U T A H   G E O L O G I C A L   S U R V E Y

SURVEY NOTES

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Nine Mile Canyon

TABLE OF CONTENTS

A Lake Divided - A History of the SPRR Causeway and Its Effects 1

New Publications 4

Too Many Wells — or Too Few 5

GeoSights: Pahvant Butte 8

Large Boulder Damages Rockville Home 9

Renaissance in Oil Shale Leasing on State Lands 10

Energy News: UGS Awarded DOE Grant 11

Teacher's Corner: Use a Settling Container 12

Glad You Asked: Crunchy Crusts on Utah Soils 13

Design by Vicky Clarke

Cover: *Nine Mile Canyon and a few of its petroglyphs.*

The Director's Perspective

by Richard G. Allis

The year 2001 has been one of the most volatile for energy-related commodities since the oil supply problems of the mid-1970s and the early 1980s. In Utah, average monthly natural gas prices peaked at over $9/mcf and electricity prices peaked at over 40 c/kWh early in the year (figure 1). Late in the year, the gas price fell to around $1/mcf, but it has since rebounded to about $2.60/mcf. Electricity has returned to its more normal range of 2 to 4 c/kWh. The local oil price declined from relatively high values of $25 to 30/barrel early in the year to less than $20/barrel in early December. The local coal price has been much more stable, probably because its price is dominated by long-term contracts.

The price volatility has demonstrated that, despite being relatively rich in energy resources, Utah is hooked into regional and national energy networks, and demand fluctuations elsewhere dominate prices here. This volatility has a flow-on, negative effect on investment in energy exploration and development. Although on a decadal time scale Utah and its surrounding western states will need more electricity (annual growth rate of 3%/y), and increased production of gas, coal, and oil, short-term price instability is inhibiting the much-needed exploration investment. Figure 2 shows that 2001 has been a boom year for exploration drilling – more productive oil and gas wells have been drilled than in any previous year (540), with most of these being gas wells. What is obscured by the annual averages is that the number of active rotary drill rigs in Utah has fallen rapidly late in the year to between 12 and 16 during December 2001. This is less than half the number active during the summer of 2001, and two less than 12 months ago. Applications for new drilling permits during late 2001 are less than half those from the same time in 2000. Unfortunately drilling activity is following the volatility of energy prices.

The pattern of drilling in Utah during 2001 indicates a risk-averse strategy to exploration. Despite being a boom year for drilling activity, the number of wildcat wells has declined to its lowest levels since this parameter was monitored closely (< 3% of total completed wells). Figure 2 shows that during the earlier boom years of the 1980s, about a third of all wells were "dry." In 2001, only 4% of wells were "dry," and interestingly, two-thirds of the few wildcats drilled were actually new discoveries. Utah has the potential for new field discoveries, and these wells will be essential for sustaining long-term oil and gas production in the state. However, the present rate of wildcat drilling means that the chances for finding new fields are slim.

One drilling parameter that is an indicator of drilling for new oil and gas plays in 2001 is the depth of the wells (figure 3). Prior to the mid-1990s, the depth profile of all wells was unimodal, peaking at around 6,000 feet. In 2001, the pattern is tri-modal, with a greater percentage of wells now being drilled below 10,000 feet. These

Continued on back cover...

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A Lake Divided - A History of the Southern Pacific Railroad Causeway and Its Effect on Great Salt Lake, Utah

by J. Wallace Gwynn

Introduction

The State of Utah is faced with the task of providing a balance between using Great Salt Lake's natural resources and maintaining a healthy lake ecosystem. Often at odds are the production of mineral salts and brines worth over $200 million annually, hydrocarbon exploration, and brine-shrimp-cyst harvesting worth over $100 million annually; implementing flood-control measures; maintaining proper brine salinities; and protecting thousands of acres of wetlands and the islands which are home to millions of birds including the American white pelican and California gull. The lake's ecosystem, its wetlands in particular, have very high environmental value. This balancing task is complicated by the unpredictable rise and fall of the lake, and the effects of the Southern Pacific Railroad (SPRR) causeway on the lake's salinity and chemistry. The causeway serves as a major transportation corridor and divides the lake into two parts. This article focuses on the history of the causeway, its effects on the lake (in particular brine flow and concentration), and the measures the State has taken to maintain a healthy ecosystem.

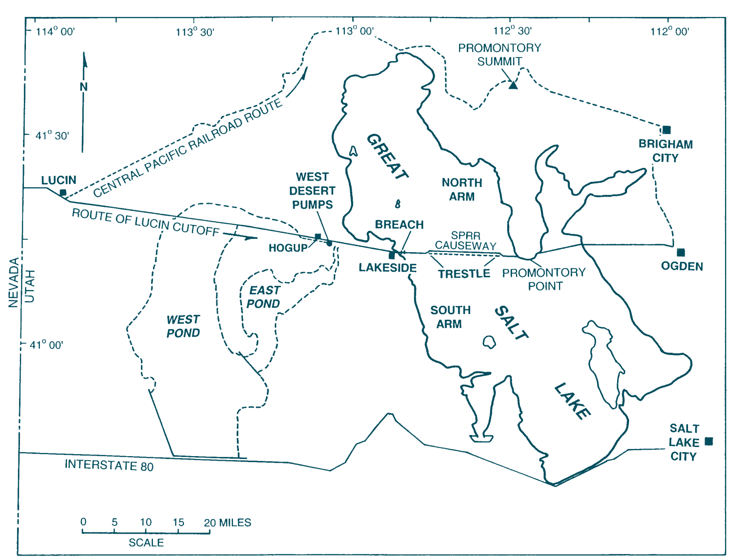
Effects of the SPRR Causeway on Brine Flow

On May 10, 1869, the completion of America's first transcontinental railroad was celebrated by the driving of the Golden Spike at Promontory Summit, near the north end of Great Salt Lake. Thirty-five years later, the Southern Pacific Railroad (SPRR) completed the Lucin Cutoff. The Cutoff traversed a route east from Lucin, located about 8 miles east of the Nevada/Utah state line, then across the lake, and on to Ogden. The original Central Pacific Railroad traversed a more difficult route, about 42 miles longer, from Lucin, around the north end of the lake to Brigham City, and then southward to Ogden. The portion of the Cutoff crossing the main body of Great Salt Lake consisted of two earth- and rock-fill embankments, one extending eastward into the lake from Lakeside and

*Great Salt Lake brine shrimp (*Artemia franciscana*) and cysts (eggs), (a male shrimp is in upper right, a female shrimp at lower right. The cysts (eggs) are the small, bright circles scattered throughout the photo. Photo courtesy of the U.S. Geological Survey.*

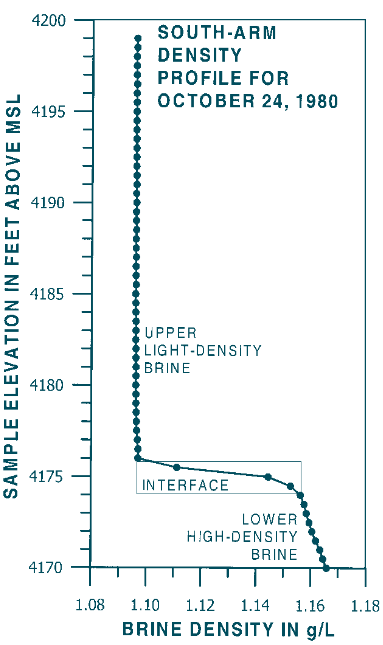
the other extending westward from Promontory Point, with a 12-mile open, wooden trestle in between. A shorter section of rock-fill embankment extended eastward from Promontory Point to the mainland. The open trestle offered little resistance to the movement and circulation of brine throughout the lake.

By the mid-1950s, Southern Pacific personnel deemed the trestle to be in need of major repairs or replacement. Engineering studies led to a decision to construct a 13-mile



rock-fill causeway parallel to and 1,500 feet north of the trestle. Construction began in 1956 and was completed in 1959 at a cost of $53 million. With the causeway's completion, the main body of the lake was partitioned into two bodies of water, the north arm and the south arm.

The causeway immediately reduced the mixing of brine between the north and south arms, and three notable changes were observed. First, the south-arm brine became less saline than the north-arm brine because all three of the major tributaries (the Bear, Weber, and Jordan Rivers) flow into the south arm. The north arm mainly received salty water that moved through the causeway from the south arm. The north arm also received less annual precipitation, and experienced slightly higher evaporation rates than the south arm, accentuating the salinity imbalance. Second, a surface-elevation differential developed across the causeway between the two arms of the lake, with the surface elevation of the south arm three and one-half feet higher than that of the north. Third, the brine in the south arm became density stratified shortly after the causeway was completed, a condition in which a brine of greater density lies on the bottom of the lake, and is overlain by an upper layer of less dense brine. The two brines are separated by a transitional zone called the interface. The greater density south-arm brine comes from, and is maintained over time by, the north-to-south flow of north-arm brine moving through the lower part of the causeway fill, and through the deeper portions of the two culverts in the causeway.



Lake brines can flow simultaneously both to the south and to the north through the causeway and its openings (referred to as bi-directional flow). Under the right hydrostatic conditions, including a surface-elevation differential (the south arm being the highest), and a density difference (the north-arm brines being the densest), there is a critical depth below the water surface at which the hydrostatic pressure of the column of brine on both sides of the causeway is the same. Above this depth, brines flow from south to north through culvert openings or through the causeway fill material; below this depth, brines flow from north to south.

Fluctuations in Lake Level Introduce New Challenges

From the time of the causeway's construction in 1959 until 1987, Great Salt Lake experienced its greatest recorded changes in surface elevation, from its low of 4,191.35 feet in 1963 to its high of 4,211.85 feet in 1987. Within this range of over 20 feet, the lake rose above and fell below its "normal" surface elevation of about 4,200 feet. Beginning in 1982-83, the lake began to rise from its "normal" elevation of 4,200 feet. The south arm rose five feet in 1983, over four feet more in 1984, and nearly three feet more by 1987 to its historical high of 4,211.85 feet.

South-arm brine pouring into the north arm through the newly created breach in the Southern Pacific causeway during the opening ceremonies on August 1, 1984.

With this rise came extensive flooding, especially around the southern arm of the lake. Roads, farms, wildlife management areas, and other facilities were inundated. State officials reviewed a number of options, and decided that breaching the causeway would bring the most immediate relief from the flooding. The breach would be constructed as a bridged opening 300 feet long, with a design bottom elevation of about 4,195 feet. Unfortunately, during construction the bottom elevation of the breach was not built at the design elevation of 4,195 feet, but was completed somewhat higher at about 4,200 feet.

The breach was quickly completed, and on August 1, 1984, south-arm water flooded into the north arm. Within two months, the head differential between the south and north arms had decreased to less than one foot. As the whole lake continued to rise, however, the hydrostatic conditions within the breach opening became favorable for bi-directional flow to occur. During the period from 1984-88, large volumes of south-arm water flowed through the upper portion of the breach opening into the north arm. By 1987, the salinity of the north arm had dropped from its 1981 level of about 27 percent salt to about 18 percent. At the same time, large volumes of north arm brine were flowing into the south arm as return flow, adding to the south arm's intermediate density brine layer. Between mid-1984 and mid-1986, the elevation of the south-arm interface had risen about 12 feet due to the large influx of dense north-arm brine.

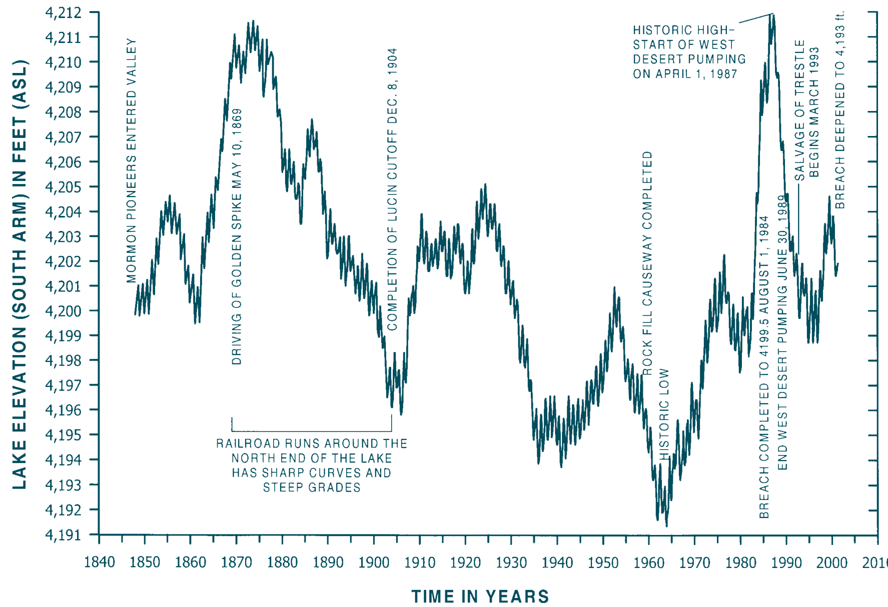
Even as the State opened the breach in 1984, the lake continued to rise, and the State decided to pump water from the lake westward into the Great Salt Lake desert (informally known as the West Desert) to provide additional evaporation area. This project became known as the West Desert Pumping Project. Three large pumps were installed near Hogup, about 13 miles west of Lakeside, that lifted brine from the north arm of the lake into a 4.1-mile canal, where it flowed westward into a shallow depression called the West Pond, located west of the Newfoundland Mountains. Pumping started on April 1, 1987, and continued through June 30, 1989. During this time, about 2.2 million acre-feet (153 billion gallons) of brine was pumped from the north arm of the lake into the West Pond. Concentrated brines were returned to the lake through the East Pond. Pumping contributed about 26 inches to the total lake-level decline of 5 feet during that period of time.

From 1989 through the mid-1990s, the lake level continued to drop. From 1993-94 through 1997-98 there was some south-to-north flow through the breach opening, but no north-to south return flow. Then, as the lake started to rise again in 1998, large volumes of south-to-north flow moved through the breach opening, but still no north-to-south flow occurred. As a result, the salinity of the south arm of the lake experienced a steady decline from 1994 through 1999. During this time, the south-arm salinity dropped from about 14 weight-percent salt in 1994 to only about 7 weight-percent in 1999. The north-arm salinity, on the other hand, remained near 25 weight percent salt.

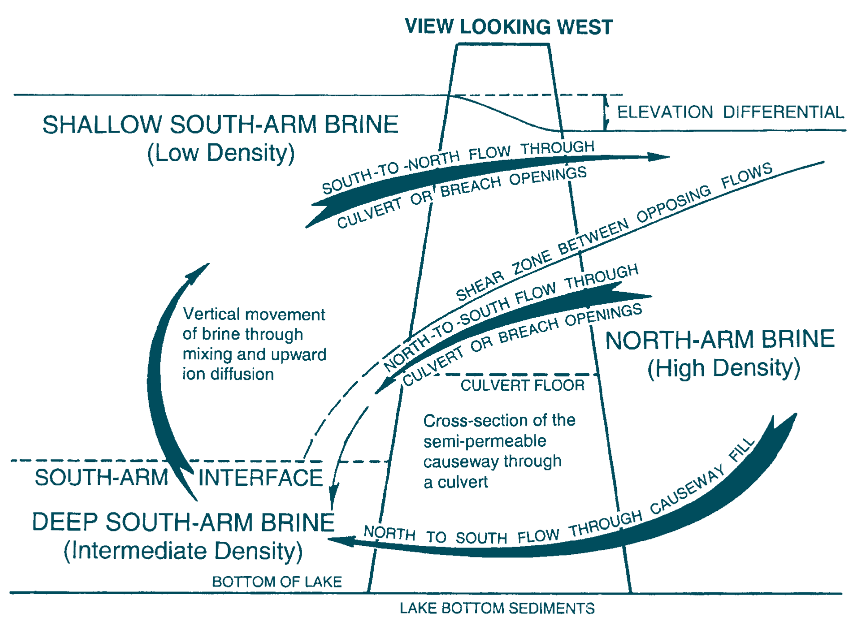
Development of a Plan to Restore a Healthy Lake Ecosystem

The steady decline of the south-arm salinity raised concerns about the future of the brine shrimp industry, the south-arm mineral extraction industry, and the overall ecological health of Great Salt Lake. One of the main effects of declining salinity on the lake's ecological health was a decline in the brine shrimp (*Artemia franciscana*) population, determined in part by the quantity and quality of the cysts collected during the annual brine-shrimp-cyst harvest. From the 1995-96 through 1999-2000 seasons, there was a steady decline in the total pounds of harvested raw biomass (shrimp cysts and debris), and a decline in the hatch rate of the eggs. Ongoing studies by the Utah Division of Wildlife Resources also suggested that the declining salinities of the lake would not only affect the brine shrimp population adversely, but also the birds that eat the brine shrimp. Additionally, lower salinity could result in an increase in algae in the lake (because fewer brine shrimp would be present to eat the algae). Eventually the overall ecological balance of the lake could be affected. The declining brine concentrations also meant less concentrated feed brines for salt companies, resulting in reduced yearly salt or brine harvests, and lower profits.

Because of these concerns, the State intensified its study of



Great Salt Lake hydrograph showing time line of events related to the Southern Pacific Railroad, the causeway, and other significant events.



Schematic diagram showing bi-directional flow through a causeway culvert, and through the causeway fill. Low-density, south-arm brine flows northward at the surface while high-density, north-arm brine flows southward at depth into the bottom of the south arm forming a layer of intermediate-density brine. The low-density brine (top) is separated from the intermediate-density brine (bottom) by the south-arm interface.

the lake system to determine (1) the cause(s) for the decline in south-arm salinity, (2) the effects of declining salinity on the overall ecology of the lake, and (3) what could be done to minimize or reverse the decline.

To help determine the cause(s) of the decline in south-arm salinity, the U.S. Geological Survey (USGS) updated its "water and salt balance" model of the lake. The model was designed to (1) help predict the long-term changes in the lake if nothing were done, (2) determine the effects that modifying the causeway would have on north- and south-arm salinities, (3) measure the hydraulic conductivity of the causeway fill (a critical component of brine flow through the causeway), (4) determine the effect of keeping the two culverts clean versus letting them remain unattended and plugged most of the time, and (5) help in developing future West Desert pumping scenarios should the lake rise again.

USGS computer modeling determined that the hydraulic conductivity of the causeway (a measure of how easily the brine flows through the causeway fill) was significantly lower after the 1980s flooding than it was before. A possible cause for this decline was the addition of fill material by the Southern Pacific Railroad during the 1980s, as it raised the level of the causeway to keep the tracks above water. Over 500,000 tons of crushed ballast and over 3 million cubic yards of quarry-run rock were used.

In the State's search for a solution to the declining salinity of the south arm, further computer modeling was done by the USGS and the Utah Division of Water Resources. This modeling suggested that the amount of north-to-south, high-density brine moving through the breach opening could be increased by deepening the existing breach opening, and keeping the two culverts free of debris. Through this action the overall salinity of the south-arm brines would be increased over time.

Based on this information, the State decided to deepen the breach. By December 2000, crews had deepened the breach opening to a completed bottom elevation of 4,193 feet. Flow measurements made by the USGS show that the new average-flow rate through the deepened breach is 330 percent greater than for the years 1998 through 1999. Density profiles show that the increased flow of brine is both increasing the salinity and the thickness (volume) of the deep, south-arm brine.

Summary

The SPRR causeway has played, and continues to play, a significant role in the history and health of Great Salt Lake. The causeway's history is an interesting story about how human attempts to re-engineer nature produce unexpected impacts. While the causeway has served as an important transportation corridor for rail traffic, it has divided the lake into two separate bodies of water, restricted the mixing of brine throughout the lake, and caused the two arms to develop their own chemical and hydrological characteristics over time. The high salinities in the north arm have been more favorable for mineral extraction than the low salinities in the south arm. The variable south-arm salinities have also presented a challenge to the mineral and brine shrimp industries, and a threat to the overall ecology of the lake. To reverse the salinity decline in the south arm of the lake, the causeway breach was deepened in 2000 to increase the return flow of high-salinity brine from the north arm into the south arm, which hopefully will restore some balance to the complex Great Salt Lake ecosystem.

Acknowledgments

Data used in this article came from the Utah Geological Survey; Utah Division of Water Resources; Eckhoff, Watson, and Preator Engineering; Southern Pacific Railroad; and U.S. Geological Survey.

Note: The Great Salt Lake Management plan is available at the Natural Resources Bookstore.

NEW UGS PUBLICATIONS

Soil and rock causing engineering geologic problems in Utah, by W.E. Mulvey, 23 p., 2 pl., 1:500,000, 1992, SS-80 (reprinted) $9.00

Geologic map of the Podunk Creek quadrangle, Kane County, Utah, by Terry L. Tilton, 18 p., 2 pl., scale 1:24,000, 9/01, MP-01-3 . . . . $8.95

Delineation of drinking water source protection zones for the Monte Verde public water supply well, Utah County, Utah, by Charles E. Bishop, 19 p. + 18 p. appendix, 10/01, RI-249 . . . . $4.30

Geologic map of the Alton quadrangle, Kane County, Utah, by Terry L. Tilton, 22 p., 2 pl., scale 1:24,000, 11/01, MP-01-4 . . . . $9.65

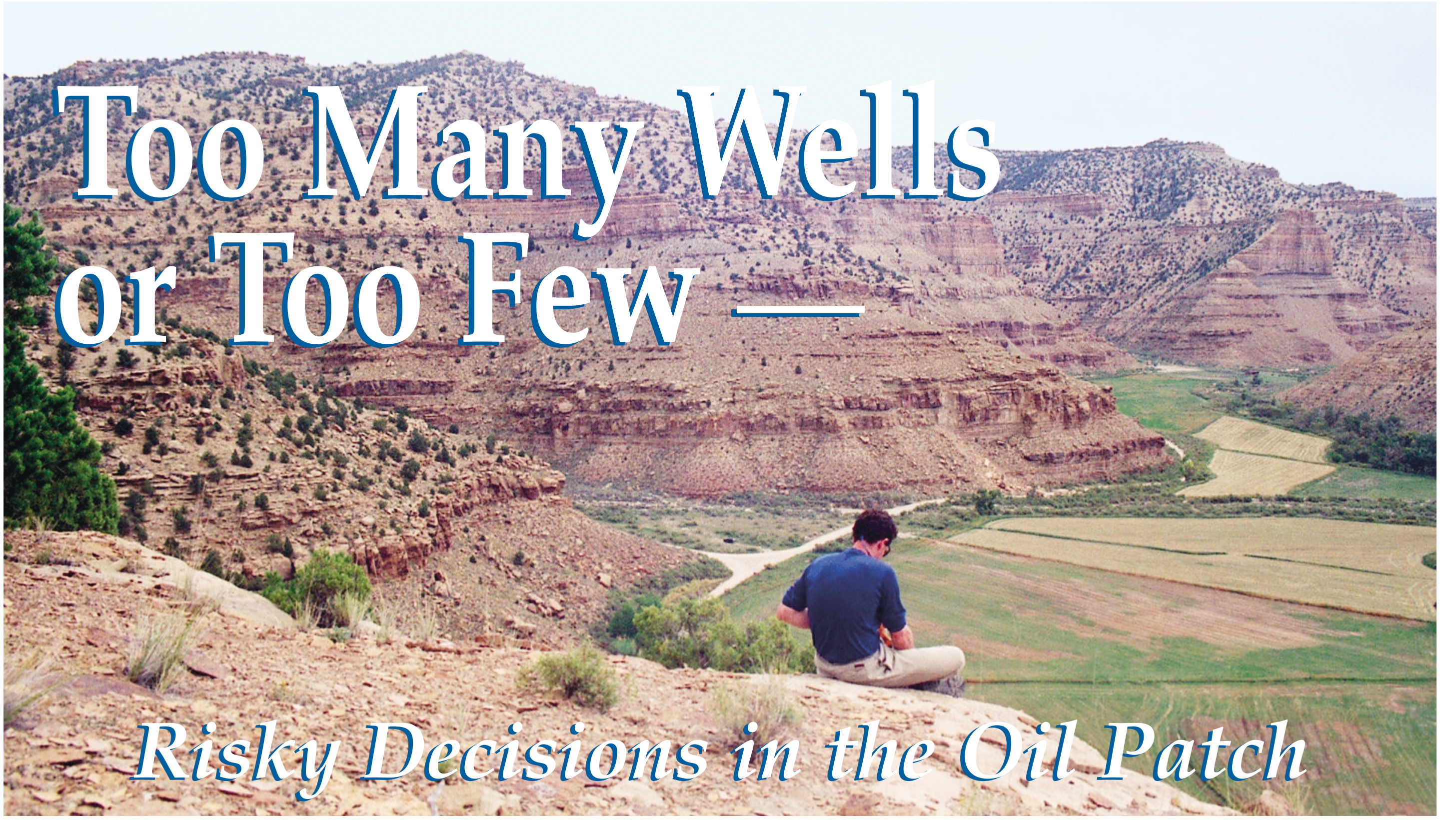
Geologic map of the Moroni Peak quadrangle, Wayne County, Utah, by Stephen R. Mattox, 14 p., 2 pl., scale 1:24,000, 11/01, MP-01-5 . . . . $6.00

Photo essay of four Utah earthquakes, 1921-1962, by Sandra N. Eldredge and Edith H. O'Brien, 22 p., 11/01, PI-72 . . . . $3.00

Landslides: What they are, why they occur, by William F. Case, color flyer, 11/01, PI-74 . . . . Free

Using geologic-hazards information to reduce risks and losses - a guide for local governments, by Barry J. Solomon, 6-page color brochure, 12/01, PI-75 . . . . Free

Site-response characterization for implementing SHAKEMAP in northern Utah, by Francis X. Ashland, 10 p., 2 pl., 1:500,000, 10/01, RI-248 . . . . $9.50



Too Many Wells or Too Few —

Risky Decisions in the Oil Patch

View from atop the Nutter's Ranch study site looking northeast to the junction of Nine Mile Canyon with Gate Canyon.

by Craig Morgan, Kevin McClure, and Tom Chidsey

Drilling for oil is risky business whether in Utah or anywhere else in the world. Companies or individual prospectors drill a wildcat well in the hope of finding a new field or oil reservoir. Typically one or two new discoveries will be made for every 10 wells drilled, or a 10 to 20 percent success rate. Once a new oil field is discovered, development wells are usually drilled to extract the oil. Although the success rate of development wells is generally higher (about 80 percent), both natural resources and money can be lost if the field is not properly developed. If too few wells are drilled, large amounts of oil will be left in the ground, but drilling too many wells is expensive and can result in a financial loss to the company. Therefore, an important aspect in the development of any oil field is to determine the minimum number of wells needed to economically (price of oil versus cost of drilling and producing a well) produce the maximum amount of oil.

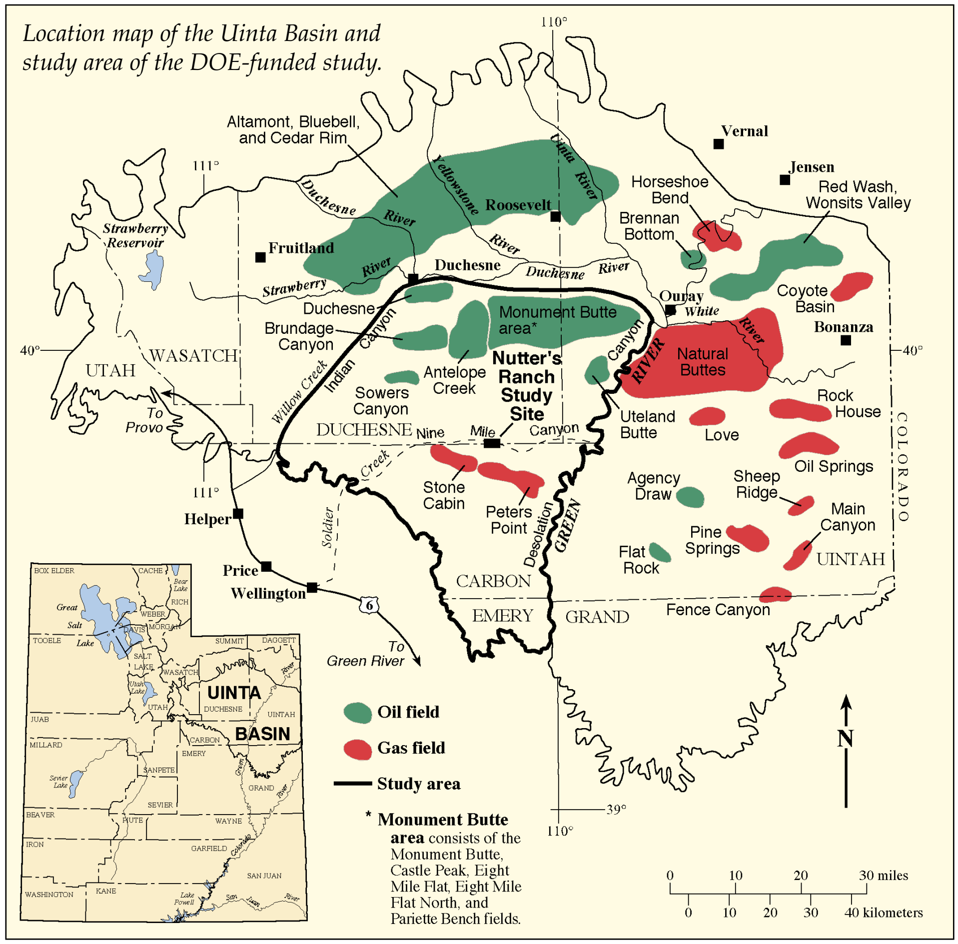
One method to help determine the number of wells needed to economically extract oil from a reservoir is to study the reservoir rock where it is exposed at the surface, typically many miles from where the rock produces in the subsurface. Geologists can develop models of how the oil and water might move through the rock by observing how the reservoir rock changes (the reservoir heterogeneity) vertically and horizontally on the outcrop. The model can be used to simulate fluid flow and well production under different scenarios to determine the most efficient spacing (distance between wells).

In the Uinta Basin of northeastern Utah, the Utah Geological Survey (UGS) is studying the reservoir characteristics of the Green River Formation in the subsurface and where the rocks are exposed at the surface. One aspect of the study is to model the reservoir heterogeneity over a distance equal to the distance between wells in the Monument Butte area (1,320 feet). To do this, the UGS studied a 100-foot-thick, 2,000-foot-long section of the Green River as exposed along Nine Mile Canyon, northeast of Price, referred to as the Nutter's Ranch study site.

More than 700 wells in the Monument Butte area of the Uinta Basin are producing oil, or injecting water to help produce oil, from the Eocene Green River Formation at a drill depth of about 5,500 feet. In this area, oil companies typically drill one well in the center of each 40-acre tract, resulting in 16 wells per square mile with 1,320 feet between wells. In a group of 16 wells, every other well will be used to produce oil and the wells in between are used to inject water in a process known as water flooding. Water injected into the sandstone reservoir rock pushes the oil towards the producing wells.

The Green River Formation consists of thousands of feet of interbedded sandstone, limestone, and mudstone that were deposited along, or near, the shore of ancient Lake Uinta. The lake occupied the present-day Uinta Basin between 55 and 45 million years ago. The shoreline and depth of Lake Uinta were constantly changing, resulting in a complex vertical and lateral mix of deposits. Channel and shallow-lake sandstone deposits are the primary oil reservoirs. The oil is derived from organic-rich mudstone that was deposited in deeper parts of the lake. The Nutter's Ranch study site contains a typical mix of sandstone, limestone, and mudstone.

The Nutter's Ranch study site was photographed, vertical sections were measured and described, and individual bed boundaries were field checked and mapped on a photomontage. Two imaginary wells 1,320 feet apart were "drilled" through the two-dimensional representation of the study site. Both "wells" encounter, from top to bottom, a limestone bed, two reservoir-type sandstone beds with interbedded mudstone, a very thin sandstone, a mudstone, and a limestone bed. Using just the well data, the simplest interpretation is that the reservoir rocks are continuous between the two wells. However, significant reservoir heterogeneity exists between the two wells based on the outcrop observations. The upper sandstone bed is actually two beds with different internal features that may not allow fluid to flow between

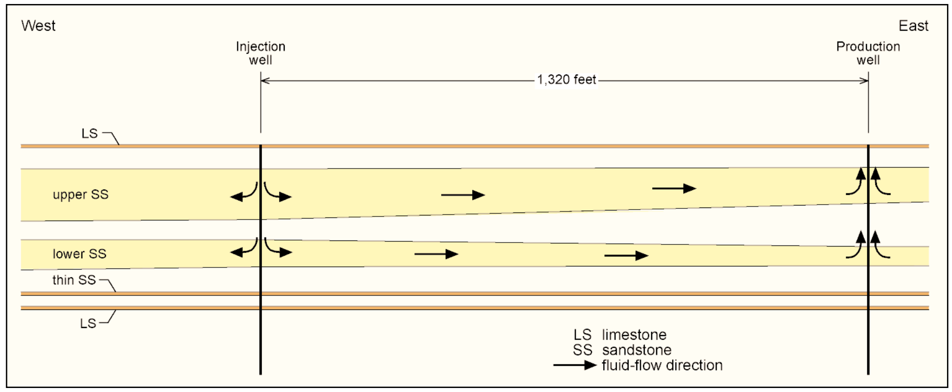


Location map of the Uinta Basin and study area of the DOE-funded study.

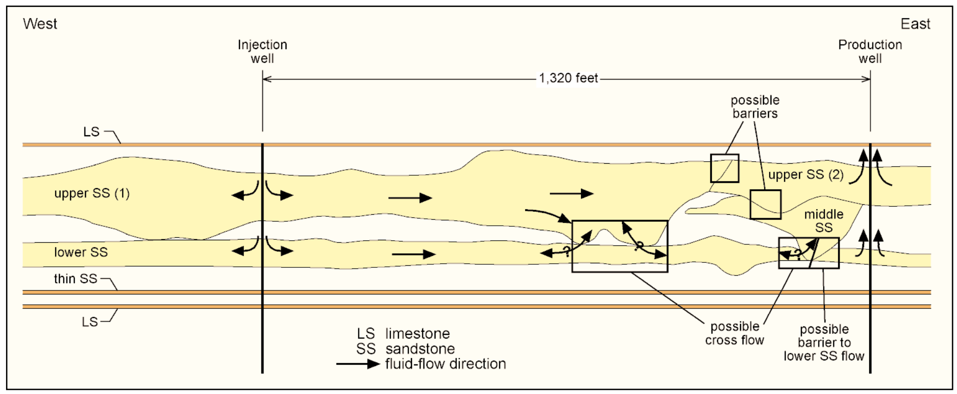
them (a barrier) if they were in the subsurface. The lower sandstone bed is nearly cut out by a middle sandstone bed that is not penetrated by either well. Oil in the middle bed may not be "produced" at all. In a few places the upper sandstone bed is in contact with the lower sandstone bed, which could complicate the fluid flow pattern by creating cross flow between the beds. The fluid-flow pattern can change significantly with different well placements and by changing the spacing between wells. The fluid flow scenarios become even more complicated if one sandstone bed contains oil and the other bed contains water.

In the Nutter's Ranch study site, hypothetical wells drilled 1,320 feet apart would probably leave a significant quantity of oil in the ground, and

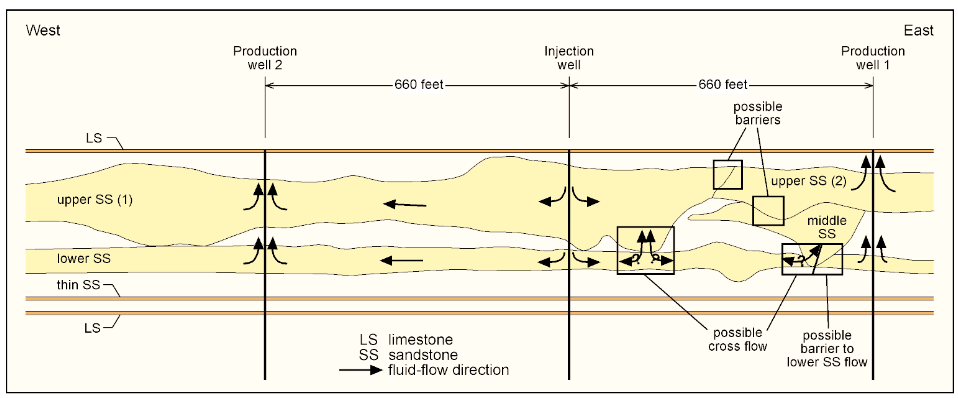
Photomontage of the Nutter's Ranch study site. The upper and lower markers are thin continuous limestone (Ls) beds that were used to define the vertical limits of the study.



Hypothetical two-dimensional correlation and potential fluid-flow pattern between two imaginary wells "drilled" at the Nutter's Ranch study site. The correlations are based only on the data the "wells" penetrate and assume a continuous reservoir (upper SS and lower SS) between the two wells.



Actual two-dimensional correlation and potential fluid-flow pattern between the same two imaginary wells "drilled" at the Nutter's Ranch study site as in the previous figure. The water flood effectiveness and the "total oil produced" is much less than in the hypothetical model due to the reservoir heterogeneity. If a barrier exists between the upper SS (2) and the upper SS (1), and a barrier exists between the middle ss and the lower ss, then oil in the upper SS (1) and most of the oil in the lower ss will not be produced. Oil in the middle SS will probably not be produced. The production "well" will only produce oil from the upper SS (2) and a very limited amount of oil from the lower SS.



Actual two-dimensional correlation and potential fluid-flow pattern assuming a third imaginary well drilled between the two wells (shown in the previous figures) "drilled" at the Nutter's Ranch study site. The volume of oil recovered from the three-well model should be larger than the volume recovered from the two-well model. If a barrier exists between the upper SS (2) and the upper SS (1), and a barrier exists between the middle SS and the lower SS, then the oil between the injection well and the barriers will not be produced by production well 1. As in the two-well model, production well 1 will produce oil from the upper SS (2) and a limited amount of oil from the lower SS. However, oil in the upper SS (2) and lower ss between the injection well and production well 2 will be produced. Oil in the middle ss will probably not be produced.

wells drilled 660 feet apart would probably be needed to produce much of the oil. However, more work is necessary to determine if additional drilling will be economical. The next steps in the study will be to:

I. Expand the geological and fluid-flow model to the third dimension to represent an actual field-size reservoir, a quarter square mile for example.

II. Calculate the increased oil recovered by drilling wells 660 feet apart instead of 1,320 feet apart.

III. Calculate the value of the increased oil production versus the cost of drilling, completing, and producing the additional wells, based on an estimated range of oil prices and costs.

For more information about the Green River Formation study visit www.ugs.state.ut.us/greenriver/greenriv.htm or at geology.utah.gov/emp/greenriver/index.html.

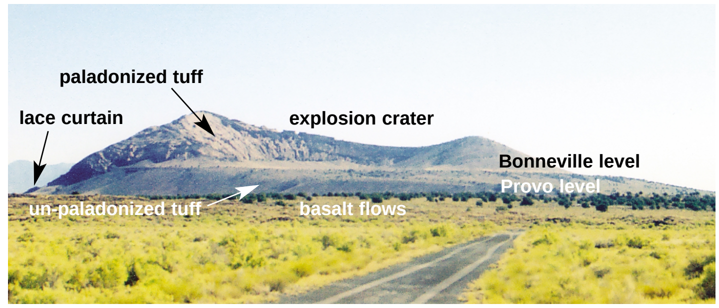
Acknowledgment

The study of the Green River Formation is part of a three-year project entitled *Reservoir Characterization of the Lower Green River Formation, Southwest Uinta Basin*. The study is partially funded by the U.S. Department of Energy (DOE) National Petroleum Technology Office in Tulsa, Oklahoma under the Fundamental Geoscience for Reservoir Characterization program, Virginia Weyland (DOE) contract manager.

GeoSights

Pahvant Butte in the Black Rock Desert, Millard County, Utah

by William F Case



Eastward view of Pahvant Butte along the turn-off from the Clear Lake Bird Refuge road.

With a tremendous explosion a volcano primed with superheated steam erupts underwater, spewing enough volcanic ash and cinders high into the atmosphere to turn day into night. The ash covers the surrounding area like snow. Wind piles ash in drifts downwind of the volcano. Large waves race over the surface of the water and crash violently onto nearby shores. Flying birds drop dead from breathing sulfur and ash. Is this a "Geofantasy" scenario, perhaps? Actually, this scenario is compiled from accounts of many worldwide historical eruptions including the 1963 Surtsey eruption that created a new island near Iceland. And perhaps this scenario was the story of the creation of Utah's Pahvant Butte

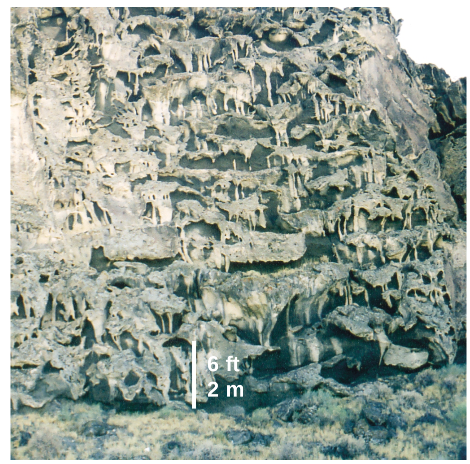
About 15,500 years ago, in a place that is now known as the Black Rock Desert in west-central Utah, a volcano explosively erupted from the bottom of the rising Ice Age Lake Bonneville. Pahvant Butte (also known as Pavant Butte or Sugarloaf) ejected shreds of basalt lava high into the air that quickly cooled into glassy particles the size of sand (volcanic ash) and gravel (volcanic cinders) collectively known as tuff. The explosion produced a crater on the south face of Pahvant Butte. During the eruption the wind must have been blowing to the northeast; black volcanic ash from the eruption is found in sand dunes northeast of Pahvant Butte. When the eruption ceased, a volcanic cone called a tuff cone was left to the mercy of erosion by Lake Bonneville.

The rising Lake Bonneville was only 50 feet (15 m) below its highest level, the Bonneville level, when the eruption occurred. The highest point on Pahvant Butte was at least 435 feet (130 m) above the water at the time. Waves carved a shelf around most of the volcano except for the north face where intense storm waves cut a vertical cliff into the cone. The cut exposes an intricate lacey pattern caused by the partial cementing of the tuff by minerals in ground water. The cliff is known as the "Lace Curtain" because of its white color and mysterious lacey pattern. Ground water also altered the tuff above the Bonneville-level beach into a yellow-brown glassy substance called palagonite. Pahvant Butte has white, partially cemented tuff at the Lace Curtain, unaltered black tuff below the Bonneville-level beach, and altered yellow-brown tuff above the Bonneville beach.

When Lake Bonneville breached its threshold at the Bonneville level about 14,000 years ago, the lake quickly dropped to its second-highest level, the Provo level. The Provo-level beach is evident near the elevation of the 30,000 to 128,000 year-old basalt flows that make up the base of Pahvant Butte.

Today, the highest point on Pahvant Butte is 5,486 feet (1,670 m) above sea level. The entire volcano is about 740 feet (225 m) above the ground surface and 2 miles (3 km) in diameter.

The Black Rock Desert has been an active volcanic area for the past 2.7 million years. The youngest basalt lava flow (600 years old) and one of the youngest rhyolite lava flows (400,000 years old) in Utah are found in the Black Rock Desert.



"Lace Curtain", a fantasy of partially cemented volcanic tuff.

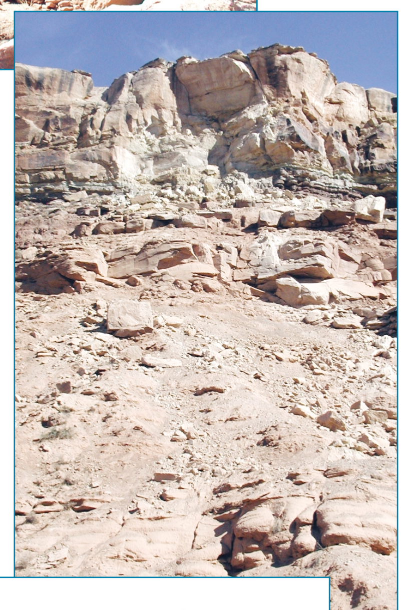
Faults provide the pathways to the surface for lava as well as ground water in the Black Rock Desert. The nearby Clear Lake Bird Refuge has a series of spring-fed ponds along a major fault.

How to get there: From Delta, take Highway 6/50 west to the intersection with Route 257 that leads to Deseret and Milford. Go south on Route 257 for 21 miles (34 km) and turn left (east) on the road to Clear Lake Bird Refuge. Drive eastward 7.5 miles (12 km) on the well-graded dirt road to the sign to Pahvant Butte. Pahvant Butte is easily visible, even from Delta.

Large Boulder Damages Rockville Home

by William R. Lund

▲ *Home in Rockville, Utah struck by a boulder that dislodged from an adjacent cliff. Note the gouge where boulder bounced across the yard.*



Shinarump Conglomerate overlying the upper red member of the Moenkopi Formation north of the damaged home. Note the fresh scar where the rock fall detached from the cliff. ►

Damage to the home. ▼

On Thursday October 18, 2001, at approximately 5:30 a.m., a large boulder dislodged from a cliff face along the south side of the Rockville Bench in Washington County, rolled and bounced down slope, and struck a private residence. The home, located in Rockville, Utah, a few miles west of the Springdale entrance to Zion National Park, was severely damaged.

The boulder, measuring approximately 16 by 16 by 12 feet and weighing an estimated 200 to 300 tons, broke loose from an outcrop of the Shinarump Conglomerate Member of the Upper Triassic Chinle Formation, which caps the Rockville Bench north of the Virgin River. The well-indurated Shinarump sandstone and conglomerate beds rest upon less-resistant shale, mudstone, and silty sandstone beds of the upper red member of the Moenkopi Formation. The Shinarump outcrop stands about 200 feet above the adjacent valley floor where the damaged home is located. The boulder was part of a larger rock fall that consisted of several boulders, at least one of which was considerably larger than the boulder that hit the home. Fortunately, the other boulders came to rest on a dirt road at the base of the slope. However, the damaging boulder continued to roll and bounce across the road and the yard of the home, leaving deep gouges in the yard before hitting the house. The boulder crashed through the outside wall of the home and entered a bedroom, narrowly missing the sleeping homeowner. In addition to the bedroom, the boulder destroyed the adjoining bathroom, service area, and living room.

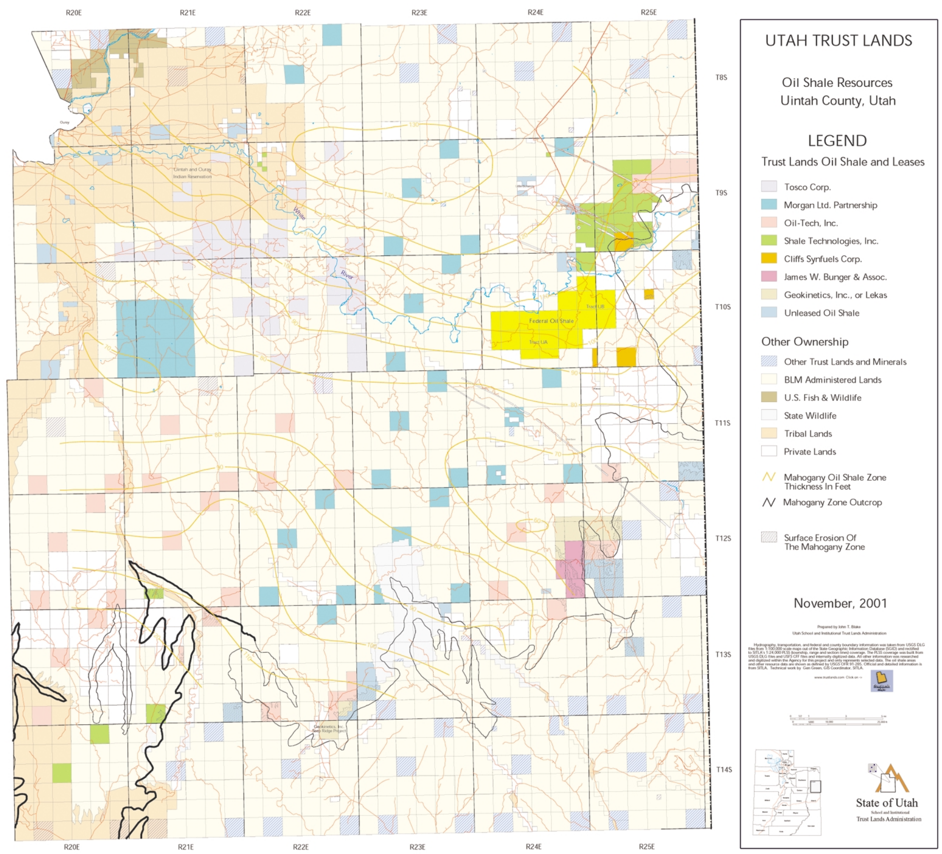
Other fresh-appearing rock-fall scars on the Rockville Bench cliff face and numerous boulders on and at the base of the steep slope capped by the Shinarump Conglomerate attest to the frequency of rock falls in the area. Even so, this rock fall was unusual in that it lacked an obvious triggering event. The weather was dry and had been for some time, so storm-related precipitation was not a factor in the failure. Similarly, no earthquakes were recorded at the time of the failure and none occurred in the area for some time prior to the rock fall. Therefore, this rock fall apparently resulted from the cumulative effects of gradual erosion and gravity. The Moenkopi strata that underlie the Shinarump sandstones and conglomerates are more susceptible to erosion than the overlying harder rocks. Over time, erosion of the softer Moenkopi strata undercut the Shinarump beds until the force of gravity was sufficient to cause the cliff face to fail. Similar rock falls can be expected at any time anywhere along the south edge of the Rockville Bench where the Shinarump Conglomerate stands in a near-vertical cliff face above the adjacent canyon floor.

Renaissance in Oil Shale Leasing on State Lands

by John T. Blake

Utah School and Institutional Trust Lands Administration

Oil shale activity is rebounding after being relatively dormant for years. During 2001 the Utah School and Institutional Trust Lands Administration (SITLA) received oil shale lease applications on approximately 46,271 acres of trust land in Uintah County, Utah. These new leases, when added to the 40,483 acres of trust land already under lease for oil shale at the end of 2000, increased oil shale lease acreage 114 percent. Over 95 percent of all trust land acreage considered valuable for oil shale in Uintah County is now under lease. Morgan Ltd. Partnership and Oil Tech, Inc. leased the additional acreage. They join long-standing lessors including: Tosco Corp.; Shale Technologies, Inc.; Geokinetics, Inc.; Mitchell Lekas; James Lekas; James W. Bunger & Associates, Inc.; and Cliffs Synfuels Corp. SITLA recently created a map, Utah Trust Land, Oil Shale Resources, Uintah County (reduced version is shown here), to show the distribution of these leases. A copy of the map may be obtained via the Internet at http:/wwwtl.state.ut.us by clicking on the Trust Lands maps button.



(Note; see ftp://lands1.state.ut.us/pub/index.htm for the full map)

Utah trust lands, in scattered school sections and in strategically located land blocks, contain more than 10.3 billion barrels of shale oil. The vast oil shale resource contained in the Uinta Basin continues to attract companies' research and development interest as a raw material from which petroleum products can be produced. Potential exists for production of large quantities of shale oil (kerogen) through underground mining and thermal extraction (retorting) at a surface facility or through in-place retorting of the kerogen. The kerogen could be used as a feedstock at an oil refinery to produce gasoline, diesel fuel, and jet fuel. SITLA receives much of the interest because of its excellent oil shale land position, and because the federal government does not have an active oil shale leasing program.

Oil shale leases upon trust lands have a primary term of 20 years and may be extended by commercial production or diligent operations. The lessee pays an annual rent of $1.00 per acre and a production royalty of 5%, gross value. SITLA Rule R850-20-3500 provides that the first 200,000 barrels of shale oil produced from trust lands shall be royalty free. To date, no one has claimed the royalty credit. SITLA advocates oil shale development and will work closely with its lessees and with other permitting agencies to facilitate the production of this important energy resource.

Biographical Note:

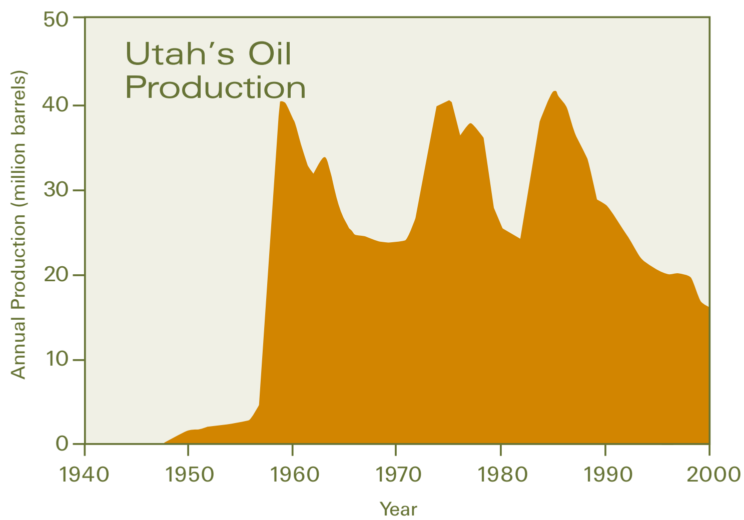
John T. Blake is a Mineral Resource Specialist with the Utah School and Institutional Trust Lands Administration. He holds Masters Degrees in Geography and Business Administration. Mr. Blake has worked in the mineral leasing of state trust lands for over 24 years. In 1991, he managed a contract with the U.S. Geological Survey to analyze oil shale resources of trust lands using geo-statistical methods. The results of the study are contained in USGS Open-File Report 91-285.

Energy News

UGS Awarded DOE Grant to Produce Play Portfolios of Utah's Major Oil Provinces

by Thomas C. Chidsey, Jr.

On September 20, 2001, the U.S. Department of Energy (DOE) awarded funding to the Utah Geological Survey (UGS) as part of its PUMP II (Preferred Upstream Management Practices) technology program, which is designed to compile and disseminate oil reservoir data and best methods for production. The overall goal of the program is to stop the decline in domestic oil production by 2005. The total cost of this new two-year UGS project, titled "Major Oil Plays of Utah and Vicinity," will be about $351,000 with 50 percent cost share from the DOE. The PUMP program is particularly important for the small, independent operators who drill many of the oil wells in Utah. These companies typically do not have the staff or financial resources to compile and assess oil field data, producing trends, or state-of-the-art drilling technologies that the UGS project will provide.

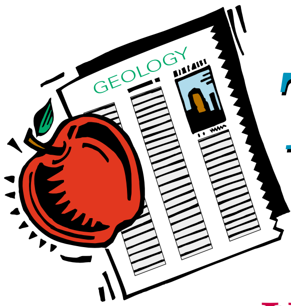


Oil production in Utah.

Utah oil fields have produced a total of 1.2 billion barrels. However, the 15 million barrels of oil production in 2000 was the lowest level in over 40 years and continued the steady decline that began in the mid-1980s. The UGS believes this trend can be reversed with the help of this new project. The overall objectives of the study are to: (1) increase recoverable oil from existing field reservoirs, (2) add new discoveries, (3) prevent premature abandonment of numerous small fields, (4) increase oil deliverability through identifying the latest drilling, completion, and secondary/tertiary techniques (injection of water or gas to flush remaining oil out of the rock after initial production rate has significantly declined), and (5) reduce development costs and risks.

These objectives will be achieved by providing the petroleum industry with comprehensive play portfolios for the major oil-producing provinces (thrust belt, Uinta Basin, and Paradox Basin) in Utah and adjacent areas. Oil plays are geographic areas having petroleum potential caused by favorable combinations of source rock (rocks rich in organic matter from which oil is generated), oil migration paths, reservoir rock characteristics (such as the amount of pore space available to store oil), and other factors. The play portfolios will include: descriptions of reservoir characteristics such as strata present and the environment in which they were deposited, alteration of rocks, folding or faulting of the strata, trap type, seal, and hydrocarbon source, and maps of the major oil plays by reservoir; production and reservoir data; case-study field evaluations; summaries of the state-of-the-art drilling, completion, and secondary/tertiary techniques for each play; locations of major oil pipelines; description of reservoir outcrop analogs for each play; and identification and discussion of land-use constraints.

All play maps, reports, databases, and other information produced during the project will be published in either an interactive, menu-driven digital (web-based and compact disc) or hard copy format by the UGS and presented to the petroleum industry through a proven technology transfer plan. The technology transfer plan includes a Technical Advisory Board composed of industry representatives operating in Utah and a Stake Holders Board composed of representatives of state and federal government agencies, and groups with a financial interest in the study area. The project will be completed in mid-2004.



Teacher's Corner

Use a settling container to determine the relative amount of sand, silt, and clay in sediment.

In the grand geological-recycling scheme, sediment is (A) the product of weathering and erosion of rock and (B) the material for future rocks. Sediment grains range in size from tiny clay particles to large pieces of gravel, and even boulders. This article describes a simple experiment using a settling container to determine the relative amounts of sand, silt, and clay in sediment. The maximum size of sediment and the relative amounts of sand, silt, and clay in sediment are clues that help geologists decipher the geologic history of the sediment and resulting sedimentary rock.

The size of grains in sediment correlates directly with the amount of energy necessary to move and deposit it. High-energy processes, such as the ocean surf, glaciers, rivers, and landslides move very large fragments. Medium- and low-energy wind and quiet-water processes transport smaller sizes.

Gravel, sand, silt, and clay are terms of grain size; the composition of the grains is immaterial to the definitions. Gravel-size grains have a diameter, or side, longer than 2 millimeters (0.08 in), about the thickness of two dimes in a stack. Sand grain diameters are between 0.0625 and 2 millimeters (0.0025 and 0.08 in), silt grains are between 0.004 and 0.0625 millimeters (0.00016 and 0.0025 in), and clay grains are smaller than 0.004 millimeters (0.00016 in).

Sand and gravel grains are visible with the unaided eye, whereas a magnifying glass is needed to distinguish individual silt grains. Silt grains are gritty between your teeth; clay grains are not gritty. Most clay grains are "sticky." Sediment that has a high percent of clay particles can be rolled between your hands into a "worm" when mixed with a little spit or water.

Wire screens (or sieves) are used to determine the relative amount of gravel- and sand-sized grains in sediment. An approximation of the relative amount of sand-, silt-, and clay-size grains in sediment can be obtained using a settling container.

The materials needed are: (1) a 2-liter plastic soda bottle, (2) a ruler that is at least 10 centimeters (4 inches) long, (3) a measuring cup, (4) a clock with a second hand, and (5) a teaspoon of dishwasher detergent.

Procedures:

1. Collect about a cup (225 grams, 8 ounces) of air-dried sediment.

2. Crush the dirt clods, and pick out any gravel, animals, and plants.

3. Put the sediment into the soda bottle, add one teaspoon of detergent, and almost fill the bottle with water.

4. Shake vigorously to mix and suspend the sediments. The detergent breaks up sticky clay particles.

5. Gently place the bottle on a flat surface where it won't be disturbed for several hours and begin timing the sediment fall.

6. After 45 seconds, place the ruler against the outside of the bottle and measure the height of the SAND deposit from the bottom of the bottle. This value is A.

7. After 1 hour measure the height of the SAND + SILT column from the bottom of the bottle. This value is B

8. The height of the SAND + SILT + CLAY column is measured when the remaining water looks like dilute tea or tainted water, after about 4 hours to several days. This value is C.

9. The percentage of SAND in the bottle is (A/C) x 100, the percentage of SILT in the bottle is ((B – A)/C) x 100, and the percentage of CLAY in the bottle is 100% minus the sum of SAND% and CLAY%.

10. You now have percentages of SAND, SILT, and CLAY in the sediment.

"Glad You Asked"

by Mark Milligan

What are those crunchy crusts found on some Utah soils?

Goblin Valley State Park in Emery County. The popcorn-like texture (gilgai) indicates soil that shrinks and expands with drying and wetting cycles. Mechanical and microbiotic crusts form a thin but hard veneer on the top of this expansive soil. The darker areas on the left are due to the presence of microbiotic crusts.

"I don't have a photograph, but you can have my footprints. They're upstairs in my socks." Groucho Marx (1935). So, where are your footprints? When not left in your socks, your footprints (or more likely boot prints) may be on a crusty soil. What are these crusts, what purposes do they serve, and how do footprints and other disturbances affect them?

Two types of crusts are common on Utah soils, mechanical and microbiotic. Mechanical crusts develop on clay-rich soil. These crusts are formed by a thin upper coating of clay particles oriented parallel to the surface.

In contrast, microbiotic crusts are produced by living organisms and their by-products that bind together soil particles at, or very near, the ground surface. Many names (cryptogamic, cryptobiotic, microphytic, biological) have been applied to a variety of these organic crusts that are found throughout the world's deserts and semiarid grasslands, shrublands, and woodlands. The existence and type of microbiotic crust depend upon variables such as soil texture, conductivity, pH (acidity), and moisture. The general appearance of microbiotic crust varies widely, depending upon the relative abundance of different crust-forming organisms. Across southeastern Utah and surrounding states on the Colorado Plateau, cyanobacteria are the most abundant crust-forming organisms.

Cyanobacteria are a group of microscopic organisms that harvest the sun's energy through photosynthesis. The cyanobacteria are not alone, as they are commonly found with green algae (another group of photosynthetic organisms). Mosses and lichen can also grow on crusts already stabilized by cyanobacteria and green algae.

Both microbiotic and mechanical crusts stabilize soil and affect infiltration of rainwater, seed germination, and plant growth. With microbiotic crust, filamentous sheaths hold soil particles in place and directly improve resistance to wind and water erosion. Mechanical crust also greatly enhances resistance to wind erosion but is not nearly as effective in improving resistance to erosion by water. Mechanical crust may also form an impermeable layer that decreases rainwater infiltration, further increasing runoff and downstream erosion.

Both microbiotic and mechanical crusts can be impacted by foot or vehicle traffic or any other human or natural disturbance. For example, a single footprint can damage mechanical crust and the filaments that create microbiotic crusts. Repeated foot traffic can completely remove this protective layer. Once damaged, the erosive powers of wind can easily blow soil particles away. The loss of microbiotic crusts increases susceptibility to the erosive power of water as well. Fortunately, damage done to crusts is reversible, though it can take a long time.

The recovery time for mechanical versus microbiotic crust varies greatly. Mechanical crusts begin to reform substantially with the first intense rainstorm; microbiotic crusts take much longer. Cyanobacteria and green algae secrete soil-binding sheaths only when wet, needing repeated wet periods to reconstruct their crust-forming network of filaments. Microbiotic crusts can begin to substantially recover in as little as 1-5 years, or may take more than 50 years, depending upon crust type, soil type, climate, and extent of initial disturbance.

In a microbiotic crust, a web of organic filaments binds soil particles together, forming an interlocking network of grains. The filaments are composed of sticky sheath material secreted around the cells of cyanobacteria and green algae. Bottom: magnification about 80x. Photo courtesy Jayne Belnap, U.S.G.S.

For more information on microbiotic crusts, see Roxanna Johnston's *Introduction to Microbiotic Crusts*, published in 1988 by the U.S. Department of Agriculture. For more information on footprints, see your socks.

Continued from Director's Perspective...

wells are targeting (and finding) deeper gas plays close to existing oil and gas fields. The development of coalbed methane production from the Ferron play in central Utah contributes to the third peak at a depth of around 3,000 feet.

The exploration boom of 2001 will be short-lived unless energy prices stabilize at levels consistent with the long-term demand for additional energy resources during the coming decade. Conservation and greater energy efficiency are both essential messages that briefly gained widespread public attention during the energy "crunch" of winter and spring, 2001. Unfortunately, cheap energy prices as we head into the winter of 2002 mean that those messages are rapidly being forgotten. Without stable, realistic energy prices, the decline in energy exploration investment will ensure that energy "crunches" become a frequent occurrence.

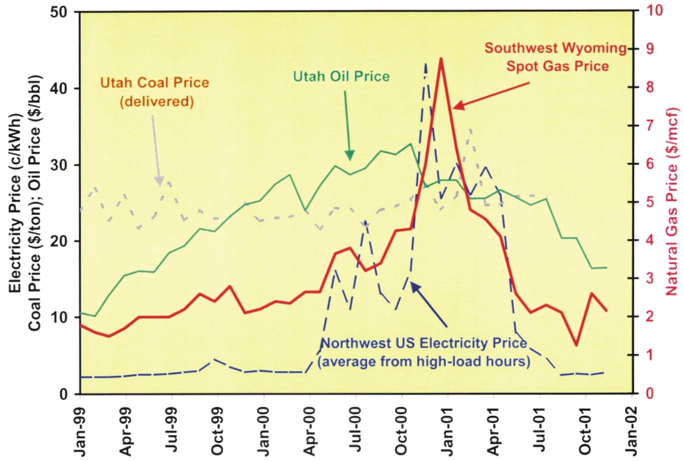


Figure 1. Trends in Utah's energy prices, showing the energy price "crunch" in natural gas and electricity that peaked in January 2001. Prices are monthly averages, and spot prices typically went considerably above the average price during times of tight supply. Data supplied by Utah Energy Office.

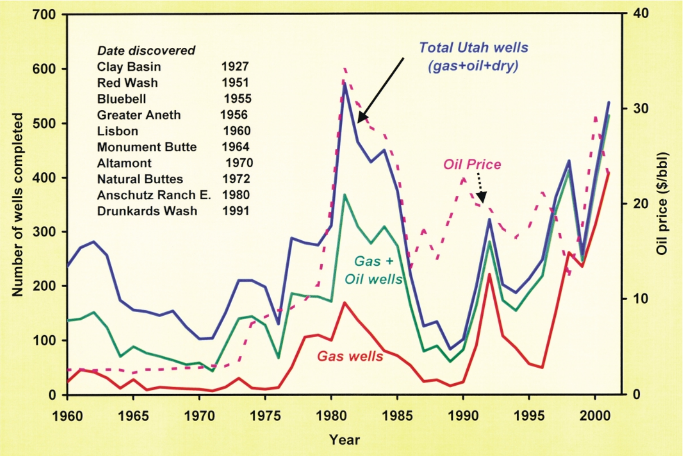


Figure 2. The annual pattern of well drilling in Utah since 1960 compared to oil price fluctuations. Note the trend towards more gas wells and less "dry" holes during the 1990s. There were more productive wells drilled in 2001 than in any previous year. Data from Utah Division of Oil, Gas and Mining.

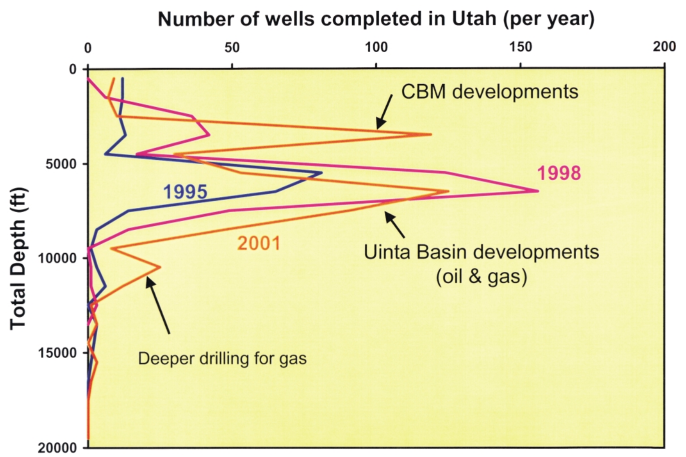


Figure 3. Depth trends in oil and gas drilling in Utah since 1995. The peak at 3,000 feet is due to the coalbed methane (CBM) developments, and the peak below 10,000 feet indicates exploration for deeper gas plays. Data from Utah Division of Oil, Gas and Mining.

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