SURVEY NOTES

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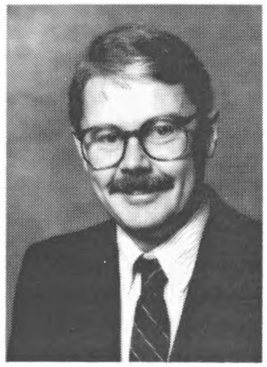
UTAH GEOLOGICAL SURVEY



The Director's Perspective

by M. Lee Allison

This year, about one-quarter of the UGS budget will come from Mineral Lease revenues – royalties collected from energy and mineral production on federal lands in Utah that are shared between the state and the federal government. Just three years ago, Mineral Lease funds made up one-third of the UGS budget. Part of the reduction in Mineral Lease funds is due to declining oil production following the collapse of oil prices in 1986. The UGS is working with industry in a variety of ways to halt or reverse this decline.

A more troubling aspect of the reduced Mineral Lease funds is a recently imposed administrative fee charged by the U.S. Department of Interior's Minerals Management Service (MMS) to collect and distribute the states' share of federal royalties. In the past fiscal year this fee was over $37 million nationally, with Utah's share amounting to $2.3 million. The UGS receives, by state statute, 2¼ percent of the state's Mineral Lease funds, and so our share of the lost revenues was $52,000.

The federal government has shared royalties with states where minerals are produced on federal lands since 1920. Then, as now, most of the mineral interests held by the federal government are in the western states. Because these federal lands could not be disposed of or developed to increase the states' tax base as happened in the rest of the country, western Congressmen argued that the states were entitled to a share of leasing revenues from the lands to help offset the cost of government services which would accompany any development of the lands or expanding state populations.

In 1976, Congress revised the formula of federal mineral royalties so the states received 50 percent, and 40 percent went to the Reclamation Fund, with 10 percent to the federal government to cover administrative costs. Attempts were made in 1984 to deduct administrative costs from the states' share of federal mineral royalties. To combat this, Congress in 1987 amended the law to specifically prohibit any administrative or other costs being deducted from the states' share of mineral royalties.

However, in fiscal years 1991, 1992, and 1993, a portion of federal administrative costs were deducted from the states' shares of federal royalties through an appropriations bill. These were the first deductions since the inception of the Mineral Lands Leasing Act in 1920.

Director's Perspective continued on page 22.

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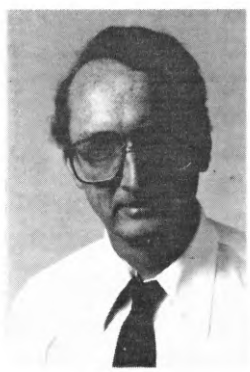
HORIZONTAL DRILLING TECHNOLOGY RE-OPENS OLD PLAY

by Craig D. Morgan

EXPLORATION FOR OIL AND GAS FROM THE FRACTURED "CANE CREEK" SHALE OF THE PENNSYLVANIAN PARADOX FORMATION USING HORIZONTAL DRILLING TECHNIQUES HAS REVIVED INTEREST IN A ONCE MARGINAL PLAY. The "Cane Creek" shale has produced hydrocarbons from several fields west and south of the town of Moab for over 30 years, but past activity has generally resulted in limited production due to the unpredictable distribution of natural fractures in the reservoir (low success ratio), rapid production decline typical of fractured reservoirs, and mechanical problems caused by the thick salt beds overlying the "Cane Creek" shale (difficult drilling, casing collapse, etc.). Horizontal drilling greatly increases the probability of encountering the near-vertical fractures, or fracture sets, needed for economic production.



Craig Morgan attended the University of Utah and received a B.S. degree in geology. He began his career as a mudlogger on drilling rigs working throughout the Rocky Mountains and worked as an exploration geologist for various oil and gas companies for 11 years. Craig began his employment with the State of Utah three years ago, spending a year as a water rights specialist for the Division of Water Rights, and the last two years as a petroleum geologist for the Utah Geological Survey.

Exploration History

Exploration for oil and gas from the "Cane Creek" shale is confined to an area known as the fold and fault belt of the Paradox basin in southeast Utah (figure 1). The area has a long history of oil and gas exploration. The first well drilled for oil in Utah was located approximately 1/2 mile south to southeast of the town of Green River (Lupton, 1912). The Bamberger & Millis well was drilled about 1891 and is believed to have reached a total depth of 1,000 feet in the Jurassic Summerville Formation (McKnight, 1940)

The first well near Moab, the Midwest Exploration and Utah Southern No. 1 Shafer, was drilled during 1924 and early 1925 (figure 2). The drill site was on the crest of the Cane Creek anticline, west bank of the Colorado River. The cable tool rig was floated 20 miles down the river by barge. The well blew out while drilling at 2,028 feet in the Paradox Formation, the rig caught fire and oil flowed for two weeks before being controlled (Smith, 1978). A second rig was brought in but attempts to complete the well as an oil producer failed. Drilling on the Cane Creek anticline in the 1940s and 1950s (figure 3) resulted in only a minor amount of oil production (1,887 barrels) from the "Cane Creek" shale of the Paradox Formation (Stowe, 1972).

Economical oil production was not established in the area until the 1957 discovery of the Big Flat field near what is now Canyonlands National Park and Dead Horse Point State Park. Big Flat field produced oil from the Mississippian Leadville Limestone until abandonment in 1988. The discovery set off a new round of exploration in the area during the late 1950s and early 1960s and resulted in the discovery of the Lisbon (1960) and Salt Wash (1961) fields, both producing from the Leadville Limestone. The Leadville exploration activity also led to the discovery of oil from the shallower "Cane Creek" shale in the Bartlett Flat (1961), Long Canyon (1962), Shafer Canyon (1962), and Wilson Canyon (1968) fields (figure 1).

Only one well, Long Canyon 1 (figure 4), produced a significant (> 100,000 barrels) amount of oil from the "Cane Creek" shale prior to the start of horizontal drilling in the 1990s. The Long Canyon 1 well has produced nearly 1 million barrels of oil since 1962 and continues to produce an average of 39 barrels of oil per day.

National attention has been focused on the "Cane Creek" play with the successful completion of a horizontally drilled oil well. Columbia Gas Development completed the Kane Springs 27-1 well (figure 5) in 1991 producing from a nearly 1,000 foot horizontal leg in the

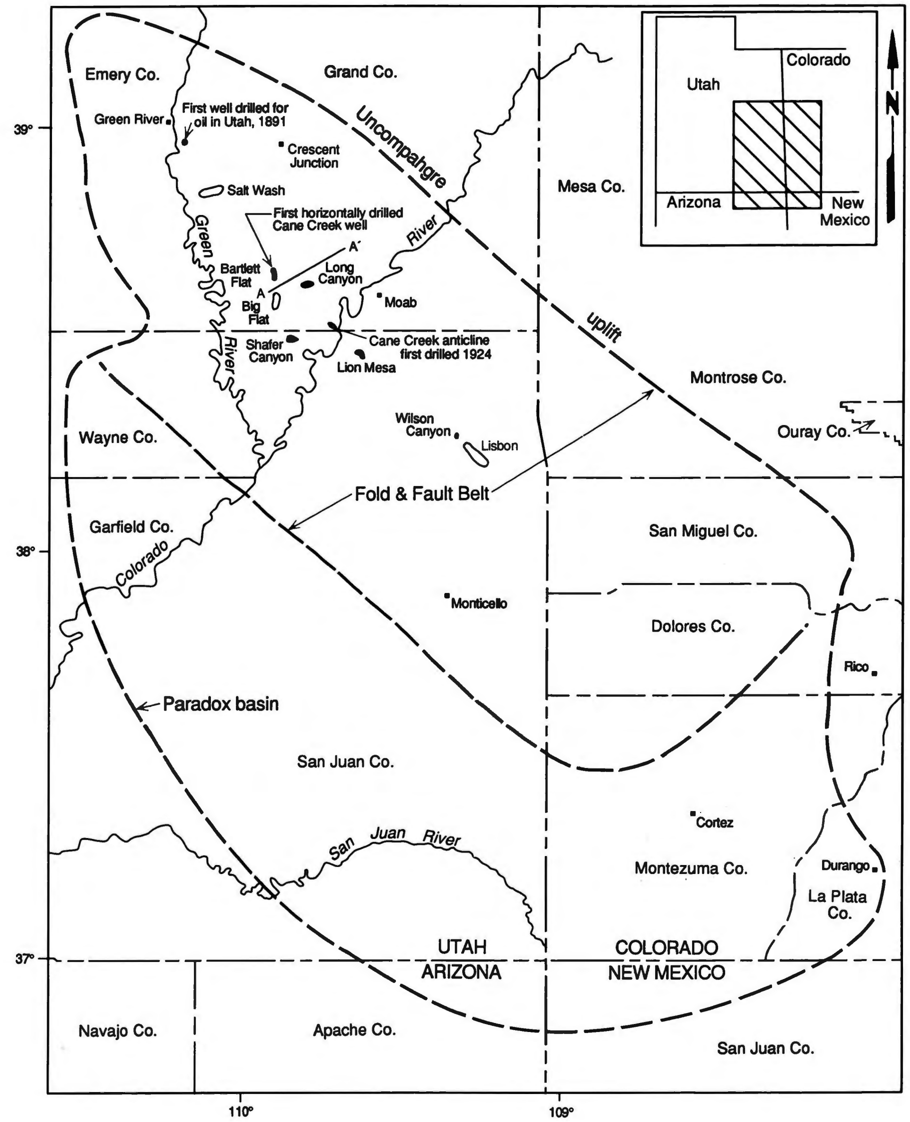


Figure 1. Index map of the Paradox basin and oil fields in the fold and fault belt. Fields that produce(d) from the "Cane Creek" shale are darkened in, open outlines are fields that produce(d) from the Leadville Limestone. Cross section A-A' is shown on figure 7.

Figure 2. The Shafer 1 well drilled in 1924-1925 on the crest of the Cane Creek anticline along the bank of the Colorado River. Photograph courtesy of Utah Historical Society.

Figure 3. MGM 1 and 2 wells drilled on the crest of the Cane Creek anticline during the 1950s. Earlier drilling (1920s) occurred along the bank of the river visible in the lower left corner of the photo. The no. 1 well tested oil from a fractured shale interval in the lower Paradox Formation, the name "Cane Creek" shale was given to that interval and has been used ever since. Photograph courtesy of Utah Historical Society.

"Cane Creek" shale. The well was drilled in the Bartlett Flat field which had produced less than 40,000 barrels of oil from the "Cane Creek" shale before abandonment. Since the completion of the 27-1 well there have been five additional wells in the area: three are dry holes, and two are completed as oil wells. Seven new locations for wells designed to test the "Cane Creek" shale have been announced.

Structure

The Paradox basin is a paleo-structural/depositional basin located principally in Utah and Colorado in what is now part of the Four Corners area. During Pennsylvanian time (300 million years ago), the area subsided along a series of northwest-trending faults forming an asymmetric oval-shaped basin with the deepest portion along the northeast boundary. The Paradox Formation was deposited in the slowly, but continually subsiding basin. The nearly equal rates of subsidence and sedimentation produced a thick sequence (greater than 6,000 feet) of cyclic carbonate, black organic-rich shale, and evaporite units deposited in a marginal marine to sabkha (arid to semiarid coastal plain) environment. The majority of the formation consists of thick beds of salt. Diapiric movement of the salt during Pennsylvanian and Permian time formed salt-cored anticlines (figure 6) paralleling some of the underlying northwest-trending faults. In the larger salt-cored anticlines, the Paradox Formation is extremely contorted and the locations of individual shale beds are unpredictable, thereby making them poor exploration targets. Structural elements associated with the underlying fault blocks, smaller salt-cored anticlines, and, in some cases, the flanks of larger salt-cored anticlines are the current exploration targets for oil in the "Cane Creek" shale (figure 7).

Stratigraphy

The Paradox Formation consists of a maximum of 29 recognized cycles of evaporation and deposition. These cycles were assigned numerical values by Hite (1960), starting with cycle 1 at, or near, the top of the formation and cycle 29 at, or near, the base. A typical cycle is bounded above and below by a disconformity and is composed of four different units designated A, B, C, and D (Peterson and Hite, 1969). Units C and B are generally interbedded and consist of anhydrite and silty dolomite respectively. Unit A, the primary reservoir, consists of organic-rich (>1 percent total organic carbon) black shale and carbonate (mostly dolomite), and is often fractured and hydrocarbon bearing. Unit D is halite, typically 100+ feet thick, with or without potash salts. The depositional order of the units within a complete cycle is C,B,A,B,C,D. Units C,B,A,B,C, make up what is often referred to as the clastic interval within a cycle (figure 8).

The "Cane Creek" shale is generally the thickest clastic interval in the Paradox Formation and was deposited throughout most of the fold and fault belt. The "Cane Creek" shale can be identified on geophysical well logs

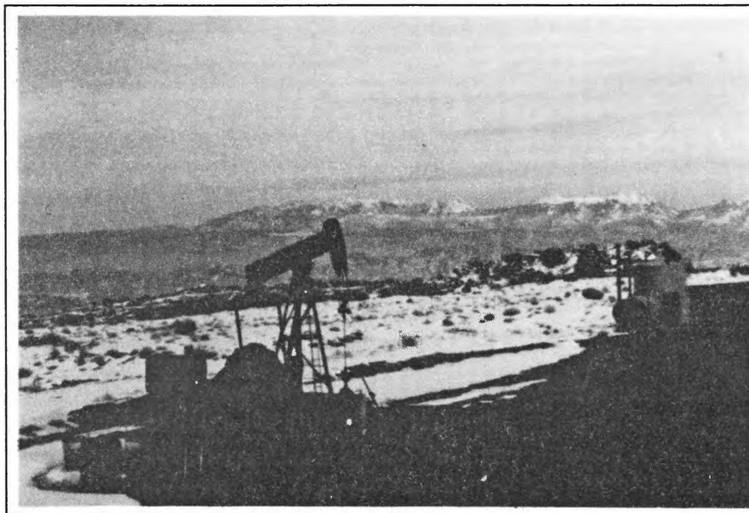


Figure 4. Long Canyon 1 well producing from the "Cane Creek" shale. La Sal Mountains in the background.

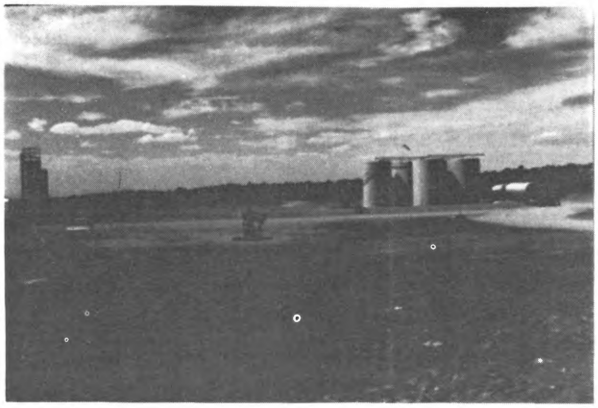


Figure 5. Columbia Gas Development Kane Springs 27-1 well. First well to horizontally drill the "Cane Creek" shale. There are no pipelines in the area so the gas is flared and the oil is trucked out.

in a 25-mile-wide (approximately) southeast-trending belt from the town of Green River to the Utah-Colorado border southeast of the Lisbon field (figure 9). The "Cane Creek" shale is generally 80+ feet thick of which approximately 50 percent is the primary reservoir, unit A. The "Cane Creek" play area is defined by the updip depositional limit of the shale to the southwest, northwest, and southeast, and the region of large salt-cored anticlines to the northeast in the deepest portion of the basin.

Reservoir Characteristics

The "Cane Creek" shale is a naturally fractured, self-sourced reservoir. Reported results from the first horizontally drilled well indicate there are two types of fractures in the "Cane Creek" shale, large-scale northeast-southwest-trending tectonic fractures and more randomly oriented associated(?) microfractures (Fritz, 1991). The tectonic fractures are the result of folding and salt flowage. The microfractures form as the organic matter is converted to hydrocarbons. The "Cane Creek," having no available pore space and sealed above and below by salt, had to fracture to make room for the hydrocarbons as they were generated. The "Cane Creek" shale probably began generating hydrocarbons in the Early Cretaceous, approximately 180 million years after it was deposited. At that time, the "Cane Creek" shale was buried at a depth of over 12,000 feet.

The "Cane Creek" shale was at its maximum depth of burial (21,000+ feet) by mid- to late Oligocene (30 to 24 million years ago). Uplift and erosion has since raised it 10,000+ feet. The reservoir pressure created at the maximum depth of burial was unable to bleed off during uplift and erosion of the area due to the sealing nature of the salt above and below the reservoir. Consequently, the "Cane Creek" shale and other Paradox clastic intervals are typically overpressured with average pressure gradients of 0.75 to 0.95 psi/ft (0.45 to 0.49 is considered normal). The high fluid pressure causes the oil to flow from wells for many years before requiring pumping and helps to hold the formation fractures open, increasing total recovery.

Future Developments

The "Cane Creek" play is clearly a geological success. Horizontally drilling the "Cane Creek" shale has effectively discovered fractures containing oil. The

Figure 6. Castle Valley, east of Moab, is formed by erosion along the crest of a large salt-cored anticline. The view is north from the loop road. Photo by Christine Wilkerson, UGS.

economics of the play are still uncertain. Horizontal drilling is typically two to four times more expensive than conventional vertical drilling. The three Columbia Gas wells are estimated to have cost over $4.5 million per well to drill and complete.

Additional horizontal drilling in the area will hopefully result in lower costs as experience is gained. Several years of production will be required to know what type of production decline can be expected from the new wells. It is difficult to determine the long-term production rate and ultimate total recovery from a fractured reservoir such as the "Cane Creek" shale. If the horizontally drilled wells decline at a rate similar to the Long Canyon 1 well, then recoveries of 500,000 to 1,000,000 barrels of oil per well can be expected.

Another promising clastic interval in the Paradox Formation not yet tested by a horizontally drilled well is the "Gothic" shale. The "Gothic" shale (cycle 3) occurs near the top of the Paradox Formation and has tested oil in many of the older wells in the basin. The "Gothic" shale, like the "Cane Creek" shale, is an organic-rich black shale that is often fractured and overpressured. The shallower depth of the "Gothic" shale means that thousands of feet of salt will not need to be drilled and cased off which may make it a far less expensive exploration target than the "Cane Creek" shale.

A Prime Area for Exploration

The Paradox basin is a prime area for exploration of fractured shales like the "Cane Creek" and other Paradox Formation shales using horizontal-drilling technology because:

1) The exploration play encompasses thousands of square miles in a sparsely drilled area of southeast Utah.

2) Current exploration has concentrated on structural closure at the "Cane Creek" horizon associated with an underlying upthrown fault block. These structural elements are poorly defined due to the difficulty in obtaining good quality seismic data through the thick salt section. Improved seismic data-gathering techniques should reveal many undrilled structures.

3) Additional traps indicated by numerous shows of oil from vertically drilled wells have not been tested by horizontally drilled wells. These include anticlinal and fault closure on both the upthrown and downthrown side of faults. Additionally, the updip reduction of fracturing due to nondeposition of underlying mobile salt may provide traps along the shallow margin of the basin.

4) Numerous vertically drilled wells had shows of oil from the "Cane Creek", "Gothic", "Chimney Rock" and other Paradox shales, but did not result in commercial oil wells. The areas where these dry holes were drilled are now prime exploration targets.

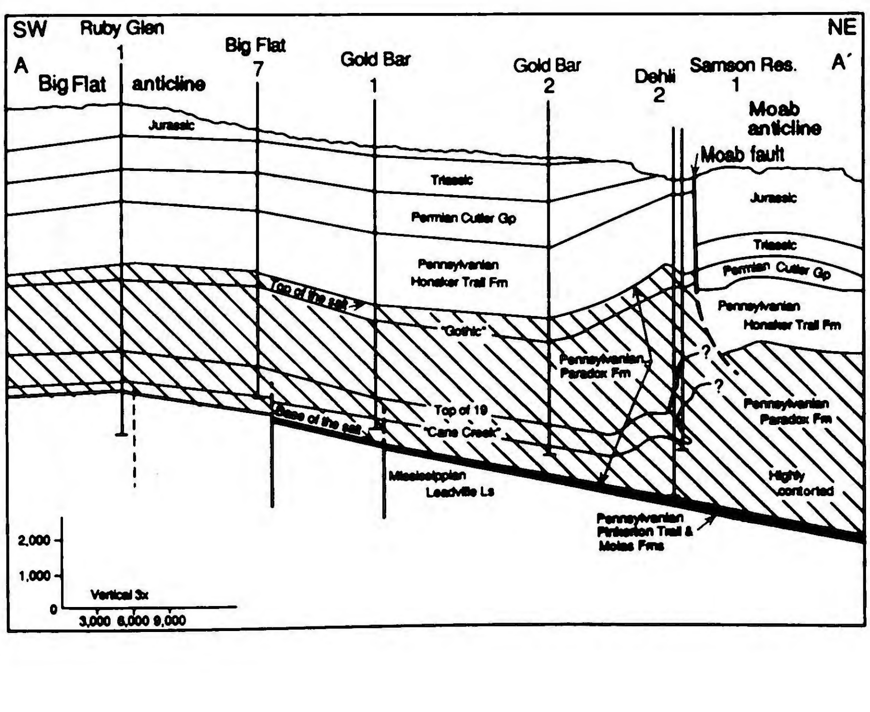


Figure 7. Structural cross section A-A' northeast to southwest, from the Moab anticline to the Big Flat anticline. The Paradox Formation is shown in a hatched pattern. The Moab anticline is a salt-cored anticline while the Big Flat anticline is formed by closure on the Leadville Limestone with thinning and depositional onlap of the overlying Paradox Formation. Both types of structural elements can form traps with fractured reservoirs in the Paradox Formation. Location of cross section shown on figure 1.

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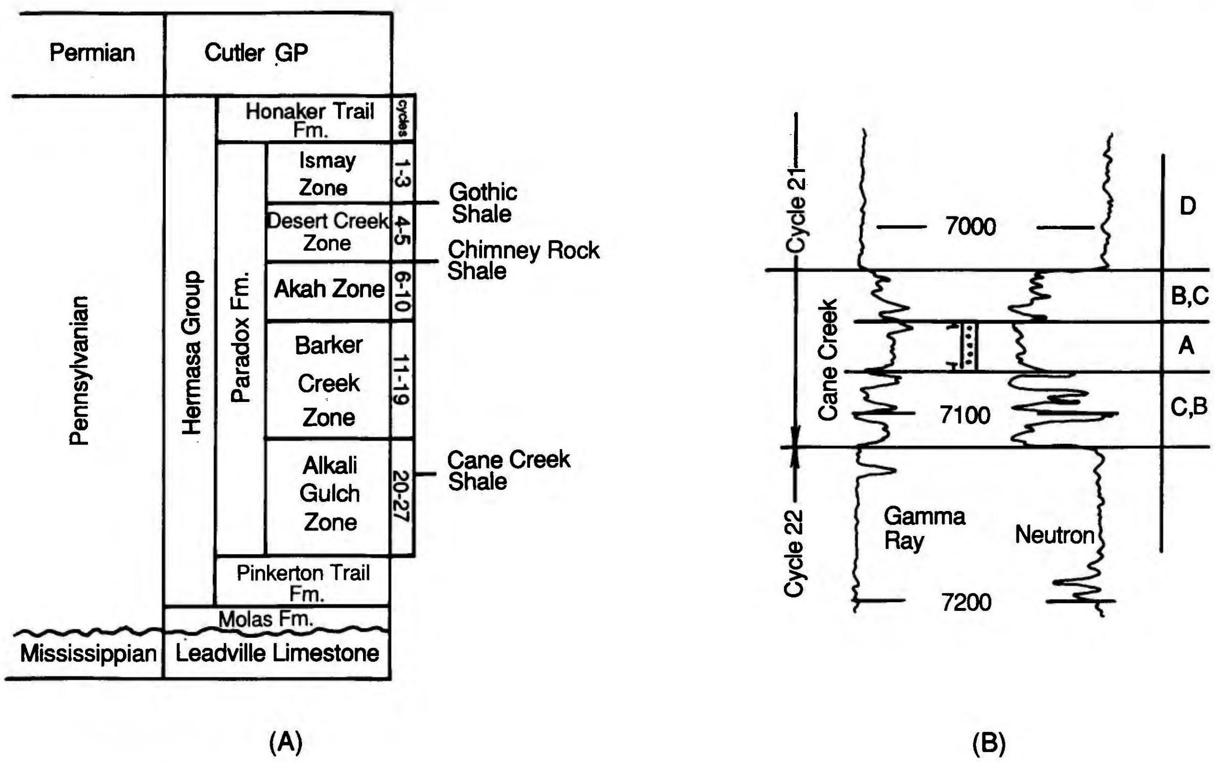


Figure 8. (A) Stratigraphic nomenclature of the Paradox Formation. The formation is divided into informal zones which are further divided into numbered cycles. The "Cane Creek" shale forms the lower part of cycle 21 in the Alkali Gulch zone. The "Gothic" (cycle 3) and "Chimney Rock" (cycle 5) both contain organic-rich black shales similar to the "Cane Creek" that are potential exploration targets. (B) The "Cane Creek" shale is divided into units C, B, A, B, C, D. Unit A is the organic-rich black shale facies that is both the primary source and reservoir for oil and gas in the "Cane Creek" shale. The log is from the Long Canyon 1 (SE¼ NW¼ section 9, T.26S., R.20E.) which produces oil from the "Cane Creek" shale (perforated 7,050-7,075 feet).

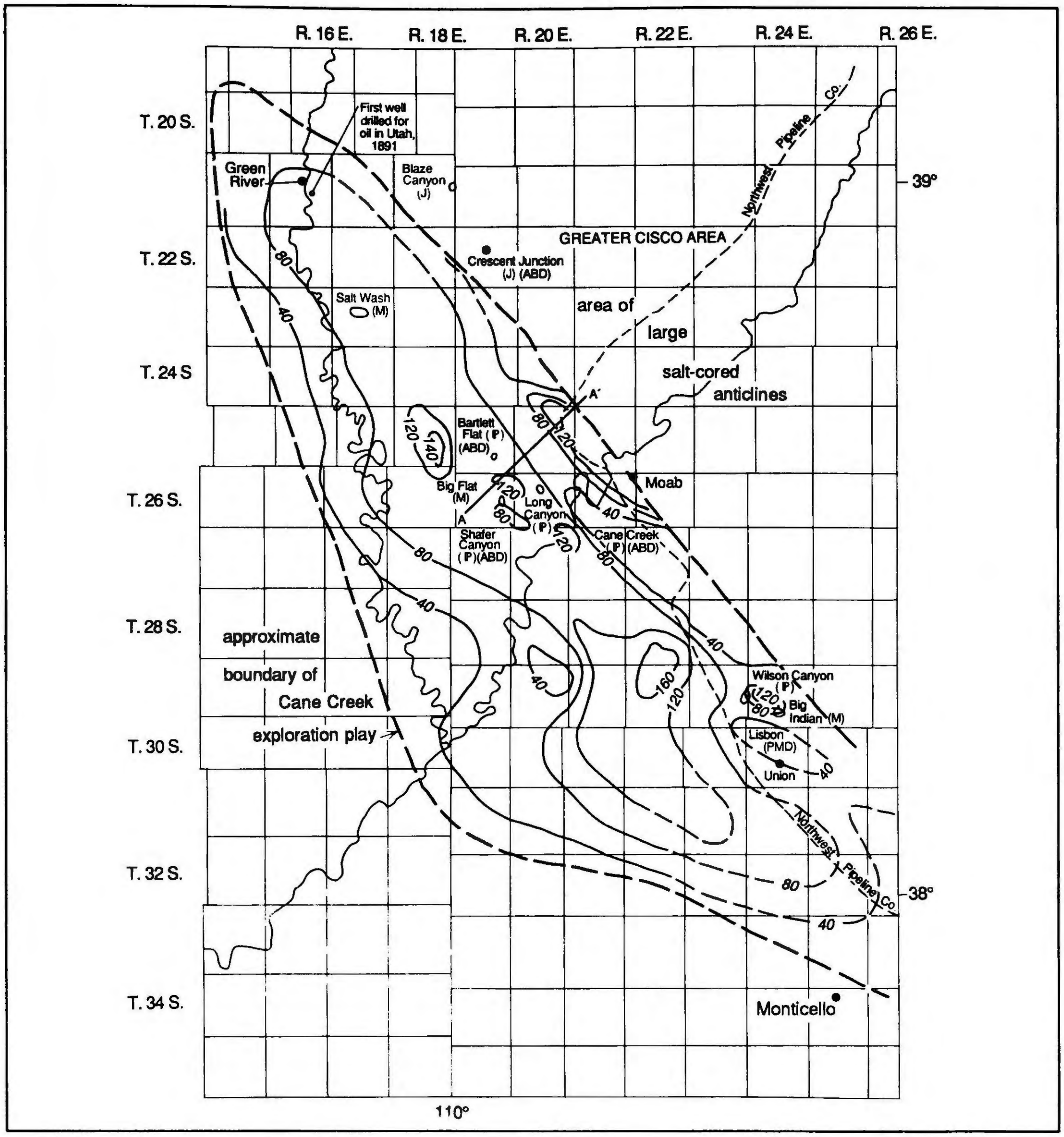


Figure 9. Generalized isochore (drilled thickness) map of the "Cane Creek" shale. Contour interval is 20 feet. The boundary of the "Cane Creek" exploration play area is defined by the updip depositional limits to the northwest, west, south, southeast, and the area of large salt-cored anticlines to the northeast. The "Cane Creek" shale is highly contorted in the area of large salt-cored anticlines making identification and correlation extremely difficult and regional exploration unpractical at this time. Modified from Morgan, 1992.

FOR MORE INFORMATION ON THIS SUBJECT, ORDER OPEN-FILE REPORT 232, "CANE CREEK" EXPLORATION PLAY AREA, EMERY, GRAND, AND SAN JUAN COUNTIES, UTAH. The report, also by Craig Morgan, consists of 8 maps and 2 cross sections at 1 inch = 2.2 miles: index map; structure contour maps of Paradox Fm. top and base of lowest salt; salt thickness map; Cane Creek Shale thickness; NW and NE-trending surface structures; Oil and gas shows; and a listing of all the wells.

Price is $20.00 – ***use the order form on page 19. Buy Now! We will begin charging for postage and handling on July 1, 1993!***

Summary of Utah Mineral Activity 1991

Compiled by Roger L. Bon, Utah Geological Survey
F. R. Jahanbani, Utah Division of Energy
Charles W. Berry, PhD., University of Utah

UTAH CONTINUED AN UPWARD TREND IN NEARLY ALL SEGMENTS OF ITS VARIED MINERALS EXTRACTIVE INDUSTRY. Total revenue generated from mining is estimated at $1.9 billion, an increase of 5.6 percent over the 1990 total of $1.8 billion (figure 1).

Mine production in the state placed it ninth among all states in nonfuel mineral production. Metal production in Utah ranked fourth nationally. The state ranks first in the production of beryllium and third in the production of gold, magnesium metal, iron ore, and copper.

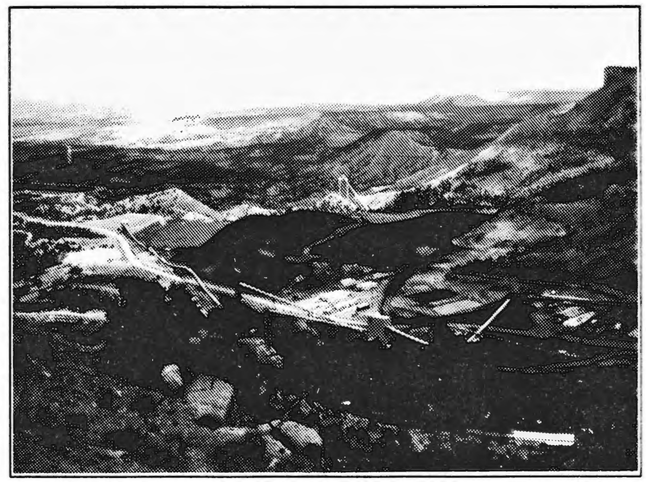
Fifty-two exploration Notices of Intent were filed with the Division of Oil, Gas, and Mining in 1991. One hundred three (103) mines reported production in 1991. Precious metals were produced from twelve operations; coal sixteen; uranium/vanadium two; iron ore four; copper one; beryllium one; industrial minerals sixty-one; and oil shale, tar sand, and gilsonite six.

Metals

The value of metals from producing mines for 1991 totaled $1.0 billion, contributing 53 percent of the total $1.9 billion mining revenue (figure 2). Continued demand for copper and increased output in gold made positive contributions, while a dramatic drop in magnesium prices substantially offset any gains in metal revenue.

Kennecott's Bingham Canyon mine continues to play a key role in Utah's mining industry. Current annual production levels are 237 million kg (521 million lb) copper, 458,000 Troy oz gold, 3.6 million Troy oz silver, and 7.0 million kg (15.4 million lb) of molybdenum concentrate.

Kennecott's Barney's Canyon mine continues to be a major gold producer with an annual production



Overview of surface loadout facilities. Cyprus-Plateau Mine, Carbon County, Utah. Photo credit: Cyprus Plateau Mining Company.

of 122,000 Troy oz. American Barrick Resource's Mercur mine and Tenneco Mineral's Goldstrike mine contributed 127,000 Troy oz and 36,000 troy oz of production respectively.

Geneva Steel continued to produce iron ore through contract mining from the Iron Springs mining dis-

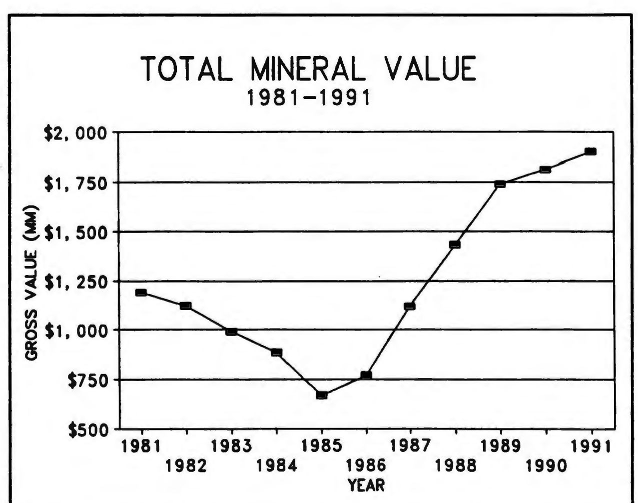


Figure 1. Value of all minerals, 1981-1991 (data: U.S. Bureau of Mines).

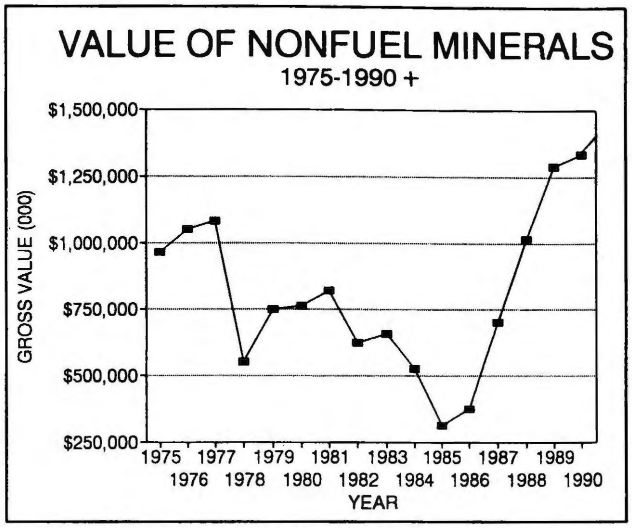


Figure 2. Value of nonfuel minerals, 1975-1990+ (data: U.S. Bureau of Mines).

trict in western Iron County. Production estimated at 794,000 tonnes (875,000 st) came primarily from the Excelsior and Chesapeak mines.

As part of a $287 million modernization program announced in February 1990, Geneva completed installation of two Basic Oxygen Process (Q-BOP) furnaces, a gas-blanketing system, and a new coilbox that is the largest in the world. The new equipment has enabled the company to increase operating efficiencies and significantly reduce air pollutants.

Utah's coal industry, which had an unprecedented seven continuous years of increased production from 10.2 Mt (11.8 million st) in 1983 to more than 20 Mt (22 million st) in 1990, experienced a small setback in 1991, falling to 19.9 Mt (21.9 million st; figure 3). The total production had a value of $472 million, 25 percent of total value of minerals produced in the state (figure 4). Electric utility consumption within the state accounted for 55 percent of total coal production.

Utah underground coal miners once again led the nation in productivity by producing 5 tonnes (5.5 st) of coal per man hour. Coastal States Energy Company, which was the second largest coal producer in Utah for a number of years, increased its Skyline mine production to 125 percent of 1990 production, thus becoming the largest coal producer in Utah. The Skyline mine is now the second most productive underground coal mine in the nation; Utah Power and Light's Cottonwood mine was the third.

Coal prices in Utah experienced the tenth consecutive decline in 1991, reaching $23.75 per tonne ($21.55 per st) down from $32.43 per tonne ($29.42 per st) in 1982. Utah Power and Light Co. installed a 1,361 tonne-per-hour (1,500 ton-per-hour) wash plant for its Cottonwood and Deer Creek mines which are two of the four largest mines in Utah.

Andalex Resources is in the process of obtaining its mine permit for the Smoky Hollow site in the Kaiparowits coal field with an anticipated completion date of 1994. The mine is designed to produce up to 1.8 Mt (2 million st) annually.

Nevada Electric Investment Company (NEICO) established a new subsidiary by the name of Castle Valley Resources in 1990 to handle the coal distribution of its other subsidiary, Genwal Coal Company, as well as other coals. In July 1991, NEICO sold 50 percent of its Genwal operation to Intermountain

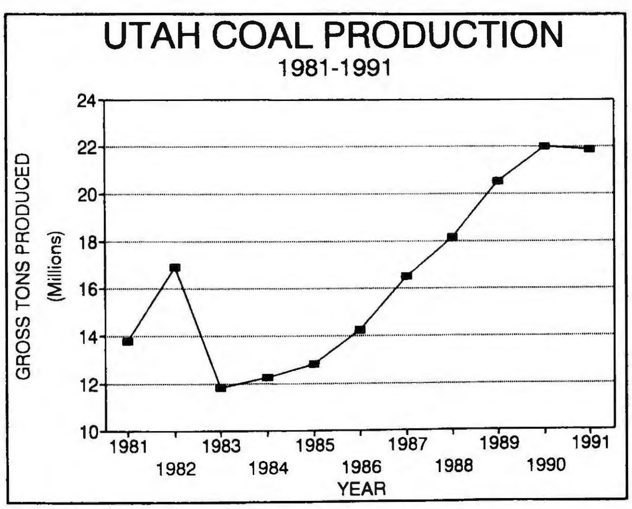


Figure 3. Utah coal production, 1981-1991 (data: U.S. Bureau of Mines).

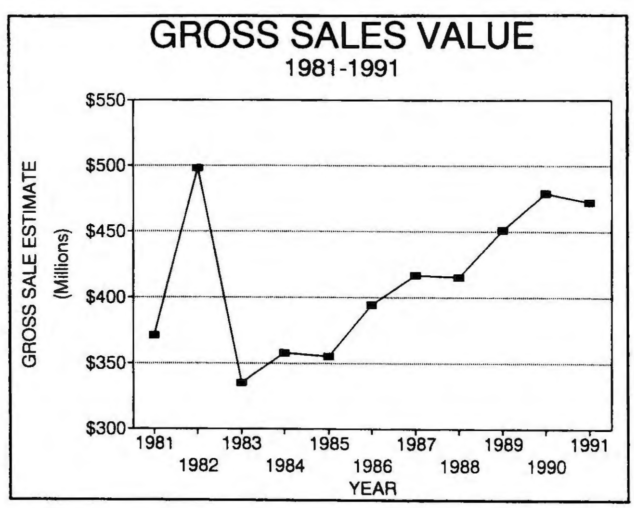


Figure 4. Value of gross coal produced, 1981-1991 (data: U.S. Bureau of Mines).

Power Agency.

There was no federal coal lease sale during 1991 in Utah; however, there are five federal coal lease applications on file. They are as follows: Mining and Energy Resource, Inc., 13.9 km^2 (3,431 acres) in Crandal Canyon; Coastal States Energy, 8.2 km^2 (2,020 acres) in Winter Quarters; Sage Point Coal Company (Soldier Creek), 4.5 km^2 (1,104 acres) in Soldier Canyon; PacifiCorp, 31.8 km^2 (7,864 acres) in Cottonwood Creek; and Genwal Coal Company, 8.0 km^2 (1,974 acres) in Crandal Canyon.

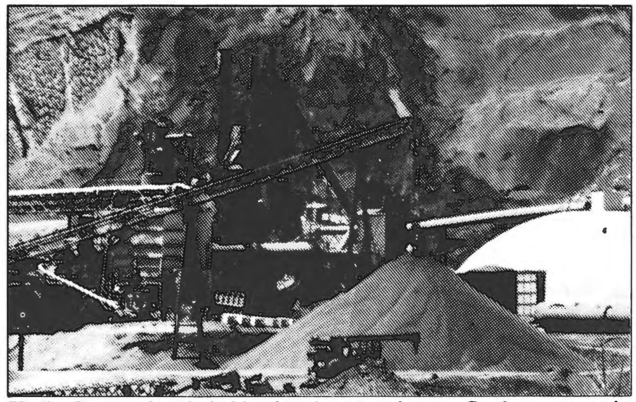
There were two Federal Coal Exploration Licenses issued during 1991; PacifiCorp received a license for 14.4 km^2 (3,565 acres) in Cottonwood Canyon, and Coastal States received one for 5.0 km^2 (1,233 acres) in Winter Quarters Canyon.

Industrial Minerals

Industrial rocks and minerals continued to be an important segment of Utah's mineral industry, comprising 29 percent ($400 million) of the $1.4 billion total nonfuel mineral production (UGS estimate). Major commodities produced included Portland cement, salt, construction sand and gravel, potash, crushed stone, lime, phosphate, common clay, and gypsum. Commodities with a smaller value included bentonite and fuller's earth, magnesium compounds, sodium sulfate, building stone, lightweight aggregate, fluorspar, masonry cement, gemstones, and industrial sand.

The slow, positive, economic growth in Utah allowed construction material producers to weather the national recession better than their counterparts in other areas of the country. Exploration and development interest focused on clay, building stone (especially marble and granite), gemstones, high-calcium limestone, humate, zeolites, pumice, perlite, diatomite, and silica sand.

There were two notable events in the industrial rock and mineral industry. Chevron sold its Little Brush Creek phosphate mine, plant, and slurry pipeline near Vernal to F.S. Industries, a joint venture between Farmland Industries of Kansas City, Missouri and J.R. Simplot of Boise, Idaho. Continental Lime, Inc. announced plans to expand its Cricket Mountain lime plant located south of Delta in Millard County. The addition of a third rotary kiln will raise plant capacity 50 percent.



Utelite Corporation shale-bloating clay operation near Rockport reservoir. Photo by C.M. Wilkerson.

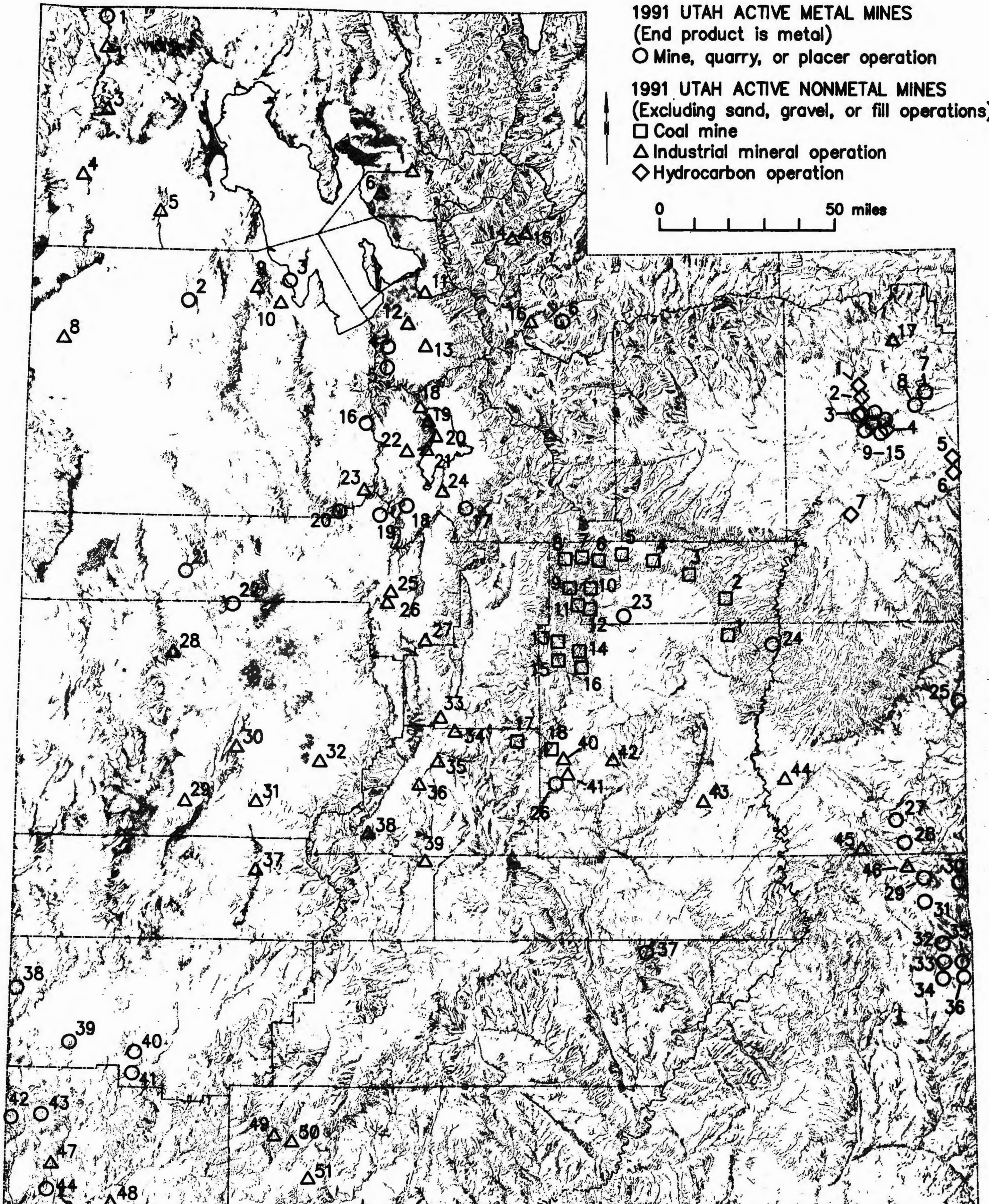
Geothermal

Utah Power and Light Company continued to operate its single-flash, Blundell geothermal power station at the Roosevelt Hot Springs geothermal area near Milford. Intermountain Geothermal Company, a subsidiary of California Energy Company and the current developer, produces geothermal fluid for the Blundell plant from four wells that tap a deep fractured reservoir in crystalline rock. Reservoir temperatures are typically between 271°C and 315°C (520°F - 600°F). The plant produces nearly 26 MW gross output (23 MW net) with all four wells operating.

The Utah Municipal Power Authority and the city of Provo jointly own and operate a geothermal power station located near Sulphurdale. The station is comprised of four binary-cycle power units rated at 3 MW (gross), a direct steam turbine generator placed upstream from the binary units rated at 2 MW (gross), and the newly constructed Bonnett geothermal plant rated at 8.5 MW (gross). Six supply wells, operated by Mother Earth Industries (MEI), produce steam from the shallow, vapor-dominated part of the geothermal system. Recent reductions of shallow reservoir pressures, however, have required MEI to drill new production wells into the deeper, liquid-dominated portion of the system. The estimated net output from all three power units is about 10 MW.

Uranium/Vanadium

Umetco, a subsidiary of Union Carbide, continued to operate its White Mesa uranium and vanadium mill near Blanding, receiving ore from both company-owned and independent mines located in San Juan County. Late in 1991, however, Umetco suspended mining operations, reduced exploration and production staff, and placed its company-owned


1991 UTAH ACTIVE METAL MINES
(End product is metal)
O Mine, quarry, or placer operation
1991 UTAH ACTIVE NONMETAL MINES
(Excluding sand, gravel, or fill operations)
□ Coal mine
△ Industrial mineral operation
◇ Hydrocarbon operation
0
50 miles

mines and the White Mesa mill on standby status.

In June, 1991 Morton Salt announced the acquisition of their Saltair facility on the Great Salt Lake by Kennecott Copper. Morton began its move in September and is now operating at the Grantsville facility some 43.4 km (27 miles) west of the old Saltair site. North American Salt has moved north from the Grantsville facility to the recently expanded Great Salt Lake (GSL) Minerals' Little Mountain salt production facilities. Both North American Salt and GSL Minerals are owned by G. Harris Associates.

GSL Minerals is presently expanding its solar ponding acreage through the construction of a 81 km^2 (20,000 acre) pond on the west side of the lake near Strongs Knob. Concentrated brines from the new pond will be conveyed eastward across the lake via an open, 32.2 km (20 mile), underwater, gravity-feed canal to their present intake site near Promontory Point. These new facilities were put in operation in August, 1992 and will continue to play an important part in nearly doubling GSL's output of potassium sulfate.

Industrial Minerals and Materials

1. Binggeli	Stone
2. Park Valley	Stone
3. Idaho	Stone
4. Montello	Clay
5. Pocohantos	Unknown
6. Great Salt Lake Minerals	Potash, salt
7. Pleasantview	Clay
8. Reilly	Potash, salt
9. Marblehead	Dolomite
10. Poverty Point	Limestone
11. Beck Street	Crushed stone
Victory Road	Crushed stone
12. Saltair	Salt
13. Western	Clay
14. Henefer	Clay
15. Devils Slide	Cement rock
16. Utelite	Lightweight aggregate
17. Vernal Chevron	Phosphate
18. Clinton	Clay
19. Black, Black Shale & Powell	Clay
20. Larson and Cedarstrom	Calcite & aragonite
21. Jim Gay and Gagon	Clay and stone
22. Five Mile Pass	Clay
23. MH Calcite	Calcite
24. Keigley	Stone
25. Nielson	Stone
26. Leamington	Cement rock
27. Painted Rocks	Clay, volcanics
28. Harris & West Desert	Fossils
29. Sevier Dry Lake	Potash, salt
30. Cricket Mountain	Stone
31. Utah Perlite	Volcanics, lightweight aggregate
32. White Mountain	Gypsite
33. Redmond	Salt
34. Redmond Limestone	Stone
35. Jumbo-Jensen	Gypsum
36. G-P Gypsum	Gypsum
37. Mineral Mountain	Unknown
38. Aggra-Insulite	Volcanics
39. Koosharem	Clay
40. Boddy Toddy	Clay
41. Daddy Dearest	Unknown
42. B & J Placer	Gypsum
43. Whitecloud	Unknown
44. Old Rock Farm	Stone
45. Potash	Potash, salt
46. Spanish Valley	Clay
47. Shivwits	Gypsum
48. Bloomington Hills	Gypsum
49. Caruso	Gemstones
50. Tetla	Gemstones
51. Legrand Hollow	Decorative stone

Coal Mines

1. Geneva Mine
2. Sunnyside Mine
3. Soldier Canyon Mine
4. Pinnacle Mine
5. Castlegate Mines
6. North Beaver Creek Mines
7. Belina Mines
8. Skyline Mine
9. South Beaver Creek Mines-Genwal
10. Star Point Mines
11. Co-op Mine
12. Hiawatha-Mohrland Mines
13. Cottonwood Mine
14. Deer Creek Mine
15. Trail Mountain Mine
16. Wilberg Mine
17. Convulsion Canyon Mine
18. Emery Mine

Hydrocarbon Mines

1. Uintah County asphalt	Tar sands
2. Aroc	Tar sands
3. Buena Ventura	Tar sands
4. Cameron Asphalt	Tar sands
5. Zeigler Gilsonite	Gilsonite
6. American Gilsonite	Gilsonite
7. ITM	Gilsonite

Utah Active Metal Mines (End-product is metal)

1. Rainbow	Gold & Silver
2. Knolls solar ponds	Magnesium
3. Rowley magnesium	Magnesium
4. Barneys Canyon	Gold & Silver
5. Bingham	Copper, etc.
6. Bear Hole	Gold
7. Sno Ben placer	Gold
8. Pebble Puppey	Gold
9. Ridge Rock	Gold
10. Yerian	Gold
11. Golden Rule	Gold
12. Golden Stirrup	Gold
13. American	Gold
14. Placer Gold	Gold
15. Golden Rule Special	Gold
16. Mercur	Gold & Silver
17. Prophecy	Gold & Silver
18. Burgin	Gold & silver
19. Lilly	Gold & Silver
20. Jerika	Lead & Silver
21. Topaz	Beryllium
22. Drum	Gold & Silver
23. Jack	Gold & Silver
24. Golden Girl	Gold
25. Pay Lode	Gold
26. Ivie placer	Gold
27. Oro	Gold
28. Sureshot	Gold
29. LaSal-Snowball	Vanadium-uranium
30. Vanadium Queen	Vanadium-uranium
31. Pandora	Vanadium-uranium
32. Rim-Columbus	Vanadium-uranium
33. Dunn	Vanadium-uranium
34. Velvet	Vanadium-uranium
35. Wilson-Silverbell	Vanadium-uranium
36. Calliham	Vanadium-uranium
37. International	Gold
38. Etna	Gold & Silver
39. Escalante	Silver
40. Excelsior-Chesapeake	Iron
41. Iron Mountain	Iron
42. Anniversary	Gold & Silver
43. Goldstrike	Gold & Silver
44. Apex	Rare Earths

COALBED METHANE ACTIVITY: NEW ENERGY SOURCE BEING DEVELOPED

by Steven N. Sommer and Robert W. Gloyn

A new source of energy is being developed in central Utah north of the town of Price. This new energy source is coalbed methane and is a "hot" topic in the natural gas industry. Coalbed methane is the natural gas produced as a by-product of converting plant matter to coal. During the process of coalification, methane, carbon dioxide, and water are produced. These products are trapped in the coal matrix, in pore spaces and in joints and fractures in the coal. Some of this gas, particularly that contained in the joints and fractures, can be commercially produced.

Coal mine operators have long known that coal seams are a source of natural gas. Methane gas has caused many tragic mine explosions. These tragedies are prevented in modern mines by venting millions of cubic feet of gas per day to the atmosphere. Today, there is an attempt to produce gas from coal beds away from the mines as an additional energy resource.

In the past, geologists considered deeply buried coal as a natural gas source rock; associated sandstones being the gas reservoir. Now, the coal is viewed as not only the source rock but also as the gas reservoir (Kuuskraa and Brandenburg, 1989).

Since the late 1970s, exploration and development of coalbed methane has occurred in basins throughout the United States. Industry is now recognizing the tremendous potential of Utah which will soon join the ranks of coalbed methane-producing states.

Cockrell Oil Corporation recently began producing coalbed methane from five test wells located north of Price. Coal beds were dewatered for nine months before gas began flowing at rates between 57 and 118 MCF/D (thousand cubic feet per day) per well (Utah Division of Oil, Gas & Mining, 1992). The production is from the Castlegate coals in the middle part of the Cretaceous Blackhawk Formation at depths of 4,200 to 4,400 feet (Petroleum Information, 2/26/92).

These wells have been in operation for over a year and through May, 1992 had produced 167 MMCF (million cubic feet) of gas and 1.02 MMBW (million barrels of water) (figure 1) (Utah Division of Oil, Gas & Mining, 1992). More importantly, the daily production of gas has been increasing and the daily production of water decreasing. For example, the average well production in May, 1992 was 121 MCF/D of gas and 318 BW/D (barrels of water per day), but seven months earlier the average gas well production was 92 MCF/D and 356 BW/D (Utah Division of Oil, Gas & Mining, 1992).

Individual well production has ranged from 58 to 179 MCF/D with the Shimmins No. 4 and No. 5 being the best and most consistent producers. The Cockrell wells are currently producing gas at an average flow rate greater than typical wells in either the Black Warrior basin of Alabama or the Piceance basin of Colorado, two major coalbed methane-producing basins (figure 2). Using a four-well comparison, the Utah wells produced 12.6 MMCF during the first month of production compared to 3.2 and 15.4 MMCF per month for the Black Warrior and Piceance respectively. However, production from the Utah wells has increased with time and the four Utah wells

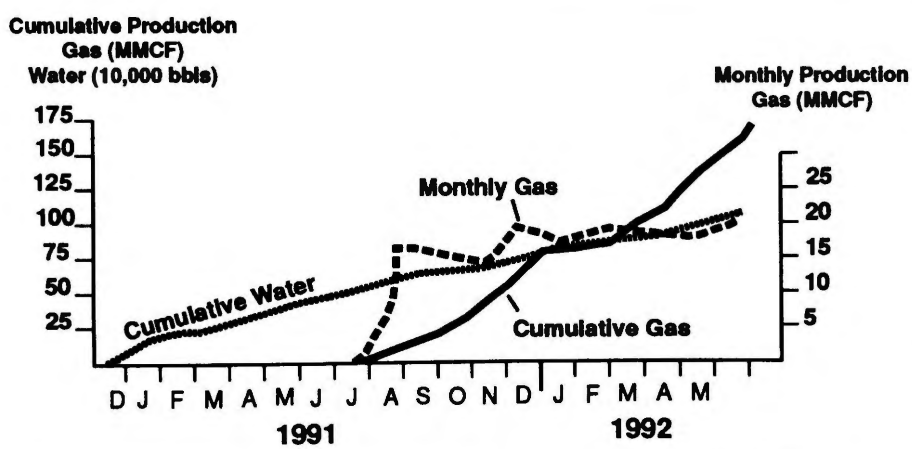


Figure 1. Cumulative and monthly production from five test wells, Book Cliffs coal field, Utah

are now producing 15.7 MMCF per month (Utah Division of Oil, Gas & Mining, 1992) which is greater than the four-well groupings for the other two basins.

Due to the success of these early wells, Cockrell announced plans for a large, aggressive drilling program covering 21,450 acres north of Price (Bureau of Land Management Environmental Impact Statement, 1992). Cockrell subsequently sold their interest to Pacific Gas and Electric Company (PG&E) who will continue with the announced program. They plan to drill 124 new wells in addition to the 11 wells previously permitted. Wells will be drilled to depths of 3,000 to 7,600 feet on 160-acre spacing to test multiple coal seams in the Blackhawk Formation. Projected average gas production per well is 300 to 320 MCF/D during the first five years of production, and the total life of the project is estimated at 25 to 30 years. Marketable gas sales should start in 1993, and the total field production is expected to reach 62 MMCF/D (million cubic feet per day) by 1997 (EIS, 1992). Plans have also been announced to construct a pipeline to connect the new gas field with an existing Questar pipeline approximately 14 miles to the east.

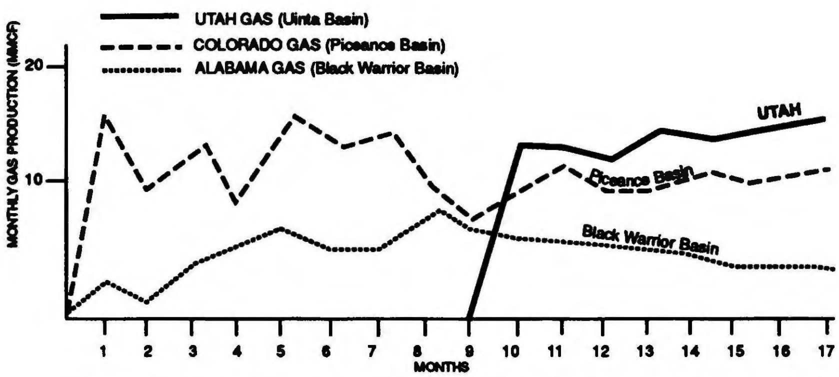


Figure 2. Comparative monthly coalbed methane production for Utah, Colorado, and Alabama for four-well groupings.

Anadarko Petroleum Corporation is testing the coalbed methane potential of the Blackhawk Formation both east and west of PG&E. Cockrell has announced plans to test the Blackhawk coals in northwestern Carbon County (figure 3).

Two companies are testing the coalbed methane potential of the slightly older Cretaceous Ferron Sandstone Member of the Mancos Shale (figure 3). To the west, PG&E has staked a location north of the Clear Creek gas field which has produced over 135 BCF (billion cubic feet) of gas from sandstone reservoirs in the Ferron Sandstone. The source of this gas is thought to be coals within the Ferron Sandstone (Walton, 1955). In the Price area, River Gas of Utah is exploring the northern Emery coal field (figure 3) and has drilled a well in the Ferron Sandstone. This well produced more than 2 MMCF/D of gas during preliminary tests (Lyle, 1991) and five additional wells are planned in the same area (Petroleum Information, 7/8/92).

Although most of the recent activity has been concentrated near Helper, many other areas in the state have potential for coalbed methane development (figure 4). Since many of the coal fields extend to depths which cannot be mined safely and coalbed gas content generally increases with depth, they are ideal areas for coalbed methane development. They are a valuable energy resource which, until recently, was not being utilized. Improved technology and industry interest may allow development of this new resource.The Uinta basin coal fields, particularly the Book Cliffs, Sego, and the Emery fields, are thought to have the best potential. Potential resources for these fields are estimated at 9 to 11 TCF (trillion cubic feet) of gas which is significantly higher than previous estimates of 0.8 to 4.6 TCF (Adams and Kirr, 1984) (table 1). Several other coal fields in the state

Table 1. Potential gas resources of the Uinta Basin coal fields

Coal field	Coal reserves to >4 ft thick <3,000 ft depth Billion tons	Coal resources to 9,000 ft. depth Billion tons	Average estimated gas content cubic per ton	In-place potential gas resources Trillion cubic feet
Book Cliffs	4.2	12.6	350-400	4.4-5.0
Emery (southern)	2.0	5.0	150-200	0.8-1.0
(northern)	2.0	5.0	400-500	2.0-2.5
Wasatch Plateau	10.3	13.5	60-100	0.8-1.4
Sego	0.5	1.5	160-370	0.2-0.6
Minor fields				0.5-0.7
			Total	8.8-11.3

such as Alton, Kaiparowits, and the Henry Mountains may also have some potential but little information is currently available.

In summary, Utah, particularly the Uinta basin, has substantial coalbed methane resources. Exploration and development of these resources has only just begun, but results to date are very promising. However, the degree of development will ultimately depend on economics, particularly the price of gas, possible tax credits, and improved technology.

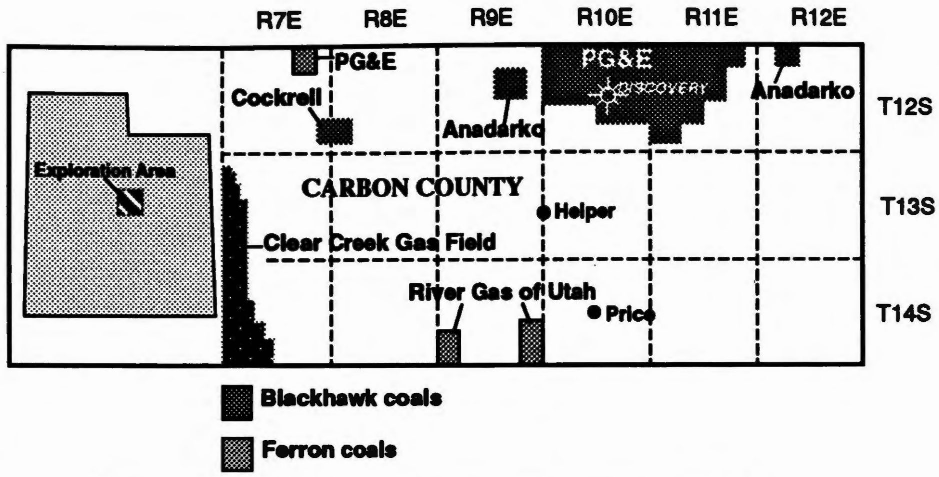


Figure 3. Coalbed methane exploration and production areas.

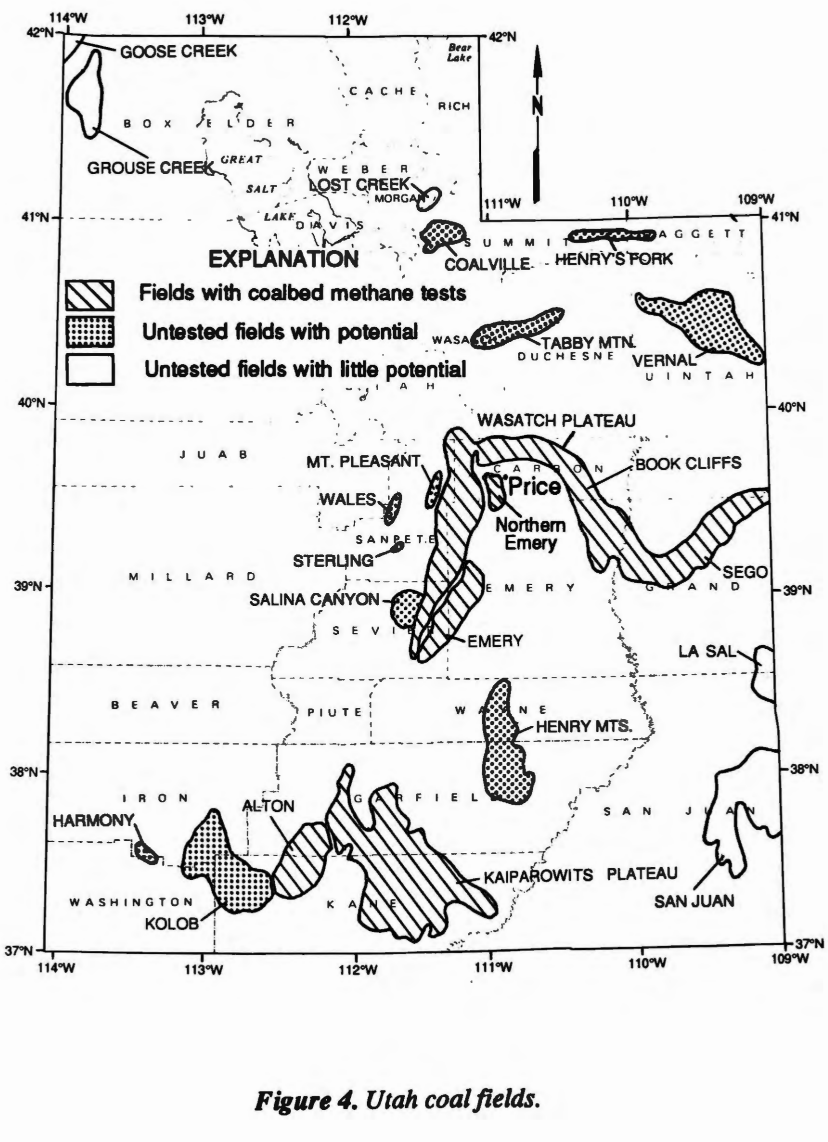


Figure 4. Utah coal fields.

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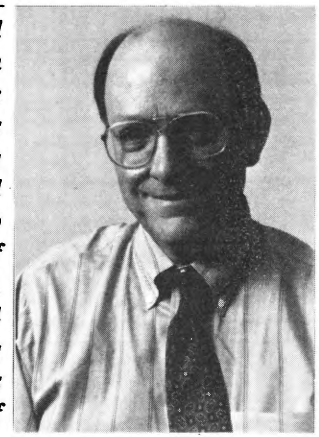
Symposium calls Uinta Basin "America's Energy Storehouse"

by Roger Lee Bon



Roger Lee Bon has directed the Industry Outreach Program for the UGS since 1989. The program is designed to develop a working relationship with the mineral operators in the state and to promote the development of Utah's mineral resources. Roger, a native Utahn, has 24 years of experience in mining and exploration in both metals and nonmetals. A graduate of Utah State University, Roger has been extensively involved in coal exploration and development in Utah and other western states. Before coming to the UGS, Roger was employed by Getty Mining Company, Wescar Inc., and Amax Coal Company. His present role in industry relations brings him in contact with many of the state's mineral producers, and oil and gas operators.

THIS SPRING SAW NEARLY 250 INDUSTRY GEOLOGISTS AND BUSINESSMEN GATHER IN VERNAL TO OBSERVE AND TO HEAR THE LATEST GEOLOGIC RESEARCH AIMED AT DEFINING NEW TARGET AREAS AND TECHNIQUES FOR UNLOCKING THE VAST HYDROCARBON RESOURCES OF THE UINTA BASIN.

The symposium was unique in that it was the first time ever that the industry's exploration community had gathered locally to address the latest geology, land and mineral ownership issues, and environmental requirements relating to both drilling and production.

The three-day event, hosted by the Utah Geological Survey, U.S. Geological Survey (USGS), Bureau of Indian Affairs (BIA), Gas Research Institute (GRI), and Bureau of Land Management (BLM), included field trips and a technical program on the latest advancements in depositional modeling, drilling applications, and issues related to Indian mineral interests, environmental compliance, and federal and state regulations.

The first commercial gas development in the basin originated in the Ashley Valley field in 1925. The first commercial oil well in Utah was drilled in the basin in 1948. To date, over 380 million barrels of oil and 1.0 trillion cubic feet of gas have been produced.

Long known for its potential, the basin contains one of the most abundant petroliferous resources in the world. With an estimated potential resource of over 1 trillion barrels of liquid hydrocarbon, the Uinta basin contains the equivalent of over 10 times the total amount of oil produced to date in the United States.

Some estimates for proven recoverable reserves are 1.5 billion barrels. Ultimate recoverable reserves could be as high as 3.5 billion barrels of oil and 6.5 trillion cubic feet of gas. Oil shale and tar sand deposits are unparalleled world wide and constitute the overwhelming bulk of untapped hydrocarbon resources with an estimated 1,300 billion barrels in oil shale, and over 29 billion barrels in tar sands.

Two field trips examined the basin's oil and gas infrastructure as well as its geology and mineral resources. The first day of technical presentations covered the most recent research in both depositional modeling and hydrocarbon migration, the history and current status of the oil and gas industry in the basin, a review of drilling and production in Utah, and an overview of the Uinta basin's formation and stratigraphic deposition.

The second day's presentations focused on land and mineral issues, including the history of the Uintah and Ouray Reservation and the development of split mineral interests on Indian lands.

Procedures for leasing mineral interests on the reservation were discussed, and presentations were made by representatives of the Allottee Management Group, Ute Distribution Corporation, and Bureau of Indian Affairs. The respective roles of the Bureau of Land Management and the Bureau of Indian Affairs were also presented. Many of the papers presented during the two-day technical session are published in the hardbound symposium guidebook (see the New Publications section of this issue). *Hydrocarbon and mineral resources of the Uinta basin, Utah and Colorado* was published

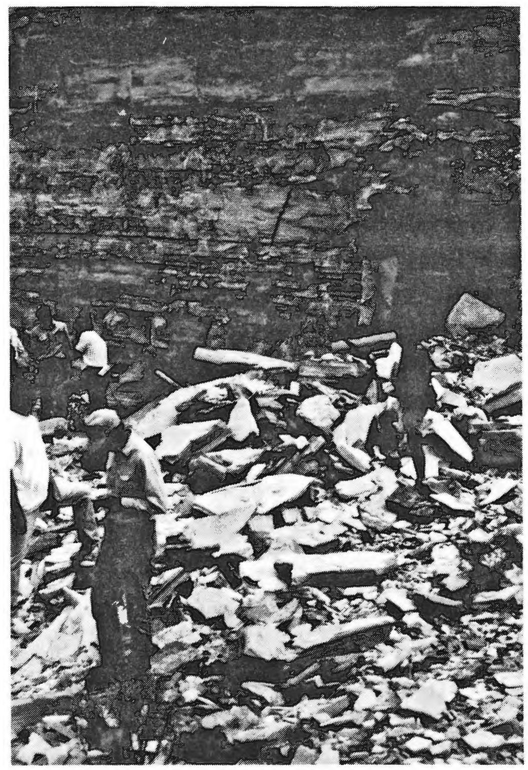
Lee Allison, UGS Director (right) with Roger Lee Bon, symposium organizer. Photo compliments of Fran Craigle.

by the Utah Geological Association, another symposium sponsor, as Volume 20 of their guidebook series. The volume contains twenty-five papers that focus on the hydrocarbon and mineral resources of the basin and on issues related to mineral leasing on Indian trust lands. Many of the papers are the result of the U.S. Geological Survey's Evolution of Sedimentary Basins Program and research carried out through the Department of Energy's Tight Sand Gas Program. The guidebook also contains road logs for the symposium's two field trips.

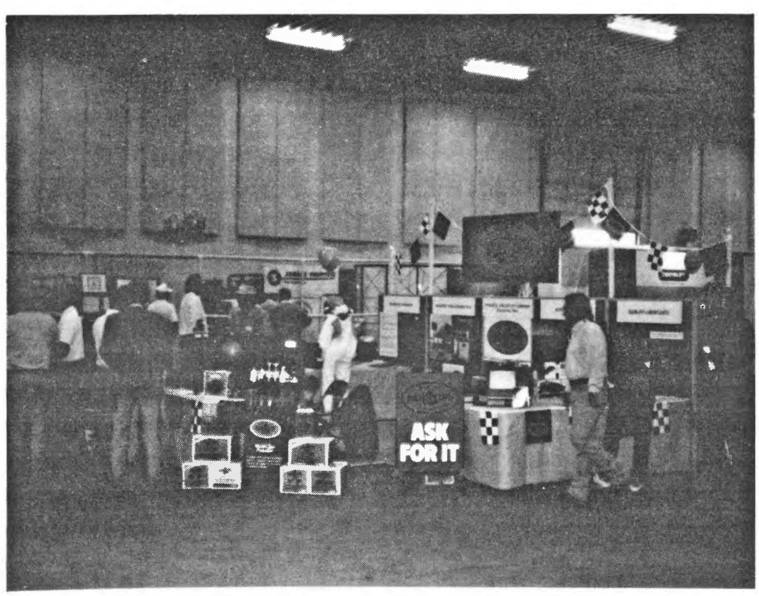
The symposium concluded with a keynote session highlighted by presentations from Lee Allison, Director of the Utah Geological Survey; Jim Peacock, Executive Director of the Utah Petroleum Association (UPA); and Shelly Cordon Teuscher, Associate Director of the Utah Petroleum Association. The keynote address was given by M. Franklin Keel, Bureau of Indian Affairs, Washington DC. Mr. Keel addressed the role of the BIA in its trust responsibility over all reservation lands and the partnership that has developed from its work within the Uintah and Ouray Reservation.

Following the symposium, the local business community sponsored "Petroleum Days," a two-day industrial trade show with numerous technical presentations devoted to drilling and production applications and to energy conservation. The industrial exhibit was open to the community and the local petroleum engineers society made sure that all school children visited the exhibits to see and to ask questions about one of the most important aspects of the basin's economy, the oil patch. Several thousand people visited the exhibits over the two-day event.

Both the symposium and "Petroleum Days" were well attended and created a week-long activity in both learning and celebration of the basin's contribution and long-term potential in satisfying the nation's energy requirements.



Oil shale test pit, Hells Hole Canyon near Colorado border. Photo by Fred Barnard, consultant, Denver, CO.



"Petroleum Days" industrial trade show. Photo by R.L. Bon

NEW PUBLICATIONS OF THE UGS

The December 1992 Publications List is available on request

Map

Provisional geologic map of the Gunnison quadrangle, Sanpete County, Utah, by S.R. Mattox, 11 p., 2 pl., 1:24,000, 1992, **$5.00**

Geologic map of the Long Ridge quadrangle, Millard County, Utah, by L.F. Hintze and F.D. Davis, 10 p., 2 pl., 1:24,000, 1992, Map 141 .... **$5.00**

Geologic map of the Red Knolls quadrangle, Millard County, Utah by L.F. Hintze and F.D. Davis, 10 p., 2 pl., 1:24,000, 1992, Map 142 .... **$5.00**

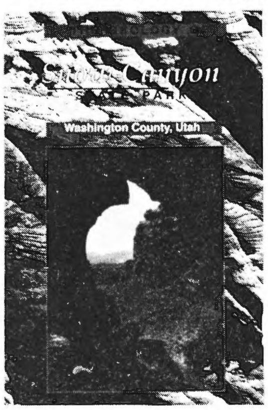
Special Study

A case study of the Newcastle geothermal system, Iron County, Utah, by R.E. Blackett and M.A. Shubat, 30 p., 2 pl., 1:24,000, Special Study 81 .... **$5.50**

Circular

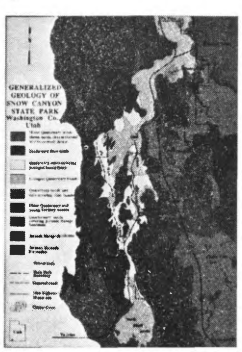
Guide for the preparation of reports for the Utah Geological Survey, by W.R. Lund, 74 p., 1992, Circular 85 **$5.50**

Public Information Series



The geology of Snow Canyon State Park, Washington County, Utah, by Miriam Bugden, 16 p., full-color booklet, PI-13, September 1992. .... **$1.75**

Geologic resources of San Juan County, by Sandra N. Eldredge, 32 p., full-color booklet, PI-14, January 1993. **$2.50**



Geologic postcard of Snow Canyon State Park, PI-15 **$0.25**

Report of Investigation

Technical reports for 1990-1991, Applied Geology Program, compiled by B.H. Mayes, July 1992, RI-222 .... **$12.70**

Open-File Report

Geologic hazards of Castle Valley, Grand County, Utah, by W.E. Mulvey, 31 p., 4 pl., 1:24,000, July 1992 OFR-238 .... **$8.00**

Landslide map of the Tremonton 30' x 60' quadrangle, by K.M. Harty, 12 p., 1 pl., 1:100,000, July 1992, OFR-239 **$3.50**

Landslide map of the Logan 30' x 60' quadrangle, Utah, by K.M. Harty, 12 p., 1 pl. 1:100,000, July 1992 OFR-240 **$3.50**

Quaternary geology of the upper Weber River drainage basin, Summit Co., Utah, by C.G. Oviatt, 40 p., 1 pl. 1:50,000, July 1992, OFR-241 .... **$4.70**

Landslide map of the Newfoundland 30' x 60' quadrangle, Utah, by K.M. Harty, 12 p., 1 pl., 1:100,000, July 1992, OFR-242 .... **$3.50**

Geologic map of the Grayback Hills quadrangle, Tooele County, Utah, by H.H. Doelling, B.J. Solomon, and S.F. Davies, 85 p., 1 pl., 1:24,000, July 1992, OFR-243 **$9.00**

Geologic map of the Hatch 7.5' quadrangle, Garfield County, Utah by R.A. Kurlich III and J.J. Anderson, 57 p., 2 pl., 1:24,000, July 1992, OFR-244 .... **$4.75**

Landslide map of the Promontory Point 30' x 60' quadrangle, Utah, by K.M. Harty, 9 p., 1 pl., 1:100,000, August 1992, OFR-245 .... **$3.50**

Interim geologic map of the Scipio Pass quadrangle, Millard County, Utah, by R.B. Michaels and L.F. Hintze, 91 p., 1 pl., August 1992, OFR-246 .... **$8.50**

Landslide map of the Ogden 30' x 60' quadrangle, Utah, by K.M. Harty, 11 p., 1 pl., 1:100,000, August 1992, OFR-247 .... **$3.50**

Landslide map of the Bonneville Salt Flats 30' x 60' quadrangle, Utah, by K.M. Harty, 10 p., 1 pl., 1:100,000, August 1992, OFR-248 .... **$3.50**

Landslide map of the Tooele 30' x 60' quadrangle, Utah, by K.M. Harty, 10 p., 1 pl., 1:100,000, August 1992, OFR-249 .... **$3.50**

Landslide map of the Kings Peak 30' x 60' quadrangle, Utah, by K.M. Harty, 10 p., 1 pl., 1:100,000, September 1992, OFR-250 .... **$3.50**

Isotopes and carbonate minerals in Lake Bonneville marl: records of lake-level fluctuations and climate change, by C.G. Oviatt, 16 p., OFR-251 .... **$1.50**

Landslide map of the Dutch John 30' x 60' quadrangle, Utah, by K.M. Harty, 12 p., 1 pl., 1:100,000, September, 1992, OFR-252 .... $3.50

Landslide map of the Wildcat Mountain 30' x 60' quadrangle, Utah, by K.M. Harty, 10 p., 1 pl., 1:100,000, October 1992, OFR-253 .... $3.50

Landslide map of the Rush Valley 30' x 60' quadrangle, Utah, by K.M. Harty, 10 p., 1 pl., 1:100,000, October 1992, OFR-254 .... $3.50

The March 16, 1992 M_L 4.2 western Traverse Mountains earthquake, Salt Lake County, Utah, by G.E. Christenson, 18 p., OFR-255 .... $1.75

Landslide map of the Provo 30' x 60' quadrangle, Utah, by K.M. Harty, 13 p., 1 pl., 1:100,000, October 1992, OFR-256 .... $3.50

Landslide map of the Duchesne 30' x 60' quadrangle, Utah, by K.M. Harty, 10 p., 1 pl., 1:100,000, November 1992, OFR-257 .... $3.50

Interim geologic map of the McCornick quadrangle, Millard Co. Utah, by F.D. Davis, 49 p. 1 pl., 1:24,000, November 1992, OFR-258 .... $5.00

Landslide map of the Vernal 30' x 60' quadrangle, Utah, by K.M. Harty, 11 p., 1 pl., 1:100,000, November 1992, OFR-259 .... $3.50

Landslide map of the Fish Springs 30' x 60' quadrangle, Utah, by K.M. Harty, 10 p., 1 pl., 1:100,000, November 1992, OFR-260 .... $3.50

Landslide map of the Lynndyl 30' x 60' quadrangle, Utah, by K.M. Harty, 10 p., 1 pl., 1:100,000, November 1992, OFR-261 .... $3.50

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Survey News

UGS Geologist Lehi Hintze Receives Governor's Medal

by Grant C. Willis

Dr. Lehi Hintze, UGS geologist, was awarded the 1992 Governor's Medal for Science and Technology on July 28. Randy G. Moon, State Science Advisor, informed UGS Director Lee Allison, who nominated Hintze, of the award.

Lehi Hintze, Professor Emeritus of Brigham Young University, has spent most of his life mapping the geology of Utah. Since retiring from BYU five years ago, he has worked half time for the UGS mapping, reviewing maps, and compiling a comprehensive work on the geology of Millard County.

As Allison stated in his nominating letter, "Dr. Hintze is an internationally known expert on the geology of Utah. He single-handedly compiled the 1980 *Geologic Map of Utah*, which is the definitive work on the geology of the state. His book *Geologic History of Utah* is used not only by geologists but has become a best-seller among the lay audience at national parks and other locations. ... He played a key role in establishing the state's geologic mapping program."

He has authored or co-authored more than 120 publications, most on Utah geology, and has served on many boards, committees, and as an officer in several professional organizations.

The UGS and the State are fortunate to have the services of such an expert. Congratulations Lehi, the award is well deserved.

Hintze Appointed to National Mapping Panel

Dr. Lehi Hintze, UGS mapping geologist, will be the representative of the state geological surveys to the EDMAP component of the National Geologic Mapping program of the U.S. Geological Survey. The EDMAP committee will oversee implementation of stronger geologic mapping training in the nation's universities and colleges.

In making the appointment, Dr. Morris Leighton, President of the Association of American State Geologists, said he was impressed with Dr. Hintze's experience in geologic mapping and commitment to teaching mapping to geology students.

Summit County Co-op

Summit County commissioners agreed to fund a $15,000 joint effort with UGS to increase oil and gas exploration in the Utah overthrust belt to help county tax revenues. Doug Sprinkel initiated the project with the county. The UGS will produce maps, catalogs and data bases to spark industry interest in the area.

New UGA Pubs Available

Two Utah Geological Association publications are now available (through the Utah Geological Survey Sales Office). ***Hydrocarbon and mineral resources of the Uinta Basin, Utah and Colorado*** is edited by T.D. Fouch, V.F. Nuccio and T.C. Chidsey, Jr..This 366 page collection of 27 papers is invaluable to anyone interested in the Uinta basin (see article on page 17). Order **UGA 20 (hardbound, $30.00).**

The second is ***Engineering and Environmental Geology of southwestern Utah*** edited by Kimm M. Harty. Twenty-five papers plus road logs for the 1992 field symposium. Of particular interest are the many papers on Washington County (St. George area). Order **UGA 21 (softbound, 342 p., $25.00).**

Please use the order form on page 19. Remember that postage and handling will be charged after July 1, so take advantage of a good deal now!

Survey News, continued

UGS GETS GEOTHERMAL GRANT

The Oregon Institute of Technology recently awarded the Utah Geological Survey an 18-month grant to study Utah's low- and moderate-temperature geothermal energy resources. The project is part of a U.S. Department of Energy (DOE) program to expand the present knowledge of commercially viable geothermal systems in the United States. The Oregon Institute of Technology Geo-Heat Center manages the program for DOE in cooperation with the University of Utah Research Institute and the Idaho Water Resources Research Institute, who direct technical aspects of the studies.

High-temperature (>400°F) hydrothermal systems in California have been producing electric power since the late 1950s, and several other resources in California, Nevada, and Utah have been developed since 1980. Power producers can now use binary technology to generate electricity from more abundant, moderate-temperature systems at prices competitive with fossil fuels and hydropower. In addition, home owners and businesses are rapidly expanding their usage of ground-source heat pumps.

Geothermal resource assessments by the U.S. Geological Survey, state geological surveys, and DOE have shown that low- and moderate-temperature (less than 300°F) geothermal systems in the U.S. make up a large, relatively unused, and non-polluting energy source. The new program encourages the use of this energy to help reduce the need for fossil fuels. Many of the larger low-temperature systems in the western U.S. have provided municipalities and businesses with low-cost energy for space heating. Important parts of the program are to bring the inventory of the nation's low- and moderate-temperature geothermal systems up to date, develop a comprehensive computer database, identify geothermal sources located near communities that could utilize the energy, and conduct detailed evaluations of promising geothermal areas.

Having just completed a case study on the Newcastle geothermal system (see New Publications), we are eager to begin the new project.

MAPPING GRANT

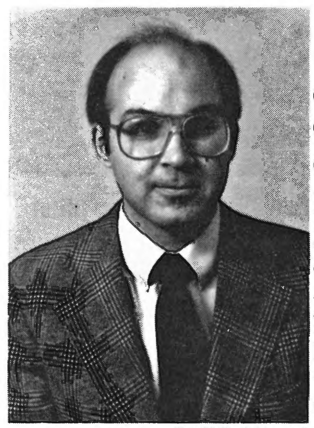
The Mapping Program of UGS has successfully won a final U.S. Geological Survey grant as part of the COGEOMAP program. This will essentially finish the works in progress and provide a program summary. The grant has provided geologists with several Quaternary studies in Utah and other states.

NEW STAFF

LaDonna Henderson is the new voice for the UGS. She is the phone receptionist and is happy to get out of the Uinta Basin. She has done accounting for Basin Pharmacy and worked for Pennzoil among others.

Garry Zubal, with over 30 years experience, is the new draftsman in editorial. He worked for Intermountain Aerial Surveys, Northwest Pipeline, and Mountain Fuel Supply.

Darwin (Dar) Day works at the UGS Sample Library and comes to us from UNISYS.



Dave Tabet is the new coal geologist at the Utah Geological Survey. He comes to the Survey with 17 years experience as a geologist, having worked previously for state government, private industry, and as an independent consultant. Dave is looking forward to directing the coal research program at the UGS. He plans to work closely with the coal industry and others interested in the coal deposits of Utah.

Dave started his career in 1975 with the New Mexico Bureau of Mines and Mineral Resources after finishing his master's degree in geology at the University of Wisconsin. In New Mexico, he established a successful coal research program of 3 geologists, and obtained funding for mapping and drilling projects from several federal grants. In 1980, he left the New Mexico Bureau to join ARCO Coal Company's Western U.S. Exploration Group in Denver. His work with ARCO involved supervising coal exploration programs in Colorado, Montana, and Wyoming, and assisting with resource appraisals of coal deposits in Utah, Texas, New Mexico, Washington, Illinois, and several foreign countries. In mid-1986, Dave began work as an independent consultant while taking night courses for an M.B.A. degree. After finishing his M.B.A. in late 1989, Dave joined Pentastar Support Services. At Pentastar, a contractor for the Bureau of Indian Affairs, Dave provided business and technical advice on mining and coalbed methane resource development issues on Indian lands.

Survey News, continued

MAPPING PROGRAM ACQUIRES NEW STEREO PLOTTER

by Grant C. Willis

The UGS Mapping Program took a big step into the future with the recent acquisition of an Alpha 2000 first-order analytical stereo plotter made by International Imaging Systems.

What is a stereo plotter? It is an instrument designed to remove the distortion from aerial photographs, and to accurately transfer onto a map base all the geologic information mapped on the photo. Two photographs of the same terrain, taken from different camera stations, permit three-dimensional viewing and comprise a stereoscopic pair. By using basic principles of geometry, the plotter compensates for the various types of distortion. If a geologist simply traced over uncorrected stereo photograph images, features might be misplaced by more than 1,000 feet on a standard 7 ½-minute topographic map.

Stereoscopic photo pairs contain three types of distortion: (1) distortion caused by irregularities in the lens surface (fortunately, this distortion is negligible in most high-quality cameras), (2) distortion caused by the airplane twisting, tilting, and changing altitude between shots, and (3) parallax, which is caused by variations in the angle between the camera and different parts of the image. Parallax distortion is compounded in rugged terrain such as is common in Utah.

Until the purchase of this instrument, UGS geologists made geologic maps by recording field information on aerial photographs. The distortion was removed by painstakingly transferring each bit of data to a corrected orthophotoquad by hand; a slow, cumbersome, and often inaccurate process. The new plotter alleviates these difficulties, saving time and improving accuracy.

Earlier stereo plotters were mechanical, with an intricate array of gears, wheels, bearings, and moveable arms, and were too cumbersome and slow for UGS needs. Recent advances in computer technology has simplified the process, making it faster and more accurate. This new technology will result in more accurate maps and reduce production costs in years to come.

Director's Perspective, continued ...

Federal agencies, including MMS, Bureau of Land Management (BLM), U.S. Forest Service, and the Army Corps of Engineers, are all charging administrative fees to the states. At present there is no limit to the size of the fees and no restrictions on what constitutes a legitimate administrative fee. A recent audit by the Inspector General of the Department of the Interior found mischarges of 100 percent in BLM costs of administering programs. In addition, federal fire-fighting costs have been charged to the states as administrative costs.

Last year, there were unsuccessful efforts in the President's budget and in Congress to increase the administrative fee by 50-100 percent. With deficit-ridden federal agencies continuing to look for new revenues, it will not be surprising to see them attempt to expropriate a larger share of the states' royalties in the future.

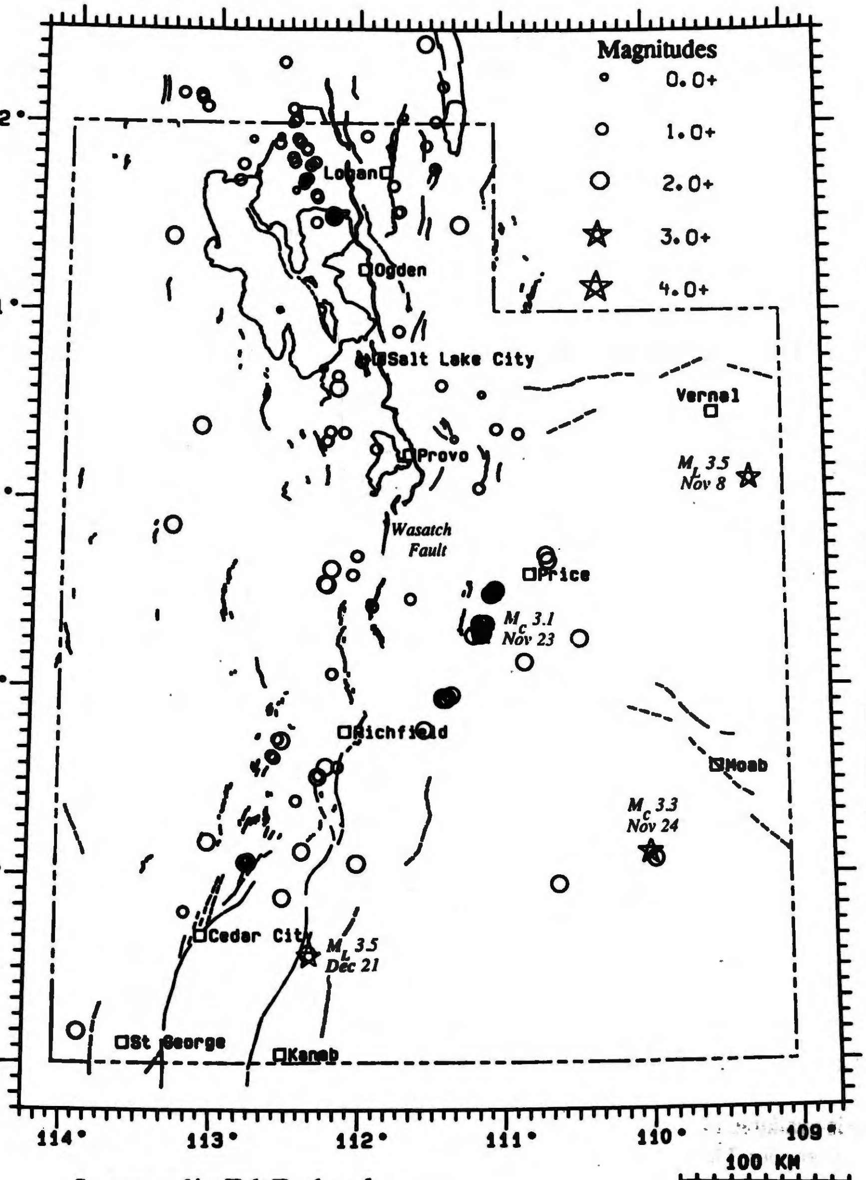
The UGS has responded to the reduced revenues by cutting all external funding programs, such as the Mineral Lease Special Projects program and the USGS Mapping Cooperative. The latter will mean a 40 percent reduction in the number of geologic quadrangles being produced in Utah. Continued loss of Mineral Lease funds will mean possible cuts in other UGS programs unless we can find alternative external funds. Fortunately, aggressive efforts by UGS geologists have brought in significant federal and industry contracts for a variety of projects that will allow us to maintain our services and capabilities for this year and next. Unless the issue of unlimited fees on state revenues is resolved though, further cuts will threaten the UGS and other Mineral Lease recipients.

EARTHQUAKE ACTIVITY IN THE UTAH REGION

October 1 – December 31, 1991

Susan J. Nava
University of Utah Seismograph Stations
Department of Geology and Geophysics
Salt Lake City, UT 84112-1183
(801) 581-6274

During the three-month period October 1 through December 31, 1991, the University of Utah Seismograph Stations located 169 earthquakes within the Utah region. The total includes four earthquakes in the magnitude 3 range, specifically labeled on the epicenter map, and 66 in the magnitude 2 range. (Note: Magnitude indicated here is either local magnitude, M_L, or coda magnitude, M_C. All times indicated here are local time, which was either Mountain Daylight Time (October 1-31) or Mountain Standard Time (November 1-December 31)).



Significant Clusters of Earthquakes

• Southwest of Price (coal-mining related): Three clusters of earthquakes (magnitude 1.7 to 3.1) make up 25% of the shocks that occurred in the Utah region during the report period.

• West of Logan – A cluster of 13 earthquakes ranging in magnitude from 0.5 to 1.7 occurred 45 km W of Logan, in the Blue Springs Hills. This is approximately the same location as a magnitude 4.8 shock which occurred on July 3, 1989.

• A cluster of 17 earthquakes ranging in magnitude from 0.5 to 2.2 occurred 40 km SW of Logan, just north of the Bear River.

Additional information on earthquakes within the Utah region is available from the University of Utah Seismograph Stations.

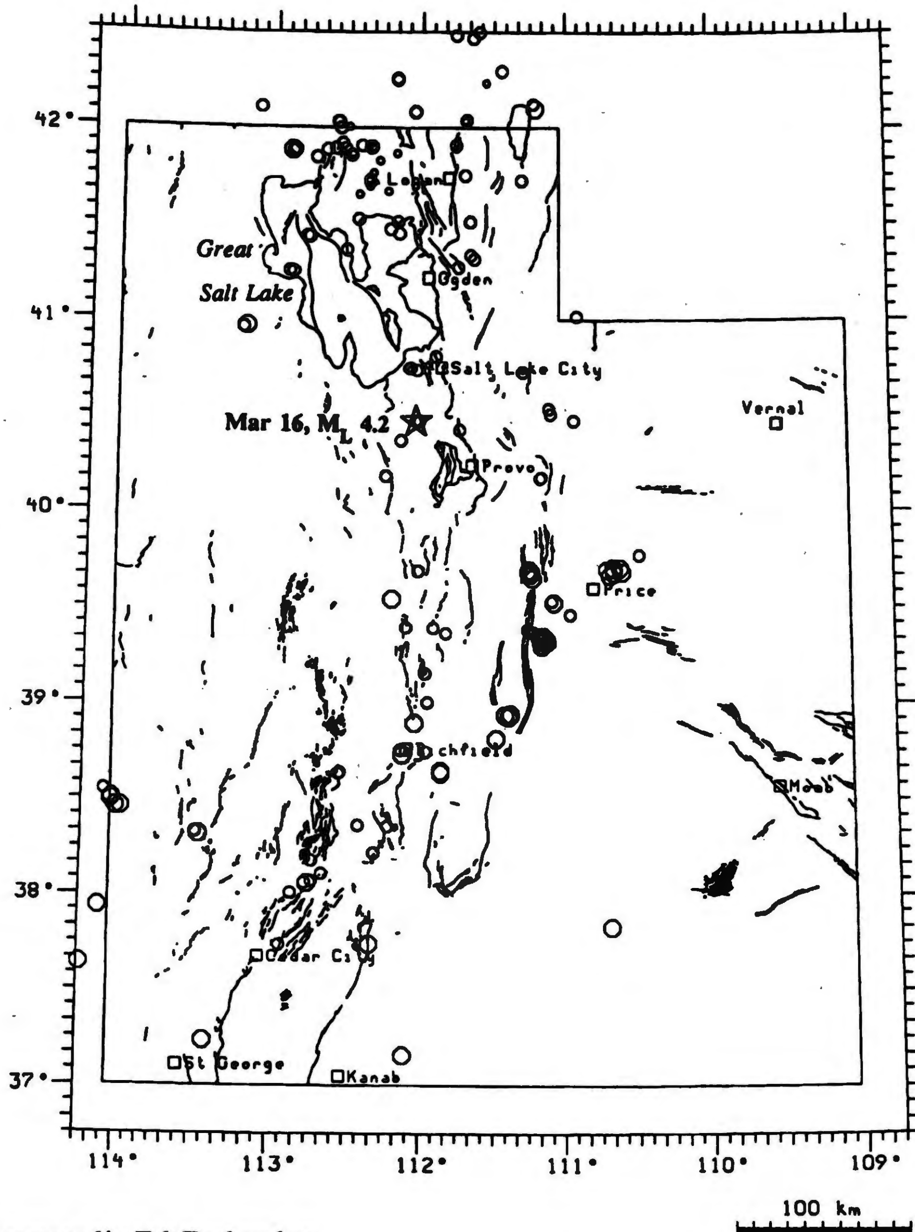
Larger and/or Felt Earthquakes

- M_L 3.5 November 8 6:15 a.m. 28 miles SE of Vernal; felt in Vernal, and in Dinosaur, CO
- M_c 3.1 November 23 9:25 a.m. 7 miles WNW of Orangeville (see SW of Price)
- M_c 3.3 November 24 8:40 p.m. 40 miles SSW of Moab
- M_L 3.5 December 21 1:26 p.m. 8 miles ESE of Hatch (see E of Cedar City); felt in Henry, Tropic, and Bryce Canyon National Park

Earthquake Activity in the Utah Region

January 1 – March 31, 1992

Susan J. Nava, University of Utah Seismograph Stations
Department of Geology and Geophysics Salt Lake City, UT 84112-1183



During the three-month period January 1 through March 31, 1992, the University of Utah Seismograph Stations located 180 earthquakes within the Utah region. The total includes one earthquake in the magnitude 4 range, specifically labeled on the epicenter map, and 64 in the magnitude 2 range. (Note: Magnitude indicated is either local magnitude, M_L, or coda magnitude, M_C. All times indicated are local time, which was Mountain Standard Time).

Larger and/or Felt Earthquakes

• M_C 2.5	February 12	7:54 p.m.	8 miles WNW of Orangeville; felt at Cottonwood Creek Mine
• M_L 2.4	March 4	7:41 a.m.	5 miles WNW of Sigurd; felt in Aurora and Sigurd
* • M_L 4.2	March 16	7:42 a.m.	6 miles SW of Riverton; felt in Salt Lake Valley and Utah Valley

*More information on this earthquake is available in, "The March 16, 1992, M_L 4.2 Western Traverse Mountains earthquake, Salt Lake County, Utah," G.E. Christenson, compiler, Utah Geological Survey Open-File Report 255, 1992.

Significant Clusters of Earthquakes

• Southwest and northeast of Price (coal-mining related): Three clusters of earthquakes (magnitude 1.5 to 2.9) make up 24% of the shocks that occurred in the Utah region during the report period.

Additional information on earthquakes within the Utah region is available from the University of Utah Seismograph Stations.

SEPTEMBER 2, 1992

M_L 5.8 ST. GEORGE EARTHQUAKE

by Bill D. Black and Gary E. Christenson

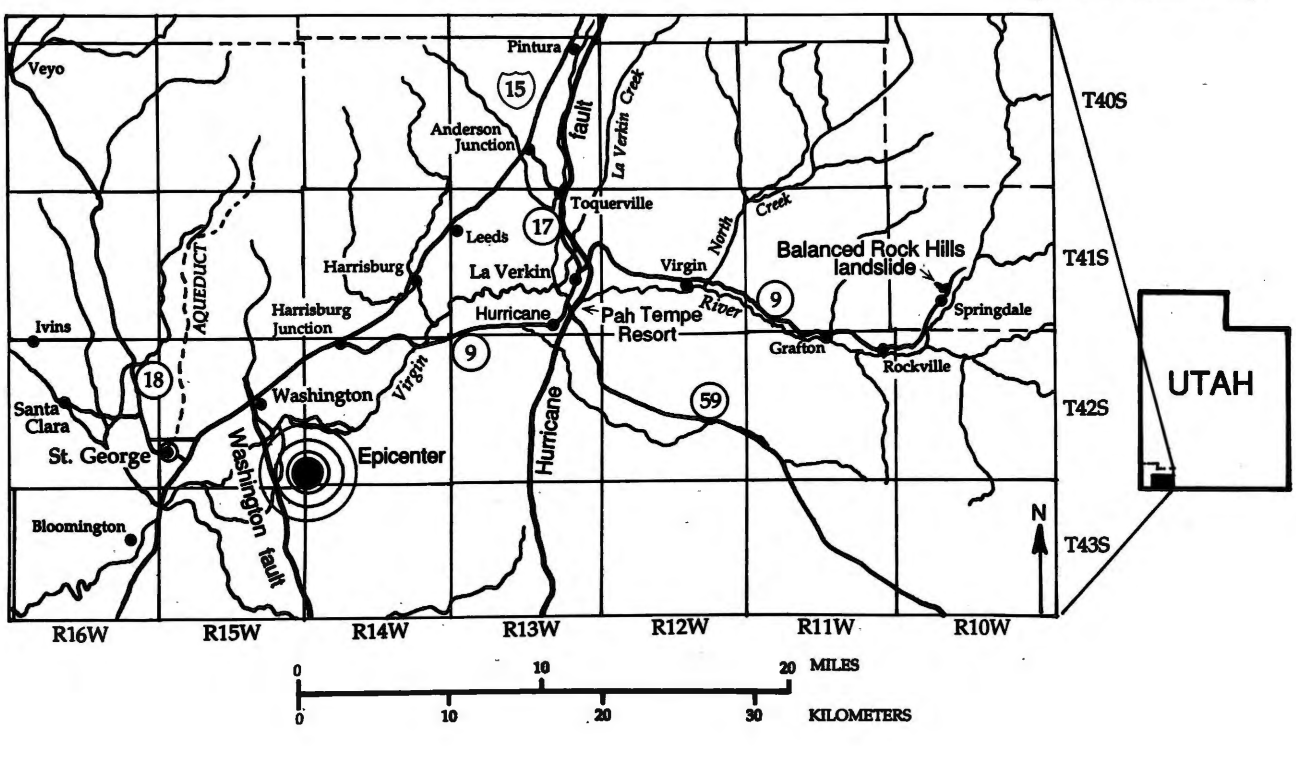
A RICHTER MAGNITUDE (M_L) 5.8 EARTHQUAKE OCCURRED AT 4:26 A.M. (MDT) ON SEPTEMBER 2, 1992. THE EPICENTER WAS ABOUT 6 MILES (9 KM) EAST OF ST. GEORGE, WASHINGTON COUNTY, UTAH (figure 1). The shock was the largest in the St. George area since 1902 and the largest in the Utah region since 1975 (Arabasz and others, 1992b). Although there were no deaths or serious injuries, the earthquake caused damage up to 95 miles (153 km) from the epicenter. Reports indicated structural damage to buildings in Hurricane (figure 2) and New Harmony, and minor damage in St. George and other communities (Arabasz and others, 1992). The earthquake also produced liquefaction along the Virgin River and triggered a destructive landslide in the town of Springdale. This landslide, referred to as the Balanced Rock Hills landslide, destroyed three homes and forced the temporary evacuation of condominiums and businesses around the periphery of the slide. There were also numerous rock falls throughout the region, which caused minor damage.

EARTHQUAKE SOURCE AND AFTERSHOCKS

Southwestern Utah is historically one the most seismically active parts of the state. The St. George area is at the southern end of the Intermountain seismic belt, a generally north-south-trending zone of seismic activity that bisects the state. The largest historical earthquake in the St. George area was an estimated magnitude 6 earthquake on November 17, 1902, in Pine Valley, 20 miles (32 km) north of St. George (Arabasz and others, 1992a).

Although no surface-faulting earthquakes have occurred in the St. George area in historical time, two faults in the vicinity of the epicenter have evidence of Quaternary movement: (1) the Washington fault, and (2) the Hurricane fault (figure 1). Preliminary seismological data indicate that the main shock was caused by dominantly normal faulting on a north-south fault of moderate dip, possibly a west-dipping subsurface projection of the

Figure 1. Location map.



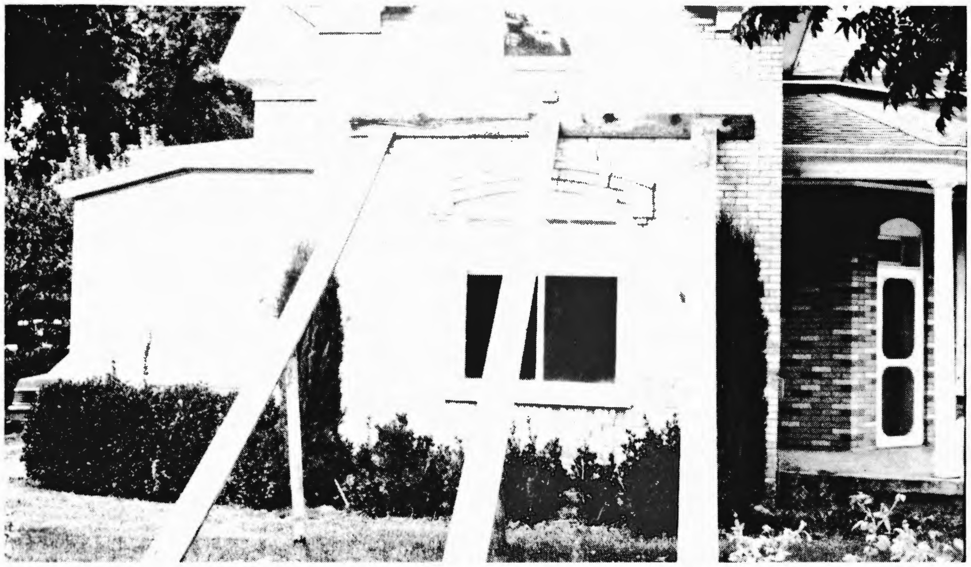


Figure 2. House in Hurricane damaged by ground shaking. Photo by B.D. Black.

Hurricane fault (Arabasz and others, 1992b). Estimated focal depth of the earthquake was about 9 miles (15 km).

The main shock was not preceded by foreshocks and has been followed by remarkably few aftershocks. The only aftershock larger than magnitude 2.0 that originated in the epicentral area was a magnitude 2.7 event on September 10, 1992 (Arabasz and others, 1992a). The absence of aftershocks is unusual for a M_L 5.8 earthquake, which is expected to be followed by about 15 aftershocks of magnitude 3.0 or larger during the first 24 hours (Arabasz and others, 1992b). Newspaper reports following the 1902 Pine Valley earthquake indicate that numerous aftershocks were felt afterwards (Arabasz and others, 1992b).

GEOLOGIC EFFECTS

Ground shaking is typically the most widespread and damaging earthquake hazard. Given the magnitude and location of the earthquake, it should have produced ground motions sufficient to cause significant damage, particularly in the St. George area. However, detailed observations failed to verify the expected damage (Reaveley, 1992). The only buildings structurally damaged were constructed using adobe bricks or stone; there were no reports of collapse (Reaveley, 1992).

Geologic effects of the earthquake, other than ground shaking, included numerous rock falls, liquefaction along the Virgin River, and the landslide in Springdale; no evidence of surface-fault rupture, such as scarps, ground cracks, or surface deformation, was found on either the Hurricane or Washington faults. There were also changes in flow from the springs at Pah Tempe Resort (figure 1). Rock falls were common because of the steep cliffs and canyons in the epicentral area. Most of these rock falls caused little damage, principally because the areas where they occurred were remote and sparsely populated. However, in St. George a car was damaged by a rock fall (unpublished Utah Division of Comprehensive Emergency Management final field report), and in Hurricane rock falls damaged footpaths and irrigation lines at Pah Tempe Resort (figure 3) and blocked an unused section of the Hurricane Canal.

LIQUEFACTION

Liquefaction resulting from the St. George earthquake occurred in alluvium along the Virgin River from roughly 1 mile (1.6 km) south of Bloomington to 4 miles (6 km) west of Hurricane (figure 1). No damage has yet been documented from liquefaction. Sediments involved were poorly graded channel sands, commonly covered by thin overbank deposits of silt and clay. Liquefaction features observed were lateral spreads, sand blows, and caved stream banks. Lateral spreads were the most common feature.

Lateral spreads occur when liquefaction of a shallow subsurface layer causes overlying intact layers to crack and "raft" downslope. They were common on flat to gentle (0.5-3 degree) slopes underlain by alluvial sands along the modern flood plain of the Virgin River. Lateral-spread cracks were arcuate, extending for roughly up to 65 feet (20 m) parallel, and up to 25 feet (8 m) perpendicular to the river. The largest extended along the river for 196 feet (60 m), and perpendicular to the river for 65 feet (20 m). Cumulative crack width, which indicates the total amount of lateral movement, was more than 19 inches (48 cm) at this location.

Small "sand volcanoes" (commonly called sand blows) form as liquefied material is forced upward and flows onto the ground surface. Sand blows were common along the Virgin River and occurred individually, in groups, and along cracks associated with lateral spreads (figure 4). Sand blankets ejected from craters of these sand blows were up to 3 feet (1 m) across, and contained pea-sized gravel at one location where construction-fill material was liquefied. Craters were commonly less than 2 inches (5 cm) in diameter, but ranged up to 20 inches (51 cm) in diameter. Sand blows were common where thin overbank deposits of silt and clay covered the sands that liquefied.

BALANCED ROCK HILLS LANDSLIDE

The most damaging result of the St. George earthquake was the Balanced Rock Hills landslide in Springdale (figure 5), which destroyed two water tanks (one of which was unused), several storage buildings, and three homes (figure 6) in the Balanced Rock Hills Subdivision. The landslide also temporarily blocked State Route (SR) 9 leading to Zion National Park (figure 5), and ruptured buried and above-ground utilities in the subdivision and along SR 9. Condominiums and businesses around the periphery of the slide were temporarily evacuated. Although movement was initiated by ground shaking, the landslide moved slowly and continued moving for several hours following the earthquake.

The Balanced Rock Hills landslide is a complex block slide that likely involves both rotational and translational elements of movement. The landslide has a

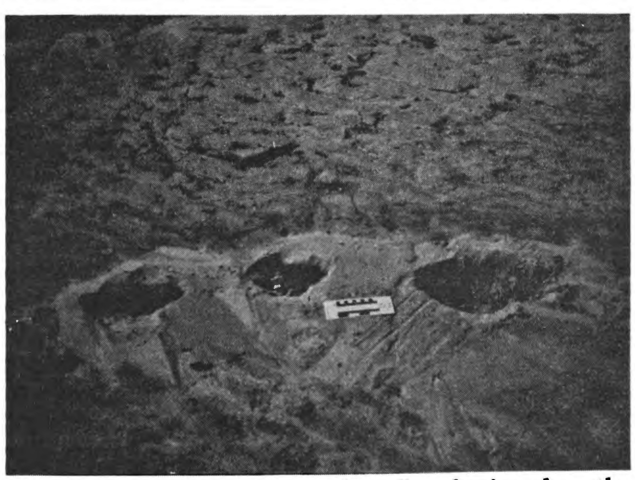


Figure 4. Sand blow resulting from liquefaction along the Virgin River. Photo by W.E. Mulvey.

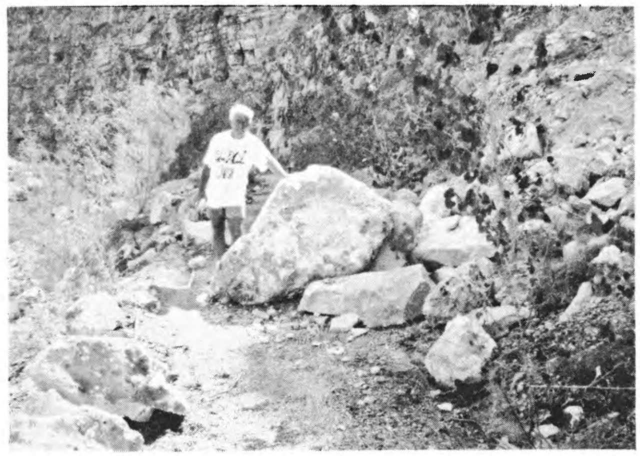


Figure 3. Rock fall at Pah Tempe Resort in La Verkin. Photo by B.D. Black.

clearly defined main scarp (figure 7), and there are numerous fissures and minor scarps that form a broken irregular topography within the slide mass. These scarps and fissures indicate that the landslide likely moved in several coherent blocks. The landslide measures roughly 1,600 feet (488 m) from the main scarp to the toe, with a width of about 3,600 feet (1,097 m). The volume of material involved is estimated to be 18 million cubic yards (14 million m^3). The Balanced Rock Hills landslide is believed to be one of the largest landslides in the world caused by a M_L 5.8 earthquake, and is much further from the epicenter than would be expected for a landslide of this type (Randy Jibson, U.S. Geological Survey, personal communication, September 1992; Keefer, 1984).

Three geologic units are mapped by Cook (1960) in the area of the Balanced Rock Hills Subdivision: (1) the Jurassic Kayenta Formation, (2) the Triassic Moenave Formation, and (3) the Triassic Chinle Formation (Petrified Forest Member). The Springdale Sandstone Member of the Moenave Formation (Harshbarger and others, 1957) forms the prominent cliff ledge north of the subdivision, above the main scarp of the landslide (figure 5). The landslide involved lower units of the Moenave Formation and the Petrified Forest Member of the Chinle Formation, and included alluvium and colluvium containing rock-fall debris derived from the Kayenta and Moenave Formations. Previous investigators have noted slope instability in the Petrified Forest Member in the Springdale area (Kaliser, 1975; Harty, 1990), and a significant number of deep-seated landslides in Utah occur in this unit (Harty, 1991).

A combination of failure-prone geologic materials, earthquake ground shaking, and long-term marginal stability of the slope is the most likely cause of the landslide. Slope movement in the subdivision was first

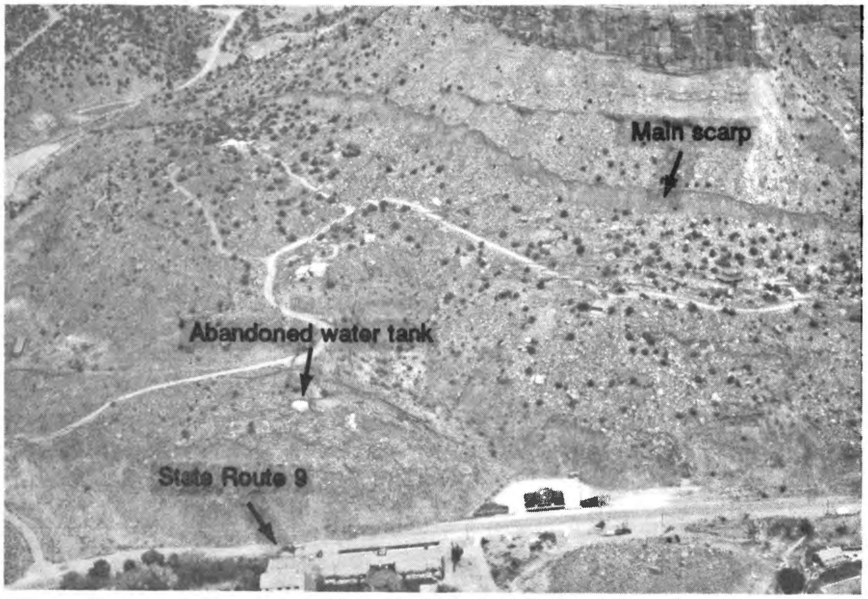


Figure 5. *Aerial photo of the Balanced Rock Hills landslide. State Route 9, the main scarp of the landslide, and the abandoned water tank in the subdivision are labeled. Photo by B.J. Solomon.*

studied in the mid-1970s by Wayne Hamilton, a geologist with Zion National Park, who reported differential movement in the hill on which the (now abandoned) Springdale water tank rests (figure 5; Kaliser, 1975). Hamilton (1992) noted 1.3 inches (3.3 cm) of movement from August 1974 to June 1975, but eventually abandoned the study when it became apparent that other areas near the hill were also moving. Water may also have contributed to the landslide. In addition to precipitation, which was 120 percent of normal for the current water year in the region (Utah Climate Center, 1992), other sources of water include effluent from wastewater disposal systems or possible leaking water lines or tanks in the subdivision. However, because no water was observed issuing from the slide, the role of water is unclear.

UGS RESPONSE

A primary role of the UGS in responding to an earthquake is to advise government officials and emergency-response personnel regarding potential dangers from geologic effects. In the St. George earthquake, the Balanced Rock Hills landslide in Springdale presented a danger where such assistance was provided. Another role of the UGS in responding to earthquakes is to document and study geologic effects to better understand what to expect in future earthquakes. Some effects are transitory and must be documented quickly before they are destroyed by erosion and post-earthquake repair and clean-up.

The UGS responds to all "significant" earthquakes, that is, those which cause damage or produce geologic effects. This includes most earthquakes greater than magnitude 5, but may include smaller earthquakes near populated areas. The immediate UGS response generally includes: (1) sending field teams to the affected area to advise government officials and document geologic effects, and (2) providing information to the public, the media, scientists, and engineers regarding geologic aspects of the earthquake. Once study of an earthquake is completed, we compile the available information into a final summary report.

In response to the St. George earthquake, the UGS sent a geologist working in Richfield directly to Springdale. He arrived around 9:00 a.m. and began assessing the landslide. During the following days he advised Washington County, Springdale Town, Utah Department of Transportation, and Division of Comprehensive Emergency Management officials at the scene regarding the hazards posed by the landslide. A UGS team from Salt Lake City arrived the afternoon of the earthquake to assess geologic effects in La Verkin, Hurricane, and St. George, and to assist in Springdale as needed. That evening, UGS geologists met with Gayle M. Aldred, Washington County Commissioner, to recommend actions to protect life safety in Springdale in the area around the landslide.

Following the initial response, UGS geologists continued work on the landslide and searched the epicentral area near St. George for evidence of liquefaction, surface faulting, rock falls, hydrologic effects, and other landslides. This investigation continued for about 2 weeks, and included helping Springdale Town establish survey stations on the Balanced Rock Hills landslide to monitor movement. During this time, the UGS responded to the public and the media regarding effects of the earthquake and hazards posed by the landslide. We also asked local newspapers to publish an earthquake survey that local residents could fill out to report specific ground-shaking effects at their houses. The response to the survey has been excellent, giving us valuable information to prepare a map of ground-shaking intensities and evaluate local site effects where reported motion was stronger or weaker than expected.

Figure 6. House in the Balanced Rock Hills Subdivision destroyed by landsliding. Photo by B.D. Black.

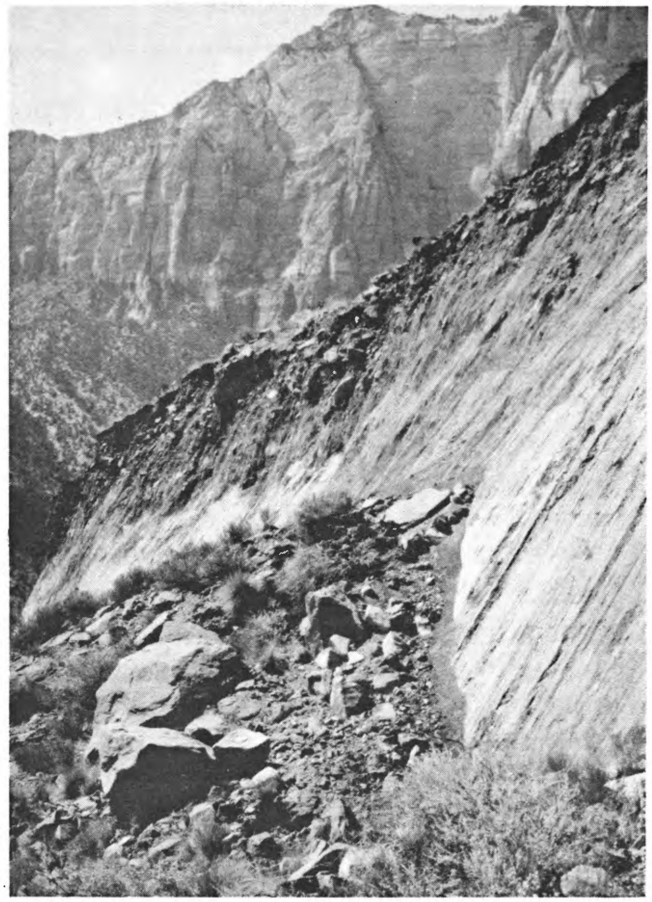


Figure 7. Main scarp of the Balanced Rock Hills landslide. Photo by W.E. Mulvey.

Earthquakes are frightening experiences and fear of aftershocks can generate great anxiety, particularly in the days and weeks following the earthquake. Understanding what happened in the main shock and what to expect from aftershocks helps to alleviate some of that fear. For this reason, the UGS puts special emphasis on rapid response to provide the public, the media, government officials, and emergency-response personnel with clear, timely information. Documenting geologic effects also helps identify what long-term loss-reduction measures are needed. Much was learned from the St. George earthquake that will aid us and other state officials in preparing for future earthquakes, whether they occur in southern Utah or elsewhere in the state.

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Fall Field Trips Full of Fun

by Sandy N. Eldredge

IN SEPTEMBER AND OCTOBER, WE ENJOYED MEETING A LOT OF ENTHUSIASTIC TEACHERS WHO PARTICIPATED IN VARIOUS FIELD TRIPS. On September 19, over 20 teachers made the Utah Section of the Association of Engineering Geologists excursion to Antelope Island. They joined 30 other people, many of whom were UGS geologists, for a day full of intriguing talks and sights of Antelope Island and the Great Salt Lake. Highlights included geologic and environmental hazards, geologic history of the area, and the hydrology of the lake.

The Wasatch Front was the focus of two, one-day field trips offered to teachers by the UGS. A total of 20 teachers took the opportunity to learn about the landforms in the Salt Lake Valley and geologic history of the area as seen in the rocks of Big Cottonwood Canyon.

Look for field trip announcements in this newsletter as well as for those advertised through the Utah Museum of Natural History.

Twenty teachers (20 seems to be the magical number) joined the Utah Geological Association on their October 24 and 25 field trip based out of St. George, which was offered for credit through the University of Utah. A total of 38 participants investigated the earthquake-generated Springdale landslide, the volcanic and geologic record in Snow Canyon State Park and surrounding areas, and the history of Silver Reef mining town. On Saturday night, the group enjoyed a wonderful catered dutch oven dinner.

For those of you who missed the fall trips, don't worry, the field season will pick up again in the spring. Look for field trip announcements in this newsletter as well as for those advertised through the Utah Museum of Natural History. Trips vary in cost; some are free, others range up to $75.00. Some field experiences are offered for credit, others are simply to promote enhanced teacher awareness. Several planned for this spring include exploring the Henry Mountains and sleuthing along the Wasatch Front.

ROCK, MINERAL AND FOSSIL KITS

Thanks to the hard work of a local 8th grader, Michael Chidsey, UGS now has 11 rock, mineral, and fossil kits. Michael, who is the son of UGS geologist Tom Chidsey, collected over 40 samples for each kit for his Eagle Scout Project. UGS was the lucky recipient of 11 of those sets.

The collection includes igneous, sedimentary, and metamorphic rocks. Other unique Utah items include crude oil from 15 Utah oil fields, tar sand, oil shale, and fossilized trilobites, worm trails, shark teeth, dinosaur bones, plus others.

Because UGS does not have staff to manage a formal, unlimited loan system, we are storing the kits here for use by our staff. However, geologists and teachers who network with UGS can borrow a kit for one week. They must be signed out through a UGS employee, with a $10.00 refundable deposit.

Other kits are available at the Utah Museum of Natural History, University of Utah. The museum has four different sets: fossils, rocks, minerals, and economic minerals. The economic minerals collection comes with booklets and posters from the National Energy Foundation. Teachers receive one free poster for their classroom with a kit checkout — a real bonus! Call Claudia Batey, Assistant Curator of Education, at 581-4887 to reserve any of these sets or for more information. It is recommended to reserve the kits one week in advance, and there is a $5.00 check-out fee.

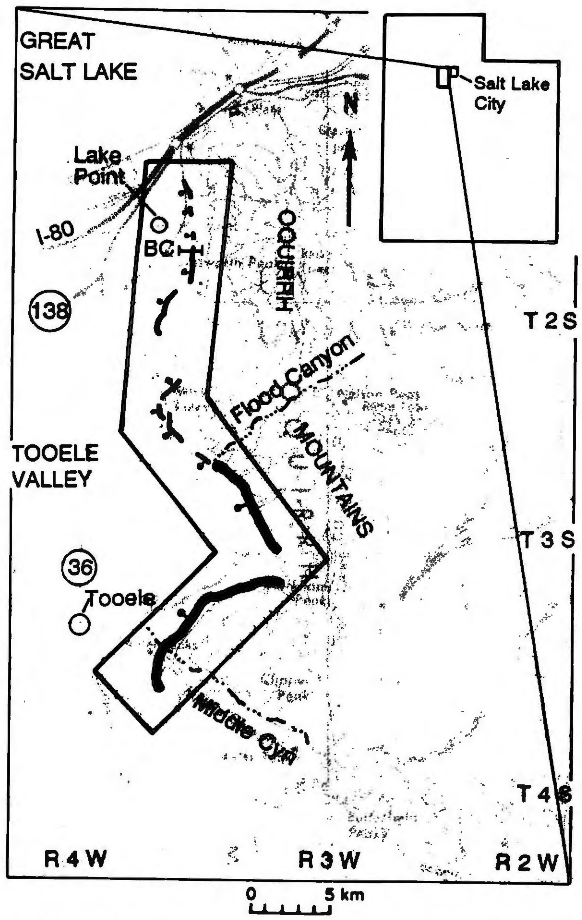
MORE VOLUNTEER ENGINEERS AND GEOLOGISTS IN THE CLASSROOM

The Society for Mining, Metallurgy, & Exploration Inc. has activated their GEM program to provide volunteer engineers and geologists in the classrooms. For those teachers who requested GEM assistance at the UEA convention this fall, Tom Breitling, who is directing the program, reports that requests scheduled through January 1993 have been arranged. Other teachers interested in inviting a local professional to their classes to discuss mining, minerals, and/or the mineral industry should call Sandy Eldredge at 467-7970.

PREHISTORIC EARTHQUAKES ON THE OQUIRRH FAULT ZONE, TOOELE COUNTY

By Susan S. Olig

HOW BIG? WHEN? HOW OFTEN? The Utah Geological Survey is looking for answers to these questions about large (surface-rupturing, probably greater than magnitude 6.5) earthquakes on the Oquirrh fault zone in eastern Tooele County. Our ongoing study involves investigating the geomorphology along the fault and excavating trenches across fault scarps to examine the earthquake-related deposits. William Lund, Bill Black, and I are conducting the one-year study with partial funding from the U. S. Geological Survey under the National Earthquake Hazards Reduction Program.

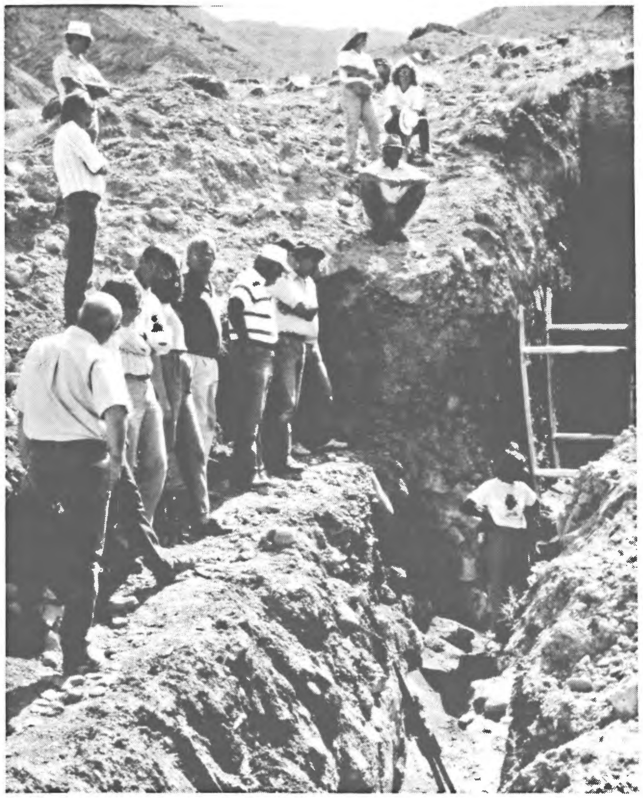


Map of the Oquirrh fault zone (after Barnhard, 1988). Thinner lines in boxed area are fault scarps in alluvium with bars and balls on downthrown side. Heavy lines are fault traces at the bedrock-alluvium contact. BC marks the Big Canyon trench site.

The Oquirrh fault zone is a normal fault that bounds the east side of Tooele Valley, dipping to the west underneath the valley. It generally extends along the base of the Oquirrh Mountains from northeast of Lake Point to southeast of Tooele. The fault zone has long been recognized as a potential source for large earthquakes (Everitt and Kaliser, 1980) that would not only affect the city of Tooele and Tooele Army Depot, but also the more populous central Wasatch Front. Even though downtown Salt Lake City is over 20 miles away, a large earthquake on the Oquirrh fault zone could cause strong shaking (ground acceleration over 0.2 g) and liquefaction, which could severely damage older buildings and bridges. Although the fault zone was mapped by Barnhard and Dodge in 1988, little is known about the occurrence of large prehistoric earthquakes on the fault. Consequently, studies of the ground-shaking hazard in north-central Utah had to make assumptions with large uncertainties about how large and how often large earthquakes occurred on the Oquirrh fault zone.

So far we have excavated and logged three trench exposures at a site near the mouth of Big Canyon. Here, the fault offsets Lake Bonneville deposits about 200 feet below the Provo shoreline (Solomon, in review). There is a wide graben formed by a single large, main fault scarp (about 50 feet high) that faces west, and a smaller antithetic fault scarp (about 5 feet high) that faces east.

Trenches across the main fault exposed similar stratigraphy with Lake Bonneville transgressive beach and deep-water sediments overlain by a debris-flow deposit on the downthrown side of the fault, and pre-Bonneville alluvial-fan deposits on the upthrown side of


Officials from Tooele County, local cities, Tooele Army Depot, and Dugway Proving Ground examine a trench exposure at the Big Canyon site.

the fault. A thick colluvial wedge (6 to 10 feet) overlies the debris-flow deposit on the downthrown side. This wedge was derived from sediment eroded off the crest of the fault scarp and deposited at the base of the scarp after the earthquake. Samples collected from the debris-flow deposit, directly under the colluvial wedge, yield radiocarbon ages of 6,840 ± 90 and 7,650 ± 90 yr B.P. These ages indicate that the most recent surface-rupturing earthquake occurred during the last 7,000 years and is much younger than previous geomorphic studies estimated (Barnhard, 1988). To better constrain the minimum age of this event, we collected samples for radiocarbon dating from unfaulted alluvial-fan sediments that bury the fault. Results are still pending.

Trenching at another site south of Big Canyon may answer questions regarding the timing of the penultimate surface-rupturing earthquake (the event prior to the most recent event; this allows an estimate of the recurrence interval) and recurrence of surface-rupturing earthquakes on the Oquirrh fault zone. We expect to be done with the project by next summer.

"Trenching at another site south of Big Canyon may answer questions regarding the timing of the penultimate surface-rupturing earthquake ..."

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Solomon, B.J., in review, Quaternary geologic map of Tooele Valley, northern Rush Valley, and the West Desert Hazardous Industry Area, Tooele County, Utah: Utah Geological Survey Open-File Report.

Recent Publications of Interest

(THESE ARE NOT AVAILABLE FROM UGS)

Neotectonics of North America, 1991, D.B. Slemmons and others, editors, 1991 (actually distributed in 1992): The Geological Society of America, 508 p., **$65.00.**

The book is part of The Geology of North America series marking the centennial of The Geological Society of America. Its main function is an explication of a series of maps: Seismicity Map of North America, Stress Map of North America, and Geothermal Map of North America, with overviews and articles on regional aspects. As synthesis, the texts are as useful to me as the maps which, at 1:5,000,000 of the North American continent, are very useful for overviews, for noting regional trends, for teaching, and for summarizing what is known about each of these data sets. But since the articles go beyond merely explaining the map compilation process, they stand on their own and provide much-needed summaries.

The set of text and 3 maps is available at a discount.

Geothermal map of North America, 1992, compiled by D.D. Blackwell and J.L. Steele, 1:5,000,000, 4 sheets, **$37.50.**

Illustrates distribution of surface heatflow and shows the locations of heat-flow data, geothermal areas (major, high-temp, and low-temp), and Pleistocene/Holocene volcanic centers. Accuracy for this scale is very good.

Seismicity map of North America, 1988, compiled by E.R. Engdahl, 1:5,000,000, 4 sheets, **$25.00.**

Historic and modern data (depicted separately) from 1534 through 1985 reveal the seismotectonic fabric of the area more coherently than previous versions. A good teaching device.

Stress map of North America, 1990, by M.L. Zoback and others, 1:5,000,000, 4 sheets, **$36.00.**

Maximum horizontal stress orientations are plotted using color to differentiate regime or method of faulting in terms of relative stress magnitude. The set is available from GSA at a discount.

Corporate exploration strategies: A worldwide analysis, 1992, by Metals Economics Group, PO Box 2206, Halifax, Nova Scotia B3J 3C4, Canada.

Oil shale, 1992. A primer for non-geologists from Utah Division of Energy, 3 Triad Center suite 450, Salt Lake City, UT 84180-1204.

Nautical chart for the south arm of the Great Salt Lake, Utah, compiled by the GSL Yacht Club, 1992. This is the first complete navigational map of the sailing/boating areas of the lake in over two decades. Printed on waterproof paper with verified soundings, all the new names for the area, at a scale of 1:90,000. Contact the GSL Yacht Club, P.O. Box 26201, Salt Lake City, UT 84126.

Pages of stone: Rocky Mountains and Western Great Plains by Halka Chronic, 1988: Seattle, WA, The Mountaineers, 168 p.

Pages of stone: Grand Canyon and Plateau Country by Halka Chronic, 1988: Seattle, WA., The Mountaineers, 168 p.

Nature's America, a book of glorious nature photography by David Muench, as well as some stunning posters (White Canyon, Slickrock, etc.) of Utah's geological diversity are available from Arpel Graphics, 32 E. Micheltorena, Santa Barbara, CA 93101.

The geochemical evolution of Great Salt Lake, Utah, by R.J. Spencer, 1983: (Ph.D. dissertation, Johns Hopkins Univ.), Baltimore, MD, 308 p.

Cambrian stratigraphy and paleontology of the Great Basin and vicinity, western U.S.- Guidebook for Field Trip 1, 2nd International Symposium on the Cambrian System, 1981, edited by M.E. Taylor and A.R. Palmer: U.S. Geological Survey Open-File Report 81-743, 182 p. All USGS publications are available through U.S. Geological Survey, ECIS, Room 8105, 125 S. State St., Salt Lake City, UT 84138.

Geologic map of Dinosaur National Monument and vicinity, Utah and Colorado by W.R. Hansen, P.D. Rowley, and P.E. Carrara, 1983 (reprint), 1:50,000: US Geological Survey Map I-1407. This is still the best geologic map of the Monument for geology and structure.

Suggestions to authors of the reports of the United States Geological Survey seventh edition, by W.R. Hansen, 1991: US Geological Survey report, 289 p. The main style guide for geologic writing!

Assessment of regional earthquake hazards and risk along the Wasatch Front, Utah, P.L Gori and W.W. Hays, eds., 1992: U.S. Geological Survey Professional Paper 1500A-J, 320 p.

Landslide deposits in the Ogden 30'X 60' Quadrangle, Utah and Wyoming, by R. B. Colton. Prepared in cooperation with the Utah Geological and Mineral Survey. 7 p., 1 over-size sheet, scale 1:100,000. OFR 91-0297. 1991

Analytical results and sample locality map for rock samples from the Detroit mining district, Juab and Millard counties, Utah, by D.R. Zimbelman, B.F. Argogast, C.J. Nutt, P.L. Hageman, R.H. Hill, D.L. Fey and J.H. Bullock, Jr, 1991. 48 p., 1 over-size sheet, scale 1:24,000 (1 inch = 2,000 ft). Open-File Report 91-0319.

Meetings and Calls for Papers

April 14-16 – Seismological Society of America annual meeting, Ixtapa, Zihuatanejo, Mexico. Abstracts due Jan 10. Contact Program Chair, c/o SSA Headquarters, 201 Plaza Professional Building, El Cerrito, CA 94530; or (510) 525-5474.

April 18-21 – Application of Geophysics to Engineering and Environmental Problems (SAGEEP), 6th Annual Symposium, San Diego, California. Contact: Mark Cramer, ExpoMasters, 7632 E. Costilla Ave., Englewood, CO, 80112. Phone (303) 771-2000.

May 14 – Seismic Design of Embankment Dams, short course presented by Geotechnical Group, Utah Section, American Society of Civil Engineers (ASCE); Salt Lake Hilton. Contact Steve Brown (801) 296-0110 or Bill Leeflang (801) 538-7293.

May 16-20 – Second USA/CIS Joint Conference on Environmental Hydrology and Hydrogeology, Washington, D.C. Contact American Institute of Hydrology, 3416 University Ave SE, Minneapolis, MN 55414-3328; or (612) 379-1030.

May 19-21 – Geological Society of America Cordilleran/Rocky Mountain Section Meeting, Reno, Nevada. Abstracts due Jan 26 to R.A. Schweickert, Department of Geological Sciences, Mackay School of Mines, Univ. of Nevada, Reno, NV 89557-0138. Contact Vanessa George, GSA, 3300 Penrose Place, Boulder, CO 80301; or (303) 447-1133.

May 25-27 – Seventh National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring, and Geophysical MEthods, Las Vegas, Nevada. Contact: Christ Miller, Conference Coordinator, National Ground Water Association, 6375 Riverside Drive, Dublin, OH 43017. Fax: (614) 761-3446.

June 13-17 – The Eleventh Rapid Excavation and Tunneling Conference, Boston MA. Contact Meetings Dept., SME, PO Box 625002, (303) 973-9550.

August 1-5 – Milton E. Wadsworth International Symposium on Hydrometallurgy, Salt Lake City, UT. Contact Meetings Dept., SME, PO Box 625002, Littleton CO 80162 or call (303) 973-9550 or fax (303) 979-3461.

September 12-15 – Rocky Mountain Section AAPG annual meeting, Salt Lake City, Utah. Hosted by Utah Geological Association, the meeting theme will be "Extending the Reach of Exploration." Abstracts due Jan 17. Contact Thomas Morris, Technical Program Chair, Department of Geology 258 ESC, Brigham Young University, Provo, UT 84602; or (801) 378-3761.

September 15-17 – WorldTech I International Congress on Mining Development in Philadelphia, Pennsylvania. Abstracts are due Nov 1. Contact Meetings Dept. SME, PO Box 625002, Littleton, CO 80162; or (303) 973-9550.

October 12 – Association of Engineering Geologists annual meeting, San Antonio, Texas. The theme will be "Ethical Considerations in the Environmental Practice of Engineering Geology and Hydrology." Abstracts due Mar 1 to Seena N. Hoose, 10394 Bret Ave., Cupertino, CA 95014; or (408) 252-5811.

October 25-28 – Geological Society of America annual meeting, Boston, Massachusetts. Abstracts due July 7 to Abstracts Coordinator, GSA, 3300 Penrose Place, P.O. Box 9140, Boulder, CO 80301-9140. Contact Vanessa George, GSA, (303) 447-1133.

October 25-28 – American Geophysical Union Fall Meeting, San Francisco, California. Abstract deadline: September 9, 1993. Contact: AGE-Meetings Department, 2000 Florida Avenue, N.W., Washington D.C. 20009. Phone: (202) 328-0566.

The cover photograph is a 2.5" x 3.5" section of a liesegang-banded rhyolite. The rhyolite is quarried near St. George, Utah for use as building veneer stone and ornamental stone for aquariums and landscaping.

Photograph by Bryce T. Tripp

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Survey Notes

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