UTAH GEOLOGICAL SURVEY

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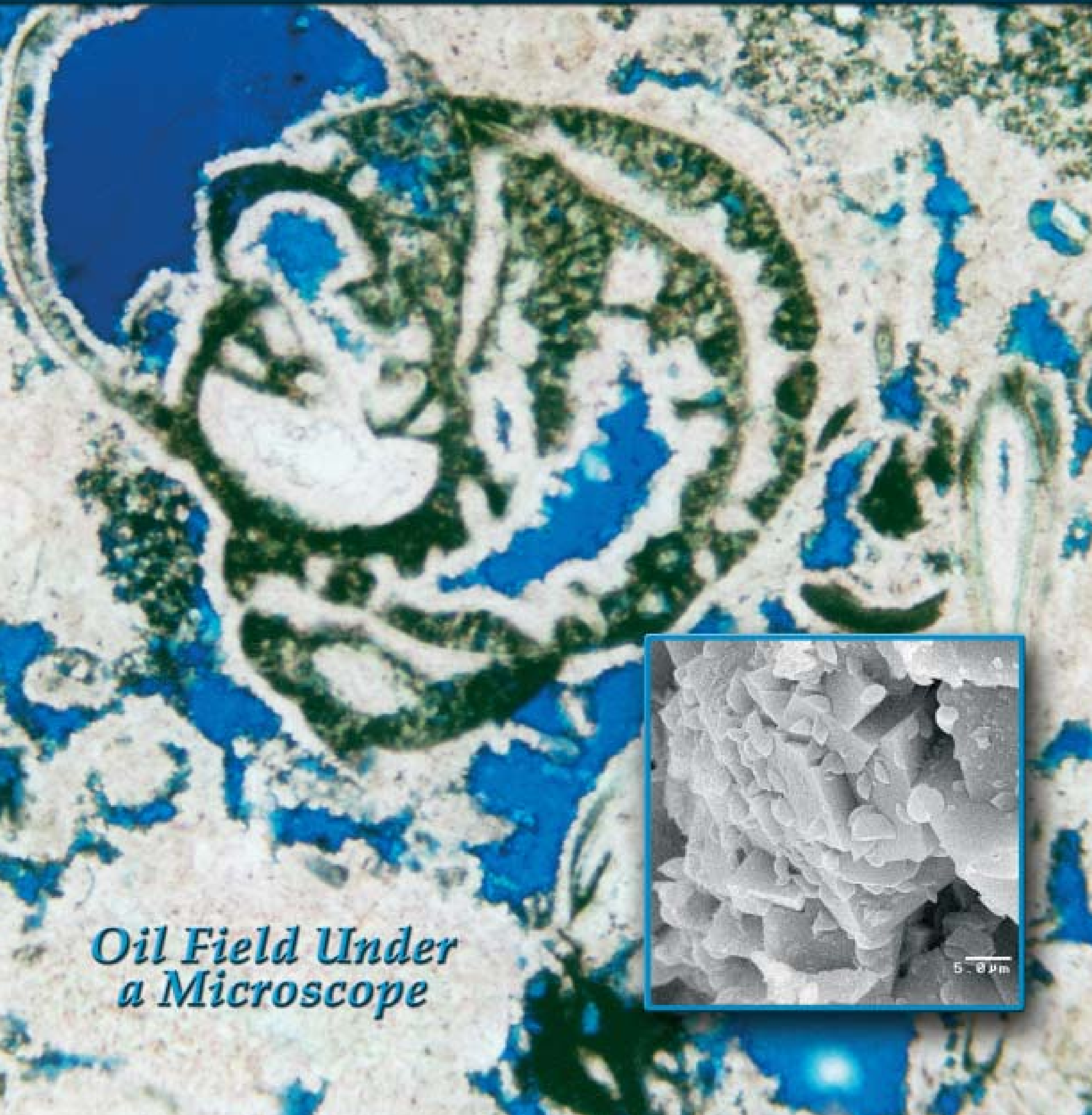

Oil Field Under a Microscope

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Design by Vicky Clarke

Cover: *Microscopic view of fossiliferous limestone from Cherokee oil field, southeastern Utah. Blue areas represent pore spaces capable of storing oil. Photo by David E. Eby. Inset: Closeup of pores and dolomite taken with scanning electron microscope. Photo by Louis H. Taylor*

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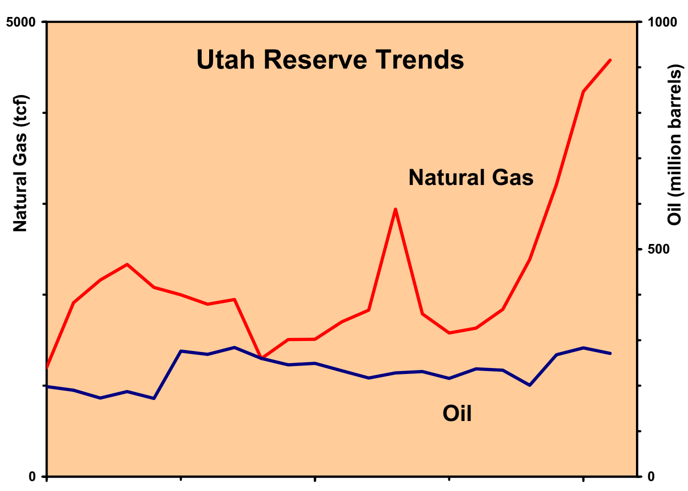
The Director's Perspective

by Richard G. Allis

This issue of Survey Notes goes to press as we prepare for AAPG's annual convention in Salt Lake City. The war in Iraq remains unresolved, and our energy and stock markets nervously wait for a clear outcome. My Director's Perspective from the January 2002 issue reviewed Utah's energy commodity trends during 2001, noting the unprecedented volatility in natural gas and electricity prices that year, following the "energy crunch" that started in California in December 2000. The price hikes in early 2001 resulted in more oil and gas wells being drilled in Utah that year (625 wells) than in any previous year, including the boom exploration years of the early 1980s. In view of the present volatility in energy markets, it is timely to review what has happened in Utah since the flurry of drilling activity in 2001.

Since 2001, the local natural gas price sank briefly to unprecedented lows (< $1/mcf) and bounced back up to very high values last month (> $5/mcf). The local oil price steadily rose through 2002 to be close to $30/barrel; the wholesale electricity price has returned to recent historic norms (2 – 3 c/kWh), and the coal price has remained close to historic lows ($17/ton). Oil and gas drilling activity in Utah dropped back to levels more typical of the late 1990s (390 wells in 2002), but has shown upward trends in March due to recent perceptions of natural gas supply shortages and the high prices.



What was the outcome of the additional drilling in Utah in 2001? The reserves of natural gas grew by 8% largely through field extensions, whereas oil reserves remained static. One third of the gas addition was from coalbed methane. Utah, along with surrounding states in the Intermountain West, has become an attractive target for gas exploration. In 2000, natural gas became the most important fossil fuel in the state for revenue generation, surpassing coal, which led during most of the 1990s, and oil, which dominated the 1980s. Continued discoveries of natural gas in Utah and relatively high prices indicate that the local gas industry has a bright future.

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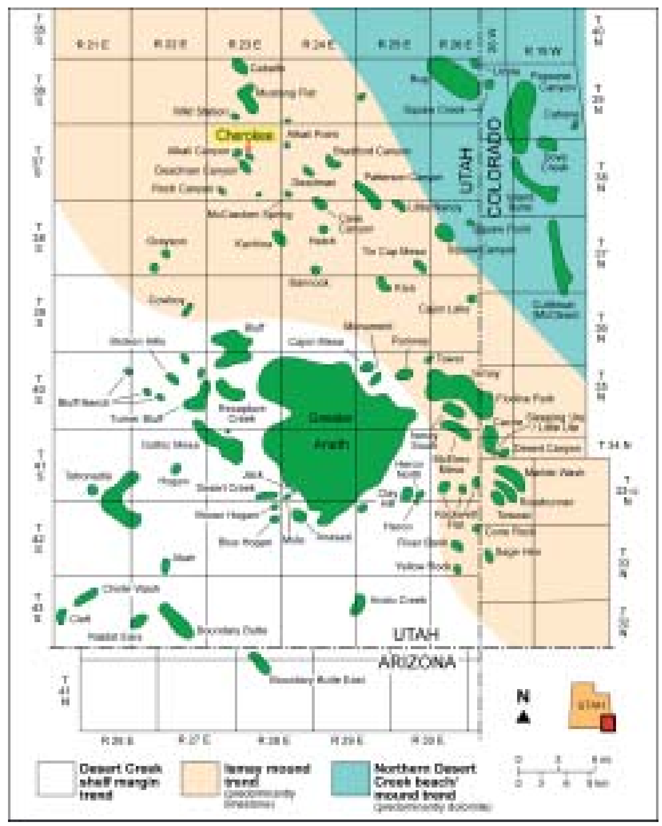
AN UP CLOSE AND PERSONAL VIEW OF CHEROKEE OIL FIELD, SAN JUAN COUNTY, UTAH

by Thomas C. Chidsey, Jr.

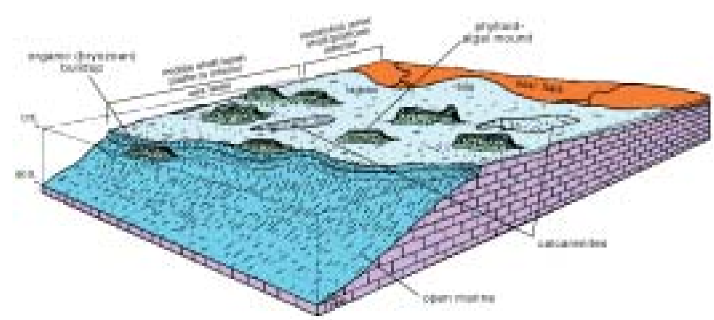
Introduction

Over 450 million barrels of oil have been produced from rocks deposited in a warm, shallow sea 310 million years ago during the Pennsylvanian Period in the Paradox Basin of southeastern Utah. Within this sea, reef-like buildups or mounds of green (phylloid) algae (similar to seaweed) created traps for oil in the Paradox Formation. Nearly 100 oil fields produce from the Paradox Formation including Utah's largest, the 425-million-barrel Greater Aneth field east of the town of Bluff. However, most of these fields are small, one to ten wells, and contain 2 to 10 million barrels of oil. Only 15 to 25 percent of this oil is recovered given the current geologic understanding of the rocks and using standard production techniques. The Utah Geological Survey (UGS), with funding from the U.S. Department of Energy (DOE) as part of its Class II Oil Revisit Program, is conducting a detailed study of Cherokee oil field, operated by Salt Lake City-based Seeley Oil Company. Cherokee field, which has produced 182,000 barrels of oil since it was discovered in 1987, is typical of the small fields in the basin. The goal of the study is to ultimately double the amount of oil that is produced from this field, and others like it.

To achieve this goal we must gain a better understanding of how oil is stored in the rock, called reservoir rock, and how it flows to the well. Oil accumulates and is stored in the rock's pore spaces like a sponge holding water. For the oil to flow, the pores must be interconnected or permeable, the measurement of which is called permeability. The more pores and the higher the permeability in the reservoir, the more oil that can be stored and produced. In the Paradox Formation, pore spaces occur between the "leaves" of algae like spaces in a bag of potato chips, and in the case of Cherokee field represent 12 percent of the rock. However, over time things can happen to the pores in the oil reservoir that affect how they are connected. Fresh or magnesium-bearing water can enhance or create new pores, while later mineralization or tar-like oil (bitumen) can plug up pores and their connections. These



Location map of the Paradox Basin, Utah and Colorado, showing producing oil and gas fields.



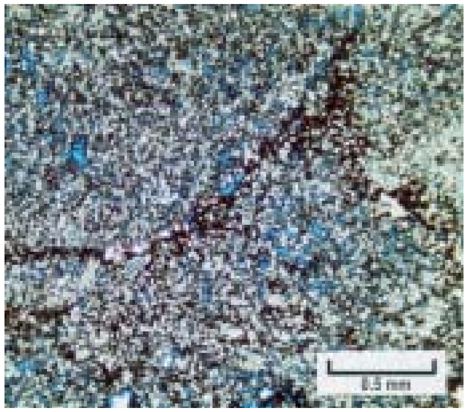
Block diagram displaying major environments of deposition, including algal mounds that serve as traps for oil, in the Pennsylvanian Paradox Formation, Utah and Colorado.

changes are referred to as diagenesis. Geologists use "up close and personal" techniques to examine the pores in reservoirs, and for Cherokee field the UGS has identified possible compartments of undrained oil that could significantly increase the field's production. Similar undrained compartments may be present in other fields in the Paradox Basin.

Thin Sections – A Slice of Rock

One of the standard techniques used to study an oil reservoir is to make a slide (called a thin section) of the reservoir rock and examine the pores under a microscope. When some of the wells at Cherokee field were drilled, a special drill bit was used to obtain core from the Paradox Formation. After describing the core, small samples were collected to make thin sections and conduct other special tests. Samples for thin-section analysis are impregnated with a special blue epoxy that fills all of the pores. The samples are then glued to glass slides, the bulk of the samples sliced off, and the remaining portions are ground down so thin that light will transmit through them. Under the microscope, one can observe the types of minerals present and, most important, the pores (seen as blue areas). Photographs taken through the microscope of thin sections are called photomicrographs.

From the thin sections of Cherokee field, we observe various types of pores including shelter pores (pores between algal leaves [plates]) and pores formed or enlarged by fresh water dissolving algal plates, fossils, and limely sand grains (moldic or vuggy porosity). Other pores are clogged with anhydrite (a late-forming evaporite mineral) and bitumen. However, the most significant and unique diagenetic characteristic observed in the Cherokee field thin sections is extensive small-scale porosity, or microporosity, that developed between crystals of the mineral dolomite. Our preliminary interpretation is that the intense microporosity developed late, by the action of

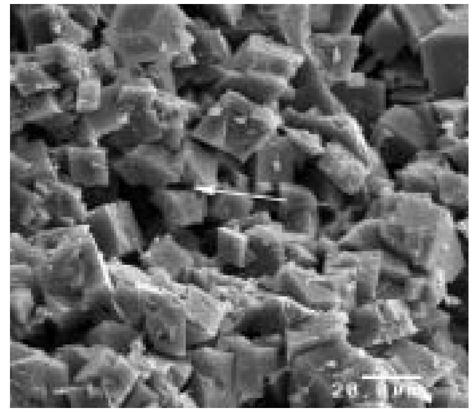


Photomicrograph (plane light) of a Cherokee reservoir rock dominated by microporosity (blue) amounting to 23 percent of the rock at that interval (Cherokee No. 22-14 well, 5,768.7 feet). Photomicrograph by David E. Eby, Eby Petrography and Consulting, Inc., Littleton, Colorado.

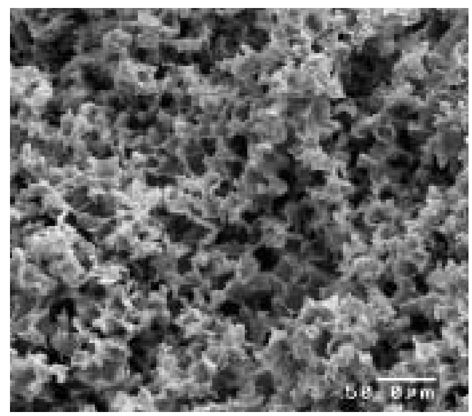
hydrothermal solutions from depth (carbon dioxide gas escaping from 350-million-year-old [Mississippian Period] Leadville Limestone or from deeply buried organic matter).

Scanning Electron Microscope – The Tube with a View

To get an even better understanding and view of these various diagenetic features, geologists use a special microscope, the scanning electron microscope (SEM). The SEM not only produces images at incredibly high magnification (from 15x to 200,000x), but does so showing every detail with extreme clarity in three dimensions. The SEM is commonly used to examine insects, plants, and bacteria, so why not rocks and minerals. Unlike the conventional microscope that uses light waves to observe thin sections, the SEM illuminates the rock samples with electrons in a vacuum chamber. The samples must be able to conduct electricity and are therefore coated with a very thin layer of gold by a machine called a sputter coater. The sample is then placed inside the SEM's vacuum column and an electron gun emits a beam of high-energy electrons downward through a series of magnetic lenses that focus the electrons to a very fine point. The focussed beam moves back and forth across the sample, releasing electrons from its surface; these electrons are



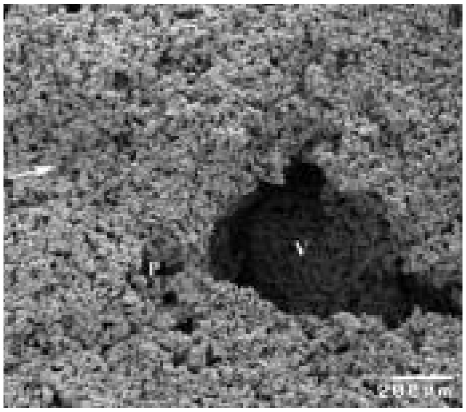
SEM photomicrograph of a sample collected from a depth of 5,781.2 feet, Cherokee No. 33-14 well, showing well-developed dolomite crystals (rhombohedrons) exhibiting abundant microporosity (arrow). Scale represents 20 microns (0.02 mm). Porosity = 24 percent. Photomicrograph by Louis H. Taylor, Standard Geological Services, Inc., Littleton, Colorado.



SEM photomicrograph of a pore cast of a sample collected from a depth of 5,768.7 feet, Cherokee No. 22-14 well. The solid areas (light gray) represent what had been porosity in the original sample, and the open areas (dark gray to black) represent what had been rock matrix; overall microporosity is relatively uniform. Scale represents 50 microns (0.05 mm). Porosity = 23 percent. Photomicrograph by Louis H. Taylor, Standard Geological Services, Inc., Littleton, Colorado.

counted by a detector to build the final image (which is black and white).

Another technique used to evaluate reservoir pore systems is pore casting. Pore casting is a special technique where the carbonate matrix of an epoxy-impregnated thin section blank (the rock material left over after the thin section is made) is dissolved by hydrochloric acid. What remains is only the epoxy that filled the entire



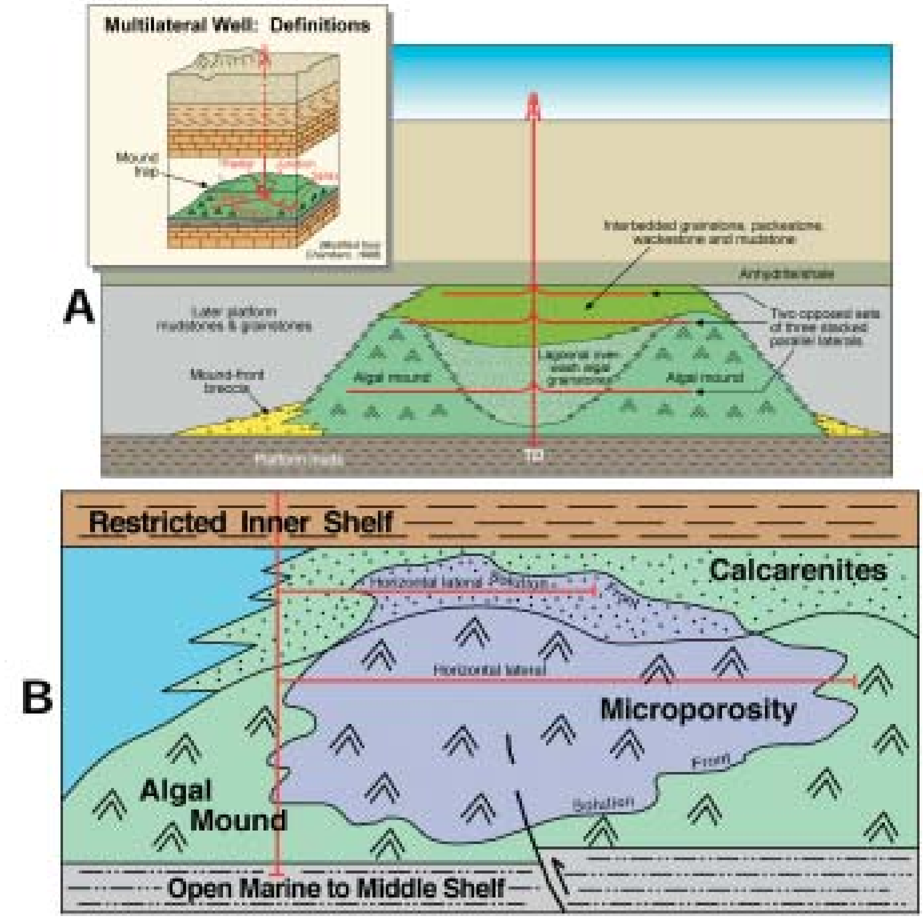
SEM photomicrograph of a sample collected from a depth of 5,768.7 feet, Cherokee No. 22-14 well, exhibiting three porosity types: microporosity (arrow), moldic microporosity (P), and a large vug (V). Scale represents 200 microns (0.2 mm). Porosity = 23 percent. Photomicrograph by Louis H. Taylor, Standard Geological Services, Inc., Littleton, Colorado.

pore system of the sample (pores and pore throats), creating a kind of "negative" of the rock in that the open space used to be mineral and the solid material used to be pores. The pore cast is then coated with gold, and studied and photographed with the SEM (the same method as if it were the actual rock).

All Cherokee samples exhibit microporosity whereas others exhibit additional pore types such as moldic and vuggy porosity. Microporosity is also well displayed by the pore casts which show the pores are well connected, thus allowing oil to flow to a well. Other SEM images show how some of the large pores or vugs have been essentially filled with the mineral anhydrite while others remain open and thus capable of storing oil. Occassionally, different minerals, such as calcite and clay (smectite), fill pore spaces. Large blobs observed on some of the SEM images (see cover inset photo) represent bitumen, the solid hydrocarbon that can clog the interconnections between pores and reduce the ability of oil to flow through the rock.

Got Oil! – Drill Horizontally

Microporosity represents an important site for untapped hydrocarbons and possible targets for horizontal drilling. Techniques developed in the late 1980s and early 1990s allow wells to be deviated from vertical to horizontal with the drilling direction and depth carefully controlled. More reservoir rock is encountered in horizontal wells, reducing drilling costs and risk while increasing production and reserves. Through proper geological evaluation of reservoirs, oil production may be increased 20 to 50 percent as a result of drilling low-cost single or multilateral horizontal legs from existing vertical-development wells. In addition, horizontal drilling from existing wells minimizes surface disturbances and costs for field development, particularly in the environmentally sensitive areas of southeastern Utah and southwestern Colorado.



(A) Schematic diagram of Paradox Formation drilling targets by multilateral (horizontal) legs from an existing field well. (B) Strategy for horizontal drilling microporosity in Cherokee and similar Paradox Basin oil fields.

An extensive and successful horizontal drilling program has been conducted in the giant Greater Aneth field. However, to date, only two horizontal wells have been drilled in small Paradox Basin fields. The results from these wells were disappointing due to poor understanding of the reservoir rocks and diagenetic changes that affect the flow of oil to the well.

The hydrothermally induced microporosity in Cherokee field could be drained with radially stacked, horizontal laterals and splays drilled from an original vertical well. The field already contains four vertical wells from which multiple horizontal laterals could be extended to penetrate undrained oil trapped in microporosity and other potential targets. Depending on the results of the UGS study of the reservoir characteristics, and successful field testing, these techniques can be applied to numerous small fields throughout the Paradox Basin.

Blue-Green Algae: It's Not Just Pond Scum

by Craig Morgan

Background

In September 2002, the Utah Geological Survey (UGS) completed a four-year study of the oil-productive Green River Formation in northeastern Utah. Objectives of the project were to increase oil and gas recovery through improved characterization of the formation. The project included examination and interpretation of both the surface (rock exposures) and subsurface (well logs and cores) data. The Green River consists of hundreds of meters of interbedded sandstone, limestone, and mudstone that were deposited in ancient Lake Uinta and along, or near, the shores of the lake, which occupied the present-day Uinta Basin 55 to 45 million years ago. Examination of fossil blue-green algae in the Green River was a very small, but interesting part of the project. Beds composed of fossil blue-green algae are commonly laterally extensive and can often be correlated from one exposure to another, providing good marker beds. The algal beds rarely are oil and gas reservoirs, but they can be used to help interpret depositional patterns and are often closely associated with the oil-productive beds within the formation.

Algae: Past and Present

Blue-green algae are one of the earliest life forms and have grown in fresh and salt waters since the Precambrian (3.5+ billion years ago). Blue-green algae are not true algae, but are cyanobacteria which are neither true plants or animals and, like bacteria, have no cell nucleus. Much of what comprises common pond scum is a present-day form of blue-green algae. Blue-green algae are the most abundant fossils in the Green River Formation in Nine Mile Canyon, and the most abundant life form in Great Salt Lake.

Fossil blue-green algae in the Green River Formation are commonly found as beds of algal mats or stromatolites. An algal stromatolite is a rock structure produced largely by growing blue-green algae that trapped and bound sediment. Stromatolites in the Green River are typically dome shaped, ranging from small cabbage-like heads a few centimeters (inches) in diameter to large domes up to 1.5 meters (5 ft) wide and 0.5 meters (1.5 ft) high. An

Algal stromatolites exposed near the shore of Stansbury Island during the lake-level low of 1964.

encrusting form of blue-green algae can be found where it grew on the tops of stromatolites and around tree trunks in swamps.

Stromatolites are currently growing on the gently sloping floor of Great Salt Lake at shallow water depths where the blue-green algae receives sufficient sunlight for photosynthesis. Fossil algal stromatolites in the Green River Formation grew in a similar setting, on a gently sloping, shallow fresh-water lake bottom. Stromatolites can form a low-relief but extensive biostrom in a lake. For example, a bed in the Green River Formation known as the C marker, in Nine Mile and Desolation Canyons northeast of the town of Price, contains well-developed stromatolites at most locations where it is exposed. The C marker biostrom may have covered more than 300 square kilometers (180 mi^2) along the southern shoreline of ancient Lake Uinta.

Additional Information

The study of the Green River Formation was part of a project entitled *Reservoir characterization of the lower Green River Formation, southwest Uinta Basin, Utah.* The study was partially funded by the U.S. Department of Energy

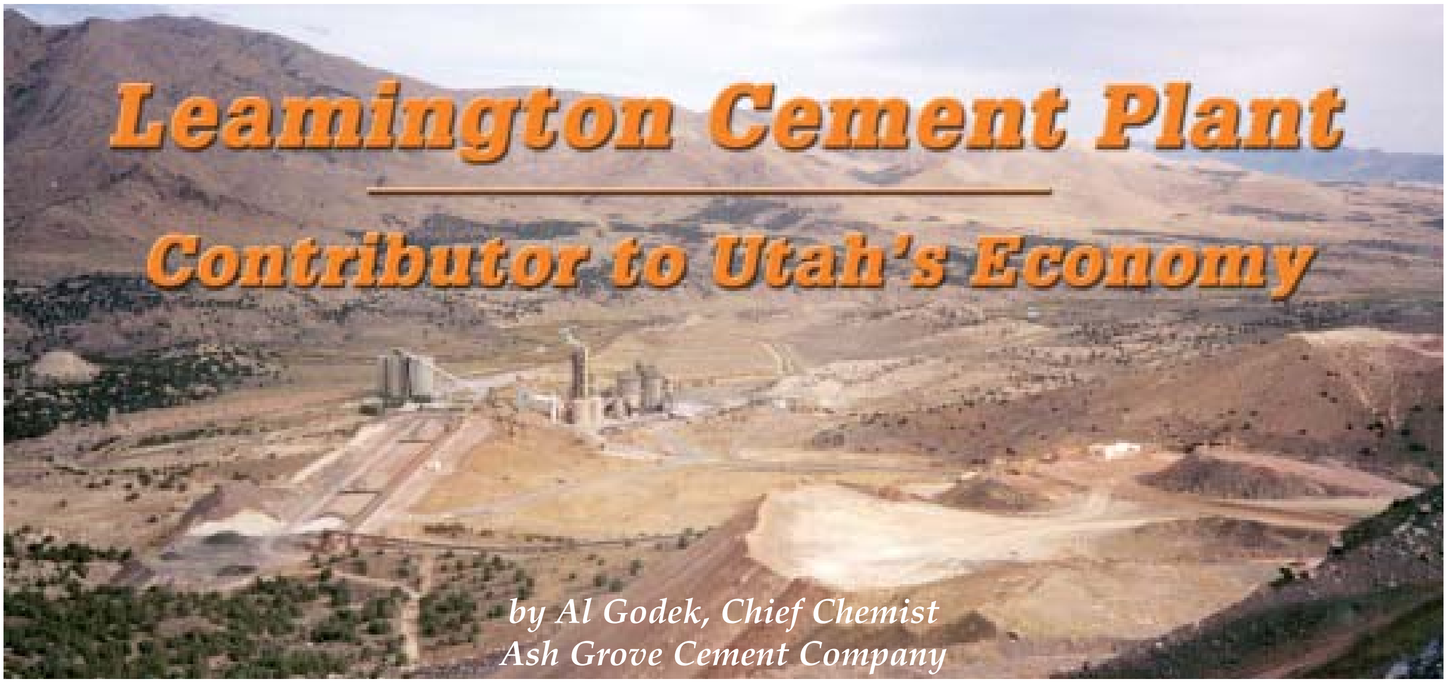
(DOE) National Petroleum Technology Office in Tulsa, Oklahoma. The project has been completed but the technology transfer of the results is ongoing. Additional information can be found at the project web page http://geology.utah.gov/emp/greenriver/index.htm.

A) Algal stromatolite in the Green River Formation, Desolation Canyon. The algal head is about 15 centimeters (6 inches) high. Photograph by Bryce Tripp.

B) S. Robert Bereskin standing next to an algal stromatolite that eroded out of the C marker bed of the Green River Formation in Nine Mile Canyon. The large algal head is overturned.

C) Small algal stromatolites (dome shapes at hand level) in the C marker bed of the Green River Formation in Gate Canyon, a tributary to Nine Mile Canyon.

D) Algae-encrusted log impressions in the base of a channel deposit in the Green River Formation in Nine Mile Canyon. The woody material of the log decomposed and the void was filled with siltstone and grainstone. The algae are evenly distributed around the log impressions, without any flat surface; therefore, the algae are believed to have grown on the tree stump while the tree was still upright in the lake swamp. The tree eventually fell over and was deposited in the stream channel.



Leamington Cement Plant

Contributor to Utah's Economy

by Al Godek, Chief Chemist
Ash Grove Cement Company

History and Location

The Leamington Portland cement plant straddles Highway 132 in eastern Juab County. Martin Marietta Corporation completed construction of this 650,000 ton-per-year plant in 1980 to supply cement for the proposed MX missile program. The U.S. Government later scrapped plans for the MX system but there was enough regional construction to justify operating the plant. Martin Marietta produced the first cement on November 15, 1981, and ran the plant until April 1984. Southwestern Portland Cement ran the plant from April 1984 until it was purchased in May 1989 by Ash Grove Cement Company, headquartered in Overland Park, Kansas. Ash Grove increased plant capacity to 850,000 tons per year in 1995-96. While most of the U.S. cement producers are foreign owned, Ash Grove is currently the largest domestically owned Portland cement company in the United States, operating nine plants.

What is Portland Cement?

Portland cement is a finely ground powder which is mixed with water to form a paste which hardens over time to bind aggregate (crushed stone or sand and gravel) together to form concrete. The term Portland cement was first used in 1824 by Joseph Aspdin, an English stone mason, to describe a new cement formula that he had patented. Mr. Aspdin thought that his cement resembled a well-known limestone building stone quarried on the British Isle of Portland. Portland cement is typically made from (1) limestone, (2) a source of silica like sandstone or quartzite, (3) a source of alumina like shale, clay, or bauxite, (4) iron ore or industrial by-product iron, and (5) gypsum.

Importance of Portland Cement

Portland cement is one of the most important building materials in the world. In 2001, the U.S. Geological Survey reported that 116 U.S. cement plants produced 85 million tons of Portland cement for construction of buildings, bridges, highways, and other structures. Cement production by Utah's two cement companies contributes to Utah's commercial, residential, and infrastructure growth. Most of the huge amount of concrete used for Interstate Highway 15 reconstruction in the Salt Lake City area incorporated Portland cement made at Leamington. On a pound-for-pound basis, more of it was used on this job than any other structural material.

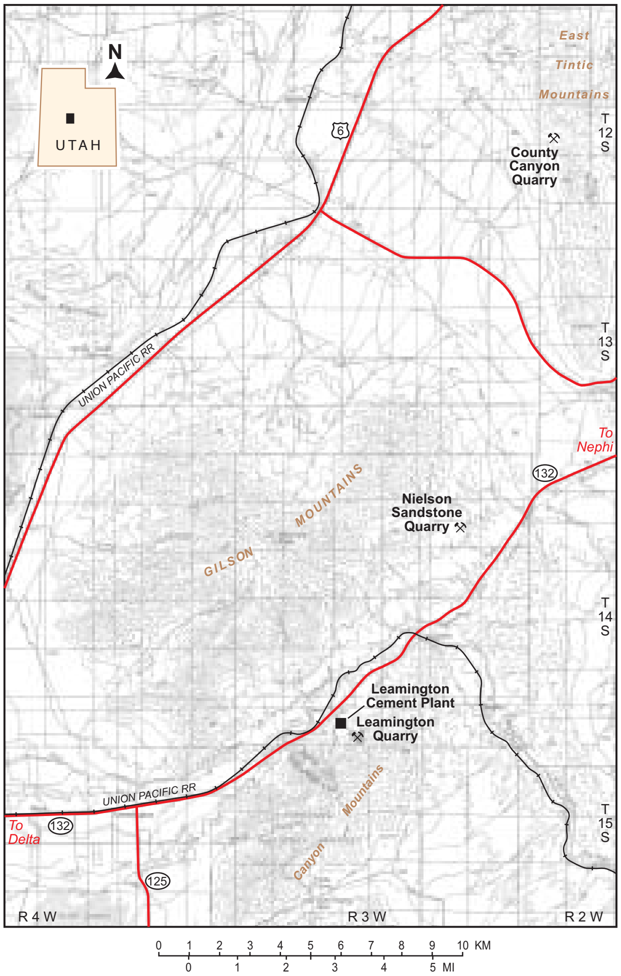
Cement Processing

Production of Portland cement is essentially a four-part process that consists of (1) quarrying raw materials, (2) grinding and mixing the raw materials, (3) burning the raw materials in a rotary kiln, and (4) finish grinding the fused cement "clinker."

Quarrying

The Leamington plant uses limestone, shale, and sandstone mined at three separate quarries. In 2002, the plant mined one million tons of limestone from the Cambrian Swasey Limestone at the Leamington quarry, 100,000 tons of shale from the Mississippian Long Trail Shale Member of the Great Blue Limestone at the County Canyon Quarry, and 75,000 tons of sandstone from the Permian Diamond Creek Sandstone at the Nielson quarry.

The Leamington quarry is drilled and blasted five or six times a year. A typical blast produces about 250,000 tons of limestone. A large front-end loader picks up broken limestone and loads it into haul trucks which move it to the primary, single-pass hammer-mill crusher. Here it is reduced to softball size or smaller. The primary crushed limestone is transported by conveyer belt to a



Location of the Leamington Portland cement plant and raw material quarries, Juab County, Utah.

stacker/reclaimer. A 25,000-ton pile is made once per week. Raw material from the County Canyon quarry and the Nielson quarry is also reduced in size and transported to the plant by dump trucks. Limestone, shale, and sandstone are placed in five storage silos at the plant.

Grinding and Mixing

Limestone, shale, sandstone, and mill scale (an industrial by-product iron powder from Geneva or Nucor Steel) are mixed in precise proportions through the use of continuous X-ray fluorescence chemical analysis. The proportioned materials are then moved to a mill which pulverizes the raw materials to the consistency of talcum powder. Hot rotary kiln exhaust gas sweeps the mill, drying the raw material and moving it to two blend silos.

Burning

Pulverized raw material from the blend silos is then transported for pyro-processing in the preheater/calciner tower and rotary cement kiln. The 268-foot-tall tower has six vessels, including the calciner vessel; the calciner burns about 60 percent of the fuel (powdered coal) used at the plant to heat the raw material to 1,481 degrees Fahrenheit to calcine the limestone (remove the carbon dioxide). The calcined product then goes into a rotary kiln where addition-

View along Leamington's 175-foot-long, 12.5-foot-diameter rotary kiln where powdered coal is burned at about 2,650 degrees Fahrenheit to finish the chemical reactions necessary to create Portland cement.

al fuel is burned to heat the calcined material to the point of incipient fusion at a white-hot temperature of approximately 2,650 degrees Fahrenheit. The rotary kiln is 12.5 feet in diameter, 175 feet long, and turns at 3.5 revolutions a minute. Heating produces an equilibrium between the solid and liquid phases of the cement compounds that are produced. The resultant crystalline material is now called Portland cement clinker. The control room operator maintains the proper reaction temperature by varying the amount of fuel going into the kiln. The plant consumes about 100,000 tons of Utah coal per year from the Crandall Canyon mine. Leamington is very energy efficient and requires only about 3.05 million Btu per ton of clinker produced. Part of the efficiency is due to the use of hot kiln exhaust gas to dry and preheat incoming raw materials.

Finish Grinding

The hot clinker is cooled and transported, along with five to six percent gypsum, into a 14-foot-diameter ball mill driven by a 5,700 horsepower motor. The gypsum slows the hardening time of the concrete made with Portland cement. About 40,000 tons per year of Utah gypsum is currently purchased from H.E. Davis Construction, Inc. who mines gypsum from the Jurassic Arapien Shale near Levan. The clinker and gypsum are ground to a fine gray powder. The cooled product is then transported to the shipping silos for distribution by truck (80 percent) or train (20 percent) throughout the state and region.

Markets

The main market for cement from the Leamington plant is the Salt Lake City area with a distribution terminal in Murray, Utah. Secondary markets in Nevada and New Mexico are served from terminals in Elko and Las Vegas, Nevada and Farmington, New Mexico. Leamington produced 834,000 tons of finished cement in 2002.

New Publications

Energy, mineral, and ground-water resources of Carbon and Emery Counties, Utah, by R.W. Gloyn, D.E. Tabet, B.T. Tripp, C.E. Bishop, C.D. Morgan, J.W. Gwynn, and R.E. Blackett, 161 p., 14 pl., scale 1:750,000, 1/03, ISBN 1-55791-679-9, B-132 . . . . **$15.95**

Geologic map of the Chriss Canyon quadrangle, Juab and Sanpete Counties, Utah, by Malcolm P. Weiss, James G. McDermott, Douglas A. Sprinkel, Raymond L. Banks, and Robert F. Biek, 26 p., 2 pl., scale 1:24,000, ISBN 1-55791-585-7, 2/03, Map 185 . . . . **$10.49**

Geologic map of the Hurricane quadrangle, Washington County, Utah by Robert F. Biek, 61 p., 2 pl., 1:24,000, ISBN 1-55791-587-3, 2/03, M-187 . . . . **$13.70**

Geologic map of the Salt Lake City 30' x 60' quadrangle, north-central Utah and Uinta County, Wyoming, by Bruce Bryant, 1990 (digital version 2003), scale 1:100,000 (digitized from U.S. Geological Survey Miscellaneous Investigations Map I-1944), CD-ROM, 1/03, ISBN 1-55791-590-3, M-190DM **$24.95**

Geologic map of the Harrisburg Junction quadrangle, Washington County, Utah by Robert F. Biek, 42 p., 2 pl., 1:24,000, ISBN 1-55791-592-X, M-191, 2/03 . . **$11.30**

Geologic map of the Center Creek quadrangle, Wasatch County, Utah, by Robert F. Biek, Michael D. Hylland, John E. Welsh, and Mike Lowe, 25 p., 2 pl., 1:24,000, ISBN 1-55791-591-1, 4/03, Map 192 . . . . **$11.30**

Quaternary fault and fold database and map of Utah, by Bill D. Black, Suzanne Hecker, Michael D. Hylland, Gary E. Christenson, and Greg N. McDonald, CD-ROM, scale 1:500,000, ISBN 1-55791-593-8, 2/03, Map 193DM **$24.95**

Ground-water quality classification and recommended septic tank soil-absorption-system density maps, Cache Valley, Cache County, Utah, by Mike Lowe, Janae Wallace, and Charles E. Bishop, CD-ROM, (31 p., 10 pl., scale 1:100,00), 3/03, SS-101 . . . . **$14.95**

Water-quality assessment and mapping for the principal valley-fill aquifer in Sanpete Valley, Sanpete County, Utah, by Mike Lowe, Janae Wallace, and Charles E. Bishop, 91 p., 13 pl., 1:100.000, 12/02, CD-ROM, ISBN 1-55791-680-2, SS-102 . . . . **$19.95**

Small mine permits in Utah 2002, by Roger L. Bon and Sharon Wakefield, 7 p., 1 pl., approx. scale 1:750,000, 12/02, OFR-405 . . . . **$4.50**

Characteristics , causes, and implications of the 1998 Wasatch Front landslides, Francis X. Ashland, 49 p., ISBN 1-55791-689-6, SS-105, 3/03 . . . . **$8.00**

Geologic evaluation and hazard potential of liquefaction-induced landslides along the Wasatch Front, Utah, by Kimm M. Harty and Mike Lowe, 40 p., 16 pl., 3/03, SS-104 . . . . **$12.95**

Ground-water sensitivity and vulnerability to pesticides, the southern Sevier Desert and Pahvant Valley, Millard County, Utah, by Mike Lowe and Ivan D. Sanderson, 28 p., 2 pl., scale 1" = 6 miles, ISBN 1-55791-684-5, 2/03, MP-03-1 . . . . **$12.45**

Interim geologic map of the Cave Flat (Mt. Pennell 2NW) quadrangle, GarfieldCounty, Utah, by Curtis Smith, 13 p., 1 pl., 1:24,000, 3/03, OFR-406 . . . . **$4.00**

Interim geologic map of the Clearfield quadrangle, Davis County, Utah, by Dorothy Sack, 32 p., 1 pl., 1:24,000, 3/03, OFR-408 . . . . **$5.50**

Interim geologic map of the Roy quadrangle, Weber and Davis Counties, Utah, by Dorothy Sack, 50 p., 1 pl., 1:24,000, 3/03, OFR-409 . . . . **$7.00**

The feasibility of collecting accurate landslide loss data in Utah, by Francis X. Ashland, 25 p., 3/03, OFR-410. **$5.75**

Geologic guide and road logs of the Willow Creek, Indian, Soldier Creek, Nine Mile, Gate, and Desolation Canyons, Uinta Basin, Utah, by Craig D. Morgan, 57 p. + 16 p. appendix of 2 measured sections, CD-ROM, 3/03, OFR-407 . . . . **$14.95**

REPRINTS

Eastern and Northern Utah Coal Fields: Vernal, Henry Mountains, Sego, La Sal-San Juan, Tabby Mountain, Coalville, Henrys Fork, Goose Creek and Lost Creek, by H.H. Doelling and R.L. Graham, 411 p., CD-ROM, 1972 (reprint 1/03), ISBN 1-55791-683-7, MO-2 . . . . **$14.95**

In the footsteps of G.K. Gilbert - Lake Bonneville and neotectonics of the Basin and Range Province; Guidebook for field trip twelve, 100th annual meeting of Geological Society of America, edited by Michael N. Machette, 120 p., CD-ROM, 1988 (reprint 1/03), ISBN 1-55791-685-3, MP-88-1 . . . . **$14.95**

Great Salt Lake: a scientific, historical and economic overview, edited by J.W. Gwynn, 400 p., CD-ROM, 1980 (reprint 1/03), ISBN 1-55791-688-8, B-116. . **$14.95**

(a color version has been released) Interim geologic map of the Escalante and parts of the Loa and Hite Crossing 30' x 60' quadrangles, Garfield and Kane Counties, Utah, by Hellmut H. Doelling and Grant C. Willis, 19 p., 2 pl., 1:100,000, 2/99, OFR-368 . . . . **$7.70**

"Glad You Asked"

by Carl Ege

How do geologists identify minerals?

Even geologists can have a difficult time identifying minerals. There are over 4,000 known minerals, and approximately 80-100 new ones are discovered each year. Of all these, only a few hundred are considered common. To help with identification, geologists must look closely at the physical properties of a mineral. These properties can include: color, streak, hardness, cleavage, specific gravity, crystal form, and others.

COLOR

Some minerals can be recognized by their color: azurite is always a deep blue and malachite is green. Generally, color alone is not the best tool in identification because color can be highly variable. Some minerals can occur in a variety of different colors due to impurities in the chemical makeup of the mineral. For example, calcite is commonly white, but can be blue, brown, yellow, orange, red, gray to black, or colorless.

STREAK

A streak test is accomplished by rubbing the mineral on a porcelain plate, also known as a streak plate. The color of the streak left by the mineral is sometimes different from the color of the mineral itself. A streak test comes in handy when identifying minerals such as hematite. Hematite can be found in various colors from black to red, but it always leaves a red streak.

HARDNESS

Hardness is a measure of a mineral's resistance to abrasion. A numerical value for hardness is determined using a scale that ranges from 1 (softest) to 10 (hardest).

Developed by a German mineralogist, Friedrich Mohs, the Mohs Hardness Scale assigns hardness values to 10 representative minerals as well as other common materials (penny, knife blade, etc.). Talc is the softest mineral and diamond is the hardest mineral.

CLEAVAGE

Cleavage can be observed in minerals that tend to break along one or more flat surfaces or planes. The number of cleavage planes, and their orientations relative to each other, can be diagnostic of particular minerals. Minerals that display cleavage include: calcite, halite, fluorite, topaz, and galena. However, not all minerals have cleavage, such as quartz and pyrite.

SPECIFIC GRAVITY

Specific gravity is the relative weight of the mineral to an equal volume of water. For example, gold has a specific gravity of 15-19.3 and is thus 15 to 19.3 times as heavy as water. It is possible to make a fairly good estimate of specific gravity by checking the mineral's weight in your hand.

CRYSTAL FORM & MINERAL HABIT

Crystal form is responsible for the mineral's geometric shape and arrangement of crystal faces. The crystal form will always remain the same in every sample found of the same mineral, although the crystal form is better displayed in some samples than in others. Sometimes, growth patterns, called the mineral habit, disguise the ideal form of the crystal. However, these habits can also aid in identification. Some commonly found habits include: botryoidal (which resembles a cluster of grapes), striated (parallel grooves on crystal faces), and acicular (needle-like).

OTHER PHYSICAL PROPERTIES

Does the mineral have a taste (for example, salt)? Is the mineral fluorescent (for example, scheelite)? Does the mineral give off an odor (for example, sulfur)? Is the mineral magnetic (for example, magnetite)? Does dilute hydrochloric acid cause the mineral to fizz or effervesce (for example, calcite)? Is the mineral radioactive (for example, uraninite)?

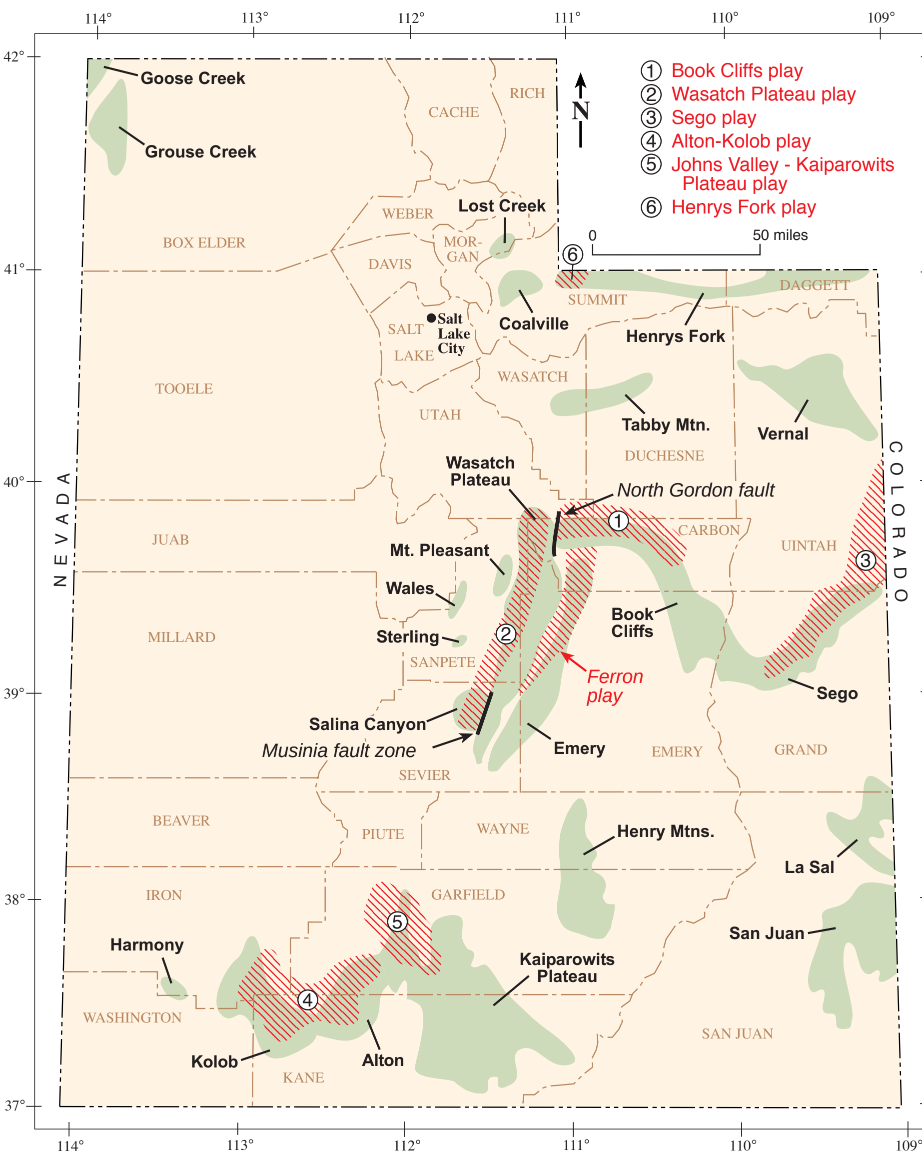
For more information regarding mineral identification guides, contact the Natural Resources Map & Bookstore – (801) 537-3320, or toll free at 1 (888) UTAHMAP.

Frontier Areas for Coalbed-Gas Exploration in Utah

by David E. Tabet and Jeffrey C. Quick

Introduction

The remarkably successful development of gas deposits in coalbeds of the Ferron Sandstone Member of the Mancos Shale in central Utah's Emery coalfield has encouraged petroleum companies to look for new coalbed-gas "plays" elsewhere in the state. There are currently six frontier coalbed-gas plays in Utah attracting industry interest: (1) Book Cliffs, (2) Wasatch Plateau, (3) Sego, (4) Alton-Kolob, (5) Johns Valley-Kaiparowits Plateau, and (6) Henrys Fork. These six frontier coalbed gas plays are in various stages of testing or development. The undeveloped portions of these six plays collectively contain an estimated in-place gas resource ranging from 2.0 to 9.8 Tcf, which is significant compared to Utah's 2001 proven gas resource of 4.6 Tcf.



Utah's six, frontier, coalbed gas plays (hatchured and numbered) in relation to the state's coal fields (shaded).

Book Cliffs Play - The best-defined frontier coalbed-gas play consists of the thick, gassy coals of the Blackhawk Formation in the Book Cliffs coalfield. Exploration began in the early 1970s, and a modest amount of coalbed-gas production took place during the 1990s. This play may be poised for full-scale development if current efforts can overcome the production problems that plagued the earlier efforts. Although extensively mined, the Book Cliffs play contains about 70,000 acres underlain by deeper coal in the Blackhawk Formation where the aggregate coal thickness ranges from 10 to 70 feet, and drilling depths range from 1,500 to 6,000 feet. The coal's gas content ranges from 60 to 435 cubic feet per ton, and thus provides a range of 0.8 to 1.9 trillion cubic feet (Tcf) of in-place gas resource. A joint venture of the J.M. Huber and Patina Oil and Gas corporations is redeveloping the previously abandoned Castlegate field; reported proven gas reserves for the 17 producing wells are over 27 billion cubic feet. A little to the east, J-W Operating Company drilled six wells in late 2002 to test the Blackhawk coals there.

Wasatch Plateau Play - Coalbeds in the Emery Sandstone Member of the Mancos Shale occur under the Wasatch Plateau of central Utah, and are not exposed at the surface. Extrapolating from a handful of oil and gas wells indicates these never-mined coals underlie about 180,000 acres of the Wasatch Plateau. At least 17 coalbeds with a collective thickness of up to 120 feet occur within the 1,600-foot-thick Emery strata. No published gas-content measurements exist for these coals, but one company reports some beds are gassier than others. The in-place gas resource for this play is estimated to range from 0.8 to 3.2 Tcf. Prima Energy Corporation is drilling on its 71,000 net acres of leases, and several other petroleum companies have drilled wells in this play recently.

Sego Play - The Neslen Formation coalbeds of the Sego coalfield are exposed along the Book Cliffs in Grand County. These coalbeds extend northward into the Uinta Basin along the Colorado-Utah state line, and underlie roughly 240,000 acres. The Neslen Formation is up to 700 feet thick, and contains an average of 14 feet of coal in one to seven beds. While shallow core samples contained less than 49 cubic feet of gas per ton of coal, there are indications the deeper coals are gassier. CDX Rockies, LLC recently tested gas contents from deeper coalbeds in the Uintah County portion of the play, but released no results. We estimate in-place gas resources range from 0.3 to 1.8 Tcf.

Alton-Kolob Play - In southern Utah, the Dakota Sandstone's coalbeds are best developed in the Alton-Kolob coalfields. The Dakota Sandstone is up to 450 feet thick and contains two coal zones. These two coal zones collectively contain up to 18 feet of coal, and have an average aggregate thickness of 13 feet. While the two reported measurements from shallow samples revealed low gas contents of 0 and 14 cubic feet per ton, this 400,000-acre play could contain nearly 1 Tcf of gas if the deeper coalbeds contain an average of 100 cubic feet per ton. Several companies have leased more than 34,000 acres in the play. Legend Energy of Utah is the most active company, and has staked 23 drill-hole locations; drilling began at two locations in November 2002.

Johns Valley-Kaiparowits Plateau Play - The thick Straight Cliffs Formation coals have attracted some interest in the Johns Valley area and the northern part of the Kaiparowits Plateau coalfield in Garfield County, outside the Grand Staircase Escalante National Monument. The 130,000-acre play contains an average aggregate thickness of 40 feet of coal within the 600- to 1,600-foot-thick John Henry Member of the Straight Cliffs Formation. A group of investors with large private holdings in the Johns Valley portion of the play is undertaking an evaluation of the coalbed gas potential on their lands. While 13 shallow samples near the outcrop had low gas contents, they hope the deeper coalbeds contain at least 100 cubic feet of gas per ton. If so, this play could contain 0.9 Tcf of gas.

Henrys Fork Play - This dual play lies in eastern Summit County, and consists of thick coals in both the Frontier and Adaville Formations. The coals are exposed in Wyoming, but in Utah they are poorly exposed or buried by younger rocks. These two coalbed gas plays occur as parallel, north-trending belts that cover a combined area of roughly 50,000 acres. Data from two Utah wells indicate that the Adaville has an aggregate coal thickness of 100 feet, while the Frontier contains an aggregate coal thickness of 50 feet. Two companies have recently tested the gas content of these coals in Wyoming, but again no results have been released. Lacking gas-content data for these coals, we estimate the in-place coalbed gas resource for both formations could range from 0.1 to 1.0 Tcf.

Survey News

Utah Core Research Center Receives Major Donation of Thin Sections

Marathon Oil Company has donated a collection of over 650 thin sections to the Utah Core Research Center. This valuable and irreplaceable collection was produced from cores taken from 32 wells in the Paradox Basin of southeastern Utah. These wells were drilled in Aneth (the largest oil field in Utah), Tin Cup Mesa, Ismay, and several other fields in the basin. This and other thin section collections at the Core Research Center are publicly available for study by students, industry, and other researchers.

Emily Toone, a volunteer from Bountiful High School, worked with Energy and Minerals Program personnel for several months analyzing mud samples from Sevier Lake with the Survey's XRF unit. Emily transformed the results of this work into an award-winning Science Fair project titled "X-ray Fluorescence Analysis of Chemical Composite of Sevier Lake," garnering top Army, Air Force, and Intel awards, the Women Geoscientists award, a Superior plaque in the Earth and Space category, and a trip to the 2003 International Science fair to be held in Cleveland, Ohio in May. Congratulations to Emily for her successful project.

GeoSights

Nature's version of a playground slide - Devils Slide, Morgan County, Utah

by Carl Ege

Geologic Information: Why take your kids to an ordinary playground slide at the park, when you can go to the slide named after the Devil himself? Unfortunately for sliders, Devils Slide is not a real slide, but an unusual geologic feature found in northern Utah.

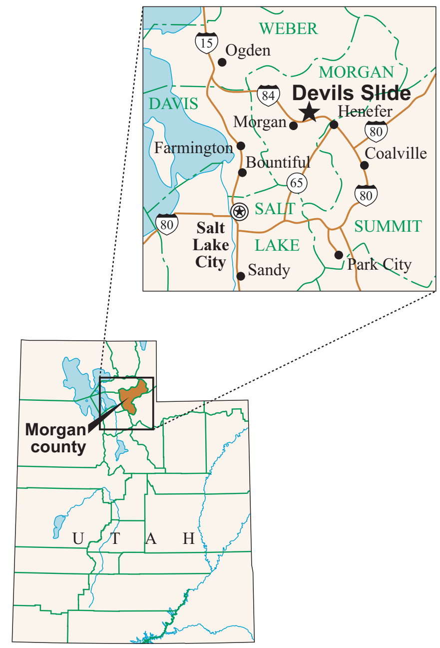
Devils Slide is a classic example of how different rock layers, depending on their composition, are affected by weathering and erosion. The sides of the slide are hard, weather-resistant limestone layers about 40 feet high, 25 feet apart, and several hundred feet in length. In between these two hard layers is a shaly limestone that is slightly different in composition from the outer limestone layers. This middle layer is softer, which makes it more susceptible to weathering and erosion, thus forming the chute of the slide.

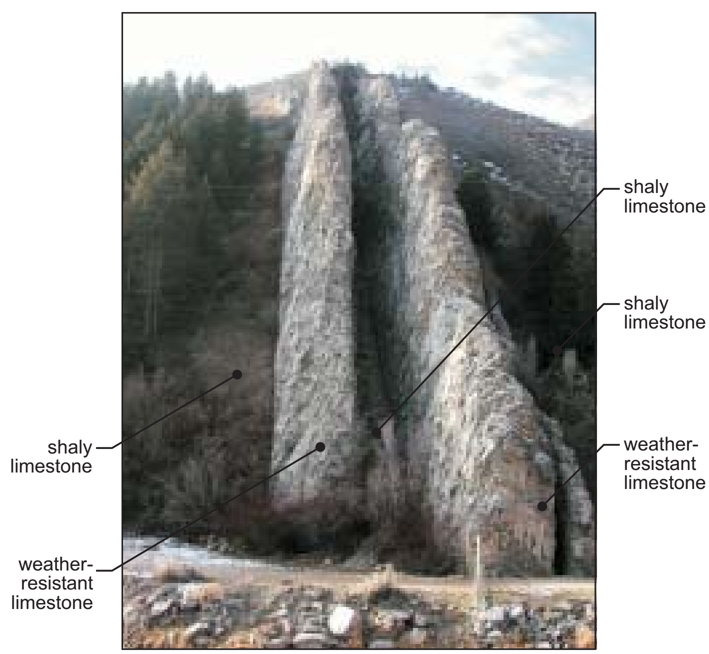
Looking like a large playground slide fit only for the Devil, this site is a tilted remnant of sediments deposited in a sea that occupied Utah's distant geologic past. Approximately 170 to 180 million years ago, a shallow sea originating from the north spread south and east over areas of what are now Montana, Wyoming, and Utah. This sea extended as far east as the present-day Colorado River and south into northern Arizona. Over millions of years, massive amounts of sediment accumulated and eventually formed layers of limestone and sandstone. In northern Utah, these rocks are known as the Twin Creek Formation and are approximately 2700 feet thick. About 75 million years ago, folding and faulting during a mountain-building episode tilted the Twin Creek rock layers to a near-vertical position. Subsequent erosion has exposed the near-vertical rock layers and created Devils Slide.

How to get Devils Slide:

*From the I-15/U.S. Highway 89 interchange in Farmington; head north on U.S. Highway 89 for 10.7 miles to a sign indicating the route to Morgan and Evanston. Turn right (east) on I-84 and travel approximately 23 miles to the scenic viewpoint turnoff located after milepost 110.

*From the southern I-15/I-80 interchange in Salt Lake City; head 11.3 miles east on I-80 to exit 134 (Mountain Dell Recreation exit). Travel north on Utah State Highway 65 for 27.7 miles to the town of Henefer. Turn left (west) and proceed 1 mile to I-84. Turn left (west) onto I-84 and travel 2 miles to the scenic viewpoint turnoff located just after milepost 111.





Devils Slide looking from the south. Gate in the foreground for scale.

Teacher's Corner

Neither snow nor rain (nor hip-deep water, sting of brine, heat of sun, muck of mud, nor sight of rattlesnakes) stays these UGSers and others from completing their mineral collecting expeditions.

Every year, UGS staff donate time with other volunteers, family members, and friends to venture out to collect rock and mineral samples to help keep the UGS and others in supply. Many of the samples are for the UGS rock and mineral kits. The UGS did not have these resources until 1994 when a staff member's son put together a collection for his Eagle Scout project. Thus began the UGS collection: cardboard boxes with 41 numbered and identified rocks, minerals, and fossils from Utah. Since then, the kits have been updated with sturdy containers, information packets, and now hold 68 specimens. In addition to the samples kept in these kits, the UGS provides hundreds of rock and mineral specimens every year to students for special events such as Earth Science Week and school science fairs.

We have also been fortunate to occasionally receive donations from various individuals and organizations to enhance our collection, especially of the harder-to-find specimens. Thanks to the fortitude of many contributors and permission of property owners, the UGS truly has a wealth of rock, mineral, and fossil specimens.

Rock, mineral, and fossil kits (we also have earthquake and dinosaur kits) are available for one-month loans, with a $25.00 refundable deposit. Contact us at 801-537-3300.

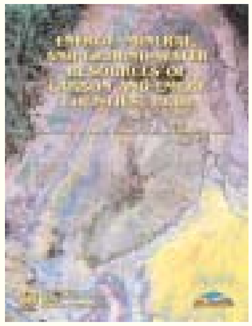
Collecting topaz specimens at Topaz Mountain.

Mucking for gypsum samples at MagCorp on the edge of Great Salt Lake.

Prying salt crystals at Cargill Salt adjacent to Great Salt Lake.

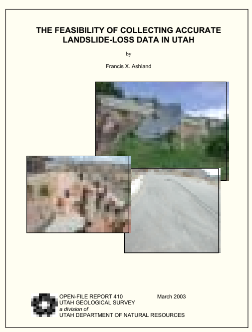
New UGS Publications

Energy, Mineral, and Ground-Water Resources of Carbon and Emery Counties, Utah



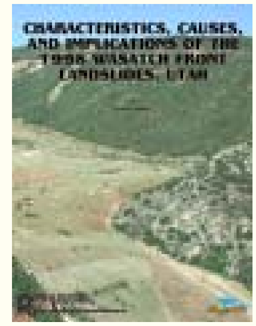
Collects and evaluates information on the known and potential energy, mineral, and ground-water resources in Carbon and Emery Counties. This report provides information for use in both short- and long-term land-planning decisions, particularly at the county level, and an indication of the present and future economic impact of mineral and energy development. Eight major commodity groups discussed: (1) oil and gas, (2) coal and coal resin, (3) coal-bed methane, (4) other energy resources (oil-impregnated rock, oil shale, geothermal), (5) uranium and vanadium, (6) metallic minerals, (7) industrial rocks and minerals, and (8) ground-water resources. 14 maps at a scale of 1:750,000 detail each commodity. B-132 . . . . $15.95

The feasibility of collecting accurate landslide loss data in Utah



This report evaluates the feasibility of collecting more accurate landslide loss (cost) estimates in Utah. Focus is on the current availability of landslide-loss data, using recent case histories. The report also compares the accuracy and availability of data from sources including media reports, county tax assessor's records, building permits, and estimates by local government officials and affected property owners. It also evaluates the potential for retrospective landslide-loss estimation using publications on the 1983 Thistle landslide, the most costly historical landslide in the U.S. OFR-410 . . . . $5.75

Characteristics , causes, and implications of the 1998 Wasatch Front landslides



Damaging landslides in the Wasatch Front increased dramatically in the late 1990s and likely caused over $1 million in damages. This publication examines the relation between long-term periods of increased precipitation in northern Utah, rising ground-water levels, and decreasing hillside stability, particularly in pre-existing landslide areas.

Using historical precipitation data, the importance is shown of excess precipitation from multiple successive wet years as the primary cause of rising ground water levels in Wasatch Front landslides. Hillside modifications for residential development along the Wasatch Front further reduce the stability of many landslides, often accelerating the rise in ground-water levels; a temporary rise associated with the late winter snowmelt and early spring wet months was locally sufficient to trigger movement in the late 1990s.

Examining the characteristics of damaging landslides concludes that the short duration and very slow rate of movement can preclude the easy recognition of movement by homeowners, building officials, and even geologists.

Also included: ten case histories; land-use approaches for future hillside development; important data on soil strength, landslide movement, and ground-water-level fluctuations; recommended approaches for landslide investigations SS-105 . . . . $8.00

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