UTAH GEOLOGICAL SURVEY

SURVEY NOTES

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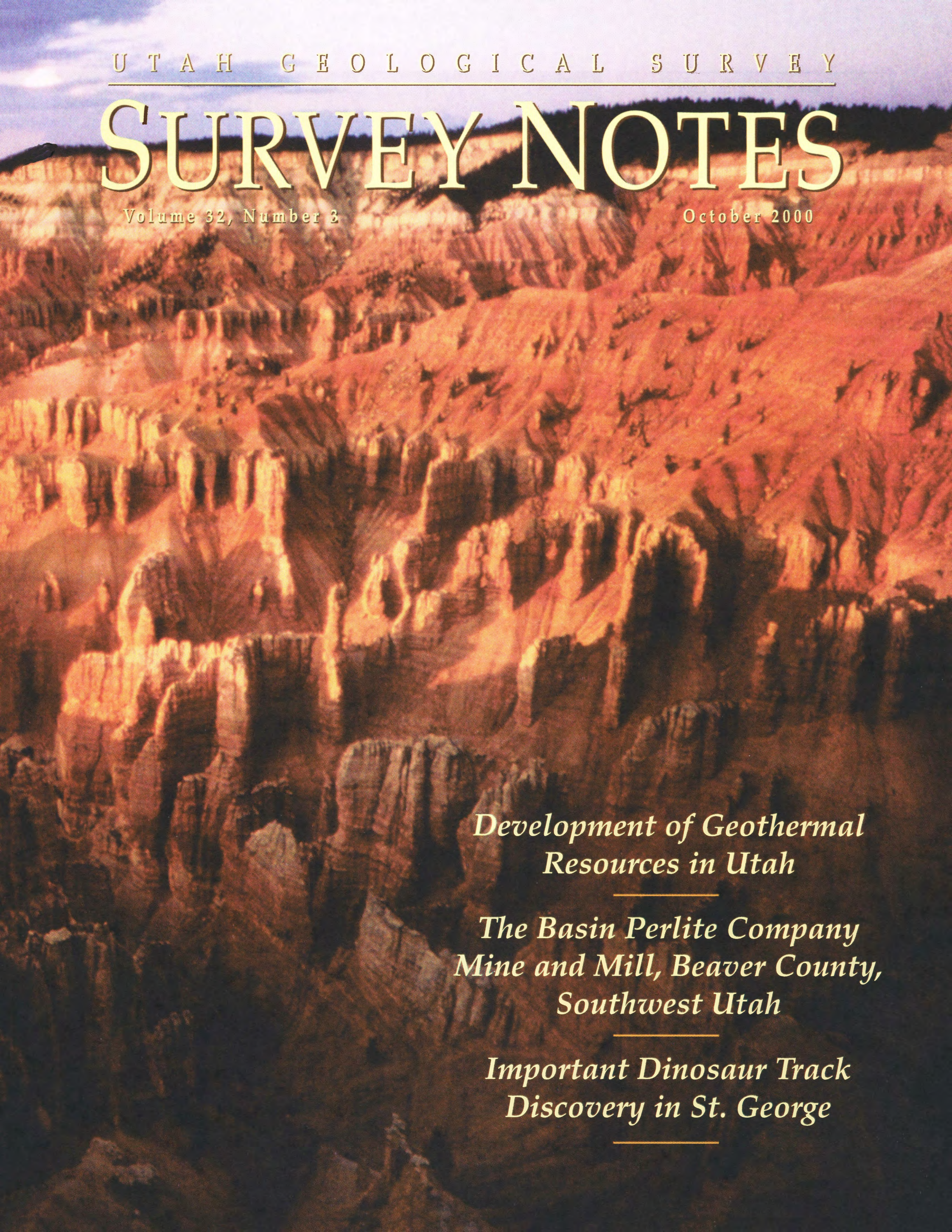

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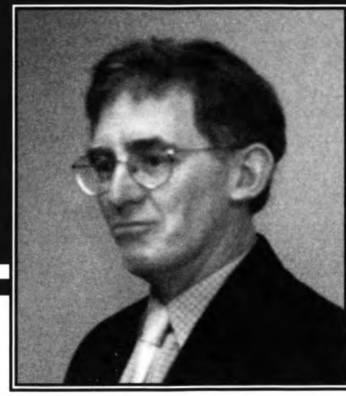
by Richard G. Allis



(This is an extract of the introductory speech made by the new UGS Director, Richard G. Allis, who will begin October 2, 2000)

A Look at the Issues Facing the Utah Geological Survey

The future role of the UGS will be challenging because of the continued population growth and continued economic development of the State - this creates tensions between the desire for economic vitality, a natural environment, and a high quality of life. The State needs sound, objective advice to assist wise decision making. The Geological Survey has an important role advising on many issues concerned with sustainable economic development

Some of the issues relevant to the UGS that are likely to crop up during the next decade may involve difficult and controversial decisions for our policy makers, planners and politicians. There may be wide diversity of opinion from interest groups, which makes it important for the UGS to be considered by everyone as a source of impartial, scientific advice. Here are my predictions of likely "hot-button" issues for the Survey:

- Renewed exploration for oil and gas in the State (driven by high oil prices; possible Federal incentives to reduce national vulnerability to overseas oil supplies; Utah is relatively rich in oil and gas resources).
- Renewed interest in more fossil-fuel-fired electricity in Utah, especially from coal (95% of present electricity generation in Utah; the current 20% surplus will be gone by 2010 at the growth rate of 1990s of 4% per year; Utah coal has preferred qualities compared to many coals in the eastern states).
- Increased demand for ground-water supplies to supplement reservoir supplies during the summer months. How far can strategic aquifers be stressed without significant impacts?
- Preserving the quality of strategic ground-water supplies - preventing contamination from sources such as agricultural waste, sewage, industrial/mining waste.
- Competing demands for land access - what are the implications based on resource/hazard/geological values?
- Ongoing requests to build on or develop hazardous sites - seismic zoning issues, land stability, Holocene flood plains.

These may involve tough decisions, and in some cases decision-makers may decide no action is the appropriate course. However an informed decision to do nothing is far superior to proceeding in ignorance. In many cases some action can be taken, and that, in my opinion, is a major justification for having an agency such as the Geological Survey. Wise decisions need to be underpinned by sound science.

Projects that the Geological Survey is likely to participate in over the next decade are going to become more multidisciplinary as we realize that the natural environment is a result of complex interactions between the geosphere, hydrosphere and ecosystems. Geologists may be working with ecologists. This is likely to occur through collaboration with experts from other State departments, universities, or possibly even the private sector. Oil exploration companies these days no longer use the term geologists - they are geoscientists. The

continued on page 14....

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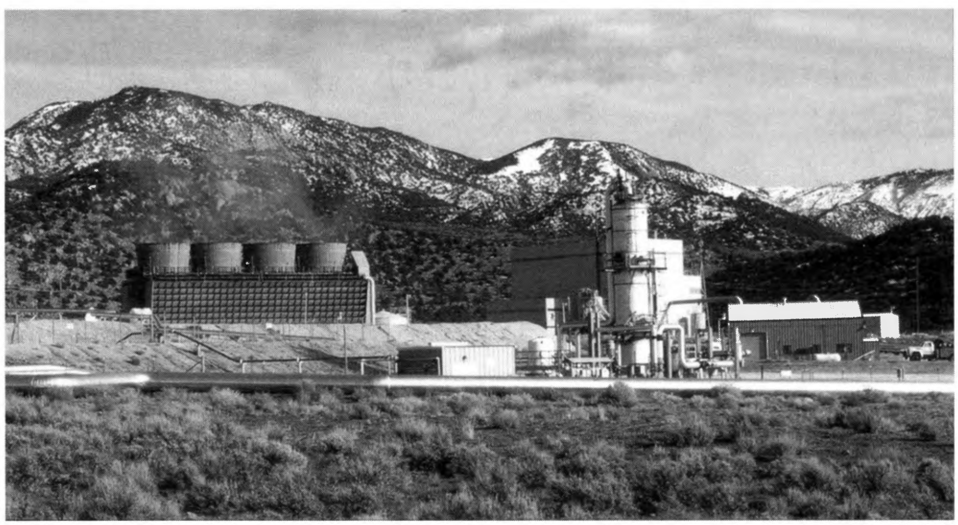
Development of Geothermal Resources in Utah

by Robert E. Blackett

Overview

Geothermal energy is the thermal energy contained in the rocks of the earth's crust and in the fluid that fills fractures and pores within the rocks. Heat is generated within the core and mantle of the earth and flows outward through the crust. Because of the influence of the earth's atmosphere, in most areas this heat reaches the surface diffuse and unnoticeable. Some areas, however, including substantial portions of the western U.S., are underlain by relatively shallow geothermal systems which manifest themselves at the surface as hot springs, geysers, and fumaroles.



Utah Power's Blundell geothermal power plant at Roosevelt Hot Springs geothermal area near Milford: cooling stacks and power plant building, with the Mineral Mountains in the background. View is to the southeast.

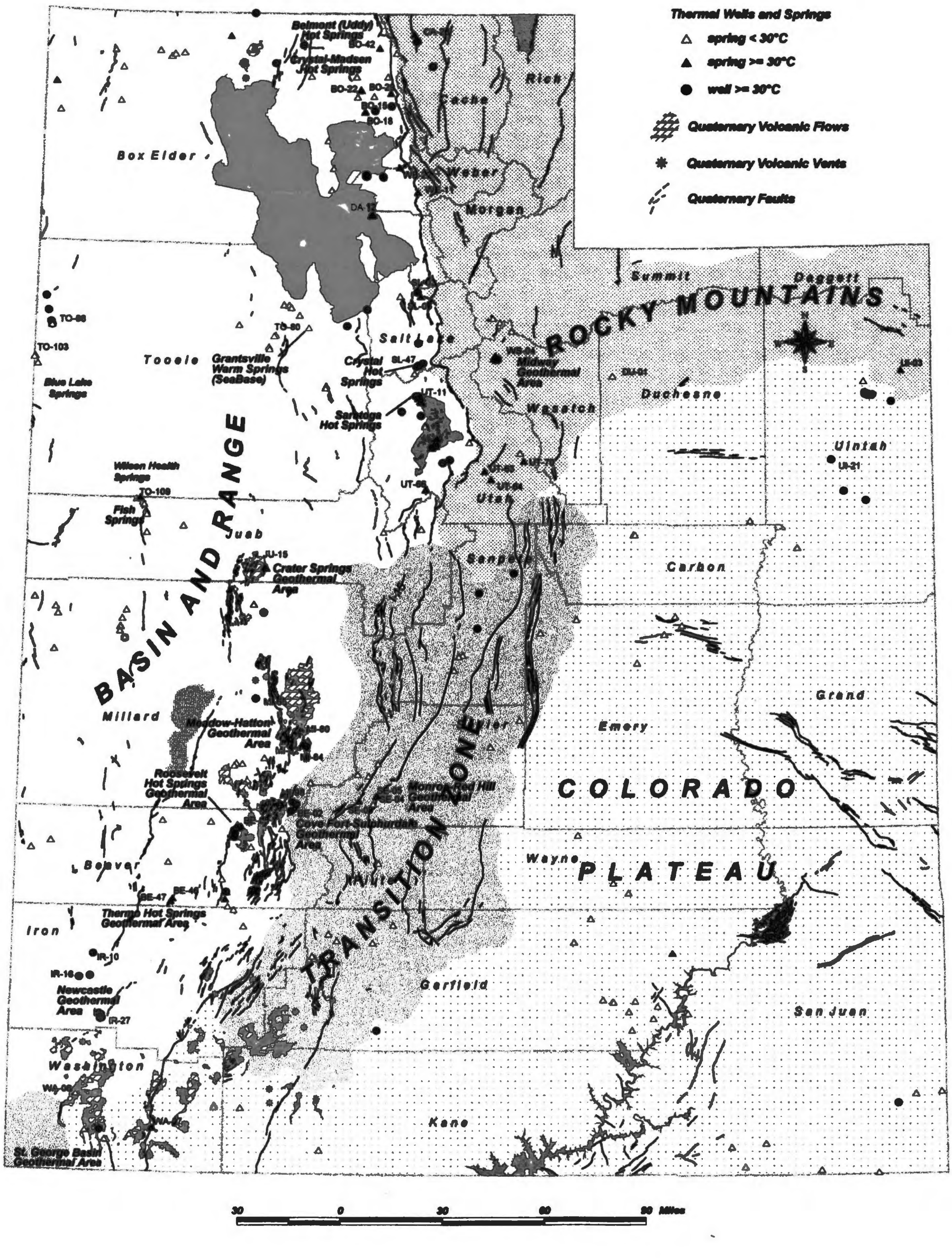
Geothermal resources are classified as low temperature (less than 194°F [90°C]), moderate temperature (194 - 302°F [90 - 150°C]), and high temperature (greater than 302°F [150°C]). High-temperature resources are generally used only for electric power generation. Current U.S. geothermal electric power generation totals about 2,200 megawatts (MW) or roughly the same as produced by four large coal-fired or nuclear power plants. Uses for low- and moderate-temperature resources can be divided into two categories: direct use and ground-source heat pumps.

Direct use involves using the heat in the water directly (without a heat pump or power plant) for heating of buildings, industrial processes, greenhouses, aquaculture (growing of fish) and resorts. Direct-use projects generally use resource temperatures between 100 to 300°F. Current U.S. installed capacity of direct-use systems totals 470 MW or enough to heat 40,000 average-sized houses.

Ground-source heat pumps use the earth or ground water as a heat source in winter and a heat sink in summer. Using resource temperatures of 40 to 100°F, the heat pump transfers heat from the soil to the house in winter and from the house to the soil in summer. The rate of installation for these systems is from 10,000 to 40,000 per year in the U.S.

Most of Utah's principal geothermal areas lie within the western half of Utah. A few occurrences are in the east-central part of Utah, and thermal water has been encountered in deep oil wells in the Uinta Basin of northeastern Utah. Most thermal springs and wells in central and western Utah are situated at the edge of valleys near mountain blocks, controlled by Basin and Range faults that have been active during the Quaternary period (past 1.6 million years).

GEOTHERMAL RESOURCES OF UTAH



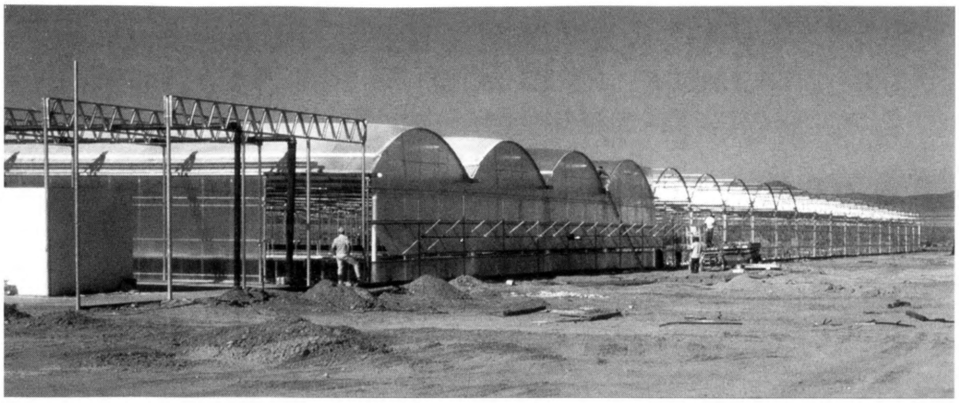
Principal geothermal springs (S), wells (W), and areas (A) in Utah. Locations are shown on the accompanying map.

NAME	MAP NO.	TYPE	DISCHARGE TEMP, °F	ESTIMATED FLOW, gal/min	RESERVOIR TEMP, °F	DEPTH, ft
Udy-Belmont	BO-42	S	127	1,585	131-194	--
Crystal Madsen	BO-29	S	133	951	140-194	--
Little Mtn.	BO-22	S	108	449	122-176	--
Stinking	BO-18	S	118	26	158-194	--
Chesapeake	BO-15	W	165	40	158-176	502
Utah	WE-22	S	136	32	158-212	--
Ogden	WE-11	S	136	5	158-212	--
Hooper	DA-14	S	140	--	176-248	--
Becks	SL-03	S	131	--	140-212	--
Wasatch	SL-06	S	108	63	122-194	--
Crystal Bluffdale	SL-47	A	136	--	194-248	--
Coleman Midway	WS-04	A	113	48	158-167	--
Saratoga	UT-11	S	111	185	140-212	--
Castilla	UT-63	S	104	--	122-194	--
Third Water	UT-70	S	131	--	149-212	--
Goshen Valley	UT-66	S	142	--	140-158	--
Bonneville DBW 3	TO-96	W	190	--	--	2,067
Blue Lake	TO-103	S	84	--	122-194	--
Wilson Health	TO-109	S	131	--	131-212	--
Crater (Abraham)	JU-15	S	189	370	212-302	--
Neels RR	MI-65	W	HOT	--	392 (?)	2,001
Meadow-Hatton	MI-80,84	S	145	5	158-248	--
Monroe-Red Hill	SE-04,05	A	180	143	194-248	--
Joseph	SE-08	S	145	32	194-302	--
Cove Fort	BE-02	A	302	--	356-437	1,214
Roosevelt	BE-05	A	464	--	500-554	8,497
Thermo	BE-46,47	A	194	8-32	248-284	--
Wood's Ranch	IR-10	W	99	--	230-248	197
Newcastle	IR-27	A	207	--	284-338	492
Veyo	WA-06	S	86	103	104-140	--
Dixie, La Verkin	WA-07	S	108	4,755	122-194	--
Split Mtn.	UI-03	S	86	2,695	--	--
Shell Oil #1 State	UI-21	W	136	--	--	5,610

Commercial Geothermal Development in Utah

Power Plants

Utah Power, a PacifiCorp company which recently merged with Scottish Power, has operated the single-flash, Blundell geothermal power station at the Roosevelt Hot Springs geothermal area near Milford in Beaver County since 1984. Intermountain Geothermal Company, a subsidiary of California Energy Company and the current field developer, produces geothermal brine for the Blundell plant from wells that tap a geothermal resource in fractured, crystalline rock. The resource depths range generally between 2,100 and 6,000 feet. The resource temperature is about 500°F. Wellhead separators are used to "flash" the geothermal fluid into liquid and vapor phases. The liquid phase, or geothermal brine, is channeled back into the reservoir through gravity-fed injection wells. The vapor phase, or steam fraction, is collected from the production wells and directed into the power plant at temperatures between 350 and 400°F with steam pressure approaching 109 pounds per square inch. The plant produces 26 MW gross output (23 MW net), roughly the equivalent of the electricity generated by burning 300,000 barrels of oil annually.



Commercial geothermally heated greenhouses under construction near Newcastle in Iron County. Geothermal water at about 190°F is pumped from production wells, circulated through the greenhouses for space heating, and returned to the geothermal aquifer via injection wells.

In cooperation with the city of Provo, Mother Earth Industries in 1985 began installation of a complex of geothermal power units at Sulphurdale in Beaver County to provide electricity for Provo City. The first plant brought on-line in 1985 was a binary-cycle plant, made up of four units capable of generating about 1.6 MW total. A "topping turbine," rated at 1.2 MW, was installed in 1987 and placed upstream of the binary units due to higher-than-anticipated reservoir pressures and temperatures. In 1990, a condensing turbine (Bonnett plant) rated at about 8.5 MW capacity was installed, and the "topping turbine" was taken off line at that time. In 1994, the Utah Municipal Power Agency began managing the operations, now referred to as "Cove Fort Power Station #1." The estimated net output capacity from both the binary and condensing power units is about 10 MW, roughly the equivalent of the electricity generated by burning 140,000 barrels of oil annually. Production wells primarily tap a shallow, vapor-dominated part of the geothermal system at depths between 1,100 and 1,200 feet. A deeper well, however, reportedly taps the liquid-dominated part of the system. Spent geothermal fluid is returned to the reservoir through a deep injection well. Because hydrogen sulfide (H_2S) gas is produced, the plant includes a sulfur abatement system designed to extract up to 1½ tons per day of sulfur.

Commercial Greenhouses

Various research organizations and energy companies became interested in the Newcastle area of Iron County in the 1970s after farmers accidently discovered a relatively shallow hydrothermal system while drilling an irrigation well. The well had encountered a hot-water aquifer with a maximum temperature of 226°F between depths of 245 and 310 feet. Subsequent studies by the UGS suggest a model of hot water rising along a range-bounding fault and discharging into an aquifer in unconsolidated Quaternary sediments, forming a broad outflow plume. Temperatures within the outflow plume generally range between 180° and 220°F. Several commercial greenhouses use the geothermal fluid from shallow production wells (~ 500 feet deep) to produce year-round high-quality flowers, vegetables, and ornamental plants.

Crystal (Bluffdale) Hot Springs is located at the southern end of the Salt Lake Valley where Bluffdale Flower Growers (formerly Utah Roses) operates a geothermal-heated greenhouse complex. The facility covers about 2.9 acres, and produces cut roses as its primary product. Utah Correctional Industries at the nearby Utah State Prison uses thermal water from a well for commercial tropical fish raising. Surface spring temperatures are about 144°F. Subsurface temperatures of 190°F+ have been reported in one of two 400-foot-deep production wells. The springs normally issue from valley alluvium into several ponds. When production wells are in operation, the surface springs and ponds reportedly dry up.

Therapeutic Baths, Resorts, and Aquaculture

Bonneville SeaBase is a scuba-diving facility developed at Grantsville Warm Springs located about 40 miles west of Salt Lake City along I-80 in Tooele County. SeaBase consists of several dive pools fed by warm springs and stocked with tropical marine fish. The facility is associated with Neptune Divers of Salt Lake City, a business devoted to scuba diving and related-product sales.

At Belmont (Udy) Hot Springs in northeastern Box Elder County, about 50 hot springs and seeps issue along the Malad River at about 125°F. In addition to a golf course and camping facilities, the resort has therapeutic hot tubs, a swimming pool, and a scuba-diving pool. The resort also operates a commercial aquaculture facility, raising lobsters and crayfish for distribution out of the local area.

Crystal (Madsen) Hot Springs Resort, near Honeyville along I-15 in Box Elder County, uses cold springs and hot springs at the same facility. The springs are situated along the northern extension of the Wasatch fault, which traverses the western side of the Wellsville Mountains. A cold spring (52°F) is used to help fill a 300,000-gallon pool, while hot springs (140°F) fill therapeutic hot tubs, mineral pools, and also flow into the swimming pool. Pool temperatures range from 85° to 112°F.

Thermal springs in and around the community of Midway in Wasatch County issue from several widespread, coalescing travertine mounds covering an area of several square miles. Temperatures in the springs generally range from 95 to 115°F. Thermal water at Midway probably is the result of deep circulation of meteoric water from recharge zones located to the north near Park City. The

Homestead, a hotel and resort complex, uses thermal water in a therapeutic bath, and also offers guests scuba diving within a 95°F thermal pool inside "the old hot pot," a large travertine mound.

The Monroe-Red Hill Hot Spring area is 10 miles south of Richfield in Sevier County. The proprietors have named the resort "Mystic Hot Springs" and offer a geothermal-heated swimming pool, therapeutic baths, camping facilities, and tropical fish ponds. The Monroe and Red Hill Hot Springs issue at about 170°F near the surface trace of the Sevier fault adjacent to the Sevier Plateau. The area was the focus of U.S. Department of Energy-sponsored geothermal studies in the late 1970s.

Volcanic activity often relates to geothermal activity. Seen here is a basaltic tuff cone within a 14,000 year-old volcanic crater at Tabernacle Hill in the Black Rock Desert of Millard County. The volcano erupted into ancient Lake Bonneville when the lake stood near the Provo shoreline.

Veyo and Pah Tempe Hot Springs resorts in southwestern Utah offer swimming and therapeutic baths. At Veyo Hot Springs Resort, located southeast of the town of Veyo along the Santa Clara River canyon, spring flows are channeled to a swimming pool at a temperature of about 89°F. At the Pah Tempe Hot Springs Resort, springs flow from a number of vents along the Virgin River near where the river crosses the Hurricane fault near the towns of Hurricane and La Verkin. The thermal water is channeled into a swimming pool and therapeutic baths.

Undeveloped Geothermal Areas

Several other known geothermal areas in Utah remain undeveloped thus far due to factors including marginal economics, remoteness, environment, or lack of infrastructure. Moreover, some thermal areas provide important habitat for migratory birds and aquatic species. Among others, the more notable undeveloped areas include: Meadow-Hatton geothermal area, Thermo Hot Springs, Crater (Abraham) Springs, Blue Lake, and the Fish Springs area. To learn more about geothermal resources and uses in Utah and elsewhere, visit the Utah Geological Survey website at <http://www.ugs.state.ut.us/> and follow the links to geothermal-related publications. Or, you can visit the U.S. Department of Energy's Energy Efficiency and Renewable Energy Network (EREN) website at <http://www.eren.doe.gov/>, and follow the links for geothermal information.

GeoPowering the West Initiative

GeoPowering the West is a new U.S. Department of Energy-led initiative to capitalize on the abundant geothermal resources found in the western United States. Geothermal energy is already a significant supplier of electricity to the western grid, with 2,800 MW installed in California, Nevada, Utah, and Hawaii. The Department of Energy expects this initiative to (1) provide new sources for generating electric power and space heating, crop processing, and aquaculture, and (2) fuel sustainable economic development, create jobs in rural areas and on Native American lands, and support cleaner local and regional environments.

Strategies for GeoPowering the West include increasing the use of geothermal energy for electricity production through identification and development of new sites, expansion of existing reservoirs, strengthening technology development efforts, and tapping more localized resources for small-scale distributed power. The initiative will also promote using the largely untapped lower-temperature resources that are broadly available across the western states to supply heating for residences and commercial establishments, and for industrial process applications.

The goals of the initiative are to (1) provide 10 percent of the electricity needs of the western states by 2020, (2) supply the electrical power or heat energy needs of at least 7 million U.S. homes by 2010, and (3) double the number of states using geothermal electric power facilities to eight by 2006. To learn more about DOE's GeoPowering the West initiative, visit their website at www.eren.doe.gov/geopoweringthewest/.

The Basin Perlite Company Mine and Mill, Beaver County, Southwest Utah

by Bryce T. Tripp

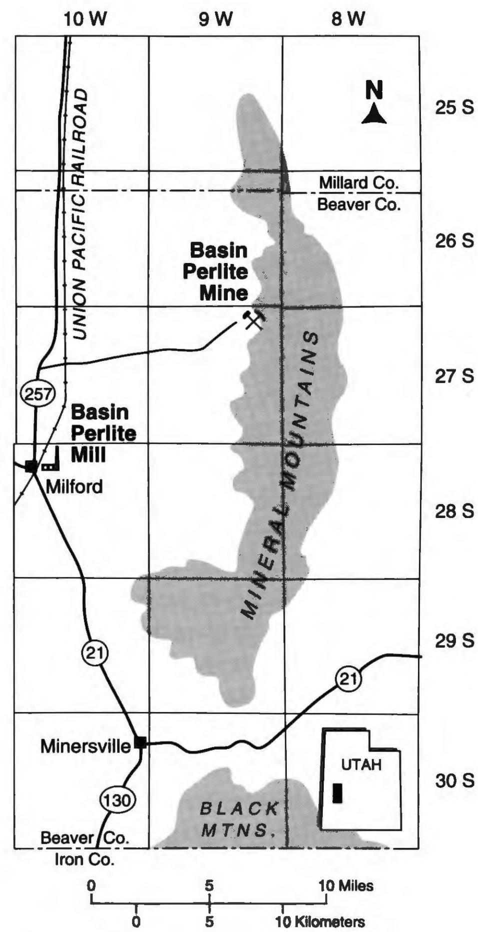
What is perlite?

Perlite is a Tertiary or Quaternary-age, silicic or rhyolitic volcanic glass that contains 2 to 5 weight-percent water. Perlite is valuable due to its ability to expand during heating into a lightweight, porous, glassy foam. Perlite can expand as much as 40 times its original volume when heated at temperatures from 1,598 to 2,012°C. Expanded perlite is as light as 2 pounds per cubic foot, is inert, and has thermal and acoustical insulating properties. Most people are familiar with perlite in horticulture; the small, lightweight perlite granules in potting soil help retain water and help aerate plant roots. Major perlite-producing countries include the United States, Greece, Turkey, and Hungary.

The Basin and Perlite Company Mine and Mill

The only mining and milling operation regularly shipping perlite in Utah is the Basin Perlite Company mine (also known as the Schoo mine and the North Pearl Queen mine). The deposit was discovered by Edward Schoo in 1949; production began in 1950, and a small portable crushing and sizing plant was set up at the mine in 1963. Regular shipments were made to Sigurd and Salt Lake City, Utah for expanding until 1966 when Edward Schoo died in an accident at the mine. Despite exploration by several mining companies, no significant additional development occurred until 1992 when geologists Frank Witzel and Charles Smith examined the property. O. Jay Gatten, President of North American Minerals and Frank Witzel entered into a partnership under the company name, Monitor Minerals (Monitor Minerals later became part of the Pearl Queen Perlite Corporation), which acquired the property and constructed a 100,000 ton-per-year crushing and sizing mill on a railroad spur in Milford, Utah. Construction of the mine and mill began in May 1997 and was finished in February 1998. Additional modifications to the mill were completed in April 1999. On December 28, 1999, the mine and mill were purchased by Basin Perlite Company (affiliated with Resource Capital Fund of Denver, Colorado) which continues to operate the mine and mill.

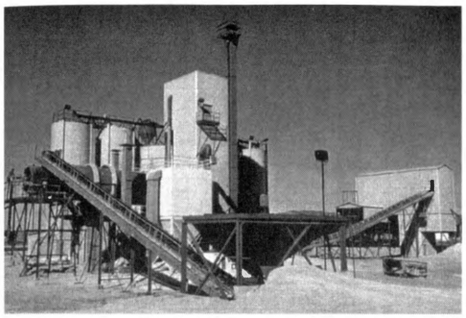
The Basin Perlite Company deposit is part of a 780,000-year-old, obsidian-rich rhyolite flow, the Bailey Ridge flow. The deposit is about 6,000 feet long, 2,000 feet wide, and 16 to 100 feet thick (averaging 80 feet thick). The deposit contains a resource of about 25 million tons of ore with about 4 million tons of proven reserves on state land (the tract currently being mined). The ore contains 2.4 to 3.4 percent water, less than 1 percent silica, and no other deleterious minerals. As mined, the ore weighs about 125 pounds per cubic foot; after heating and expansion it yields products ranging from 2 to 16 pounds per cubic foot. The ore is texturally zoned with an outer layer of pumiceous and shardy perlite, a middle layer of granular perlite, and an inner zone of classical "onion-skin" perlite. The term "onion-skin" refers to the pearl-grey-colored, concentric layering of perlite that results from volume expansion during hydration of the volcanic glass.



Basin perlite mine and plant, Beaver County, Utah.

Outlook

There are many positive factors contributing to the future success of the Basin Perlite Company operation. The mine contains a large amount of high-quality perlite. The mill is conveniently located on the Union Pacific



Basin Perlite Company mill (photo credit: North American Exploration).

Basin Perlite Company mine showing portable crushing plant, June 1998 (photo credit: North American Exploration).

rail line. The perlite market has been growing; apparent consumption rose from 820,000 tons in 1995 to an estimated 922,000 tons in 1999 while the price per ton rose from a 1995 national average of $27.93 to $31.59 (estimated) in 1999. Due to its location, the Basin Perlite Company (and ten other western U.S. perlite companies) are somewhat insulated from competition with inexpensive perlite imported from Greece to the United States. During 1995-1998, 100 percent of the foreign imports into the U.S. came from Greece. However, the most important factor affecting the future of Basin Perlite Company's operation will be its ability to increase its sales.

Currently, Basin's largest customers are the ceiling tile and roof insulation system manufacturers. Additional customers buy perlite for horticulture, formed construction products, fillers, and other industrial uses.

Acknowledgment

Much of the data used in this article was taken from a presentation given by O. Jay Gatten, President of North American Exploration, at the national meeting of the Society of Mining, Metallurgy, and Exploration, Inc. held in Salt Lake City, Utah, in February 2000 and from an accompanying handout.

Other sources of information are: the Perlite Institute Inc. website at www.perlite.org and the U.S. Geological Survey minerals information website at minerals.usgs.gov/minerals/pubs/community/perlite/. Publications are Perlite by W.P. Bolen, 2000, from the USGS, and the section on perlite by Breese and Barker, 1994, in *Industrial minerals and rocks*, sixth edition, Littleton, Colorado, Society for Mining, Metallurgy, and Exploration, Inc.

Survey News

Rob Nielson is our newest employee in the bookstore. He is filling the position just vacated by **Chris Ditton** who's setting up shop on his own. Rob comes to the store with a lot of experience, having worked at Map World for 5 years - he knows his maps!

Scott Gerwe joined the Economic Program this week. He has attended Idaho State University and Utah State University and worked for several years in Nevada gold exploration and Idaho phosphate development. He will be working with us on mineral potential inventory project.

Nicole Pickett is our new secretary/receptionist, replacing **Cheryl Wakefield Gustin** who did enough front-desk penance to transfer to the Economic Section.

Basia Matyjasik went to Mapping after being in Economic doing GIS work. **James McBride** joins the Economic Program as well for GIS work. He just received his geology degree from Weber State. **Brenda Nguyen** left her post as secretary for Applied, and **Dan Aubrey** has moved on from lugging core at the Sample Library.

A note from **Alan Titus** (he worked for the UGS Paleo group and is now the Paleontologist for the GSENM): "Dave Gillette has had incredible luck out here. His hadrosaur turns out to be a nearly complete tail section (10-15' long, with all chevrons, neural spines, etc. in place) with a possibility that the anterior is similarly preserved. Spectacular specimen!" Alan's new book on Late Mississippian ammonoids is due out soon (see back cover).

David Madsen recently returned from a five-week expedition to the Tengger Desert in northwestern China. This is a two-year project sponsored by the U.S. National Science Foundation and the Chinese Academy of Science toward understanding millennial-scale climatic change events as recorded in mid-latitude desert lakes such as those in western Utah and Nevada. The Chinese-American team collected cores from the bed of three lakes and is currently involved in dating lake events represented in the cores and analyzing climate proxys such as pollen and ostracodes.

Geothermal Resources of Utah - A Digital Update of the 1980 Resource Map

As part of a U.S. Department of Energy, state-cooperative geothermal program in the late 1970s, the Utah Geological Survey compiled a geothermal resources map of Utah for general use. Published in 1980, the "Geothermal Resources of Utah" map was compiled using geothermal and water-resource data from existing publications and other data sets. Although the information presented on the map was of a general nature, it showed locations of thermal wells and springs and listed individual source temperatures, water-quality data, and flow rates. The map also outlined areas of prospective value for geothermal resources, and provided descriptive information about individual geothermal areas. It was published through the National Oceanic and Atmospheric Administration and was made widely available free of charge. As a result, stores of the map quickly dwindled. Presently, the 1980 map is available only in limited, library collections.

The Utah Geological Survey, Utah Department of Community and Economic Development, and Office of Energy and Resource Planning have begun a cooperative project to produce a new, interactive, digital map and report using geographic information system (GIS) technology to be published on compact disk (CD-ROM). The new CD-ROM will be similar to the other digital products of the UGS using the wealth of information now available in various reports and data sets. It will contain technical information on geothermal resources in Utah for scientists and engineers, but will also contain descriptive information, and will be interactive enough for the more general user.

Various GIS themes, or coverages, will be generated at a general statewide scale of 1:500,000, although some themes may be at more detailed scales. The CD-ROM will include software to view, layout, and print the various GIS themes, and will also include guides and interactive digital documents. These documents will contain the GIS-generated geothermal map of Utah with links to supporting text, database, and image files similar to the UGS's *Geological resources atlas of Utah* and the *Digital geologic map of Utah.*

For immediate gratification, turn to page 2 for a sample of the first several layers that have been compiled.

The CD-ROM should be completed and made available for public distribution sometime in 2001. To learn more about the new CD-ROM, contact UGS geologist Bob Blackett in our Southern Utah Regional Office in Cedar City at (435) 865-8139, or e-mail him at "blackett@suu.edu."

Teacher's Corner

Field Trip on Saturday, October 14 .... Everyone is Welcome.

Come celebrate the culmination of Earth Science Week (October 8-14, 2000) with the Utah Geological Survey on Saturday, October 14. The UGS will host a free, 1/2-day field trip along the Wasatch Front and invites teachers and the public. See and learn about the Wasatch fault, ancient Lake Bonneville, glaciers and more!

Contact Sandy Eldredge at 801-537-3325, or nrugs.seldredg@state.ut.us. Please provide your name, phone number, e-mail address, and street address. You will then be notified of details before the trip. Also visit our web site, which will provide details at http://www.ugs.state.ut.us.

Limit is 25 participants.

IMPORTANT DINOSAUR TRACK DISCOVERY IN ST. GEORGE

by Martha Hayden

Since Sheldon Johnson discovered dinosaur tracks in sandstone blocks on his property on the outskirts of St. George in February 2000, thousands of visitors have come to the site for a unique educational experience. Sheldon, a retired optometrist, and his wife LaVerna, have spent countless hours hosting visitors and educating them about the scientific value of their discovery.

The tracks are preserved as natural casts mostly on the basal surface of a sandstone bed that overlies the mudstone in which the tracks were formed. Mudcracks are also preserved, indicating that the environment was a mudflat across which the dinosaurs walked. These layers are part of the Lower Jurassic Moenave Formation, which is about 200 million years old. At least two types of tracks, both from carnivorous theropod dinosaurs, are preserved at this track site. The tracks, which are referred to by the ichnogenera or track names *Eubrontes* and *Grallator* (these are not the names of the dinosaurs that made the tracks), are common throughout Lower Jurassic strata of the western United States and other regions. However, these are among the best-preserved examples of these ichnogenera ever recorded. The *Eubrontes* tracks are about 32 to 42 cm (13-17 inches) long and 24 to 33 cm (10-13 inches) wide, whereas the *Grallator* tracks are about 10 to 19 cm (4-8 inches) long and 8 to 11 cm (3-4 inches) wide. Although less common at this site, the *Grallator* tracks are preserved on both the lower and upper surfaces of the sandstone blocks. It is thought that a dinosaur similar to *Coelophsis* produced these tracks, while one similar to *Pilophosaurus* made the *Eubrontes* tracks.

Paleontologists have been excited about the discovery and are conducting scientific investigations of the track site. Scientists examining the site include State Paleontologist Dr. James Kirkland, Utah Geological Survey, who has visited the site to offer advice to the landowners and to study the tracks. He called in dinosaur track expert Dr. Martin Lockley, a geology professor from the University of Colorado in Denver. Studies are ongoing as these and other scientists uncover more tracks, map the trackways, and make molds of the tracks so they can be reproduced for museum displays and educational institutions.

Although the site is on private land, the Johnson family has decided that the tracks should be preserved for the common good of the community, and for their scientific and educational value; they have built a shelter for the tracks. The city of St. George built a fence around the site, and has provided volunteers to manage the crowds and educate the public. The family also hopes that a museum or other facility can be built on site, or elsewhere in St. George, so that the tracks are preserved within the local community. The site location is 2100 East Riverside Drive in St. George, and is open to visitors 9 a.m. to 8 p.m. Monday through Saturday, and 4 to 7 p.m. on Sundays.

Landowner Sheldon Johnson at tracksite. Sandstone block displays dinosaur track (left) and interconnected mud cracks.

A trackway (a sequence of tracks from a single animal) preserved in one of the sandstone blocks.

Energy News

320-Million-Year Old Limestones That Produce Oil in Southeastern Utah Have Modern Counterparts

by
Thomas C. Chidsey, Jr., Utah Geological Survey
David E. Eby, Eby Petrography & Consulting, Inc.

Over 400 million barrels of oil have been produced from distinctive buildups of Paradox Formation limestone that were deposited about 320 million years ago in the Paradox basin of southeastern Utah. These buildups formed in a variety of marine environments during the Pennsylvanian Period when southeastern Utah was a subsiding basin that contained a warm, shallow sea. The Utah limestones that were deposited have been studied and compared with modern deposits found near the coasts of Florida and Australia, and the Bahama Islands.

The Utah Geological Survey (UGS) study of the Paradox Formation limestone is part of an ongoing U.S. Department of Energy-funded project. Since many of these limestones are not exposed at the surface, cores of rock taken from exploratory and producing petroleum wells in the region were examined at the UGS Sample Library. The cores consist of both non-producing (oil) rock and producing rock -- or the oil reservoir. Most of these cores are part of the permanent Sample Library collection.

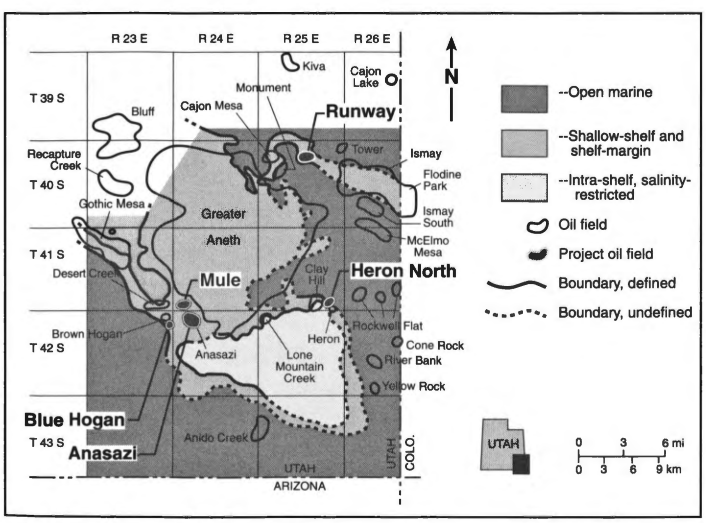


Figure 1. Paradox basin oil fields in southeastern Utah, and regional environments of the Paradox Formation based on cores from exploratory and producing wells.

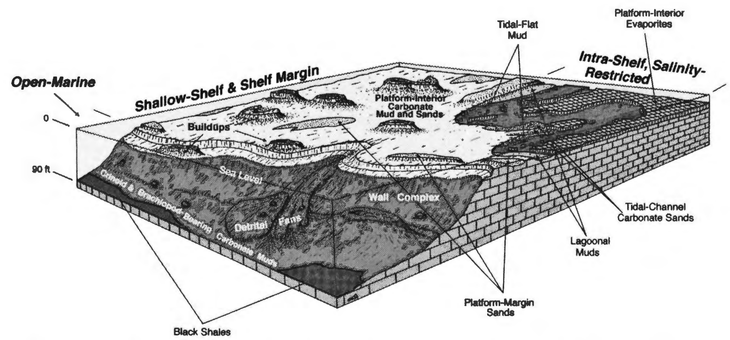


Figure 2. Schematic block diagram of environments of the Paradox Formation in southeastern Utah during Pennsylvanian time.

As part of this study, the extent of ancient marine environments of the Paradox Formation were mapped. We recognized and mapped deposits from three environments (figures 1 and 2): (1) shallow-shelf/shelf-margin, (2) open-marine, and (3) intra-shelf/salinity restricted. Modern coun-

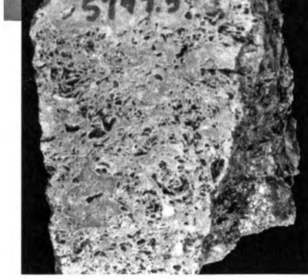


Figure 3. Inset - "Potato chips" of leafy algae in core of the oil reservoir rock from Mule field, San Juan County, Utah; Islands along Florida Bay mud banks.

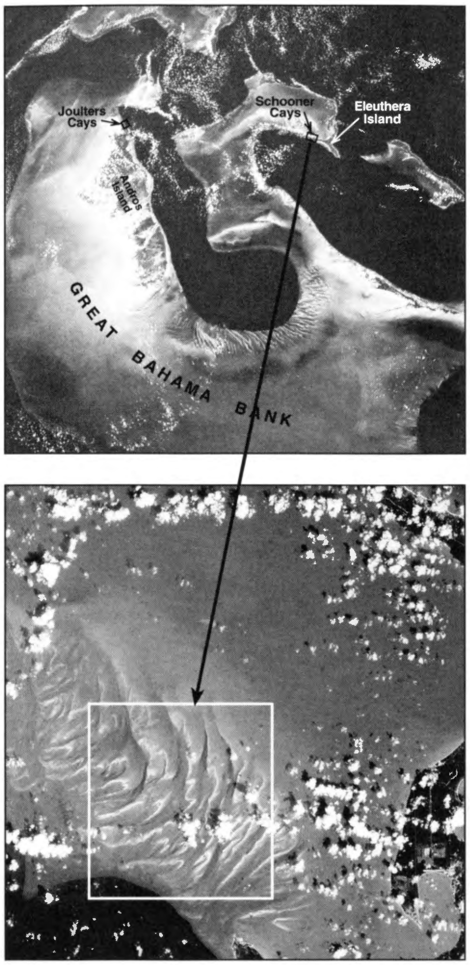


Figure 4. Shallow marine sandbanks, Schooner Cays; satellite image of the Great Bahama Bank.

terpart deposits for each ancient deposit were identified.

The shallow-shelf/shelf-margin environment includes the oil-productive carbonate buildups which were reef-like mounds composed of leafy limestone growths of algae, island beaches, or offshore sandbanks. Broken limey leaves of algae formed mounds like big piles of potato chips (figure 3, inset); the oil ultimately filled in the spaces (pores) between the "potato chips." To see similar kinds of mounds, one could go to Florida Bay. Mud bank islands built up by turtle grass (*Thalassia*) are beautifully displayed and are roughly the same size and shape as many of the small oil fields in the Paradox basin (figure 3). Space shuttle astronauts get an excellent view of island beaches and offshore sandbanks in a warm shallow sea when they pass over Schooner Cays along the Great Bahama Bank (figure 4). They also see a modern open-marine environment over the Straits of Florida to the west.

The intra-shelf/salinity-restricted environment represents small sub-basins within the shallow-shelf/shelf-margin environment. The limited circulation of open ocean seawater within these warm, very shallow shelf areas resulted in the deposition of lagoonal muds and evaporitic salt and anhydrite (figure 5, inset). However, none of these deposits have sufficient pores capable of storing oil. To find similar deposits in a modern environment, one could travel to Sharks Bay on the western coast of Australia (figure 5). Sharks Bay is a similarly shallow area with a restricted flow of water to the Indian Ocean that makes the water there extra salty.

Comparisons of ancient and modern environments such as these help geologists to estimate how the oil reservoir (oil-producing rock) changes between wells and how much oil it may store and produce. We also use these comparisons to identify new areas in southeastern Utah that may have petroleum potential. Geologists need not travel to Florida Bay, the Bahamas, or Australia to see fine examples of deposits from various types of shallow marine environments; they just need to open a box of Paradox Formation core at the UGS Sample Library and they are there!

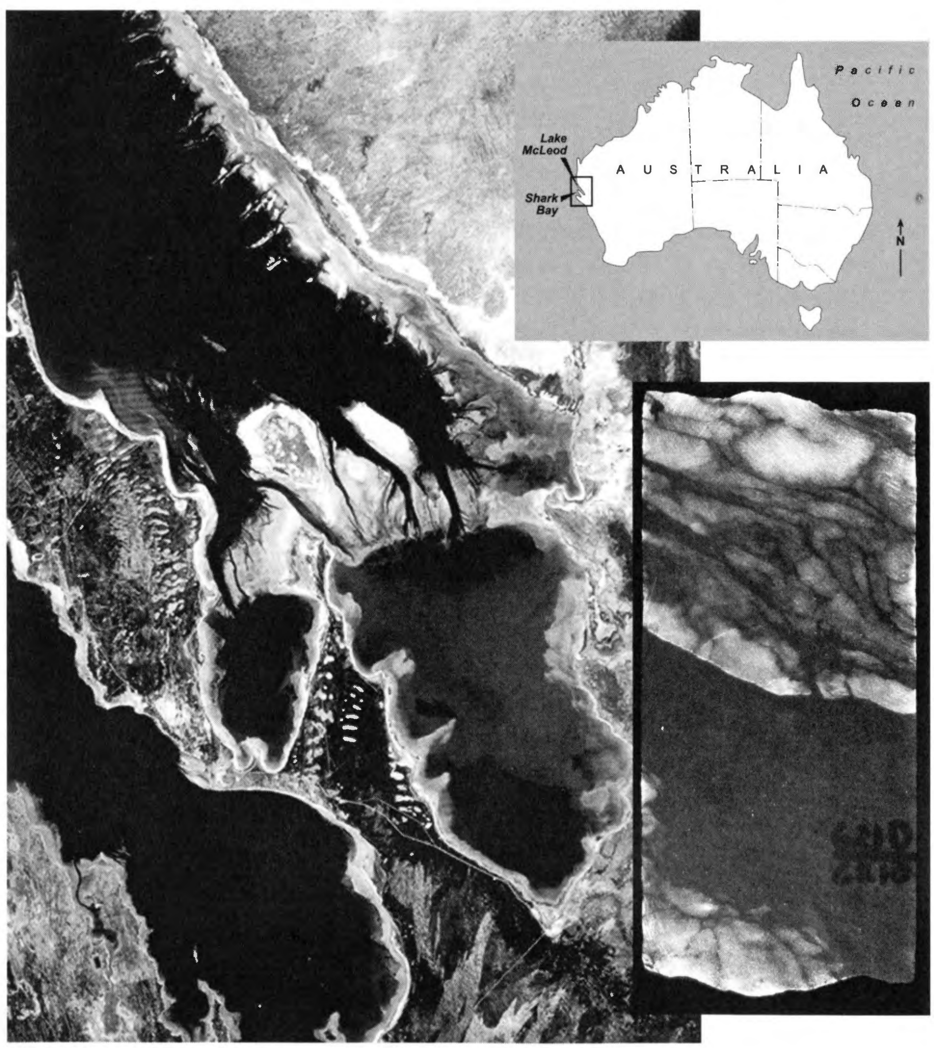
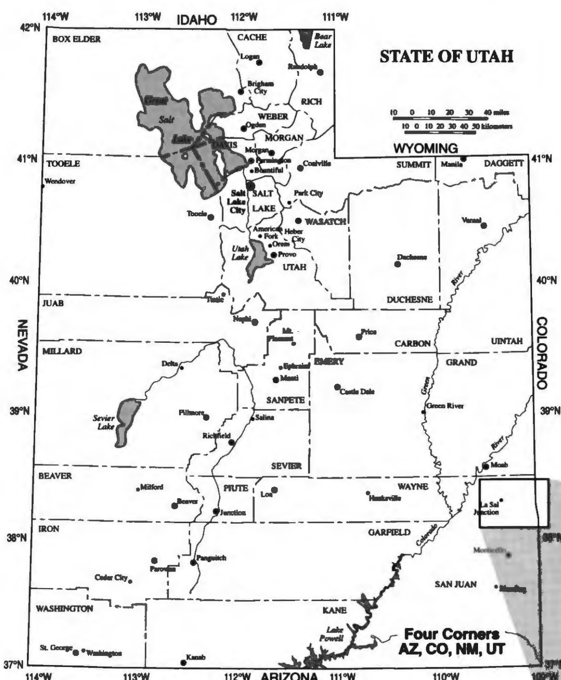


Figure 5. Inset - Bedded anhydrite (evaporate mineral) and dense, black muddy limestone, from a core of the Coral No. 11A-1 wildcat well, San Juan County, Utah; satellite image of Shark Bay, western coast of Australia.

"Glad You Asked"

by William F. C

Why does the eastern border of Utah have a kink in it?

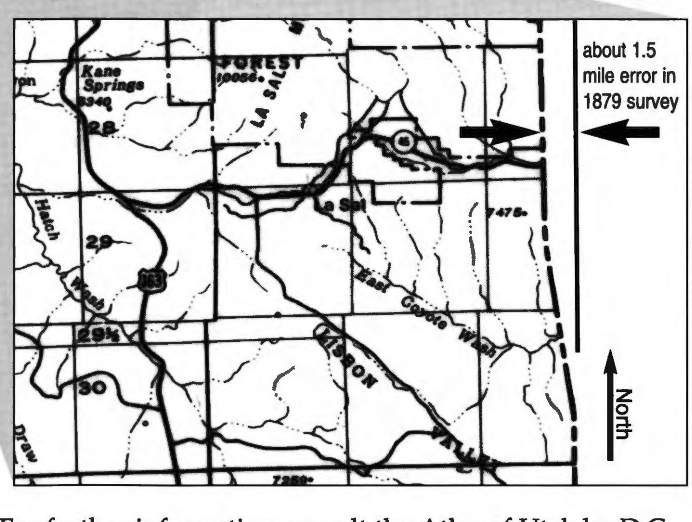


Utah's present boundaries are much different than the original "state" of Deseret boundaries proposed by Mormon church leaders in 1849. Deseret included pieces of today's Utah, Nevada, California, Arizona, New Mexico, Colorado, Wyoming, Idaho, and Oregon. When the "state" of Deseret became the official Utah Territory in 1850, it was compressed between latitudes 37°N and 42°N, and between California and the Territory of Colorado. From 1861 to 1868 pieces of the Utah Territory were parceled out to adjoining territories. An eastern piece went to Colorado, three western slices became Nevada, and Utah's northeastern "notch" went to the Wyoming and Idaho (yes, Idaho) Territories.

Utah's boundaries are not defined by landforms such as mountain divides or rivers. Surveyors mapped Utah's boundaries using transit and compass, chronometer and astronomical readings, previous surveys, and interviews with residents. The boundaries were intended to run parallel to lines of latitude and longitude.

So, why the westward jog of more than one mile? In 1879 a survey to establish the western border of Colorado started at Four Corners, the only place in the USA where four states share a point, and continued on a true-north line to the southern border of Wyoming. The survey continued north about 276 miles to the Wyoming border but ended about one mile west of where they expected to intersect the Wyoming line; somewhere there was a westward jog in the border. An 1885 survey found an error of slightly over one mile between mileposts 81and 89 (81 and 89 miles north of Four Corners), and an 1893 survey by the U.S. Coast and Geodetic Survey found a half-mile error between mileposts 100 and 110.

Why didn't the surveyors change the boundary when they found errors? Once a boundary is marked on the ground and accepted by all interested parties it is a true line even though it doesn't follow the written description. A boundary between two states may be changed by agreement of the state legislatures and must be approved by Congress. The Colorado/Utah border stands as surveyed!



For further information consult the Atlas of Utah by D.C. Greer, 1981, Weber State College and Brigham Young University Press, or J.O. Johnson's State of Deseret, 1992, from Macmillan Publishing Company, Encyclopedia of Mormonism, v. 1. Web users can try *www.mormons.org/daily/history/1844_1877/deseret_state_eom.htm* (accessed 30 May, 2000). And there is F.K. Van Zandt's 1966 Boundaries of the United States and the several states published by the U.S. Geological Survey as Bulletin 1212.

GeoSights

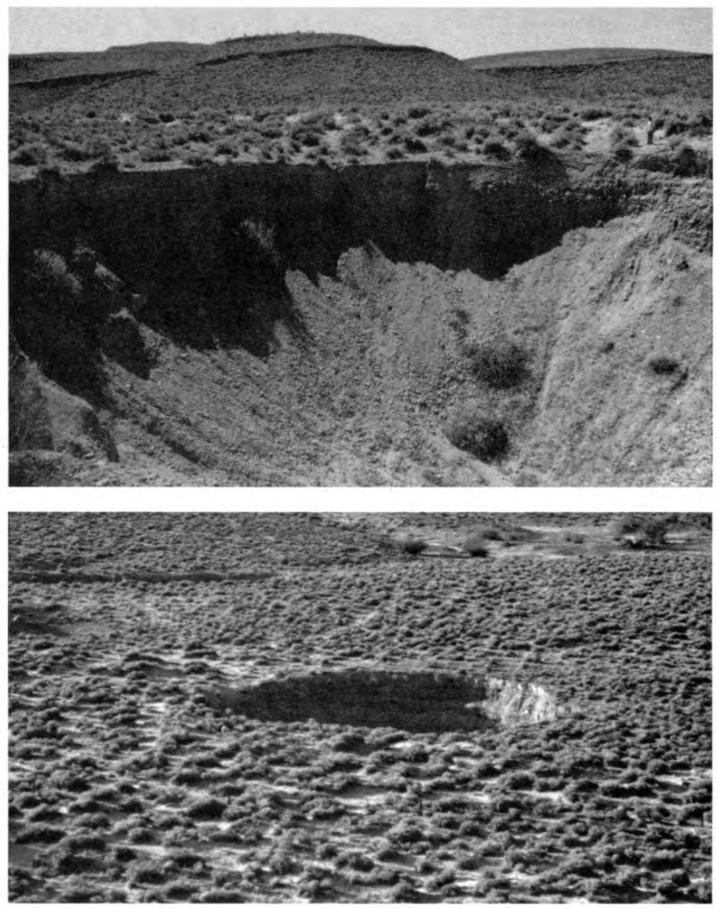
by Mark R. Milligan

Sinkholes in Big Round Valley, Washington County

GEOSIGHTS is a new column replacing The Rockhounder column. GeoSights will not just highlight locations to collect, but places to get out and view some of the many outstanding attributes that make Utah a geologic wonderland.

Geologic information: A sinkhole is a surface depression or hole created by the collapse of an underlying cave. Perhaps you've seen stories on the news about sinkholes in Florida swallowing cars and whole buildings, and thought that's one type of geologic phenomenon Utahns don't have to concern themselves with. Sinkholes do, however, occur in Utah. Some have swallowed rivers: for example, Washington County's Virgin River and La Verkin Creek. For several months in 1985 a sinkhole guzzled the entire Virgin River 2 miles (3 km) east of Pah Tempe Hot Springs. In 1996 La Verkin Creek disappeared into a sinkhole for nearly a week. Both of these sinkholes have since been backfilled by a bulldozer and are no longer visible, but several other spectacularly large sinkholes can be seen adjacent to the Virgin River just north of the Arizona border in Big Round Valley, Washington County.

The most spectacular of the sinkholes in Big Round Valley is large enough to swallow several buildings. It occupies over 1/10 acre (0.05 ha), measuring approximately 80 feet (24 m) in diameter and 60 feet (18 m) deep! This and nearby sinkholes are found in stream-terrace sediments deposited by the Virgin River before it carved out its current channel. A veneer of wind-blown sand and silt covers the gravelly stream-terrace deposits.



Closeup and bird's eye views of the most spectacular of several sinkholes found near the Virgin River in Washington County, just north of the Arizona border. Note the adult standing near the edge of the hole, on the right side of the closeup photo. The hole is approximately 80 feet (24 m) wide and 60 feet (18 m) deep! The walls of the sinkholes are steep and unstable. Stay back from the edges of the sinkholes and keep children and pets at a safe distance.

The origin of these collapse features and similar ones elsewhere in Utah is not always clear. They form when the roof of an underlying cave collapses, but what creates the underlying hole and how far below the surface is it? The 1985 Virgin River and 1996 La Verkin Creek sinkholes are both attributed to dissolution of underlying limestone bedrock, a process in which acidic ground water dissolves part of the limestone and carries it away in solution. In Big Round Valley, the underlying caves were probably created by a similar process when the mineral gypsum was dissolved and carried away by ground water. The Harrisburg Member of the Kaibab Formation underlies the sinkholes and is known for such gypsum "karst" features elsewhere in the area. Alternatively, or in conjunction with gypsum dissolution, part of an underlying limestone bed might have been dissolved and carried away in ground water.

A third possible scenario involves a process called sediment piping, where ground water traveling along initially small cracks or holes carries away clay and silt-size particles. In this scenario, fine sediment is carried away in suspension by flowing ground water, and the small cracks can grow to large channels, or pipes. Piping features are usually much smaller than these sinkholes. At Big Round Valley, however, stream-terrace gravels solidified by calcareous cement may form a somewhat stable roof over the pipes, allowing the pipes to grow unusually large before finally causing collapse at the surface. For piping to occur, the removed silt and clay needs a sink or place to be deposited. Therefore, piping features usually end at the base of a river bank or other steep slope. However, the bed of the Virgin River is about 20 feet (6 meters) higher in elevation than the bottom of the biggest sinkhole in Big Round Valley. Thus the river channel cannot act as a sink and piping is not a very satisfying explanation. This brings us full circle to needing a bedrock cave created by limestone or gypsum bedrock.

How to get there: While Big Round Valley is in Utah, it is accessed from just south of the state's border in Arizona. Travel south on I-15 and take the first exit south of the border, Exit 27 - Black Rock Road. Turn right (west) at the end of the off ramp. A short distance from the off ramp and immediately after crossing over a cattle guard turn right onto a dirt road leading north. Stay on this main, relatively well-traveled dirt road and you will come to a barbwire fence and gate 1.2 miles beyond the cattle guard. Continue on but leave the gate as you find it, either open or closed. (This is merely a cattle fence. The road and sinkholes are on public land managed by the Bureau of Land Management.) Approximately 2.4 miles from the cattle guard is a fork in the road; take the right fork heading uphill. Approximately 3 miles beyond the cattle guard is a three-way fork. From this point, the sinkholes are approximately 400 yards to the right. If you see the river, but have trouble finding the sinkholes, climb the low ridge to the south and the sinkholes will become obvious from that vantage point. WARNING: THE DIRT ROAD IS ROUGH. A high-clearance vehicle is needed and four-wheel drive would be helpful. If you are uncomfortable with the condition of the road at any point, park and walk the rest of the way.

Director's Perspective continued...

UGS will need to ensure that its expertise reflects the changing geological needs of Utah.

I believe it is very important that the Survey stays in touch with these needs. One goal I have set as Director is to visit senior officials in each county during my first year. This provides an opportunity for the counties to outline any problem areas that we may be able to help with. It also gives me a chance to explain what the Survey has done in the past, is presently doing, or may be planning to do. It is essential to have good communications at both state and local government levels, and with the private sector and the general public, if the benefits the Survey offers to Utah are to be widely recognized.

I look forward to helping the Geological Survey perform a valuable service for the State over the coming years. We have some challenging tasks in front of us.

New Publications from the UGS

Geologic map of the Merrimac Butte quadrangle, Grand County, Utah by H.H. Doelling and C.D. Morgan, 22 p., 2 pl., scale 1:24,000, 2000, M-178, ISBN 1-55791-578-4 .... $8.50

Interim geologic map of the Center Creek quadrangle, Wasatch County, Utah, by R.F. Biek, M.D. Hylland, J.E. Welsh, and Mike Lowe, 105 p., 2 pl., 9/00, OFR-370 .... $12.50

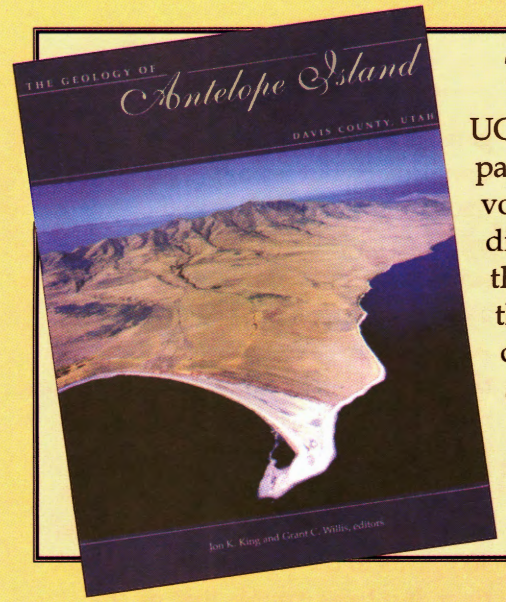
Late Mississippian (Arnsbergian Stage-E2 Chronozone) ammonoid paleontology and biostratigraphy of the Antler foreland basin, California, Nevada, Utah, by Alan L. Titus, 109 p., 10/2000, 1-55791-649-7, Bulletin 131 .... available in October

Ceratosaurus (Dinosauria, Theropoda), a revised osteology, by James H. Madsen Jr., and Samuel P. Welles, 80 p., 4/00, MP-00-2, 1-55791-380-3 .... $11.95

Interim geologic map of the Clear Creek Mountain quadrangle, Kane County, Utah, by M.D. Hylland, 12 p., 2 pl., 9/00, OFR-371 .... $4.50

Late Quaternary paleoecology in the Bonneville basin, by David B. Madsen, 190 p., 10/2000, 1-55791-648-9, Bulletin 130 .... available in October

The geology of Antelope Island, Davis County, Utah, edited by Jon K. King and Grant C. Willis, 163 p., 9/2000, 1-55791-647-0, MP-00-1 . .available in October



The Geology of Antelope Island, Davis County, Utah

UGS Miscellaneous Publication 00-01 is a compiled volume of 12 technical papers on most aspects of the geology of Antelope Island State Park. The volume represents the culmination of several years of research by 19 different scientists and covers topics such as: the petrology and history of the Precambrian Farmington Canyon Complex, Proterozoic rocks and their regional correlation, Tertiary rocks and history, shorelines and chemistry of the Great Salt Lake, engineering geology, geologic hazards, and water resources of the island. These detailed papers go beyond the previous UGS maps and publications on the island, and provide information for the more dedicated geologists, enthusiasts, and managers. . . . . *available in October*

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Paleoseismology of Utah, Volume 1: Fault behavior and earthquake recurrence on the Provo segment of the Wasatch fault zone at Mapleton, Utah County, Utah, by W.R. Lund, D.P. Schwartz, W.E. Mulvey, K.E. Budding, and B.D. Black, 41 p., 1991, #SS75 . . . . **$7.00**

Paleoseismology of Utah Volume 2: Paleoseismic analysis of the Wasatch fault zone at the Brigham City trench site, Brigham City, Utah and the Pole Patch trench site, Pleasant View, Utah, by S.F. Personius, 39 p., 1991, #SS76 . . . . **$6.00**

Paleoseismology of Utah Volume 3: The number and timing of paleoseismic events on the Nephi and Levan segments, Wasatch fault zone, Utah, by Michael Jackson, 23 p., 3 pl., 1991, #SS78 . . . . **$6.50**

Paleoseismology of Utah Volume 4: Seismotectonics of north-central Utah and southwestern Wyoming, by Michael W. West, 93 p., 5 pl., 1994, #SS82 . . . . **$15.00**

Paleoseismology of Utah Volume 5: Neotectonic deformation along the East Cache fault zone, Cache County, Utah by J.P. McCalpin, 37 p., 1994, #SS83 . **$5.00**

Paleoseismology of Utah Volume 6: The Oquirrh fault zone, Tooele County, Utah: surficial geology and paleoseismicity, W.R. Lund, editor, 64 p., 2 pl., 1:24,000, 1996, #SS88. . . . . **$14.50**
Surficial geology of the Oquirrh fault zone, Tooele County, Utah, by B.J. Solomon; Paleoseismic investigation of the Oquirrh fault zone, Tooele County, Utah, by S.S. Olig, W.R. Lund, B.D. Black, and B.H. Mayes

Paleoseismology of Utah Volume 8: Paleoseismic investigation at Rock Canyon, Provo segment, Wasatch fault zone, Utah County, Utah, by W.R. Lund and B.D. Black, 21 p., 2 pl., 1998, #SS93 . . . . **$8.00**

Paleoseismology of Utah Volume 7: Paleoseismic investigation on the Salt Lake City segment of the Wasatch fault zone at the South Fork Dry Creek and Dry Gulch sites, Salt Lake County, Utah, by B.D. Black, W.R. Lund, D.P. Schwartz, H.E. Gill, and B.H. Mayes, 22 p., 1 pl., 1996, #SS92 . . . . **$5.25**

Paleoseismology of Utah Volume 9: Paleoseismic investigation of the Clarkston, Junction Hills, and Wellsville faults, West Cache fault zone, Cache County, Utah by B.D. Black, R.E. Giraud, and B.H. Mayes, 23 p., 1 pl., 2000, #SS98 . . . . **$10.50**

and related publications:

Surficial geologic map of the West Cache fault zone and nearby faults, Box Elder and Cache Counties, Utah, by Barry J. Solomon, 20 p., 2 pl., 1:50,000, 1999, #M-172 **$6.95**

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Dating methods applicable to Quaternary geologic studies in the western United States, edited by Steven L. Forman, 80 p., 1989, #MP-89-7 . . . . **$6.75**

Soils as a tool for applied Quaternary geology, by P.W. Birkeland, M.N. Machette, and K.M. Haller, 63 p., April 1991, #MP-91-3 . . . . **$6.50**

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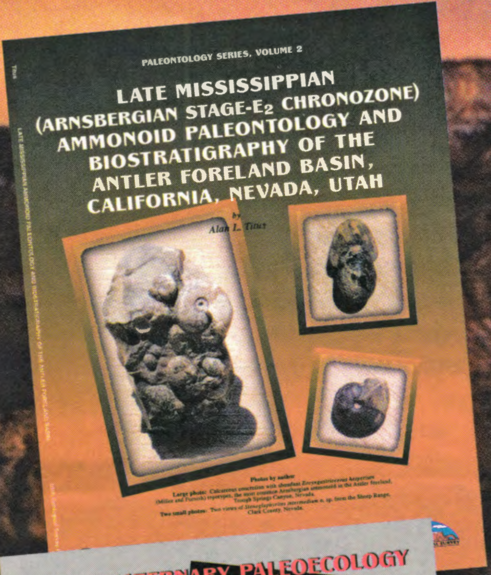

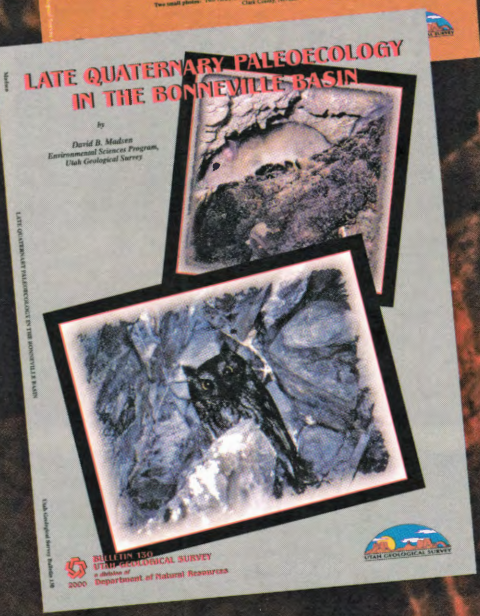

Late Mississippian (Arnsbergian Stage-E2 Chronozone) ammonoid paleontology and biostratigraphy of the Antler foreland basin, California, Nevada, Utah

Bulletin 131, by Alan L. Titus, 109 p., available in October. Strata throughout the Antler basin contain an abundant ammonoid fossil record. This record is rivaled by no other fossil group for intercontinental correlation, and yet is only just beginning to undergo intensive study. This paper is the very first of a series of comprehensive systematic studies on this extremely significant fauna which, when completed, will help to establish the Antler foreland in Utah, Nevada, and California as a global reference for Carboniferous research. *available in October*

Late Quaternary paleoecology in the Bonneville basin

Bulletin 130, by David B. Madsen, 190 p., available in October. With contributions by J.M Broughton, Donald K. Grayson, J.M. Hunt, S.D. Livingston, C.G. Oviatt, J. Quade, David Rhode, D.N. Schmitt, and M.W. Shaver III, this volume explores the eastern edge of the Great Basin's varied paleoecology in 13 extensive papers. . . . . *available in October*

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