UTAH GEOLOGICAL SURVEY

SURVEY NOTES

Volume 41, Number 1

January 2009

Anniversary Edition

Utah Geological Survey

60 years

1949–2009

The Director's Perspective

by Richard G. Allis

In 1949 the legislature appropriated $25,000 and appointed Arthur Crawford as the first director of the Utah Geological and Mineralogical Survey, now the Utah Geological Survey (UGS). This year is the 60th anniversary of the Survey. Its budget in recent years of $8–$10 million reflects how its mission has expanded, and this issue of *Survey Notes* gives examples of the diversity of work.

The UGS is involved in ground-water assessment (page 1), paleontological investigations (page 5), and many cutting edge projects evaluating Utah's traditional energy resource potential and assisting technology development (e.g., oil shale as reported on page 7, shale gas in Paleozoic formations, carbon dioxide sequestration, water disposal in the Uinta Basin, Leadville oil and gas potential). Possibly less well known, however, is that the UGS is also very active in renewable energy assessment, and recently played an important role on the Governor's Utah Renewable Energy Zone Task Force. The task force was commissioned in July 2008 to identify where utility-scale renewable energy development for electric power is possible in Utah, and what economic issues (such as generation costs and distance to transmission lines) are constraints to future development. Evaluating the possibility of co-located renewable energy potential and the presence of renewable energy "zones" was also part of the study. Phase I, which has just been completed, focused on quantifying the renewable energy power potential, and an evaluation of economic constraints was deferred to Phase II. The report from Phase I can be found at http://geology.utah.gov/sep/renewable_energy/urez/index.htm.

The Phase I report investigated the potential of Utah's solar, wind, and geothermal electric power potential. Not surprisingly, Utah's best solar potential is in the southern part of the state, where it reaches 85-90 percent of the best solar potential in the country. Concentrated solar thermal with storage is capable of following the summer electrical demand peak, and in ideal sites (nearly flat) can generate power at about 100 megawatts (MW) per square mile of collectors. The potential in southern Utah is very large if it becomes economic. Utah's wind resource is also large, and is concentrated in some of the broad valleys of southwest Utah and along the Utah-Wyoming border. More localized sites were identified in many parts of the state. The geothermal resource assessment had the greatest challenge because the resource is largely hidden underground, and involves greater uncertainties. Three large resource areas were identified in the Escalante – Sevier basin region, along the Wasatch Front, and in deep oil and gas wells of the Uinta Basin.

When the three types of renewable resource power potential are overlain, the best solar, wind, and geothermal coincide in southwest Utah. The renewable energy industry has probably already recognized this, as a new geothermal power plant was recently commissioned at Thermo Hot Springs in Escalante Valley (10 MW, Raser Technologies Inc.), ground-breaking has taken place at a wind farm near Milford (203 MW, First Wind), and solar developments are also under consideration in this part of the state. The new power contracts are with California consumers because of their higher electricity prices. Hopefully, technology advances will soon make it economic to sell in the Utah power market and this will contribute to the legislature's challenge for 20 percent renewable energy by 2025. This possibility will be assessed in Phase II of the study.

Contents

Design: *Stevie Emerson*
Cover: *Clockwise from upper right: West desert monitor-well drilling and development; UGS scientist excavating a large sauropod bone in eastern Utah; new wind farm at the mouth of Spanish Fork Canyon; UGS mapping geologist examining Cretaceous rocks on the Kolob Plateau, southwestern Utah; UGS scientist working with students during Earth Science Week; oil shale specimen; UGS scientist examining earth fissure in Escalante Valley.*

Survey Notes is published three times yearly by Utah Geological Survey, 1594 W. North Temple, Suite 3110, Salt Lake City, Utah 84116; (801) 537-3300. The Utah Geological Survey provides timely scientific information about Utah's geologic environment, resources, and hazards. The UGS is a division of the Department of Natural Resources. Single copies of *Survey Notes* are distributed free of charge within the United States and reproduction is encouraged with recognition of source. Copies are available at *geology.utah.gov/surveynotes.* ISSN 1061-7930

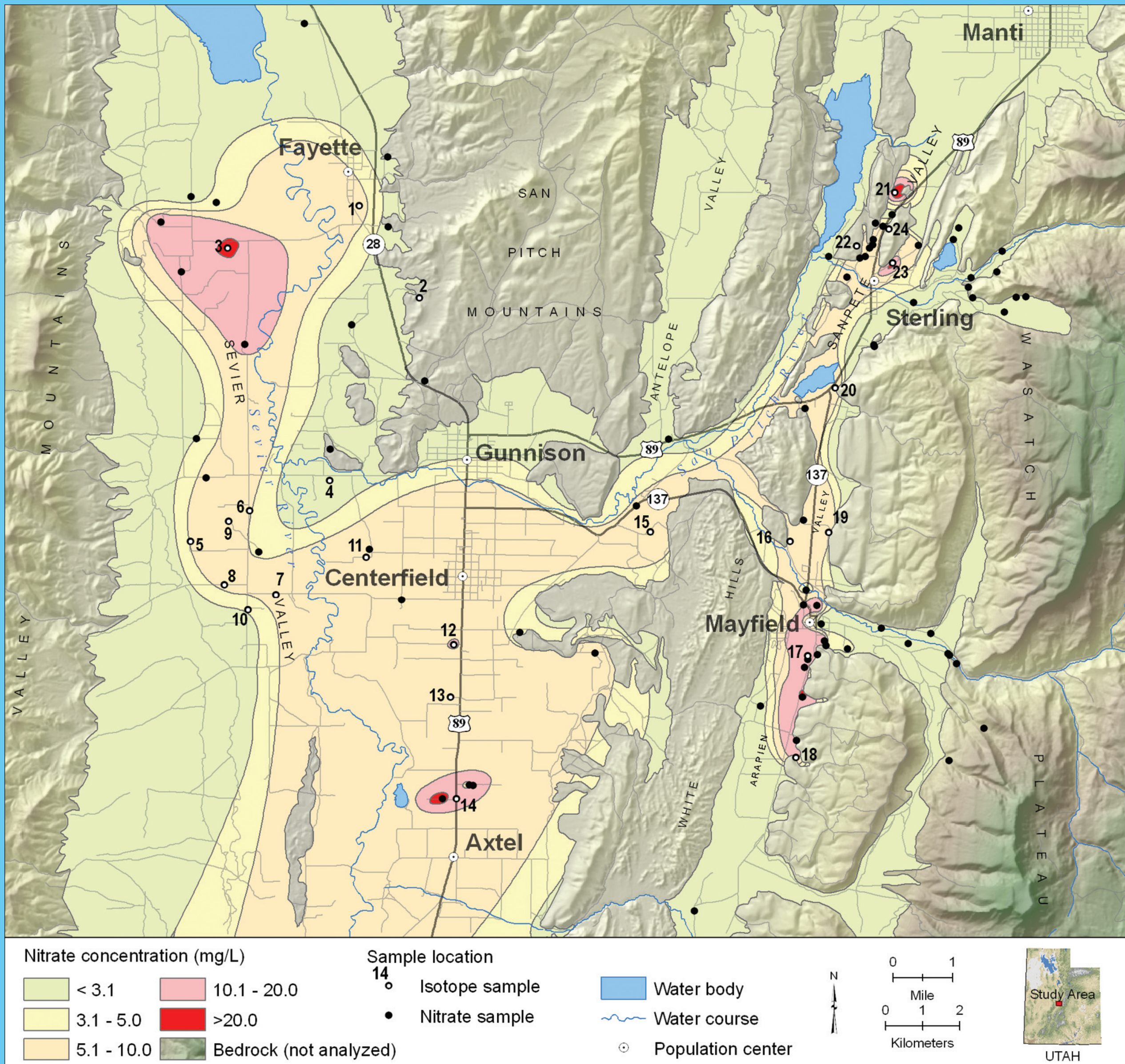
Unusually High Nitrate Concentrations in Southern Sanpete County's Ground Water: Natural or Human-Related?

By Janae Wallace

Many rural areas in Utah rely on ground water from underground aquifers to quench their thirst. Ground water can contain a variety of dissolved chemical constituents derived from both natural and human-related (anthropogenic) sources. We all drink water containing dissolved elements such as calcium, sodium, and magnesium– constituents that occur naturally in ground water– but may not realize the water we drink can also contain constituents such as arsenic or nitrate that, if present in high concentrations, can be a health hazard. If water from a public water supply source contains any constituent that exceeds the U.S. Environmental Protection Agency's primary drinking water-quality standards and cannot be treated, it is deemed unfit for use.

Nitrate is a nutrient that is considered a health risk when concentrations exceed 10 milligrams per liter (mg/L). High nitrate levels in ground water have been documented in the southern Sanpete County area of central Utah. Reports of relatively high nitrate concentrations in public-supply wells and springs prompted the UGS to evaluate water quality in southern Sanpete and central Sevier Valleys and try to determine the nature of the source of nitrate. State and local government officials are concerned about the impact of nitrate contamination on groundwater resources in this rural area and would like to understand the relationship between geology and water quality so that they can help the growing town of Centerfield site a new public-supply well that will have nitrate concentrations below the 10 mg/L water-quality standard.

Most residential development and agricultural activities in southern Sanpete and central Sevier Valleys are located on unconsolidated valley-fill deposits, which are the principal drinking-water aquifers. The aquifers consist of a mixture of sediments including clay, sand, and gravel. Nitrate in the ground water can be from either natural or anthropogenic sources, although the latter source is typically the main contributor. Natural sources include atmospheric, biologic, and geologic components, and common anthropogenic sources include septic tanks, agricultural fertilizer, and manure from livestock. An engineering consultant's study recently reported some wells in southern Sanpete County as having high nitrate concentrations attributed to natural "geologic" nitrate from bedrock. One of these wells, having a nitrate concentration exceeding the EPA standard, was drilled (now sealed) for the town of Centerfield in a remote canyon where there is no apparent upgradient anthropogenic source of nitrate. Similarly, a public-supply spring for Centerfield issuing from bedrock (not a common nitrate source) near a mapped fault zone (a possible pathway) has had a relatively high and persistent nitrate concentration since 1984.



Map shows contours of concentrations for all sampled sites for nitrate and selected numbered sites for environmental tracer data. See table for well ID and corresponding isotope and nitrate data.

So, why does nitrate matter? Under aerobic (high oxygen) conditions, ammonium from septic-tank effluent or animal manure can convert to nitrate, contaminating ground water and posing potential health risks to humans. In infants, nitrate can cause methemoglobinemia, or "blue-baby syndrome," an illness in which body tissues are deprived of oxygen. Additionally, studies involving lab rats ingesting a combination of nitrate and heptamethyleneimine (a complex organic compound [$C_7H_{15}N$]) in drinking water reported an increase in tumor occurrence. Some epidemiological studies involving humans have shown an increase in stomach cancer associated with nitrate in drinking water. With continued population growth and installation of septic tanks in new developments, or substandard agricultural practices, the potential for nitrate contamination will increase.

Our study assessed water quality in the aquifers of southern Sanpete and central Sevier Valleys to determine likely sources of nitrate pollution and determine the relative age of high-nitrate water from selected sites. The study involved sampling water from 77 sites including wells, springs, and streams, and then analyzing the samples for nutrients (nitrate, nitrite, ammonia, and phosphate). Samples having high nitrate concentration were also analyzed for environmental tracers including tritium, carbon isotopes, chlorofluorocarbons (CFC), and nitrogen and oxygen isotopes in nitrate. Isotopes can be useful tracers of ground-water recharge ages and flow paths, and hence are indicators of the source(s) of waters bearing similar isotopic signatures. Specifically, nitrogen and oxygen isotopes help determine the sources of nitrate (such as fertilizer), and tritium, carbon isotopes, and CFCs help determine the relative age of the ground water.

The water samples had nitrate concentrations ranging from less than 0.1 mg/L to 39 mg/L, with an average of 6.5 mg/L (typical background nitrate is approximately 3 mg/L in other rural areas of Utah). Fifty-three percent of the samples had concentrations greater than 5 mg/L, and 22 percent had concentrations exceeding 10 mg/L. Ground water having nitrate concentrations exceeding 3 mg/L is typically associated with high densities of animals (including humans).

We can use the age-tracer isotope data to determine how long the water has been in the ground-water system. Ground-water age in the high-nitrate wells varies throughout the area. Tritium analysis indicates that high-nitrate ground water was recharged before, after, and during above-ground nuclear testing of the 1950s when tritium concentrations in the atmosphere were at their low, medium, and peak levels, respectively. CFC data show most high-nitrate wells have an average recharge year of 1976, with an overall range from 1943 to 2000. Carbon isotope ground-water ages range from modern to 19,000 years old, indicating the high-nitrate ground water is from a mix of old and young sources.

Data from nitrogen and oxygen isotopes indicate most high-nitrate wells may have been contaminated by an animal source (including humans), but many could also have nitrate derived from soil nitrogen, ammonia in fertilizer and rain, or a mixture of

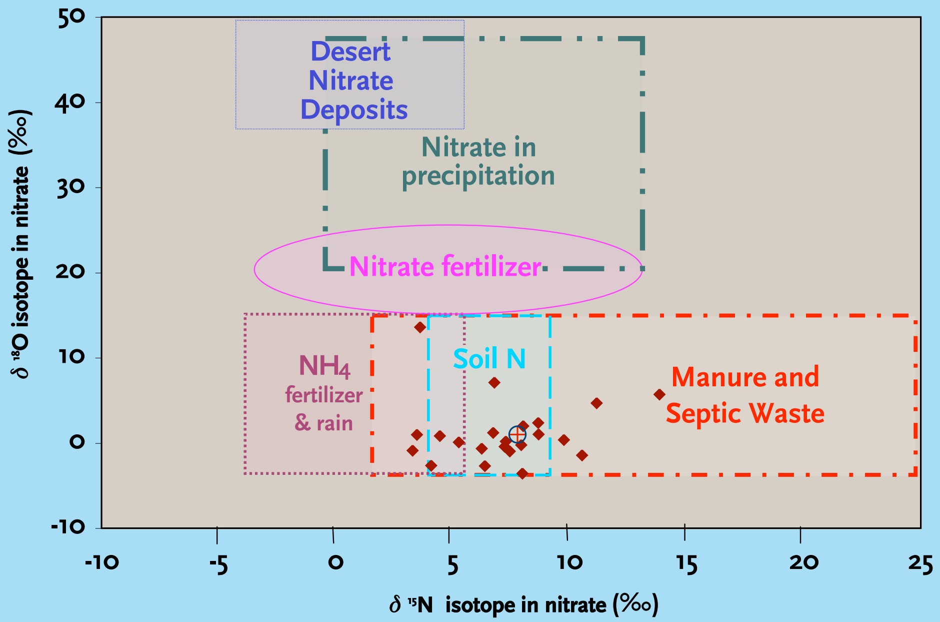
Table shows environmental tracer and nitrate data for selected samples in southern Sanpete and central Sevier Valleys. (1) Well ID on map; (2) Tritium ages from Clark and Fritz (1997); (3) T.U. is tritium units; (4) Calculation of ground-water age (expressed in years before present [yr B.P.], where "present" is A.D. 1950) from raw carbon isotope data was performed by Dr. Alan Mayo, Brigham Young University (May 2008); (5) Modern refers to <10 years.

GROUND-WATER AGE

Well ID[1]	Tritium Age[2]	Tritium T.U.[3]	C-14 Age[4] (yr B.P.)	CFC-11 Recharge year	CFC-12 Recharge year	CFC-13 Recharge year	Interpreted age	Nitrate (mg/L)
Northern Central Sevier Valley								
1	pre-1952	0.0	5,750	1985.5	1987.5	1983	mixed	8.53
2	pre-1952	0.0	19,000	1966.5	1968	1970	mixed	<0.1
3	modern[5]	5.9	3,750	1974.5	1980	1975.5	mixed	24.2
4	mixed/ modern	4.4	-	-	-	-	mixed	<0.1
5	modern	5.6	10,500	1972	1971.5	1972.5	mixed	4.95
6	modern	6.0	modern	1974.5	1984.5	1976.5	mixed	6.42
7	modern	7.5	modern	1974	1985	1975.5	mixed	9.18
8	mixed	1.6	9,250	1959	1963.5	1943	mixed	6.33
9	modern	7.0	modern	1976	1996	1977	mixed	8.23
10	modern	8.5	500	-	-	-	mixed	2.5
11	modern	9.8	modern	-	-	1981	modern	9.5
Southern Central Sevier Valley								
12	modern	9.3	modern	-	-	-	modern	11.5
13	1952	10.0	-	-	-	-	1952?	8.8
14	modern	7.4	modern	-	1981.5	1971	mixed	11.6
Mayfield area								
15	1952	10.2	modern	1989.5	1986	-	mixed	7.48
16	1952	10.2	modern	1989	2000	1943	mixed	9.64
17	-	-	-	1989	1978	1943	mixed	19.3
18	mixed	2.7	2,500	1977.5	1980	1977	mixed	11.1
19	modern	9.5	modern	-	-	-	modern	7.37
20	1952	11.1	modern	-	-	-	mixed	6.95
Sterling area								
21	1952	10.8	modern	-	-	-	mixed	34.1
22	modern	8.0	modern	-	1986.5	1943	mixed	5.32
23	modern	9.5	modern	1982.5	1975.5	1943	mixed	39.1
24	1952	13.4	modern	1981.5	1989.5	1978	mixed	6.41

these. Field investigation confirmed fertilizer and/or animal nitrate as a possible source. Also, septic-tank systems likely contribute nitrate from effluent to many of the samples. Determining whether the nitrate has a geologic source, for example from soil or fault zones, is complex, and requires future work to assess ground-water flow conditions to better estimate the potential for ground-water nitrate loading from these sources. Because the data points fall within overlapping fields on the nitrogen/oxygen isotope plot, we cannot pinpoint an exact sole source of the nitrate.

Based on all of the environmental tracer data, most of the sampled ground water in southern Sanpete and central Sevier Valleys reflects a mixed source. One spring and two shallow wells contain water characterized as modern, seven wells contain water greater than 500 years old but that also has a modern-age component, and thirteen wells and one spring have mixed ground water recharged during the 20th century. Because environmental tracer data show all samples as having a historical recharge component, the major sources of nitrate contamination in ground water are probably from human-related activities rather than from a natural geologic source.



Nitrogen and oxygen stable isotope concentrations in nitrate (parts per thousand) for 22 wells (diamonds) and two springs (overlapping circle and cross) in the study area. Data fall into three categories: manure and septic waste, soil nitrogen, and ammonia in fertilizer and rain.

Environmental Tracers

- ***Isotopes*** are atoms of the same element having the same atomic number (based on protons) and chemical properties, but a different number of neutrons. For example, common isotopes for nitrogen are ^{14}N and ^{15}N, where ^{15}N has the same number of protons (seven), but one more neutron than ^{14}N. Some isotopes can be used to determine ground-water sources.

- ***Chlorofluorocarbons*** (CFCs) are stable synthetic compounds first introduced into the environment in the 1930s during production of refrigerants, propellants, and electronics. The compounds CFC-11 and CFC-12 are associated with coolants in air conditioning and refrigeration, blowing agents in foams, insulation, propellants in aerosol cans, and solvents. The CFC-13 compound is typically used by the electronics industry.

- ***Tritium***, a radioactive isotope of hydrogen, is associated with nuclear weapons testing during the 1950–60s.

- ***Carbon isotopes*** (^{14}C) have a half-life of 5730 years and can provide information on ground water of relatively old (including prehistoric) ages. Other environmental tracers only provide relative ground-water ages for the 20th century.

About the Author

Janae Wallace is a project geologist for the Utah Geological Survey in the Ground Water and Paleontology Program, where she has been employed since 1996. Her principal duties include ground-water quality projects, with an emphasis on aquifer classification, septic-tank density recommendation maps, pesticide sensitivity and vulnerability maps, and water-well cuttings analysis. She is a co-recipient of the UGS 2003 Arthur L. Crawford Award (for outstanding contributions to Utah's geology) and the Utah Water Quality Board's 2008 Calvin K. Sudweeks Water Quality Award (for outstanding contributions in the water-quality field in Utah). She is certified as an onsite system professional and UST ground-water and soil sampler. From 1998 to 2000, she served as Environmental Affairs committee chair for the Utah Geological Association, and has been Scholarship Chair for the Salt Lake Chapter of the Association of Women Geoscientists since 2001.

SCIENTIFIC INVESTIGATIONS BEGIN AT GIANT HANKSVILLE-BURPEE DINOSAUR QUARRY

By Jim Kirkland

BLM personnel consult with Burpee Museum staff and volunteers as to the next step in researching and preserving the Hanksville-Burpee Dinosaur Quarry.

Utah's spectacular geology preserves the most complete dinosaur record in the United States. From this 160-million-year record, Utah is most famous for its dinosaurs from the Late Jurassic Morrison Formation (152-145 million years old), with world-renowned sites such as Dinosaur National Monument and the Cleveland-Lloyd Quarry. Even so, hundreds of miles of stunning Morrison badlands have never been examined by trained paleontologists. Rock hounds have long known that the Hanksville area of south-central Utah preserves many large dinosaurs, but no paleontological research had been done in the area. When the Burpee Museum of Rockford, Illinois, contacted the Utah Geological Survey two years ago about where to find some big dinosaurs for a new exhibit hall, we recommended the Hanksville area.

Once the Burpee Museum staff (led by Scott Williams and Mike Henderson) had their surface collecting permits in hand last May, they checked in at the local Bureau of Land Management (BLM) office in Hanksville. BLM geologist Francis "Buzz" Rakow showed them a few sites outside of town, one of which had been known to local citizens for decades and had been subject to recurrent vandalism for years. Buzz hoped that a scientific investigation of the site might help put an end to this tragic and senseless destruction. The Burpee paleontologists quickly realized that they were looking at a major dinosaur bone bed where possibly dozens of dinosaur skeletons are preserved. After securing excavation permits for the site from the BLM, the Burpee Museum invited Dr. Matt Bonnan, a sauropod (giant long-necked) dinosaur expert from Western Illinois University to provide additional scientific expertise on the project. The museum also requested that the Utah State Paleontologist join them to help evaluate the site.

A volunteer excavates the limb bones of sauropod dinosaurs at the Hanksville-Burpee Dinosaur Quarry. Deposited in flowing water, these bones came to rest against one another forming a logjam of bones.

The Hanksville-Burpee Dinosaur Quarry is a gigantic site. It represents a large eastward flowing, braided-river channel with isolated dinosaur bones and many relatively intact skeletons shallowly buried in an area about a third of a mile long and 300 feet wide (roughly 10 acres). The site compares well with the largest known Morrison dinosaur sites, such as the Carnegie Quarry at Dinosaur National Monument, and is the southernmost such megasite known in the Morrison Formation outcrop belt. Five species of dinosaur tentatively identified in the field include a diversity of long-necked

Several articulated neck vertebrae from a sauropod dinosaur at the Hanksville-Burpee Dinosaur Quarry.

PALEONTOLOGICAL PERMITTING ON BLM AND STATE LANDS

Permits are required of qualified paleontologists to collect vertebrate fossils (e.g., fish, dinosaurs, and mammals) and their traces (e.g., tracks and eggs). Permit applications must include a research plan. Additionally, all fossils collected must be placed in a recognized repository, such as a museum with properly catalogued fossil specimens and the financial stability to care for these collections in perpetuity. The State of Utah (permits issued by UGS) and the BLM are largely uniform in their paleontological permitting policies. There are three types of permits:

1. Surface collecting permits for initial investigations of a region, where no excavations larger than a cubic meter (about 27 cubic feet) are allowed.
2. Excavation permits for conducting large-scale excavations at specific sites. Site inspections are made to ensure there are no losses of other significant resources by the excavation process.
3. Mitigation permits are specifically for paleontologists investigating areas of planned surface disturbance to ensure there is no loss of significant fossil resources. Qualifications for these permits are more restrictive than other types of paleontological permits because the permittees are making recommendations that affect the public good.

Other land management agencies also protect significant fossil resources, but differ in the process by which they issue permits. One should always verify land ownership and/or management and specific permit requirements prior to extracting anything.

For more information about fossil collecting on state or federal land, refer to the following Web sites:

geology.utah.gov/online/pdf/pi-23.pdf

www.fs.fed.us/geology/fedfos.pdf

www.blm.gov/ut/st/en/prog/more/cultural/Paleontology.html

sauropods (*Apatosaurus, Diplodocus, Camarasaurus*, and perhaps *Brachiosaurus*) and Utah's State Fossil, the carnivorous *Allosaurus*. The fossils indicate that young animals dominate the site. Additionally, the site preserves fossil freshwater clams and snails as well as fossil plants, so eventually the food webs of this part of the Morrison ecosystem may be worked out.

The Burpee Museum is committed to this exciting project that will certainly require decades of field and laboratory research, and the UGS is gratified by the collaborative spirit demonstrated by the Burpee Museum. In addition to the numerous graduate students and professional paleontologists that will work on this project, Utah, and in particular the small community of Hanksville, will benefit from this ongoing research and the future interpretation of the site. The BLM is currently revising its management plan for the area to ensure that all of Utah's citizens receive the maximum benefit from this important discovery.

Now that the preliminary site investigation has been done, the real work begins as the Burpee Museum seeks sponsors and grants. The Burpee Museum joins a large fraternity of researchers studying dinosaurs in Utah. Currently, there are more institutions permitted to conduct dinosaur excavations in Utah than in any other state. Many of these projects are focused on increasing our knowledge of dinosaurs already well represented in Utah museums. Meanwhile, Utah paleontologists continue to search some of our less famous but no less exciting rock layers for undiscovered dinosaur sites, adding to our already impressive list of dinosaur species known from nowhere else in the world.

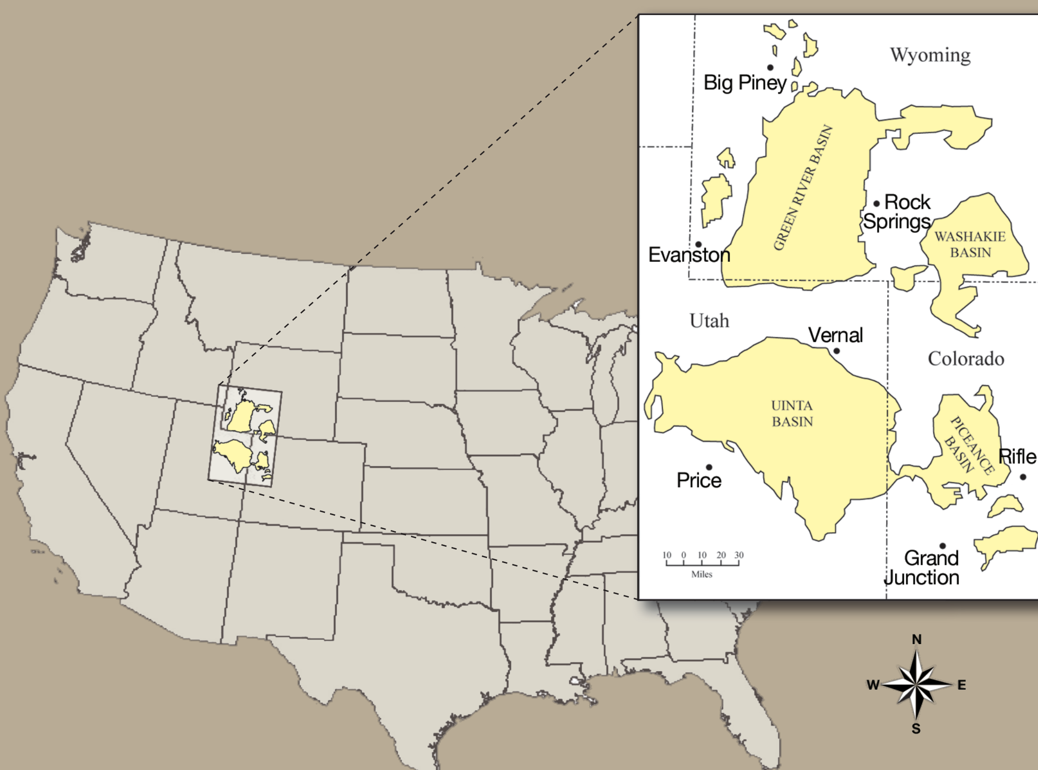
Energy News

Evaluating Utah's Oil Shale Resource

By Michael D. Vanden Berg

"We stand here on the precipice of very interesting things happening in oil shale," was the thought of Utah Governor Jon Huntsman, Jr. as he delivered the keynote address at the 28th Oil Shale Symposium held at the Colorado School of Mines in October 2008. Indeed, there has been a renewed effort by researchers to once and for all unlock the potentially enormous resource of kerogen-rich rock filling major sedimentary basins of Utah, Colorado, and Wyoming. The most significant factor behind this renewed interest is record-breaking crude oil prices, which peaked at $147 per barrel this past summer. In addition, the country's continued need for safe domestic petroleum production makes the western deposits of oil shale even more attractive. Oil shale may have its critics, but most people agree that further research and the initiation of pilot-scale projects are needed, so if this petroleum resource is someday tapped, it can be extracted in an environmentally responsible manner. Utah researchers, including geologists at the Utah Geological Survey (UGS), are at the forefront of this exciting new era of oil shale research. As Governor Huntsman declared at the October symposium, "My bottom line to you is that we in our state are open to business as it relates to oil shale."

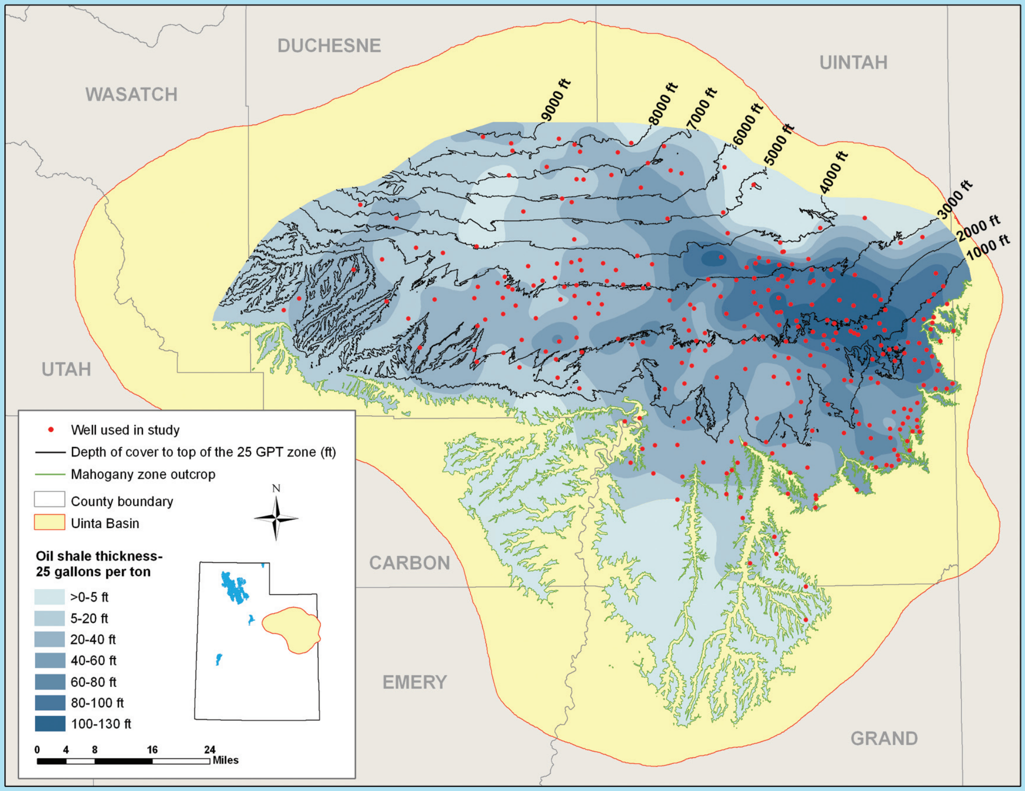
The largest known oil shale deposits in the world are in the upper portion (Parachute Creek Member in Utah) of the 50-million-year-old Green River Formation, which covers parts of Utah, Colorado, and Wyoming. Sediments of the Green River Formation were deposited in two large lakes that occupied a 25,000-square-mile area and are currently preserved in the Piceance, Uinta, Green River, and Washakie sedimentary basins. During arid times, the lakes contracted in size and the lake waters became increasingly saline and alkaline. The warm alkaline waters provided excellent conditions for the abundant growth of cyanobacteria (blue-green algae), which are thought to be the major precursor of the organic matter in the oil shale. The preserved organic matter in the shale is called kerogen, which when heated can produce crude oil and natural gas. The section with the richest oil shale is named the Mahogany zone, where individual beds, such as the Mahogany bed, can exceed 70 gallons of oil per ton of rock and the entire zone is commonly over 100 feet thick.



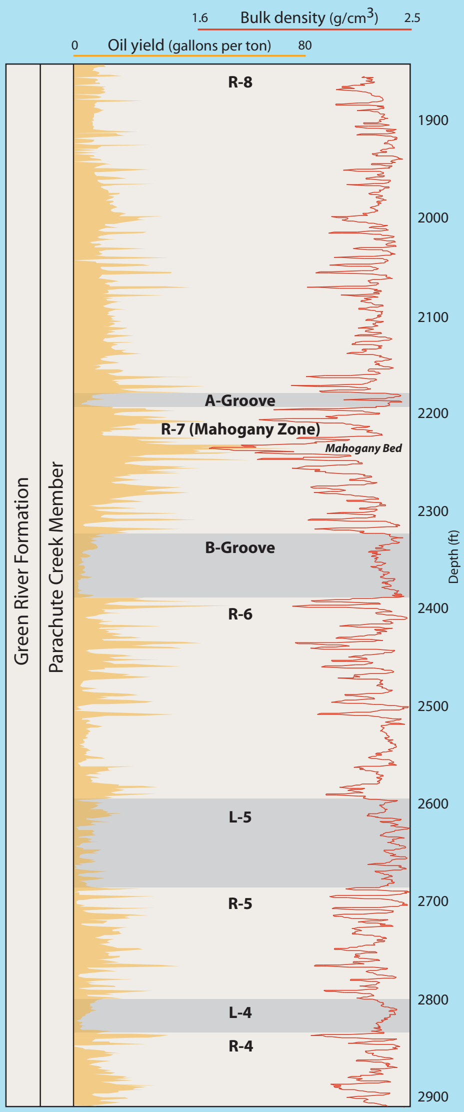
Oil shale resource areas of Utah, Colorado, and Wyoming.

Past oil shale resource assessments for Utah, the first conducted in 1964 and subsequent studies continuing through the early 1980s, concentrated on the Green River Formation's Mahogany zone in the southeastern part of the Uinta Basin, and were limited by the amount of drill-hole data available at the time. The UGS has broadened the investigation to include the entire Uinta Basin, taking advantage of hundreds of geophysical logs from oil and gas wells drilled over the past two decades. In total, we used 293 wells to create a basin-wide picture of Utah's oil shale resource. These widespread data were used to map oil shale thickness for intervals with oil yields of 15, 25, 35, and 50 gallons of shale oil per ton (GPT) of rock. From these thickness maps, we calculated new basin-wide in-place resource numbers for each richness grade.

The thickest and richest oil shale zones are in central Uintah County, where overburden thickness ranges from zero in the east to almost 4000 feet in the northwest. A continuous interval of oil shale averaging 50 GPT contains an in-place oil resource of 31 billion barrels in a zone ranging up to 20 feet thick. Likewise, an interval averaging 35 GPT, with a maximum thickness of 55 feet, contains an in-place oil resource of 76 billion barrels. The 25 GPT zone and the 15 GPT zone contain unconstrained resources of 147 billion barrels and 292 billion barrels, respectively. The maximum thickness of 25 GPT rock is about 130 feet, whereas the maximum thickness of 15 GPT rock is about 500 feet.



Oil shale thickness and depth of cover for a continuous interval averaging 25 gallons of oil per ton of rock.



Stratigraphy of the upper Green River Formation oil shale zone illustrated with bulk density and oil yield curves from the USGS Coyote Wash 1 well (T9S, R23E, Sec 22). "R" refers to a rich oil shale zone and "L" refers to a lean oil shale zone.

After calculating total in-place resource estimates, we imposed several constraints on the total endowment to offer a more realistic impression of Utah's potentially economic oil shale resource. These constraints are subjective since commercial oil shale technologies on which to base them currently do not exist. The constraints used were:

1. deposits having a richness of at least 25 GPT (assumed minimum grade),
2. deposits that are at least 5 feet thick (assumed minimum mining thickness),
3. deposits under less than 3000 feet of cover (maximum underground mining depth),
4. deposits that are not in direct conflict with current conventional oil and gas operations (this does not mean that oil shale deposits located within oil and gas fields will be permanently off limits—it simply demonstrates that regulators will need to recognize that resource conflicts exist and plan their lease stipulations accordingly), and
5. deposits located only on U.S. Bureau of Land Management, state trust, private, and tribal lands.

Accounting for these constraints, Utah's potential economic oil shale resource equals approximately 77 billion barrels. This is roughly 26 percent of the total unconstrained resource of 292 billion barrels calculated at 15 GPT and 52 percent of the total unconstrained resource of 147 billion barrels calculated at 25 GPT, and is a more realistic estimate of the potential recoverable resource.

As demand for crude oil steadily increases and desires grow to expand domestic sup-

continued on page 12...

Glad You Asked

Why Does A River Run Through It?

By Jim Davis

Even though we are a "desert" state, Utah's rivers are world-renowned among river runners and geoscientists. Several of America's early geologists, including G.K. Gilbert, W.M. Davis, C.E. Dutton, and J.W. Powell contributed to theories of stream evolution from observations made in Utah. Rivers typically originate in the mountains, flow away from them in a more-or-less constant direction, enter increasingly broad river plains, and terminate at an ocean. But many rivers in Utah flow toward and across mountains, run contrary to valleys, make U-turns, and many never reach the ocean.

Over long time spans, rivers tend to change course in response to tectonic processes (such as rising mountains and lowering basins) or changing climate. Streams can also adjust their course rapidly, sometimes instantaneously, in response to catastrophic events such as flooding, volcanic eruptions, landslides, earthquakes, or by stream capture (stream "piracy"), where a river intercepts a neighboring river and diverts or "steals" water from its drainage basin. Whether the changes are fast or slow, water needs to flow downhill, but in some places a river's seemingly bizarre behavior can leave one struggling to come up with a reasonable explanation!

All three of Utah's physiographic provinces—Colorado Plateau, Rocky Mountains, Basin and Range—have textbook examples of streams that exhibit anomalous courses. Within the Colorado Plateau, for example, the Paradox Basin is named for the Colorado River's paradoxical pattern of flowing perpendicular to valleys and faults. This is largely due to the presence of thick layers of salt buried beneath other layers of sedimentary rock. In the Rocky Mountains, there are numerous well-known examples of rivers that run directly across mountain ranges. This phenomenon can arise when river erosion exhumes buried geologic structures, and the river subsequently cuts down through them while maintaining its prior course; these are known as "superimposed" streams. Another case of mountain-dissecting streams is "antecedence," where mountains rise and pre-existing streams cut into them as quickly as they rise, the streams again maintaining their original course. Finally, no major streams in the Utah part of the Basin and Range Province make it to the Pacific Ocean, instead emptying into closed basins of the west desert, but this has not always been the case. The following are a few of the numerous occurrences of Utah streams that run extraordinary courses.

THE COLORADO RIVER

After emerging from a canyon carved into sandstone bedrock, the Colorado River flows westward across the marshy northern end of Moab Valley. Then, in defiance of the imposing sandstone cliffs on the west side of the valley, the river turns toward the cliffs and flows into them at The Portal, continuing on its way through another sandstone canyon. The Portal is perhaps the most striking example of the Colorado flowing across, rather than along, valleys within the Paradox Basin. The elongate valleys of the Paradox Basin are the result of subterranean salt, originally deposited through evaporation of seawater in a shallow embayment some 300 million years ago, leaving behind the ocean salts. During burial, the low-density salt was squeezed and flowed upward to form diapirs (masses of salt that pierced or intruded the overlying strata) or walls of salt up to 2 miles thick. The valleys form as the underlying salts dissolve, and the overburden collapses in a process known as "salt tectonics." The Colorado River, indifferent to the sinking valleys beneath it, maintains its original course.

Rivers and selected sites discussed in this article.

The Colorado River cuts across Moab Valley and exits through The Portal.

THE GREEN RIVER

The Uinta Mountains once separated the drainages of the two largest rivers in Utah, the Green and Colorado Rivers. Previously, the Green had flowed eastward to join the greater Mississippi River drainage system, which empties into the Gulf of Mexico, and the Colorado flowed southward to empty into the Gulf of California. Now, the Green flows toward the Uintas, then parallels them, and then turns and crosses their eastern flank, eventually joining the Colorado River in Canyonlands National Park. The modern cutting of the Green River through the eastern Uintas intrigued geologist and explorer John Wesley Powell, and has been described as the "classic conundrum" of drainage anomalies. Although the story is complex and not fully understood, a combination of antecedence, superimposition, and stream capture is suspected. Regardless of the mechanism, the union of the Green River Basin in southwestern Wyoming and the Colorado River drainage greatly energized the entire stream system, causing it to erode the spectacular canyons of Dinosaur National Monument (Canyon of Lodore, Whirlpool Canyon, Split Mountain Canyon). Farther downstream, increased discharge also contributed to the incision of the amazing canyons of the Colorado Plateau.

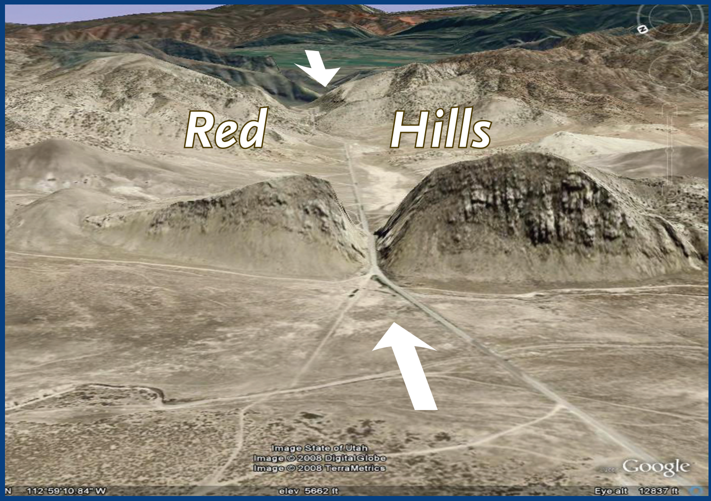
PAROWAN GAP

Parowan Gap, the product of a bygone stream, is a 600-foot-deep canyon carved into the Red Hills northwest of Parowan. Millions of years ago, the hills began to rise as a result of fault movement, and the stream eroded the Parowan Gap canyon across the emerging ridge. An often-used analogy is that of a buzz saw (the river) slicing a groove (Parowan Gap) into a log rising up from below (the Red Hills). The situation persisted for some time, but the equilibrium between rising hills and eroding river came to an end when either the hills rose too rapidly, or more likely the local climate became drier, or perhaps a combination of both. In any case the stream eventually vanished, but it left its mark as a "wind gap." Similarly, the Provo, Weber, and Ogden Rivers are actively cutting canyons across a rising Wasatch Range. Like the river that bisected the Red Hills, these rivers are antecedent to the range and eroding into the rising mountains.

THE BEAR RIVER

The Bear River is the longest continuously flowing river in North America that does not reach the ocean. The Bear River's headwaters are in Utah's Uinta Mountains; the river then flows into Wyoming, back into Utah, back into Wyoming again, into Idaho, and then returns to Utah where it drains into Great Salt Lake. After traveling a several-hundred-mile horseshoe-shaped course, the river ends only about 90 miles from its source. Yet, water of the ancestral Bear River did reach the ocean when it was a tributary of the Snake River, flowing into the Columbia River and on to the Pacific Ocean. Eruption of lava flows in southeastern Idaho diverted the Bear into the Great Salt Lake drainage basin, which has been the river's terminus for the past 50,000 years.

Formerly buried beneath the landscape, erosion has uncovered Split Mountain, and the channel of the Green River is now superimposed onto it. The river has cut through soft and hard rock, producing wide valleys and narrow gorges, respectively. Scale varies in this perspective. High altitude oblique view looking east. The Green River flows from left to right. Image courtesy of the Image Science & Analysis Laboratory, NASA Johnson Space Center, ISS015-E-28000, http://eol.jsc.nasa.gov.



Parowan Gap (between arrows), Iron County. Oblique view looking east-southeast. GoogleEarth image. Scale varies in this perpective.

GEOSIGHTS

Fantasy Canyon

Uintah County, Utah

The detailed fretwork of Fantasy Canyon's sandstone exhibits numerous protrusions, knobs, arches, and hollows.

By Jim Davis

Fantasy Canyon is crowded with intricate and peculiar stone figures that are a unique expression of rock weathering and erosion. Covering only a few acres, this miniature canyon can be viewed up-close on a short 0.6-mile loop trail. Eagle Scout projects have improved the site with footpaths, an eight-sided bench, and identification markers for more than 20 stone sculptures named after what they resemble (with some imagination): Prowling Coyote, Diving Duck, Boxing Bear, Flying Witch, Six-Pack Man, and Ant Castle in the Sky, to name a few.

Geologic Information: The sandstone layer in which the pinnacles, pillars, arches, and knobs of Fantasy Canyon are formed consists of ancient river channel sediments. The underlying and overlying rock layers sandwiching the sandstone layer, and creating scenic badland topography around the canyon, are finer grained floodplain deposits. During the Eocene Epoch, 55 to 34 million years ago, the Fantasy Canyon area was at the fringe of a vast subtropical lake—Lake Uinta—that at peak level stretched from the Wasatch Plateau to western Colorado. The lake was in a drying phase and retreating westward by the end of the Eocene. Rivers en route to the dwindling lake deposited sand, silt, and clay shed from nearby mountains. Once buried, these sediments eventually solidified into layers of sandstone, mudstone, and claystone. Collectively these rocks are a part of the Uinta Formation that spans extensive areas of the Uinta Basin and nearby Colorado.

Differences in the rate of weathering and erosion between dissimilar rock types ultimately shaped Fantasy Canyon. The mudstone and claystone have been stripped away by water and wind, leaving the slightly more durable sandstone to be carved into bizarre, melted wax-like forms. Although the sandstone is more resistant to erosion relative to adjacent rocks, it is in fact extremely fragile. The sandstone is fine grained, porous, soft, poorly cemented, brittle, and crumbly. When touched, grains of sand dislodge from the rock surface. This delicacy was underscored in September 2006 when "Teapot," the centerpiece of Fantasy Canyon and the site's most recognized and photographed stone figure, toppled from its base and shattered at the bottom of the canyon floor. The cause of Teapot's fall remains a mystery.

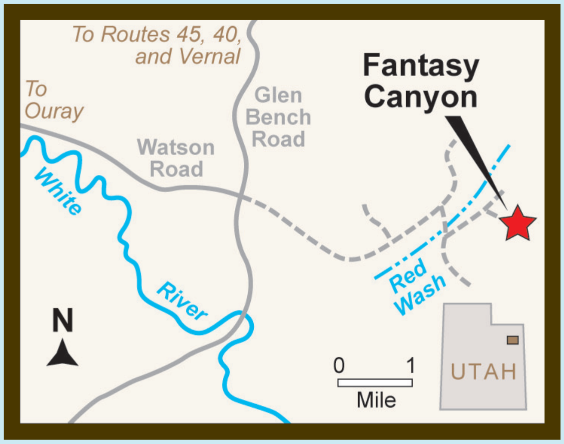
The dull, light khaki gray color of Fantasy Canyon sandstone transforms to a glowing pale orange at sunset. This sculpture is named "Prowling Coyote."

On top of the sandstone, a mudstone layer with alternating gray, olive, and reddish-purple stripes erodes into characteristic badland topography with guttered slopes.

How to get there: The Bureau of Land Management (BLM) administers Fantasy Canyon. We highly recommend visiting the Vernal BLM Field Office at 170 South 500 East, in Vernal (phone: 435-781-4400) for directions, maps, and other information. From Vernal take U.S. Route 40 until it curves southeast and then turn right (south) on Utah State Route 45. After crossing the Green River, travel about 13 miles, then turn right onto Glen Bench Road. The BLM signs for Fantasy Canyon begin here. Following these signs is the best way to prevent getting lost because this area is a confusing labyrinth of oil company service roads. Once on Glen Bench Road drive 0.3 miles and veer left, staying on the paved road. After about 13 miles take a left (southeast) onto an unpaved road (Watson Road—the road is unpaved in this direction and paved on the opposite, northwest side of the intersection). Go 2.4 miles and veer right, then 0.9 miles and take another right, then 0.5 miles—crossing Red Wash on the way— and turn left, and then after 0.6 miles take a right turn for the final tenth of a mile. Avoid going in rainy weather or if the dirt roads are wet because they are very slick, potholed, and cross washes. Also, this is a gas field buzzing with a high volume of truck traffic and the road is fairly rough, so please drive cautiously. The BLM alerts visitors to the presence of pygmy rattlesnakes, and in the summer season the canyon is hot and buggy.

Useful Maps: Red Wash SW 7.5' topographic map, Vernal 30'x 60' topographic map (BLM 2006 edition labels Fantasy Canyon, USGS 1980 edition does not label Fantasy Canyon).

Topographic maps can be obtained from the Natural Resources Map & Bookstore, 1594 West North Temple, Salt Lake City, Utah, 84116 (801) 537-3320 or 1-888-UTAHMAP, mapstore.utah.gov.



continued from page 8...

Utah's total and constrained in-place oil shale resource measured in billions of barrels.

	Total in-place resource	Resource under less than 3000 ft of cover	Resource by landownership					Resource located in association with oil or gas fields	
			BLM	Tribal	Private	State	Other*	Outside field	Within field
50 GPT	31	26 84%	15 48%	6 19%	4 13%	3 10%	3 10%	23 74%	8 26%
35 GPT	76	61 80%	38 50%	15 20%	12 16%	7 9%	4 5%	56 74%	20 26%
25 GPT	147	113 77%	72 49%	28 19%	25 17%	13 9%	9 6%	107 73%	40 27%
15 GPT	292	228 78%	148 51%	53 18%	49 17%	27 9%	15 5%	209 72%	83 28%

*U.S. Forest Service, State Wildlife Reserve, National Wildlife Refuge, State Parks, State Sovereign Lands, Colorado portion of Uinta Basin

Note: percentages are of total in-place resource.

plies, researchers will continue to pursue unconventional resources such as oil shale. With Utah's vast tracts of rich, near-surface oil shale, the state will continue to play a major role in future oil shale development and research.

For more information on Utah's oil shale resource, refer to recently released UGS Special Study 128 and visit the Utah Geological Survey's Web site at geology.utah.gov/emp/oilshale.

Survey News

2008 Lehi Hintze Award

The Utah Geological Association and Utah Geological Survey presented Dr. Peter D. Rowley the 2008 Lehi Hintze Award for outstanding contributions to the understanding of Utah geology. Dr. Rowley spent over half of his career mapping in Utah while working for the U.S. Geological Survey, and continued mapping and studying Utah geology after he retired, establishing Geologic Mapping, Inc., a highly respected company located near Cedar City. Dr. Rowley has authored or coauthored 40 geologic maps on several different parts of Utah and 40 papers on Utah geology. By rough estimate, Pete has personally mapped an incredible 8000 square miles of Utah, much of that in the most rugged and geologically complex terrain in the state. Several of his publications are considered landmark contributions.

Named for the first recipient, Dr. Lehi F. Hintze of Brigham Young University, the Lehi Hintze Award was established in 2003 by the Utah Geological Association and the UGS to recognize outstanding contributions to the understanding of Utah geology.

Employee News

Lance Weaver has accepted the Project Geologist position with the Geologic Information and Outreach Program. He has a B.S. in Geology from Brigham Young University. Congratulations, Lance!

Update on West Desert Ground-Water Monitoring Project

By Hugh Hurlow

The Utah Geological Survey's west desert ground-water monitoring project continues to progress rapidly. Two drilling crews from the U.S. Geological Survey were active from early September through late October 2008, and a single crew continued until December 11. The project was three-fourths finished by the end of 2008. Twenty-seven well sites are complete, including 50 boreholes and 67 PVC wells. Twelve of these sites include wells completed in the Paleozoic carbonate aquifer, which is thought to accommodate regional ground-water flow toward Fish Springs. Preliminary results show high-quality ground water above a depth of 1000 feet and water levels that are consistent with previous work showing a regional head gradient from Snake Valley toward Fish Springs.

Wells completed this past fall include a pumping well for a future aquifer test in the carbonate aquifer, a new site in the basin-fill and carbonate aquifers near proposed ground-water pumping wells in Nevada, wells in the carbonate aquifer upgradient from Fish Springs National Wildlife Refuge, and shallow (150 feet maximum depth) nested piezometers near environmentally critical springs.

Recent developments on the Southern Nevada Water Authority's (SNWA) proposed ground-water development project include the delay of the State Engineer's hearing on the Snake Valley applications until fall 2009; more information is available from the Nevada Division of Water Resources (water.nv.gov; note link to Snake Valley hearing issues on right side of page). The U.S. Bureau of Land Management will soon release its draft Environmental Impact Statement for SNWA's proposed water pipeline for public comment; see www.blm.gov/nv/st/en/prog/planning/groundwater_projects/eis_home_page.html for details.

More information about the west desert ground-water monitoring project is available at the UGS project Web page, geology.utah.gov/esp/snake_valley_project/index.htm.

NEW PUBLICATIONS

Interim geologic map of the Snow Basin quadrangle and part of the Huntsville quadrangle, Davis, Morgan, and Weber Counties, Utah, by Jon K. King, W. Adolph Yonkee, and James C. Coogan, 33 p., 1 pl., OFR-536 .... **$8.50**

Geologic hazards and adverse construction conditions, St. George–Hurricane metropolitan area, Washington County, Utah, by William R. Lund, Tyler R. Knudsen, Garrett S. Vice, and Lucas M. Shaw, CD (88 p., 14 pl., [contains GIS data]), ISBN 1-55791-802-3, SS-127..................... **$24.95**

Geology and ground-water chemistry, Curlew Valley, northwestern Utah and south-central Idaho—Implications for hydrogeology, by Hugh A. Hurlow and Neil Burk, CD (185 p., 2 pl.), SS-126...... **$19.95**

Delineation of drinking water source protection zones for the Day Star Adventist Academy public-water-supply well, Grand County, Utah, by Charles E. Bishop, 31 p., RI-262 .... **$8.00**

Small Mines in Utah 2008, by Roger L. Bon and Sonja Heuscher, CD (7 p., 1 pl.), C-108... **$14.95**

Analysis of reservoir properties of faulted and fractured eolian thrust-belt reservoirs, by Dustin Keele and James Evans, CD (50 p., 3 pl.), OFR-529 ....**$14.95**

Ground-water conditions in the Green Pond landslide, Weber County, Utah, by Francis X. Ashland, Richard E. Giraud, Greg N. McDonald, and Ashley H. Elliott, 8 p., OFR-528 .... **$4.95**

Hydrocarbon potential of Pennsylvanian black shale reservoirs, Paradox Basin, southeastern Utah, by S. Robert Bereskin and John McLennan, 19 p. + 34 p. appendices, OFR-534 ....**$14.95**

The Wasatch Fault Flyby Video, by Utah Geological Survey staff, CD (video recording), PI-92 .... **$4.00**

Historic aerial photography, 1938 Salt Lake Aqueduct Project, Salt Lake, Utah, and Wasatch Counties, Utah, by Steve D. Bowman and Kieth Beisner, DVD (2 p,. 1 pl., [contains KMZ and GIS data]), OFR-537 .... **$24.95**

Building stone quarries and yards, Utah and parts of Arizona, Idaho, Montana, Washington, and Wyoming, by David E. Boleneus, CD (103 p. + 236 p. appendices, 3 pl.), OFR-521 ....**$14.95**

Interim geologic map of the Mount Carmel quadrangle, Kane County, Utah, by Janice M. Hayden, 15 p., 1 pl., scale 1:24,000, OFR-531... **$8.50**

Interim geologic map of the Rays Valley quadrangle, Utah County, Utah, by Kurt N. Constenius, 12 p., 1 pl., scale 1:24,000, OFR-535.. **$7.50**

Interim geologic map of Dugway Proving Ground and adjacent areas, parts of the Wildcat Mountain, Rush Valley, and Fish Springs 30' x 60' quadrangles, Tooele County, Utah (year 2 of 2), by Donald L. Clark, Charles G. Oviatt, and David Page, 3 pl., scale 1:75,000, OFR-532........... **$13.95**

Earthquake site conditions in the Wasatch Front corridor, Utah, by Greg N. McDonald and Francis X. Ashland, CD (41 p., 1 pl.), ISBN 1-55791-792-2, SS-125 ....**$14.95**

Interim geologic map of the Utah part of the Deer Lodge Canyon, Prohibition Flat, Uvada, and Pine Park quadrangles (east part of the Caliente 30' x 60' quadrangle), Iron and Washington Counties, by Peter D. Rowley, David B. Hacker, David J. Maxwell, Joshua D. Maxwell, and Jonathan T. Boswell, 20 p., 1 pl., scale 1:24,000, OFR-530.. **$9.95**

Tar sand data for the P.R. Spring and Hill Creek areas, Uintah and Grand Counties, Utah, by J. Wallace Gwynn, CD (52 p. + 191 p. appendices), OFR-527............... **$19.95**

Teacher's Corner

Teachers—get your own (complimentary) copy of The Wasatch Fault Flyby Video

When the Utah Geological Survey created this 10-minute video in September, it was uploaded on YouTube. Within days, we received news that some other states as well as Utah's schools are blocked from accessing YouTube. Therefore, we now have the video available on CD.

The video uses the technology of Google Earth to provide a visually educational and informative narrative of the 240-mile-long Wasatch fault. The focus is a "flyover" of the Salt Lake City segment (between Corner Canyon/Draper to the south and North Salt Lake to the north).

In addition to providing the geologic story of the fault, the video allows you to see where the fault traverses along the eastern edge of Salt Lake Valley as well as highlighted features along the fault.

The CD contains two versions of the video, one of which is closed captioned.

If you are interested in receiving a complimentary copy of the CD, please give Sandy Eldredge your mailing address, including the name of your school. Contact Sandy at 801-537-3325 or sandyeldredge@utah.gov.

Information about how the UGS made the flyby video can be viewed at:

geology.utah.gov/utahgeo/hazards/eqfault/wfault_flyby.htm

2008 UGS Employee of the Year

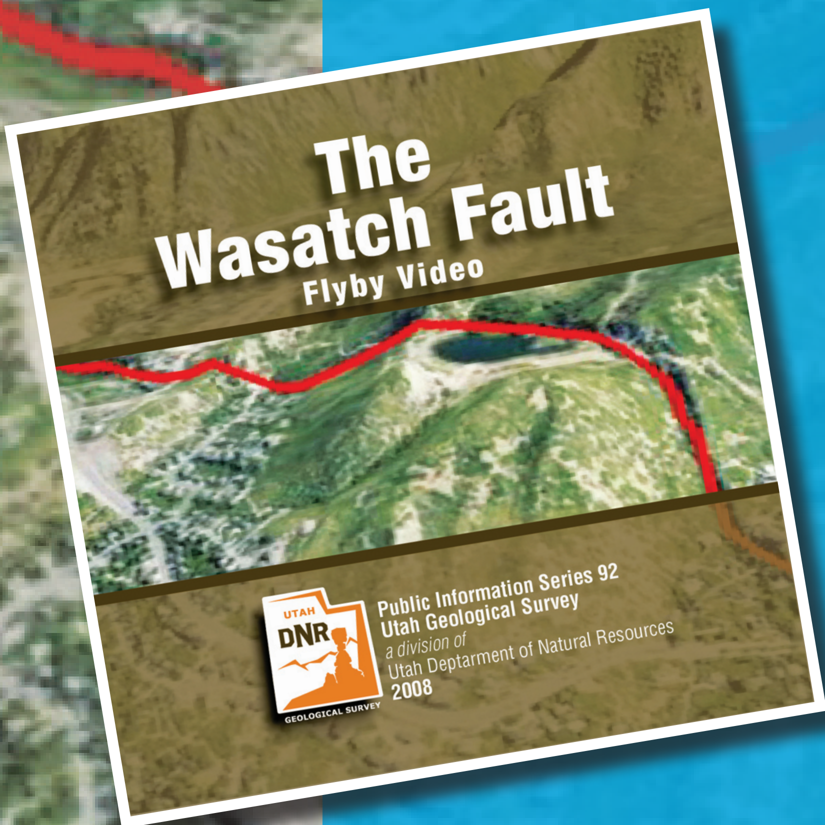
Jim Parker was honored as the 2008 UGS Outstanding Employee of the Year. Jim was a cartographer in the Editorial Section for 30 years. He was one of our hardest working employees, fully dedicated to doing the best job possible. Sadly, Jim passed away shortly after receiving this award. He will be sorely missed by all who knew him.

Natural Resources Map & Bookstore

1594 W North Temple
Salt Lake City, UT 84116

801-537-3320 or 1-888-UTAHMAP
mapstore.utah.gov

Monday–Thursday 7:00 a.m.–6:00 p.m.



The Wasatch Fault Flyby Video

This groundbreaking video combines the results of rigorous scientific investigation with cutting-edge digital technology to educate the public about Utah's foremost earthquake hazard. The video uses realistic three-dimensional imagery and easily understood narrative to take the viewer on a guided virtual flight along the central part of the notorious Wasatch fault.

The video has been uploaded to the Internet site YouTube, and has generated tremendous interest among the public in Utah and as far away as New Zealand and Mongolia. To date, the video has been viewed on the Internet more than 23,000 times since its official launch on YouTube in September 2008. On three separate occasions, the video was viewed online between 2,000 and 3,000 times in a single day.

To view the video and for more information about how it was made, visit our Web site at: geology.utah.gov/utahgeo/hazards/eqfault/wfault_flyby.htm

Teachers – Please refer to the "Teacher's Corner" article in this issue of *Survey Notes* to find out how you can receive a complimentary copy of the video.

Copies are available at the Natural Resources Map & Bookstore
PI-92.. $4.00

UTAH DNR GEOLOGICAL SURVEY

UTAH GEOLOGICAL SURVEY
1594 W. North Temple, Suite 3110
Box 146100
Salt Lake City, UT 84114-6100

Address service requested
Survey Notes

PRSRT STD
U.S. Postage
PAID
Salt Lake City, UT
Permit No. 4728