south-southwest to Salt Lake City. Questar operates two underground sandstone-reservoir gas storage units in Chalk Creek Canyon (Chalk Creek and Coalville) that help handle peak load demands during Utah's cold winter mornings.

The gas storage units are on the northeast-trending Coalville anticline, which is partly defined by the exposures of the upper Frontier Formation. Gas is stored in porous and permeable Cretaceous sandstone beds; the storage unit at Chalk Creek is a sandstone bed in the Kelvin Formation, and at Coalville it is the Longwall Sandstone of the lower Frontier Formation. The trap at both storage units is formed by faults and sealed by overlying impermeable shale. Observation wells at both gas storage units are used to monitor the gas pressure in the storage units and to check for gas in shallower beds to ensure that the gas is not leaking and migrating upward.

Drilling at the Chalk Creek gas storage unit began in 1960. The average depth to the Kelvin sandstone is 1800 feet. The Chalk Creek unit holds a maximum 1.2 billion cubic feet (BCF) of gas, of which 256 million cubic feet (MMCF) is usable or "working gas." About 900 MMCF of "base gas" is kept in storage as a buffer between the working gas and the water in the reservoir, and helps push the working gas out by gas expansion. A maximum of 10 MMCF of gas per day can be injected when filling the Chalk Creek unit and a maximum of 35 MMCF of gas per day can be produced.

Drilling at the Coalville gas storage unit began in 1973. The average depth to the Longwall Sandstone is 2400 feet. The Coalville unit holds a maximum 2.8 BCF of gas, of which 692 MMCF is working gas and 2.1 BCF is base gas. Gas can be injected into the Coalville unit at a maximum rate of 20 MMCF of gas per day and produced at a maximum rate of 60 MMCF of gas per day.

Remember, when you get into the shower on one of those cold winter mornings you aren't alone; 700,000 others are joining you. So be thankful for a couple of sandstone beds whose stored gas helps meet those peak-load demands. Without them, you might find yourself in a chilly predicament.

The map and cross section are based on the work of Lyle Hale published in the 1976 Rocky Mountain Association of Geologists guidebook. Tom Yeager and Chad Jones of Questar Corporation provided helpful information for this article.

GeoSights

Fisher Towers – The towering red rock sculptures of Grand County, Utah

by Carl Ege

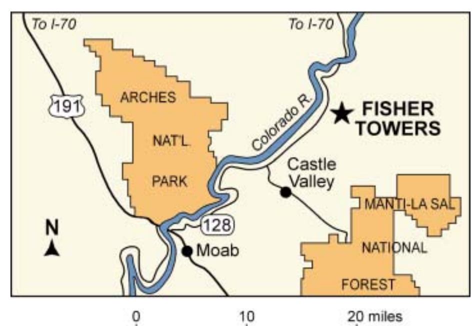
Fisher Towers, located about 20 miles northeast of Moab in southeastern Utah, is one of the most scenic landscapes along the Colorado River. Administered by the Bureau of Land Management, Fisher Towers Recreation Site is a popular destination for hikers and rock climbers. A moderate 2.2-mile (one way) hiking trail takes you along the base of the towers and spires to a scenic overlook of Professor Valley and the Colorado River.

Geologic Information:

Fisher Towers contains layers of sedimentary rock in various shades of red-brown, red-purple, and maroon. The colors are a result of varying amounts of hematite (an iron oxide). The upper, darker part of Fisher Towers consists of the lower sandstone member of the Triassic Moenkopi Formation (approximately 245 million years old). The middle and lower parts of the towers are sandstone, mudstone, and conglomerate of the Permian Cutler Formation (approximately 290 million years old). The

Fisher Towers seen from the road leading to the trailhead. The lower and middle parts of the towers are the Cutler Formation. The lower member of the Moenkopi Formation forms the upper darker part.

conglomerate contains sub-rounded to rounded cobbles and pebbles of quartz, feldspar, mica, granite, schist, and quartzite that were eroded from nearby Precambrian (over 1 billion years old) metamorphic and igneous rocks. These rocks originated from the Uncompahgre highland, a mountainous region that formed at the beginning of the Pennsylvanian period (approximately 320 million years) in western Colorado and eastern Utah. Rivers and streams flowing south from the Uncompahgre highland eroded, transported, and then deposited rock and sediment in channels and flood plains. By the end of the Permian period (250 million years ago), the Uncompahgre highland no longer existed; it had been reduced to low hills and plains. The Colorado Plateau region was uplifted starting



approximately 80 to 50 million years ago, and over the past several million years many of the existing erosional features of the Colorado Plateau were created, including canyons, mesas, buttes, arches, bridges, hoodoos, spires, pedestals, and towers. At Fisher Towers, erosion continues to sculpt the towers, spires, and pedestals. One area, approximately one mile from the start of the trailhead, contains several rock pedestals capped by large sand-

Close-up view of a conglomerate layer within the Cutler Formation. Hammer for scale.

A rock pedestal, approximately 25 feet high, sculpted from the Cutler Formation and capped by a large sandstone slab from the lower member of Moenkopi Formation.

stone slabs of the Moenkopi Formation. These rock slabs fell from the cliffs high above. The sandstone, more resistant to erosion than the softer underlying layers of the Cutler Formation, protects and preserves the soft rock underneath, creating rock pedestals. In a similar manner, the Moenkopi Formation has provided a resistant cap for some of Fisher Towers, allowing erosion to carve the awe-inspiring spires and towers that we see today.

How to get there:

From Moab, travel 2 miles northwest along U.S. 191 to the turnoff for Utah State Highway 128. Turn right (northeast) and travel approximately 21 miles to the turnoff for Fisher Towers Recreation Site (just past milepost 21). Turn right (east) and proceed 2.2 miles to the trailhead.

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logic and engineering problems. In 1980, an American Gilsonite employee estimated that about 5 million tons of mineable reserves remained in the basin. However, the potential for discovery of new veins, as well as increased resource estimates for small, known veins, may increase gilsonite resource values in the basin.

Mining Techniques

Due to gilsonite's unusual mode of occurrence in narrow, deep, vertical veins; and the explosion hazard associated with gilsonite dust, gilsonite mining is labor intensive. Mining initially consisted of surface trenching, but all recent work has been underground mining through large-diameter shafts drilled along the veins. Miners use air-powered chipping hammers to carefully break the gilsonite while avoiding contaminating the ore with broken wall rock. Product purity is important to customers. The broken ore rolls down the steep slope to the bottom of the underground mined area where it enters a vacuum tube and is pneumatically conveyed to the surface. Explosives are occasionally used. Gilsonite companies have used other mining equipment in the past including, bulldozers, a small tunnel-boring machine, and water-jet cutters mounted on mine cars and surface drill rig bits. The American Gilsonite Company is currently testing a compressed-air-powered, continuous mining machine with a rotary mechanical cutting head.

Conclusions

Gilsonite is remarkable for its unusual geologic origin, mode of occurrence, and chemical and physical properties. Also notable are the ingenuity and persistence of the gilsonite company personnel who created a new industry and over the past 100 years have solved mining, processing, transportation, marketing, and other problems to continue to supply this unique Utah material to the world markets.

Additional Reading

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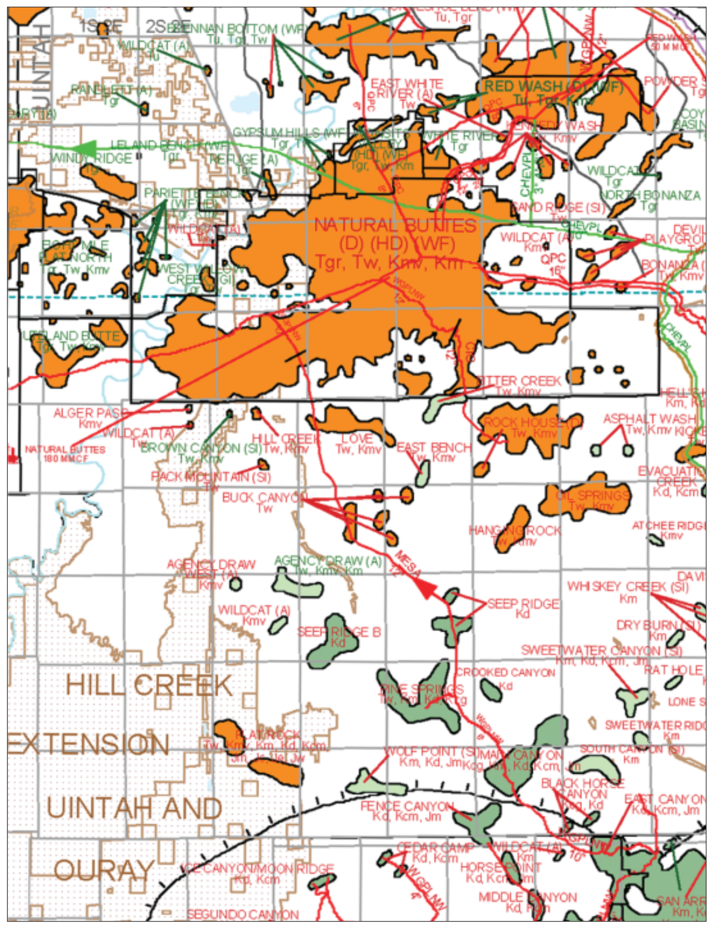
New Oil and Gas Fields Map of Utah – Just the Facts!

by Thomas C. Chidsey, Jr. and Sharon Wakefield

Many Utah citizens, the majority of whom live in the heavily populated Wasatch Front, do not realize that Utah is a major petroleum-producing state. In fact, Utah has over 200 oil and gas fields and 5200 producing wells; more than 1.2 billion barrels of oil and 7.8 trillion cubic feet of gas have flowed from these fields! Utah consistently ranks in the top 15 oil-and-gas-producing states. Oil and gas pipelines crisscross many areas of Utah. The most visible signs of the petroleum industry along the Wasatch Front are the cluster of oil refineries in North Salt Lake and Woods Cross. However, there are no pump jacks, wellheads, or drilling derricks in that area.

So, where are all the oil and gas fields in Utah? The answer to that question can be found on a new map, *Oil and Gas Fields of Utah* (Utah Geological Survey Map 203DM), available in both hard copy and digital format. This map presents a wealth of information, and shows more than just the location of oil and gas fields. The color of the fields is coded to the geologic age of the oil- and gas-producing rocks (reservoirs). The names of the producing fields are also color-coded — red for natural gas and green for oil. By each field is the name of the producing rock formation (typically more than one), and various special field designations. These designations include status (abandoned, shut-in, or gas storage), unique types of produced gases (helium, carbon dioxide, hydrogen sulfide, and coalbed methane [natural gas from coal]), and distinct projects designed to increase production (horizontal drilling, waterflooding, and gas injection). When a petroleum geologist proposes a plan to drill a new well, one of the first questions managers often ask is "Where is the nearest pipeline?" Produced oil can be trucked from the wells, but gas has to be transported via a pipeline. The new map shows the approximate locations of major oil and gas pipelines in Utah, pipe diameter, direction of flow, and current operators. Natural gas processing plants and oil refineries, daily capacities, and operators are also shown on the map.



A sample from the new map.

The map outlines key geologic/physiographic features such as major plateaus, uplifts, and sedimentary basins. Most oil and gas fields are located in two large basins - the Uinta and Paradox Basins in eastern and southeastern Utah, respectively. The map shows where both Precambrian (greater than 570 million years old) metamorphic and Tertiary/Quaternary (66 million years or younger) granitic and volcanic rocks are exposed on the surface. Very little oil and gas have been found in areas where rocks of these types are present.

Other items identified on the map include major roads, reservoirs, and rivers; county boundaries and seats; Indian reservations; wilderness areas; and national parks, monuments, and recreation areas. Thus, the map shows where the oil and gas fields and pipelines are in relation to these various features, many which are environmentally sensitive.

The new oil and gas fields map was produced not just for oil and gas companies. It can be used by government land managers, regulators, and decision-makers; environmentalists; Native American groups; and farmers, ranchers, and mineral-lease owners. This map will help inform all Utahns as to where the oil and gas resources are located without taking sides on the issues of exploration and development. Some may be surprised by what it shows. For example, new gas exploration proposed near the archeologically rich Nine Mile Canyon area northeast of Price has created a storm of controversy written up in local newspaper articles. However, the map indicates that there are already several gas fields in the area (which include 22 gas wells, some just off the road, that have produced over 10 billion cubic feet of gas) and a 20-inch gas pipeline running through the canyon. The map also shows a string of producing and abandoned oil fields between Arches and Canyonlands National Parks, while another abandoned oil field, Virgin, lies just west of Zion National Park. A 26-inch-diameter gas pipeline crosses through the middle of Arches National Park. One oil field, Upper Valley, is partly within Grand Staircase-Escalante National Monument. This field has 21 wells that produce nearly 17,000 barrels of oil per month (trucked to market) totaling about 27 million barrels of oil since its discovery in 1964. Finally, it may amaze many to learn that there are major oil and gas fields only 40 miles east–northeast of Salt Lake City. The same rocks that produce in those fields (the 200 million-year old Jurassic Nugget Sandstone and Twin Creek Limestone) crop out at the mouth of Parleys Canyon along Interstate 80. These fields have produced 165 million barrels of oil and 158 billion cubic feet of gas!

A map showing mineral resources and methods of transport is nothing really new. In 1815, an Englishman named William Smith, self-taught engineer, fossil collector, and "canal digger," published the world's first geologic map - a geologic map of Great Britain. This remarkable map showed where the various rock formations crop out and predicted where they were in the subsurface. However, the map also included the location of mineral resources and mines - coal, tin, lead, and copper. In addition, the map specifically displayed the railroads, rivers, and canals capable of transporting these mineral resources to markets, factories, and smelters. Ever since Smith's map was published, geologists have produced geologic and mineral resource maps, which now include oil and gas fields and pipelines.

Whether one thinks Utah has enough or needs more oil and gas wells, hopes oil is found on the family farm or ranch, wants things preserved as they are, is exploring for or purchasing oil and gas, or is just interested in science and energy, the *Oil and Gas Fields of Utah* map will be a valuable source of information. This map provides, as Sergeant Joe Friday used to say on the 1960s TV show *Dragnet*, "just the facts."

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This different behavior of eastern and western U.S. coal has been attributed to the higher chlorine content of eastern coal, which promotes the formation of ionic, water-soluble forms of mercury in the stack gas that is readily trapped by conventional (wet) stack-gas scrubbers. Other elements that may influence the effectiveness of mercury-control technologies include the iron, sulfur, sodium, and calcium in coal; eastern and western U.S. coals contain substantially different amounts of these elements.

In recognition of the lack of universally effective technologies to control mercury emissions from power plants, the EPA has proposed less stringent mercury emission limits for plants that burn western subbituminous or lignite coal. However, as currently proposed, the rules require power plants that burn Utah bituminous coal to meet the same emission limits as plants burning eastern bituminous coal. Meeting these limits may prove challenging for both Utah coal producers and consumers.

For more information see the following references, or contact the author (jeffreyquick@utah.gov) who is investigating how geographic variation of coal chemistry can be used to optimize mercury control technologies, in a project funded by the U.S. Department of Energy (contract No. DE-FC26-03NT41901; Web Site geology.utah.gov/emp/mercury/index.htm).

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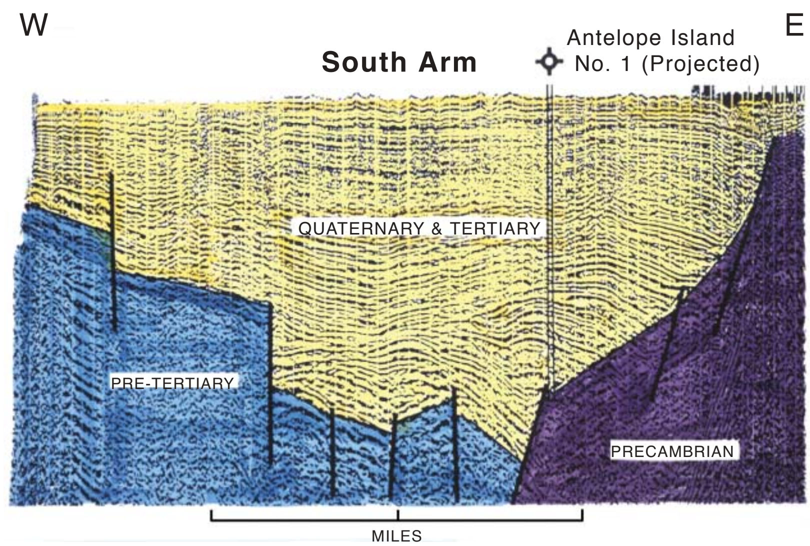
“Glad You Asked”

by Mark Milligan

What are seismic surveys and how much “shaking” do they create?

Like Superman, geologists have X-ray vision – well, sort of. Seismic surveys use reflected sound waves to produce a “CAT scan” of the Earth’s subsurface. Seismic surveys can help locate ground water, are used to investigate locations for landfills, and characterize how an area will shake during an earthquake, but they are primarily used for oil and gas exploration.



Two-dimensional seismic section across a sedimentary basin located under Great Salt Lake west of Antelope Island. After data collection, images are processed by computers and interpreted by geologists or geophysicists. Figure provided by Craig Morgan, UGS.

Early “wildcatters” found oil by drilling natural oil seeps and large folds (anticlines) in exposed rocks. These “easy” oil prospects were all quickly discovered and drilled, and geologists turned to seismic surveys to find less obvious oil and gas traps. Seismic technology had been used since the early 1900s to measure water depths and detect icebergs, and by 1924, crude seismic data were first used in the discovery of a Texas oil field.

Seismic images are produced by generating, recording, and analyzing sound waves that travel through the Earth (such waves are also called seismic waves). Explosives or vibrating plates generate the waves and a line or grid of geophones records them. Density changes between rock or soil layers reflect the waves back to the surface, and how quickly and strongly the waves are reflected back indicates what lies below.

The amount of shaking associated with different seismic surveys varies, depending on site-specific factors such as soil and rock type, how deep the survey needs to image, and the required source. A steel plate struck with a sledgehammer generates enough energy for shallow (less than 60 feet) soil investigations used for engineering or environmental surveys. To “see” a little deeper, a trailer- or pickup truck-mounted drop weight might suffice. To get a really deep picture (miles), as is needed for oil and gas exploration, dynamite charges or vehicle-mounted vibrator plates (called vibroseis trucks and buggies) are used to generate waves from multiple source points.

Dynamite charges are commonly buried in 50- to 100-foot-deep holes (called shot holes). Relatively small amounts of explosives are used in shot holes. For example, the

This historic postcard of Huntington Beach, California depicts numerous oil wells – an early twentieth century drilling plan. Now, seismic surveys can paint a picture of the subsurface in order to better target oil and gas reserves. This results in fewer dry holes and less drilling, or even no drilling if seismic data suggest a low potential for oil or gas.

petroleum industry's Stone Cabin 3D seismic survey scheduled for this summer near Nine Mile Canyon in Carbon County will use 10 and 20 pounds of explosives in shot holes. In comparison, 30 pounds might be used for a large construction-site blast and 2,000 to 4,000 pounds for a medium-sized quarry or mine blast. With any of these detonations, if you are at the source you will feel the ground move. However, because the charge is smaller and deeply buried for seismic surveys, you probably would feel only a small pulse up to a few hundred feet away, and beyond that you are not likely to feel anything at all.

Seismic waves generated by explosives can be compared to the Richter magnitude scale used to measure an earthquake's size. Utah's seismograph network consistently records earthquakes as small as magnitude 1.5 (earthquakes below magnitude 2 are rarely felt). Approximately 320 pounds of explosives would be needed to produce seismic waves similar to a magnitude 1.5 earthquake. During 2003, seismographs recorded 702 magnitude 1.5 or greater events in Utah; 321 were naturally occurring earthquakes and 381 resulted from activities such as mining, quarrying, or military bomb testing.

Vibroseis trucks and buggies come in a variety of designs and sizes, but all of them generally release less energy than is generated from shot holes. All have a large pad that is lowered from the vehicle to the surface and then vibrated to generate seismic waves. In an urban environment, vibroseis-generated waves are less than background noise generated by buses, trucks, and trains (repeated signals are used in order to be distinguishable from background noise). At its source you can feel a vibroseis shake the ground but as you move away your ears will hear the airborne sound waves much longer than your feet can feel those in the ground.

SURVEY NEWS

A friend of the Survey, **Kenneth C. Thompson** died in an automobile accident March 28. He worked for the Survey (then the UGMS) between 1958 and about 1970, beginning as the Curator for the Oil Well Sample Library and as assistant draftsman and sample collector. From 1964-68 he was Chief Draftsman, then finished his Ph.D in geology, authoring "Mineral deposits of the Deep Creek Mountains" published by the UGMS. He had been a teacher at Southwest Missouri State University since leaving Utah.

Don Currey passed away on Sunday, June 6, at the age of 70. Don was a geologist in the Geography Department at the University of Utah. He was an authority on Lake Bonneville and Great Basin Quaternary geology. Some of Don's graduate students included former UGS director Genevieve Atwood, former UGS mapper Jack Oviatt, and current UGS GIO geologist Nancy Carruthers. Don was an outstanding scientist, an exceptional storyteller, and a genuinely kind person. He will be greatly missed.

The UGS Board announced the annual Crawford Award recipients: **R. Gloyn**, **D. Tabet**, **B. Tripp**, **C. Bishop**, **C. Morgan**, **J. Gwynn**, and **R. Blackett**, for their publication "Energy, Mineral and Ground-water Resources of Carbon and Emery Counties, Utah" UGS Bulletin 132, 2003. The Crawford Award recognizes outstanding achievement, accomplishments, or contributions by a current UGS scientist in some aspect of Utah geology. Crawford was the first director of the UGS.

Mike Lowe was named DNR's Manager of the Year and was one of the finalists for the State Government Manager of the Year. Way to go Mike!

Congratulations and welcome aboard (officially) to **Darryl Greer**. Darryl has been with us for a while on a temporary status, but recently was chosen for the permanent GIS opening in the Mapping Program. Darryl is in the GIS room, which is now looking pretty full, with **Neil Burk** and **Chris DuRoss** also in the new cubicles, plus the addition of a well-log scanner.

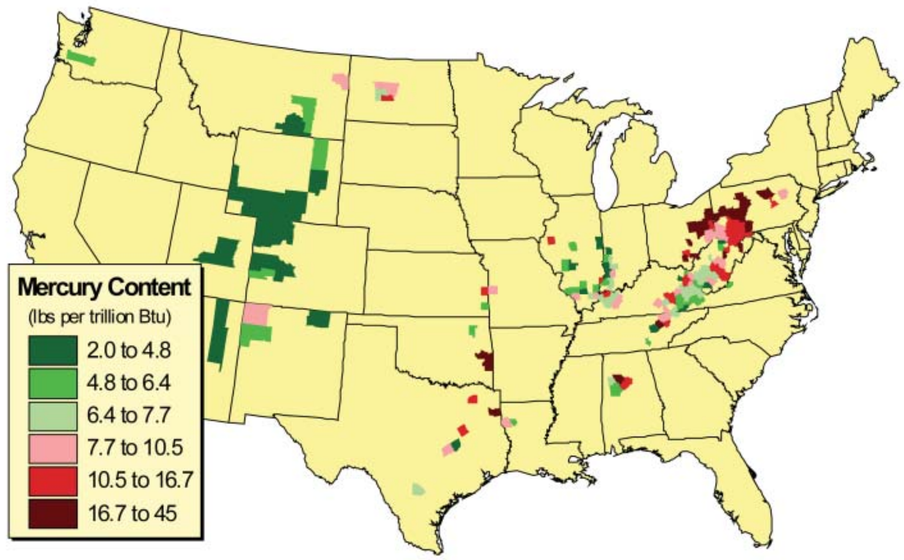
Two new Project Geologists have come aboard. They are the first permanent hires to the UGS geology career ladder in seven years. **Don Clark** joined the Mapping Program in early June. Don was a consulting geologist from the Chicago area, with an MSc from Northern Illinois University. His thesis was a geologic map in Utah, and he has subsequently mapped here on a volunteer basis. The second position is an addition to the Ground Water Section, resulting in part from extra funding granted by the Utah Legislature for ground-water work. **Juliette Lucy** is a hydrogeologist joining us from Norwest Corporation.

Energy News

New rules limiting mercury emissions from coal-fired power plants

by Jeffrey C. Quick

The U.S. Environmental Protection Agency (EPA) is expected to issue new rules limiting mercury emissions from coal-fired electric power plants by March 15, 2005, with enforcement beginning as early as April 2008. Those of us who remember playing with mercury in grade-school science class or from an accidentally broken thermometer may wonder why the EPA is concerned about mercury emissions. After all, mercury is a naturally occurring element that is added to eye drops, childhood vaccines, and dental fillings. Moreover, mercury emissions from power plants do not make the air hazardous to breath, or the water unsafe to drink.



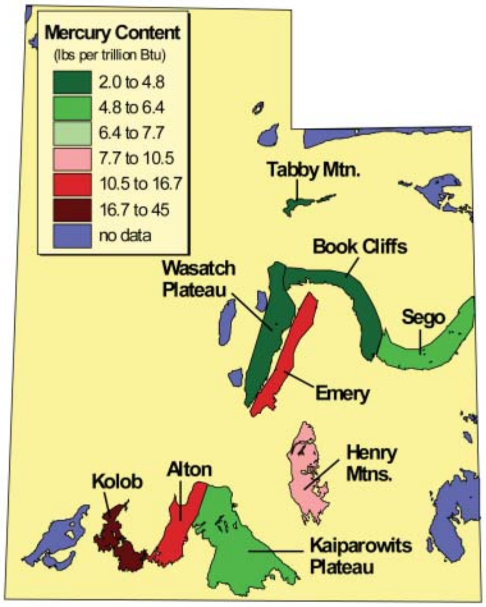
Average mercury content of coal shipped to power plants during 1999, by U.S. county-of-origin.

In a word, the problem with mercury is fish – and not just any fish, but large freshwater fish coveted by recreational fishermen, as well as a few ocean fish sold at the grocery store (swordfish, shark, king mackerel, and tilefish). Government guidelines say that children, and women of childbearing age, should not eat these fish because they contain potentially hazardous amounts of methylmercury, which is a highly toxic, mercury-containing organic compound. Regularly eating fish that contains high amounts of methylmercury can cause neurological damage in developing fetuses and children, which results in diminished cognitive, motor, and verbal abilities.

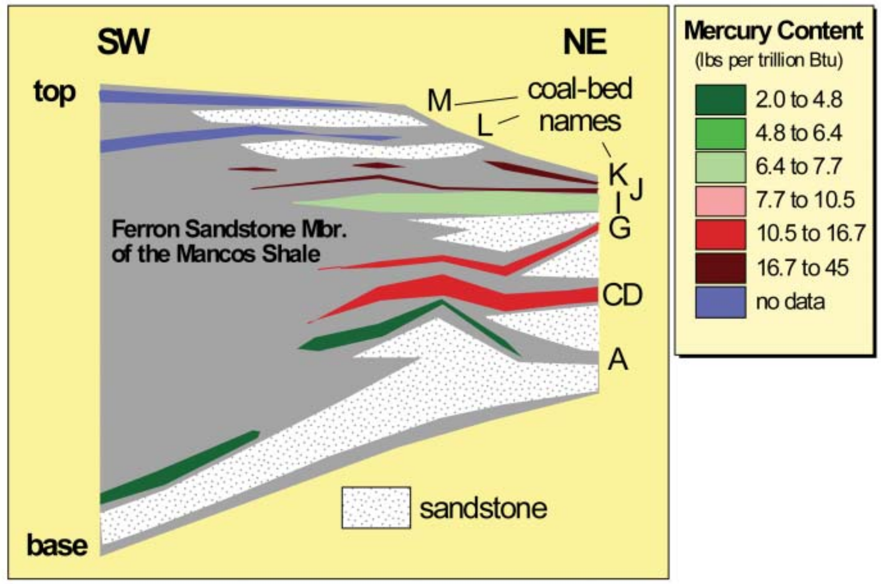
In its December 2000 finding that regulation of mercury emissions from coal-fired power plants is appropriate and necessary, the EPA determined that there is a plausible link between mercury emissions from coal-fired power plants and methylmercury concentrations in fish. This determination was largely based on the observation that coal-fired power plants are the largest human source of mercury emissions in the U.S. Indeed, as much as 20 percent of the mercury deposited in the U.S. originates from coal-fired power plants. Other major sources include municipal and medical waste incinerators (17 percent), chlorine plants (3 percent), and hazardous waste incinerators (2 percent); these sources have already been regulated. Finally, at least 40 percent of mercury deposition in the U.S. is from sources that are not easily controlled (international sources, natural emissions, and re-emission of accumulated human emissions). Atmospheric mercury becomes a problem when it is deposited by rainfall and enters streams and lakes where some of it is converted by microbes into methylmercury. The methylmercury is concentrated through the food chain and can reach high levels in large predator fish.

Fortunately, fish from Utah rivers, lakes, and reservoirs do not contain harmful levels of mercury. Likewise, nearly all commercial fish, such as salmon, catfish, canned light tuna, and the generic breaded fish stick, are also considered safe (and nutritious) for young women and children to eat. However, the low mercury content of fish in Utah is little comfort to recreational and subsistence fishermen in the upper Midwest and New England where mercury advisories have been posted for nearly all inland and coastal water bodies.

Mercury emissions from coal-fired power plants originate from trace amounts of mercury in coal. Although the average mercury content of U.S.



Average mercury content of coal in Utah coalfields.



Vertical section through the southern Emery coalfield strata showing the average mercury content of different coal beds.

coal is similar to the average crustal abundance of mercury (~0.08 parts per million), the enormous amount of coal burned in the U.S. results in potentially large mercury emissions. For example, 950 million tons of coal containing 75 tons of mercury was burned at nearly 500 U.S. power plants during 1999. About 30 tons of this mercury was effectively trapped in coal-ash waste or desulfurization residues. The remaining 45 tons of mercury was emitted to the atmosphere with the stack gas.

The mercury content of U.S. coal varies geographically. High-mercury coal is produced from the northern Appalachian region (Ohio and Pennsylvania), whereas low-mercury coal is produced in Utah and other western states. The low-mercury coal currently produced in Utah originates from the Wasatch Plateau and Book Cliffs coalfields. However, not all Utah coalfields have low-mercury coal. For example, coals in the Alton, Emery, and Kolob coalfields have relatively high mercury contents. Future production is especially likely from the southern part of the Emery coalfield. This area has thick coal beds, is close to central Utah electric utilities, and has favorable mining conditions.

Besides geographic variation, the mercury content of coal also varies from bed to bed. For example, although the average mercury content of coal in the Emery coalfield is relatively high, the mercury content of some coal beds is relatively low. Recent work in Canada, Indiana, and Kentucky has also shown substantial variation of mercury within individual coal beds; similar intra-bed variation is likely for Utah coal beds.

Because earlier rules limiting sulfur emissions from power plants effectively increased demand for low-sulfur Utah coal, an analogous outcome from the new rules might be anticipated for low-mercury Utah coal. This analogy is misleading. Because the Clean Air Act classifies mercury as a toxic pollutant, larger emission reductions may be required for mercury than for sulfur. Moreover, unlike sulfur emissions, which can be controlled using stack-gas scrubbers, a universally effective technology to control mercury emissions does not exist. Although stack-gas scrubbers effectively control both sulfur and mercury emissions from power plants burning eastern U.S. coal, scrubbers do not reduce mercury emissions from power plants burning western U.S. coal. Consequently, modern coal-fired power plants with particulate filters and stack-gas scrubbers that burn high-mercury eastern coal can have lower mercury emissions than similarly configured power plants that burn low-mercury western coal.

Continued on page 9 . . .

How much of the mercury entering U.S. watersheds is from coal-fired power plants?

Between 40 to 75 percent of the atmospheric mercury deposited in the contiguous U.S. originates from international emissions, natural emissions, and the re-emission of accumulated human emissions. This wide range of possible values illustrates our limited understanding of the origin of mercury deposition. However, ignoring the sources of these contributions, about one-third (33%) of atmospheric mercury emissions in the U.S. are attributed to domestic, coal-fired power plants. Accordingly, the calculated contribution of mercury emissions from coal-fired power plants to mercury deposition into U.S. watersheds is as little as: $\frac{33 \times (100-75)}{100} = 8\%$, to as much as: $\frac{33 \times (100-40)}{100} = 20\%$. Thus, although the actual value is uncertain, domestic coal-fired power plants contribute between 8 and 20 percent of the mercury deposited into U.S. watersheds. However, the depositional burden is unequally distributed. For example, most of the mercury deposited in the northeastern U.S. is from domestic, industrial emissions, whereas emissions from Asia and the Pacific Rim appear to be the dominant sources of mercury deposition in Utah.

NEW UTAH MINERALS

by Carl Ege

Bobjonesite, $V^{4+}O(SO_4)(H_2O)^3$

Bobjonesite is a vanadium sulfate found at the North Mesa mine group in the Temple Mountain mining district, Emery County. The mineral is found as crusts or crystals less than 1 mm in size. Bobjonesite is pale blue to blue-green with a pale blue streak. The mineral has a hardness of 1 and a density of 2.28 g/cm^3.

Bobjonesite was found in a fossilized log in the Shinarump Conglomerate Member of the Triassic Chinle Formation. The mineral is associated with ferricopiapite, kornelite, rozenite, szmolnokite, anorthominasragrite, and sulfur. Bobjonesite is named for Robert (Bob) Jones, a senior editor of Rocks and Gems magazine.

Anorthominasragrite, $V^{4+}O(SO_4)(H_2O)_5$

Anorthominasragrite is also a vanadium sulfate found at the North Mesa mine group in the Temple Mountain mining district, Emery County. The mineral is found as crusts or spherical granular aggregates approximately 1 mm across, and as individual crystals less than 0.1 mm. Anorthominasragrite is blue-green to pale blue with a white streak. The mineral has a hardness of 1 and a density of 2.12 g/cm^3.

Anorthominasragrite was found in a fossilized log in the Shinarump Conglomerate. The mineral is associated with orthominasragrite, minasragrite, and bobjonesite. Anorthominasragrite is named for its relationship with the mineral minasragrite.

For more information:

Cooper, M.A., Hawthorne, F.C., Grice, J.D., and Haynes, P., 2003, Anorthominasragrite, $V^{4+}O(SO_4)(H_2O)_5$, a new mineral species from Temple Mountain, Emery County, Utah - description, crystal structure, and hydrogen bonding: The Canadian Mineralogist, v. 41, p. 467-471.

Schindler, M., Hawthorne, F.C., Huminicki, D.M.C., Haynes, P., Grice, J.D., Evans, H.T. Jr., 2003, Bobjonesite, $V^{4+}O(SO_4)(H_2O)^3$, a new mineral species from Temple Mountain, Emery County, Utah: The Canadian Mineralogist, v. 41, p. 83-90.

NEW PUBLICATIONS

Geologic postcard of Goblin Valley, 6/04, PI-82 . . . . $0.25

Geologic map of the Navajo Lake quadrangle, Kane and Iron Counties, Utah, by David W. Moore, L. David Nealy, Peter D. Rowley, Stanley C. Hatfield, David J. Maxwell, and Eric Mitchell, 2 pl., 1:24,000, 6/04, M-199 . . . . $9.95

Geologic postcard of Utah, by Grant Willis, PI-81, 6/04 . . . . $0.35

County geologic reports: Piute, Garfield (reprints of Bull 102 & 107) on CD, 6/04 . . . . $14.95

The available coal resource for eight 7.5-minute quadrangles in the southern Emery Coalfield, Emery and Sevier Counties, Utah, by Jeffrey C. Quick, David E. Tabet, Brigitte P. Hucka, and Sharon I. Wakefield, 37 p., 6/04, SS-112 . . . . $7.75

Earthquake-hazards scenario for a M7 earthquake on the Salt Lake City segment of the Wasatch fault zone, Utah, by Barry J. Solomon, Neil Storey, Ivan Wong, Walter Silva, Nick Gregor, Douglas Wright, and Greg McDonald, CD (59 p., 6 pl. scale 1:250,000), 5/04, [CD contains GIS data] SS-111DM $24.95

Geologic hazards of Monroe City, Sevier County, Utah, by Richard E. Giraud, digital compilation by Justin P. Johnson, 51 p. + CD [CD contains GIS data], 5/04, SS-110 . . . . $13.95

The geology of Cedar Valley, Utah County, and its relation to ground-water conditions, by Hugh A. Hurlow, 4/04, CD (74 p., 4 pl., 1:100,000), 2004, SS-109 . . . . . . $19.95

Descriptions, petrology, photographs, and photomicrographs of core from the Green River Formation, south-central Uinta Basin, Utah, by S. Robert Bereskin, Craig D. Morgan, and Kevin P. McClure, CD (203 p.), 4/04, MP-04-2 . . . . $19.95

Ferron Sandstone drill-hole database and lithologic logs, Ferron Creek to Last Chance Creek, Emery and Sevier Counties, Utah, by Brigitte P. Hucka, Steven N. Sommer, Douglas A. Sprinkel, and David E. Tabet (a recasting of OFR-317, 317DF, and 331), CD, 4/04, OFR-429 . . . . $14.95

Newcastle, Utah small-scale geothermal power development project - exploratory drilling, by Robert E. Blackett, 8 p. + 21 p. appendix, 4/04, RI-252 . . . . $6.00

Oil and gas fields of Utah, by Thomas C. Chidsey, Jr., Sharon Wakefield, Bradley G. Hill, and Michael Hebertson, 1 pl., scale 1:700,000, 7/04, M-203DM (paper plot available for $19.95) [CD contains GIS data] $24.95

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