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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The Traverse Mountains

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Design by Vicky Clarke

***Cover**: View northeast along Steep Mountain to the southeast part of Salt Lake Valley. This and nearby areas are at the forefront of unprecedented suburban development.*

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The Director's Perspective

by Richard G. Allis

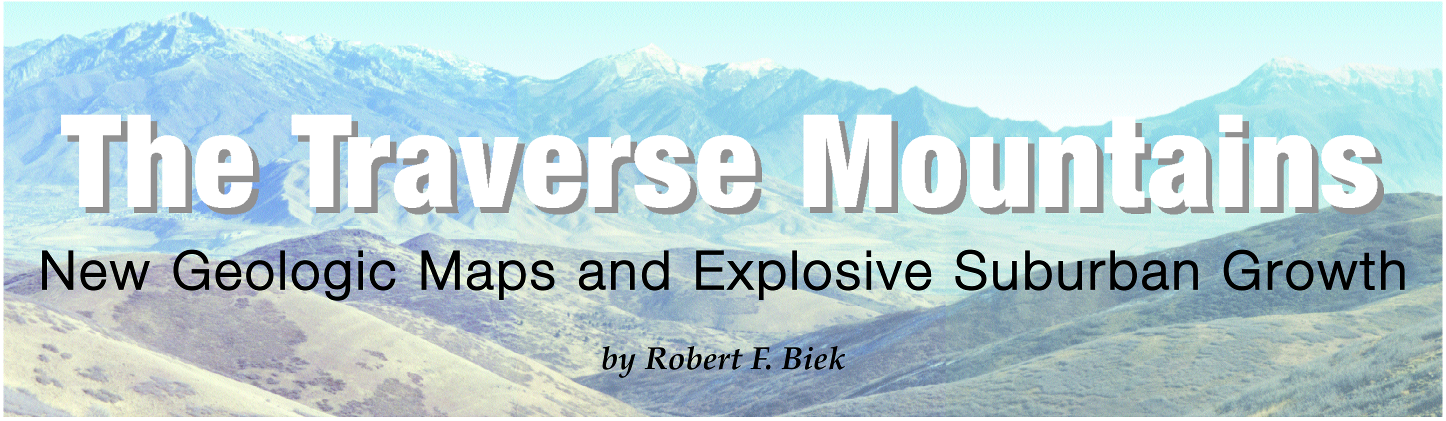
Geologic hazards have been in the news over the last few months, beginning with the powerful demonstration of the effects of a Magnitude 9 earthquake near north Sumatra on December 26, 2004, and the tragic consequences of the Indian Ocean tsunami, which caused about 300,000 deaths. Closer to home, we have seen the geologic consequences of near-record rain and snowfall in southern California, and recently, also in southern Utah. Landslides destroyed homes in California, and in St George, Utah, over 28 homes were destroyed and many more damaged when the Santa Clara River flooded and expanded its flood plain by several hundred feet in places. Utah's first fatality in over 20 years due to landslides occurred last month when stream-cut cliff bank failure occurred on the Kanab Creek, also in southern Utah. With above-average precipitation in many urban areas since September, and above-average snow pack still in place at higher elevations in Utah, the Utah Geological Survey (UGS) has advised local governments to watch for signs of earth movement that may be precursors of more dangerous landsliding. Twenty-two years ago, the massive Thistle landslide (reviewed in this issue of Survey Notes, page 10) occurred after an exceptionally wet winter.

High energy prices, particularly for gasoline and natural gas, have also been grabbing the headlines and raising questions about both the supplies and efficient use of these essential commodities. Utah is rich in fossil fuels, and this has been highlighted by recent news about a new oil discovery in central Utah (see page 8). This has stimulated a new wave of oil exploration along Utah's central thrust belt known as the "hingeline." Natural gas exploration in the Uinta basin is also at historic high levels, with close to 30 drill rigs active, and applications for permits to drill in the first three months of 2005 exceeding last year's record activity by about 20% for this quarter. The average drilling depth has increased by 1,000 feet, and 38% of the wells drilled last year had a total depth between 8,000 and 10,000 feet. Targets for deeper gas accumulations include tight sands in the upper Cretaceous Mesaverde Group and underlying eolian sandstone formations. The UGS has also noticed a marked increase in interest in Utah's oil shale and tar sand deposits.

Historically high prices for many mineral commodities have been stimulating the mining sector in Utah over the last 6 months. Both the School and Institutional Trust Lands Agency, and the BLM offices in southeast Utah, report a surge in claims for uranium prospects, with International Uranium requesting to reopen the Tony M mine in Garfield County, while U.S. Energy has applied for a permit to reopen the nearby Tikaboo uranium mill. Kennecott has expanded operations at their Bingham mine, with molybdenum becoming their most valuable product, and Palladon Ventures-Western Utah Copper has announced plans to redevelop the iron deposits west of Cedar City to produce steel. Constellation Copper will begin copper production from a sedimentary copper deposit near Lisbon, San Juan County, at the end of this year.

Both the heightened awareness of geologic hazards, and the recent increase in energy and mining activities, highlight the important role that geology, and the UGS, will continue to play in everyday life, and in Utah's future economic development.

Survey Notes is published three times yearly by Utah Geological Survey, 1594 W. North Temple, Suite 3110, Salt Lake City, Utah 84116; (801) 537-3300. The UGS is an applied scientific agency that creates, evaluates, and distributes information about Utah's geologic environment, resources, and hazards to promote safe, beneficial, and wise use of land. The UGS is a division of the Department of Natural Resources. Single copies of *Survey Notes* are distributed free of charge within the United States and Canada and reproduction is encouraged with recognition of source. Copies are available at http://geology.utah.gov/surveynotes



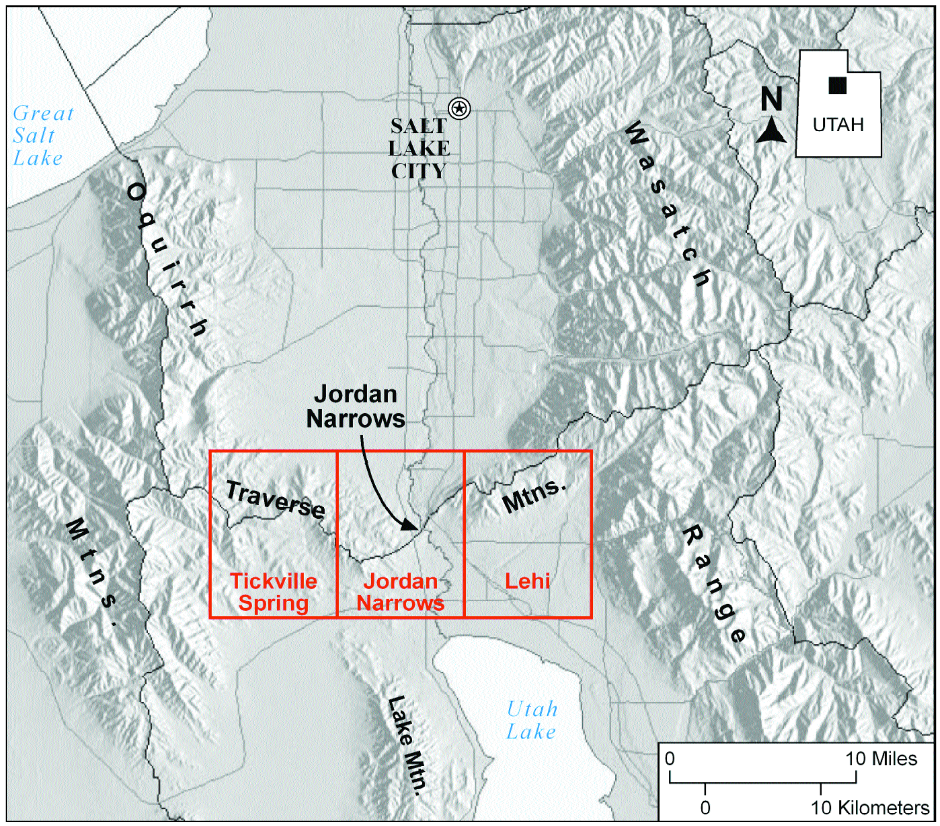
The Traverse Mountains

New Geologic Maps and Explosive Suburban Growth

by Robert F. Biek

Introduction

Imagine a mountain range, virtually unknown to the hundreds of thousands of people who live within its shadow and to the countless tens of thousands who commute through it twice daily. Do the names Red Rock, Potato Hill, or Hog Hollow (where early pioneers once let hogs roam in an effort to control the rattlesnake population) register in your mind? Perhaps you know of Jordan Narrows, which divides the range in two and now serves as a major transportation and utility corridor; Pony Express riders used to traverse the Narrows, often faster than we are able to today in commuter gridlock. These and other place names find their home in the Traverse Mountains, an east-west-trending range of low hills that separate Salt Lake and Utah Valleys. While the Traverse Mountains lack the grandeur of the adjacent Wasatch Range, geologically speaking they are far more interesting than their sage- and oak-brush-covered slopes suggest. They are also at the forefront of explosive suburban growth. The mix of local geology and development pressures clearly demonstrates the need for detailed geologic maps of the Traverse Mountains, which were recently completed and published by the UGS.



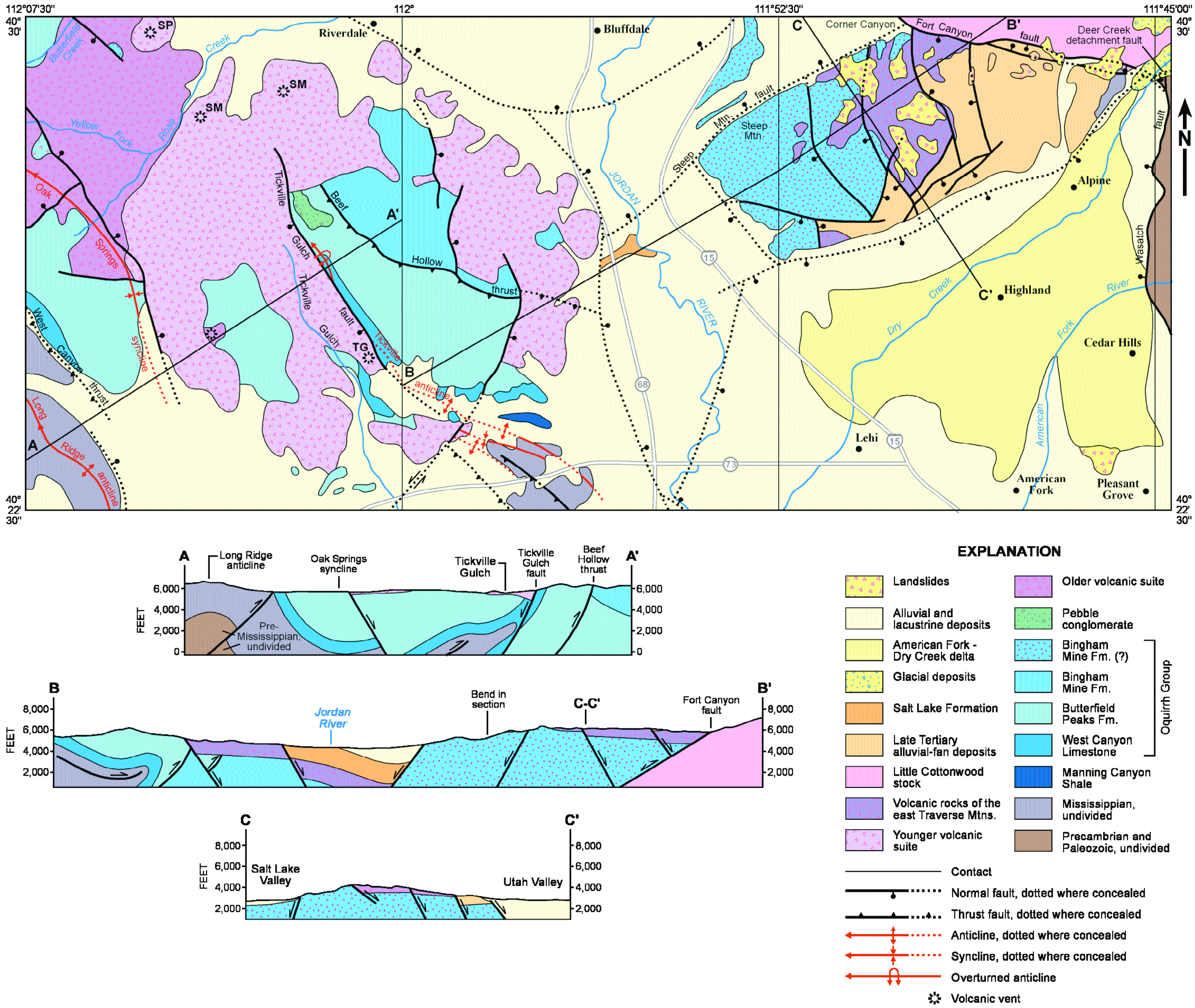
Shaded-relief image showing the Traverse Mountains and the location of new geologic maps of the Tickville Spring, Jordan Narrows, and Lehi quadrangles. The maps are part of a state-mandated effort to provide basic geologic information necessary for environmental, resource-availability, geologic-hazard, planning, and educational needs. Mapping was jointly funded through a cooperative agreement between the UGS and the U.S. Geological Survey under the National Geologic Mapping Act.

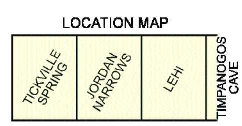
Geological Overview of the Traverse Mountains

In broad terms, the geology of the Traverse Mountains can be viewed in three parts: (1) Late Paleozoic shallow-marine rocks, now exposed as large northwest-trending folds, record one small part of the collision of the North American continent with the ancestral Pacific Ocean basin in a mountain-building event that geologists call the Sevier orogeny, (2) a variety of middle Tertiary intrusions, associated volcanic rocks, and younger basin-fill strata deposited over the eroded Sevier orogenic highlands, and (3) Basin and Range extensional tectonics and the evolution of the modern Traverse Mountains.

The Foundation of the Traverse Mountains

The oldest widely exposed rocks in the Traverse Mountains are those of the Oquirrh Group, a vast thickness of sandstone and limestone laid down in a shallow ocean basin. Sedimentary structures such as cross-beds, and reef-building fossils such as bryozoans, corals, and crinoids, show that these strata were deposited in relatively shallow water as the deposi-





Simplified geologic map and cross sections of the Traverse Mountains. Eruptive centers include: SP = Shaggy Peak, TG = Tickville Gulch, SM = Step Mountain (near Rose Creek), and SM = South Mountain (southwest of Riverdale).

tional basin slowly subsided, eventually accumulating up to 25,000 feet of strata. This group of rocks takes its name from the Oquirrh Mountains, where they are well exposed; Oquirrh, pronounced "O-ker," is a Goshute Indian word meaning "wooded mountain." Geologists have subdivided the Oquirrh Group into several formations and informal members, which allows a more detailed assessment of the structure and geologic history hidden within this great thickness of rocks.

In the west Traverse Mountains west of Jordan Narrows, and in the adjacent Oquirrh Mountains and Lake Mountain, Oquirrh Group rocks are folded into several northwest-trending anticlines (upwarps) and synclines (downwarps), much like a folded rug. These folds are part of the deformation associated with the Cretaceous to early Tertiary (about 140 to 50 million years ago) Sevier orogeny, the mountain-building event caused by the collision of the North American continent and the Farallon (ancestral Pacific Ocean basin) plate. During this time, great thicknesses of rock from the basin were folded and thrust eastward over both correlative and younger rocks deposited on the continental shelf. The Traverse Mountains are part of the now faulted and dismembered upper plate of the Charleston-Nebo thrust sheet, which reveals about 25 miles of eastward displacement; the Charleston thrust, since reactivated as the Deer Creek detachment fault and later as the Fort Canyon fault as described below, trends east through Corner Canyon to Heber City and beyond. In the west Traverse Mountains, these folds culminate in the Tickville anticline, which formed above the smaller Beef Hollow thrust. East of Jordan Narrows, equivalent rocks contain few marker beds and are so badly shattered by all this faulting that no folds are recognizable.

The Age of Volcanism

The subduction of the Farallon spreading center and development of the San Andreas transform boundary between the North American and Pacific plates signaled the end of the Sevier orogeny. In north-central Utah, this occurred in Eocene time, about 40 million years ago. With the end of compressional deformation came collapse and erosional stripping of the Sevier orogenic highlands. The thrust belt collapsed westward along low-angle detachment faults, placing younger rocks on older rocks. The Deer Creek detachment fault is one such fault in which the upper plate slipped westward about 4 miles during the period from about 40 to 20 million years ago. The white garnet-bearing marble exposed north of Alpine, which is metamorphosed Mississippian Doughnut Formation, was transported from its original position near what is now Silver Lake high in the Wasatch Range to its present position by movement on the Deer Creek fault.

Volcanism accompanied the collapse of the Sevier orogenic belt, and in the Traverse Mountains produced three groups of volcanic rocks deposited over a landscape of eroded Paleozoic strata. The oldest group, at the west end of the range, erupted from the Bingham volcanic center about 37 to 40 million years ago. The volcanic cone that must once have towered above the Bingham Copper Mine has long since been eroded away.

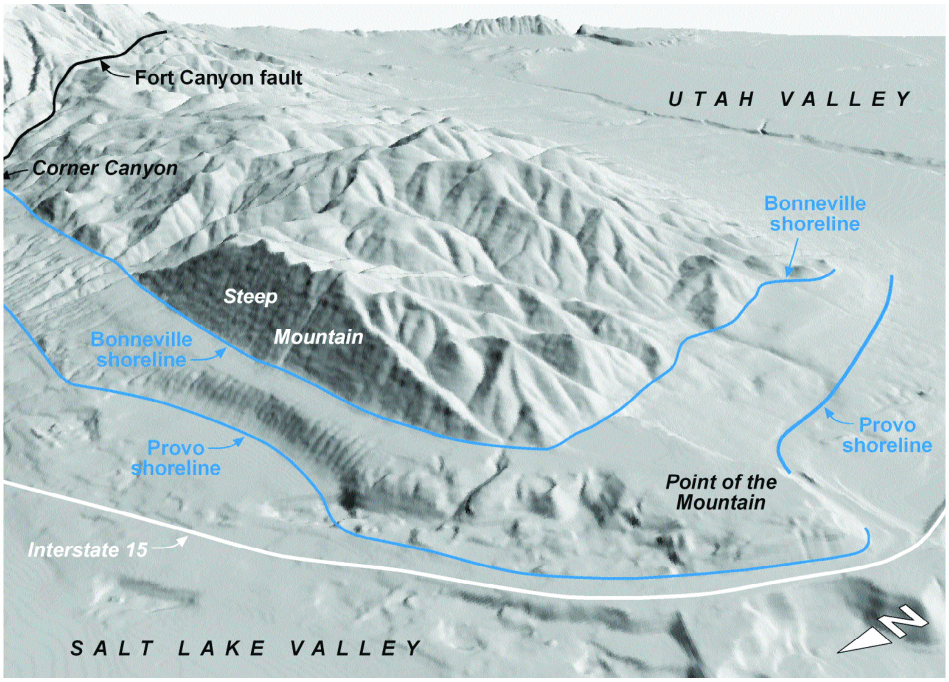
View northeast to the entrance of Corner Canyon. Note the prominent Bonneville shoreline, Bonneville barrier bar, and Wasatch fault scarp (bar and ball on downthrown side). Trench in the foreground was dug to investigate the "Potato Hill" landslide, which overrode the Bonneville shoreline sometime after the lake receded from its highest level.

A gap of several million years separates the Bingham volcanic rocks from overlying younger volcanic rocks. This younger volcanic suite – which consists of 30- to 33-million-year-old andesitic to dacitic block and ash flow tuffs, lava flows, and intrusions, a rhyolite plug dome, and a separate rhyolite lava flow – erupted from a number of vents in the west Traverse Mountains, including South Mountain, Step Mountain, Shaggy Peak, and possibly unknown vents now buried beneath southwestern Salt Lake Valley.

The age and trace-element chemistry of the third group of volcanic rocks, those of the east Traverse Mountains, suggest that they may have erupted from the eastern part of the Wasatch intrusive belt, and so may be more closely related to the Keetley Volcanics of Kamas and Heber Valleys than they are to the volcanic rocks of the west Traverse Mountains. East Traverse Mountains volcanic rocks are made up principally of 35- to 37-million-year-old block and ash flow tuffs and few lava flows. The volcanic rocks are typically deeply weathered such that resistant volcanic boulders accumulate at the surface. Due to hydrothermal activity possibly associated with intrusion of the Little Cottonwood stock about 30 million years ago, locally these volcanic rocks were completely altered to massive silica, creating a colorful but brittle opalite that grades outward to clay-rich rock. Weathering of these volcanic rocks contributes to significant landslide problems in the east Traverse Mountains.

Evolution of the Modern Traverse Mountains

Aligned as they are east-west, the Traverse Mountains trend perpendicular to most western Utah mountain ranges, yet they are part of the same tectonic regime that created the north-trending basins and ranges of the Great Basin. They owe their anomalous trend to an inherited, long-lived tectonic boundary (the Cheyenne suture zone) between the ancient Precambrian Wyoming, Mojave, and Yavapai Provinces, now manifested as



Shaded-relief image of the east Traverse Mountains, created by UGS computer specialist Kent Brown from digital elevation models of parts of the Lehi and Jordan Narrows quadangles. The Bonneville- and Provo-level shorelines are dramatically carved into the north flank of the Traverse Mountains; most of the sediment eroded from the Steep Mountain area was carried by longshore currents and redeposited in the Point of the Mountain spit. Note the landslide at the east end of Steep Mountain and the corrugated appearance of Steep Mountain due to the downslope creep of colluvium. The Fort Canyon fault is also shown. View is from the northwest; the entrance to American Fork Canyon, at the east edge of the Lehi quadrangle, is in the upper right of the image. Photo shows view of Steep Mountain and the Bonneville bench; note beveled surface of highly fractured, light-colored Oquirrh strata, overlain by about 150 feet of sand and gravel deposited at the Bonneville highstand.

the Uinta-Cottonwood arch. It is this pre-existing east-west-trending zone of crustal weakness that influenced the location of the Charleston thrust and Deer Creek detachment faults, and that now lives on in the anomalous orientation of the Traverse Mountains.

This ancient zone of crustal weakness also coincides with the Fort Canyon fault, which links the Salt Lake and Provo segments of the Wasatch fault. These two segments have different rupture histories, but both are characterized by impressive composite fault scarps tens of feet high; at Corner Canyon, the Lake Bonneville shoreline is offset about 65 feet across several splays of the Salt Lake segment of the Wasatch fault, and at Dry Creek, glacial moraines are similarly cut by the Provo segment. The Fort Canyon fault has no such readily apparent scarps due to its low angle and oblique slip. However, like the better known segments of the Wasatch fault, the Fort Canyon fault is active and shows evidence of late Holocene surface-fault rupture. It is readily discernable as a wide trough at the base of the Wasatch Range where it juxtaposes volcanic rocks and basin-fill deposits against the Little Cottonwood intrusion. Studies of unusual fault-generated rocks at Corner Canyon show that faulting there began by about 18 million years ago.

The Traverse Mountains are girdled on all but their topographically high northeast and west ends by deposits and landforms of the Bonneville lake cycle. Lake Bonneville was the largest Late Pleistocene lake in western North America and rose and fell throughout its transgressive/regressive cycle from about 30 to 12 thousand years ago. At its highest (Bonneville) level, the lake covered about 20,000 square miles of western Utah and parts of adjacent Nevada and Idaho and was about 1000 feet deep near the present Great Salt Lake. The Bonneville shoreline is spectacularly etched into the north flank of the Traverse Mountains, particularly at Steep Mountain.

A New Era

The Traverse Mountains used to be a barrier, the crest of the range separating two metropolitan areas. However, development in the east Traverse Mountains, and in the foothills surrounding Camp Williams in the west Traverse Mountains, has had the effect of making the range more accessible than ever before. The Traverse Mountains are low in elevation only compared to adjacent ranges; they reach nearly 2000 feet above the adjacent Salt Lake and Utah Valleys and offer splendid views in all directions: north to the sprawling urban and suburban grid of Salt Lake Valley, east to the Wasatch Range, south to Utah Lake and the wave of development creeping northward in Utah Valley, and west to the Oquirrh Mountains and western valleys not yet blanketed by development.

It is not surprising that the area is now becoming a refuge for affluent Utahns seeking to escape the hassles of urban life. It remains for city and county officials, developers, and ultimately an informed public to make wise land-use decisions, based in part on an understanding of local geology. The region still contains some of the Wasatch Front's best sand and gravel and aggregate sources needed to support local construction; it still produces clay used to make brick and other structural clay products; and it is host to a variety of geologic hazards, including landslides, debris flows, and active earthquake faults, among others. Planning, based on detailed geologic maps, is the single most cost-effective way to mitigate geologic hazards and ensure the wise use of geologic resources, and nowhere is this truer than on the fringe of major urban corridors. The new geologic maps of the Traverse Mountain region (see sidebar) will aid local communities in crafting effective land-use policies.

New Geologic Maps of the TRAVERSE MOUNTAINS

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Biek, R.F., in press(a), **Geologic Map of the Lehi quadrangle and part of the Timpanogos Cave quadrangle**, Salt Lake and Utah Counties, Utah: Utah Geological Survey Map 210, 2 plates, scale 1:24,000. Available in June.

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—in press(b), **Geologic Map of the Jordan Narrows quadrangle**, Salt Lake and Utah Counties, Utah: Utah Geological Survey Map 208, 2 plates, scale 1:24,000. Available in June.

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Biek, R.F., Solomon, B.J., Keith, J.D., and Smith, T.W., 2004, **Interim geologic maps of the Copperton, Magna, and Tickville Spring quadrangles**, Salt Lake and Utah Counties, Utah: Utah Geological Survey Open-File Report 434, 4 plates, scale 1:24,000, CD. $14.95

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The maps will be available at the Natural Resources Map & Bookstore — see back cover for contact information.

Survey News

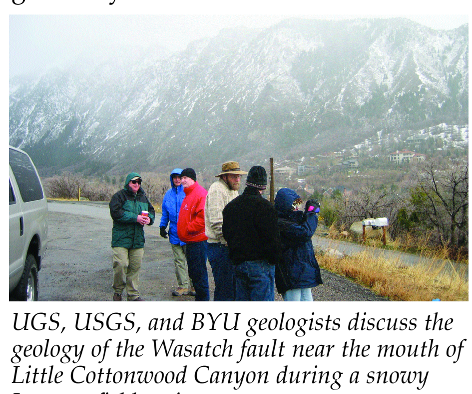
Ken Krahulec joins the Energy group as the new minerals geologist. He worked for many years in Kennecott's exploration companies. **Denise Beaudoin, Mike Vanden Berg, Nykole Littleboy, Glade Sowards,** and **Kim Mellin** join us as the new State Energy Program.

UGS Geologic Mapping Program Receives STATEMAP Grant

The Utah Geological Survey Geologic Mapping Program continued its successful record of obtaining large grants through the STATEMAP component of the National Cooperative Geologic Mapping Program. In December the UGS was notified that it was awarded a grant of $226,749 for the 2005-06 fiscal year. This grant is down from the previous year's award of $274,923 because of budget cuts in the national program; however, it was still the 6th largest among the 50 states. The funds will be used to continue 7.5′ quadrangle mapping near Utah Lake, Brigham City, Logan, and Kanab; and 30′x60′ quadrangle mapping in Washington County, the eastern Uinta Mountains area, and near Capitol Reef National Park. STATEMAP funds are matched equally with state-appropriated general funds, making this the largest single project at UGS.

National Cooperative Geologic Mapping Program Administrators visit UGS

January may not be the best time for a geology field trip, but when you have no choice, it's amazing how much great geology you can see. That was the case when the UGS Geologic Mapping Program received a January visit from Reston, Virginia-based U.S. Geological Survey (USGS) administrators of the National Cooperative Geologic Mapping Program, which provides funding to the UGS through its STATEMAP component and to educators through its EDMAP component. An important part of the visit was to review areas we had mapped using STATEMAP funds – in the field! – and to highlight examples of how recent geologic maps are being used. We would have preferred to review our geologic maps in the spring or fall when Utah's weather is at its best, but the USGS administrators were already in the area for other business. As it turned out, the day of the field review was cold and snowy, but those involved still saw a lot of great geology around the southern part of Salt Lake Valley. The wet, miserable weather even seemed to accentuate the potential for landslides and other geologic hazards discussed on the trip – and it sure didn't dampen the spirits of the participating UGS, USGS, and Brigham Young University Geology Department geologists who firmly believe that any day in the field is a good day!



UGS, USGS, and BYU geologists discuss the geology of the Wasatch fault near the mouth of Little Cottonwood Canyon during a snowy January field review.

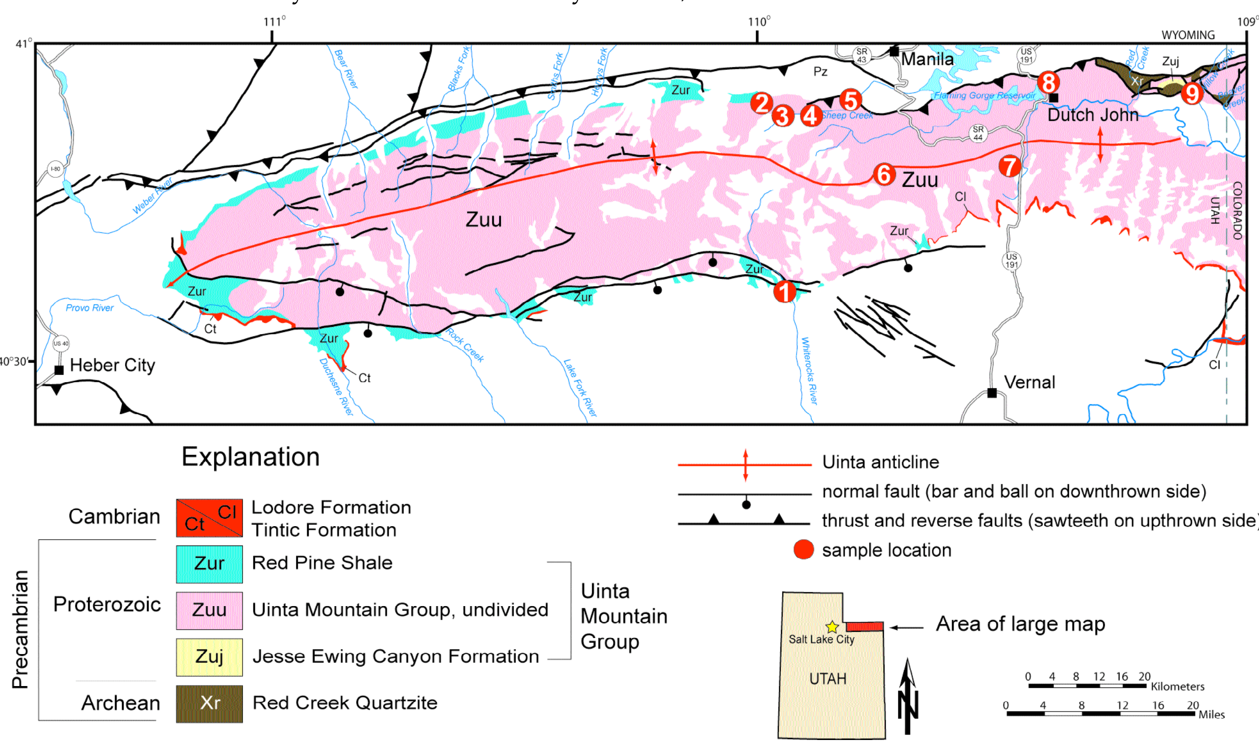
UTAH'S OLDEST FOSSILS
are found in the Uinta Mountains

by Douglas A. Sprinkel, Utah Geological Survey, and Gerald Waanders, Consulting Palynologist

An amateur geologist negotiates the final miles of a dirt road to a Cambrian outcrop in western Millard County, Utah, that promises a rich zone of trilobites. Meanwhile, a geologist mapping on the San Rafael Swell walks across Jurassic limestone beds that contain a diverse assemblage of crinoids, ammonites, pelecypods, and echinoderms. Finally, a group of volunteers are helping a vertebrate paleontologist recover a dinosaur from the Cretaceous Cedar Mountain Formation near Arches National Park. Utah has long been known as a fertile area to hunt for all kinds of fossils – from marine invertebrates, to reptiles, to many species of mammals – because of its nearly complete and depositionally diverse sedimentary record. Utah's fossil record has recently been extended to rocks older than Cambrian with the discovery of microscopic fossils in the Proterozoic Uinta Mountain Group.

Most of the world's oldest commonly known fossils come from rocks of Cambrian age (543 to 490 million years ago). Many of these fossils are already rather complex organisms that, by that time, had advanced through evolution to the level of brachiopods and arthropods. The older Archean and Proterozoic (Precambrian) rocks of the world were long thought to be barren of preserved fossils. However, paleontologists eventually discovered simple microscopic fossils in these rocks that pushed the appearance of life almost 3 billion years earlier to the Archean Eon (3.5 to 2.5 billion years old). For the most part, those organisms were very simple anoxic archaebacteria. In Proterozoic time (2.5 billion to 543 million years ago), living organisms diversified to include both prokaryotes (archaebacteria and cyanobacteria) and eukaryotes (algae, protozoans, and other higher organisms). By carefully recording the types of fossilized organisms and plant tissues they recovered from Proterozoic rocks, paleontologists have been able to subdivide the Proterozoic Eon into the Paleoproterozoic (Early), Mesoproterozoic (Middle) and Neoproterozoic (Late) Eras.

Archean and Proterozoic rocks are well exposed in several of Utah's mountain ranges, but until now, only a few microfossils had been found in these rocks and all were recovered



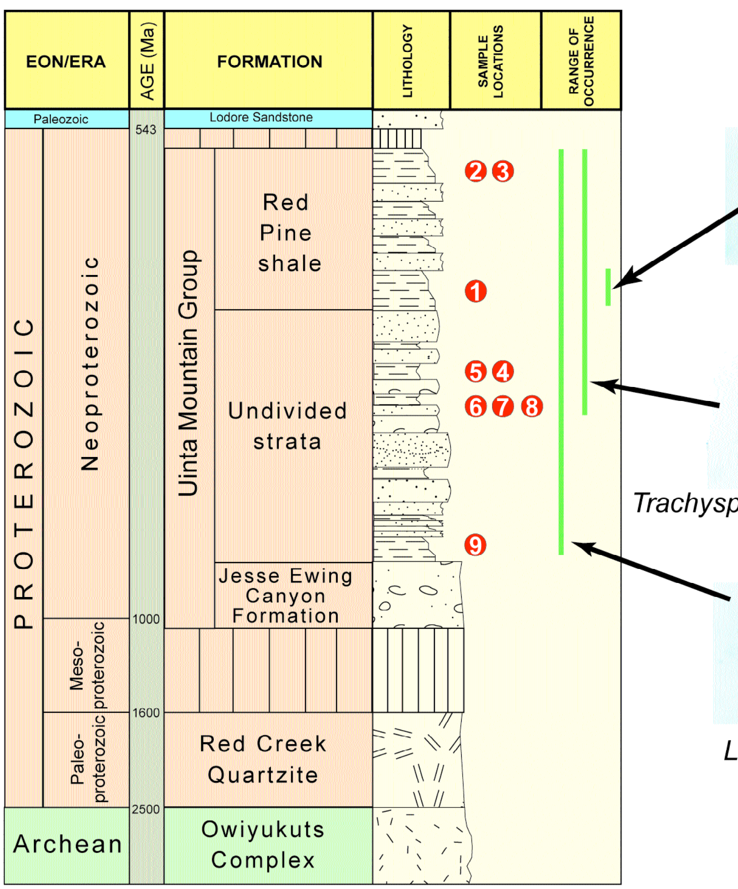
General geologic map of the Uinta Mountains showing sample locations (see accompanying figure).

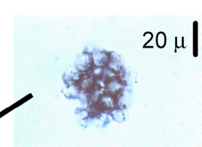
from the Red Pine shale in the western Uinta Mountains. In the course of geologic mapping in the eastern Uinta Mountains, which was funded by the STATEMAP component of the National Cooperative Geologic Mapping Program, we sampled dark-gray and gray-green shale from the Proterozoic Uinta Mountain Group in hopes of recovering evidence of organic microfossils. Surprisingly, the samples contained the remains of microscopic life identified as species of cyanobacteria. What we found are likely Utah's oldest fossils, possibly ranging in age from Mesoproterozoic to early Neoproterozoic (1.6 billion to 750 million years ago); pending radiometric data may help constrain their ages.

These fossils also provide clues to the environment in which the organisms lived. Based on the fossil assemblages we have collected, the older lower part of the Uinta Mountain Group includes simpler forms of cyanobacteria that occur as filaments or single-celled organisms. They probably lived in a quiet, shallow-water, marine to marginal-marine environment. Higher in the section and later in time, we see changes in the flora that include species with more complex cell walls and with the ability to form colonies. These organisms are probably from a shallow but somewhat more marine environment. Some of these changes may reflect nothing more than varied environmental conditions or the degree of effective preservation. However, these changes may also represent evolutionary processes that were happening during early to middle Neoproterozoic time.

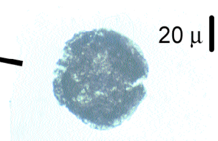
The Uinta Mountain Group has been described as a thick (as much as 24,000 feet) sequence of metasedimentary rocks; however, we see little evidence of metamorphism in rocks exposed in the eastern Uinta Mountains. In addition, the presence of preserved fossil cyanobacteria suggests that these rocks were not metamorphosed. When viewed with a microscope in transmitted light, their color is a clue to their burial history. We know that the color of organic material in rocks changes from light brown to black as the rocks are buried and subjected to increasing heat and pressure; in general, the darker the color the greater the amount of heat that has been applied. The color of the organic material preserved in the samples we collected is medium to dark brown, which means that these rocks were not metamorphosed. This begs the question, how can rocks as old as Neoproterozoic and as much as 24,000 feet thick not be metamorphosed as previously thought? Part of the answer may be that the Uinta Mountain Group is actually less than 24,000 feet thick. Burial history modeling using the color alteration of the organic material in the Uinta Mountain Group as a guide suggests that the group is more likely about 15,000 feet thick. This is still thick, but much less than previously thought.

Work continues to map the geology of the Uinta Mountains and to understand the rocks that comprise the Uinta Mountain Group. No doubt more fossils will be found in some of Utah's oldest rocks.

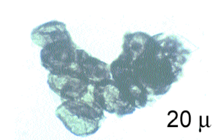




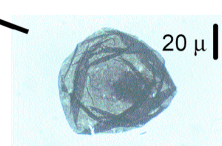
Eohyella sp.



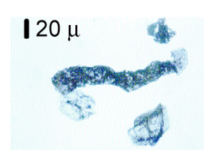
Trachysphaeridium laminaritum



Eossacharomyces sp.



Leiosphaera sp.



carbonaceous filaments

Photomicrographs of fossil cyanobacteria, and a stratigraphic column of the Uinta Mountain Group in the eastern Uinta Mountains showing sample locations and range of fossil occurrence. Sample numbers correspond to locations on geologic map.

Energy News

"Elephant" Discovered in Central Utah?

by Thomas C. Chidsey, Jr. and Douglas A. Sprinkel

You can't miss it! Drive south of Interstate 70 on State Highway 24, and a few miles past Sigurd you'll see the "elephant" – oil patch jargon for a major oil discovery. Just east of the highway is a large drilling rig, wellhead, and a battery of eight tanks, each capable of storing 400 barrels of crude oil. The wellhead, also called a "Christmas tree," is on the discovery well for the Covenant oil field in Sevier County, the only oil field for over 100 miles. It just may be the first of several huge "elephants" in central Utah. The No. 17-1 Kings Meadow Ranches discovery well, drilled by Michigan-based Wolverine Oil & Gas Company, reportedly is pumping nearly 900 barrels of oil per day, and the field has already produced over 210,000 barrels since May 2004. At least nine additional wells are planned to develop the new field, which may contain several hundred million barrels of oil. The last major new oil find in Utah was the 1975 discovery of Pineview field east of Coalville in Summit County in the northern part of the state. Pineview has produced over 31 million barrels of oil and is still pumping nearly 15,000 barrels each month.

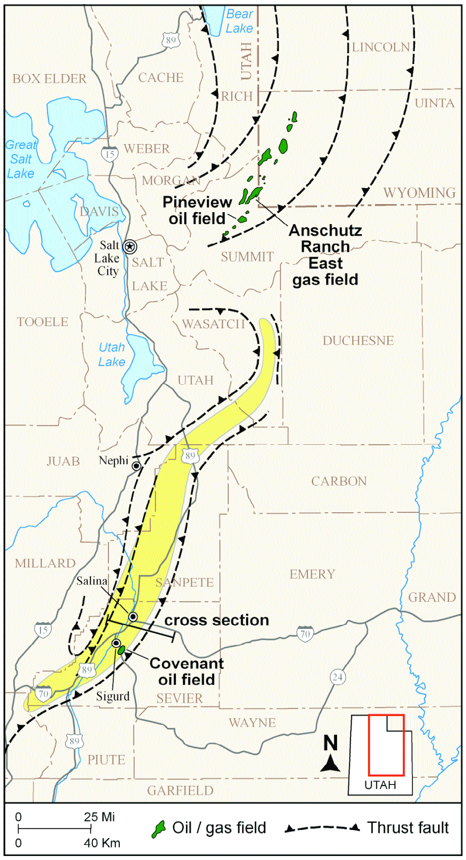
Oil companies have been exploring central Utah off and on for over 50 years, with no success until now. So why did it take so long to find oil in this area? The main reason is the extremely complex geology. This region is part of the central Utah thrust belt, also referred to by geologists as "the Hingeline." The Hingeline basically follows Interstate 15 south from Nephi to the southwest corner of the state. Throughout this

Wolverine Oil & Gas Company's No. 17-1 Kings Meadow Ranches well "Christmas tree" (right), and rig (above) drilling a new well near Sigurd, Sevier County.

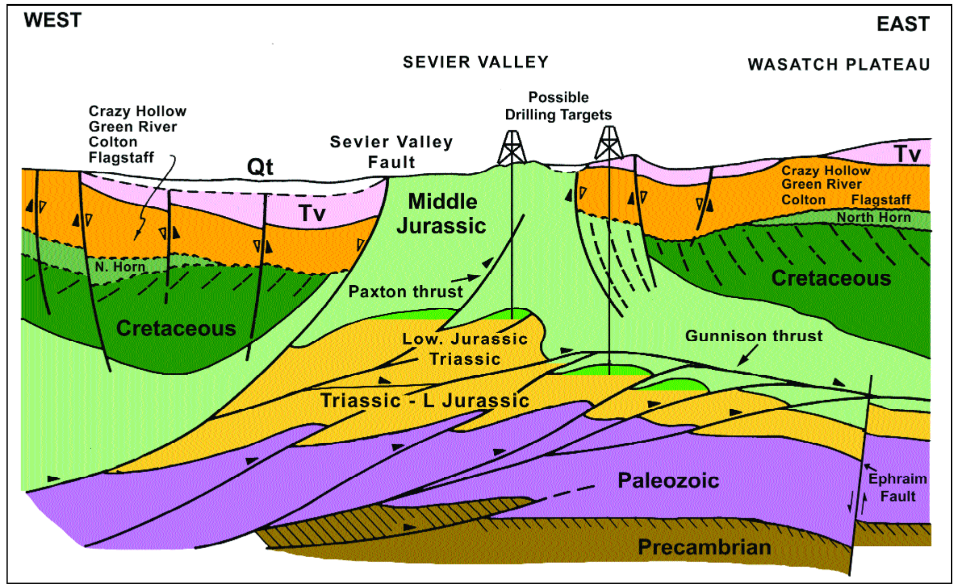
area's geologic history, the Hingeline has marked a pronounced boundary between different terrains. During Late Proterozoic to Devonian time (1 billion to 360 million years ago), it marked the boundary between a very thick sequence of sediments deposited in western Utah and a thin sequence deposited in eastern Utah. Later, the Hingeline coincided with the eastern edge of a mountain belt that formed during the Sevier orogeny, a mountain-building period that took place during Cretaceous to early Tertiary time (about 140 to 50 million years ago). Today it marks the general boundary between the Basin and Range and the Colorado Plateau physiographic provinces.

During the Sevier orogeny, compressional forces produced stacks of thrust faults – low-angle faults that moved huge sheets of older rock tens of miles eastward over younger rocks. To better understand this phenomenon, imagine you are in a cafeteria and place your tray on a conveyor belt with other trays. If one tray were to get jammed, the other trays would stack up and slide over each other, similar to the process of thrust faulting. Associated with thrust faults are large anticlines, folds in the rocks between the faults. The crests of these anticlines are some of the best places to trap oil. Pineview and other fields in Summit County produce oil and gas from these types of features.

However, one needs more than just anticlines for big oil fields to form, and the Covenant discovery suggests central Utah may have all the right conditions. There must be organic-



Central Utah thrust belt with colored band (yellow) showing area of greatest oil potential; Covenant oil field, Sevier County, Utah, is by the town of Sigurd.



Schematic east-west structural cross section through Sevier Valley, Utah (line of section shown on map), just north of the 2004 discovery of Covenant oil field, showing potential exploratory drilling targets in anticlines between thrust faults. Modified from Villien and Kligfield, AAPG Memoir 41, 1986.

rich source rocks, which have been sufficiently buried and "cooked" to generate and then expel oil. Known potential Mississippian (360 million years old) and Permian (290 million years old) source rocks are present north and west of the new field. There must be thick reservoir rock – porous rock capable of storing large amounts of oil. The No. 17-1 Kings Meadow Ranches well is producing from the Jurassic (205 million years old) Navajo Sandstone (which is equivalent to the Nugget Sandstone in northern Utah, the major reservoir rock that produces in Pineview and most other fields in Summit County). The Navajo is a massive sandstone that was deposited as great sand dunes in a Sahara-like environment that covered much of Utah (the spectacular canyons of many southern Utah national parks, such as Zion, are carved in the Navajo). The reservoir rock must be sealed by impermeable rock in order to keep the trapped oil from leaking to the surface or into other layers. In central Utah, the Navajo and overlying Twin Creek Limestone, another reservoir rock, are sealed by mudstone and evaporite (halite [common table salt] and gypsum) beds of the overlying Jurassic Arapien Shale. Finally, as in life where it is often said "timing is everything," the large anticlines must have formed at the right time. For example, if an anticline develops after oil from the source rock has migrated through the area, it will be "dry."

The Covenant discovery demonstrates central Utah has all "the right stuff" – large anticlines, source rock, reservoir rock, sealing rock, and good timing. However, the Arapien Shale, which outcrops at the No. 17-1 Kings Meadow Ranches well site and along the eastern side of Sevier Valley, as well as underlies the farmland in much of the valley, adds another level of complexity to the geology. The outcrops at the well and especially near the mouth of Salina Canyon are typically highly contorted and faulted. This is due to the plastic nature of the Arapien; the mudstone and evaporite beds are favored locations for thrust faults, and they have a tendency to flow when squeezed and compressed. As a result, what you see at the surface does not necessarily reflect what exists 7000 feet below. Thus, the real trick is to identify deep drilling targets using state-of-the-art seismic data, three-dimensional models, well information, high-quality surface geologic maps, geochemical analyses, and other techniques.

Wolverine believes there may be 25 additional geologic structures in central Utah that could contain oil reserves comparable to Pineview or Anschutz Ranch East fields. The latter, also located in Summit County, has produced nearly 128 million barrels of oil. The company is conducting a seismic program (460 miles of lines) to further define these and identify other potential features. Industry interest in the area is extremely high. Recent lease rates of federal (Bureau of Land Management) and state (School and Institutional Trust Lands Administration) lands range from $10 to over $1200 an acre.

The Covenant oil field discovery is not a real elephant, but a potentially huge economic boom to Sevier and surrounding counties, and the state of Utah. If the oil reserve estimates of the area become reality, Utah will make a significant contribution in reducing the nation's dependency on foreign oil.

GeoSights

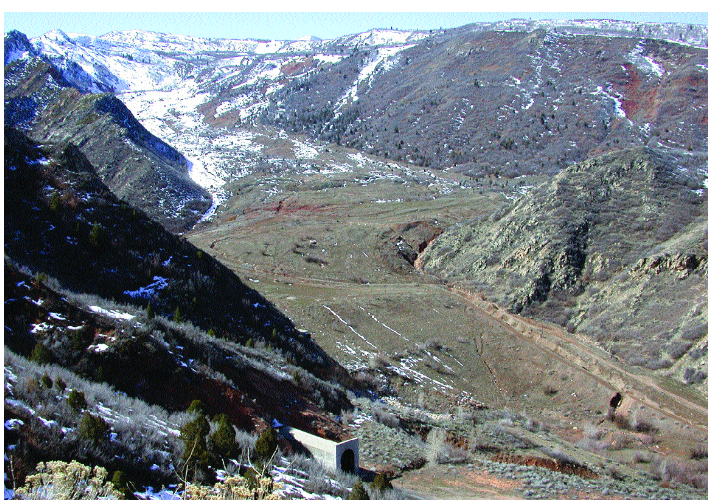
Thistle Landslide Revisited,
Utah County, Utah

by Mark Milligan

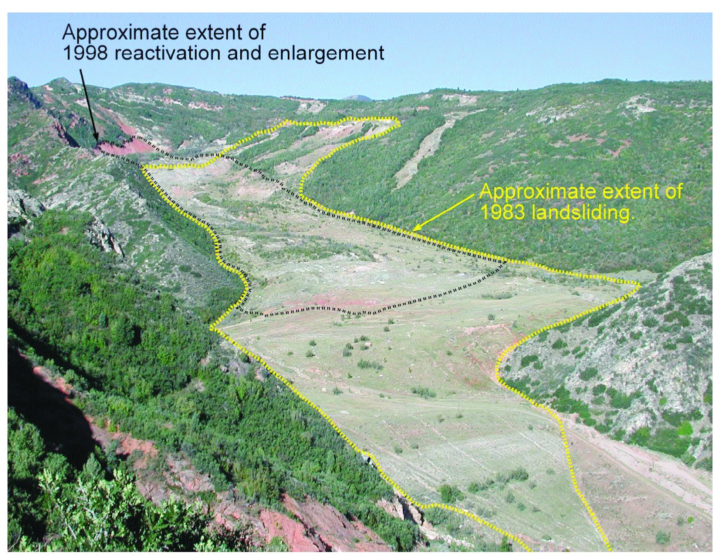
Geologic Information: Many readers, but not all, will have vivid memories of the most costly landslide to date (2005) in U.S. history. How long ago did the Thistle landslide occur? It has been 22 years. For reference, if you were born when the slide began to move in April 1983, you might be graduating from a university this spring. Whether you were there or have only read about it, the slide and remains of the destruction it left behind are worth a look.

Record-breaking precipitation in the fall of 1982, followed by a deep winter snow pack, then warm spring temperatures and rapid snowmelt in 1983 set the stage for the Thistle landslide. Once triggered, the slide reached a maximum speed of 3.5 feet per hour and dammed Spanish Fork River within a few days. The landslide ultimately reached 1000 feet in width, nearly 200 feet in thickness, and over one mile in length. The lower end of the slide formed a 220-foot-high dam where it abutted against a sandstone cliff at the base of Billies Mountain. Behind this dam, "Thistle Lake" reached a maximum depth of 160 feet before being drained by diversion culverts. The Thistle landslide and "Thistle Lake" severed railroad service between Denver and Salt Lake City, flooded two major highways (U.S. 6 and U.S. 89), devastated the town of Thistle, and resulted in Utah's first Presidential disaster declaration. Direct damage exceeded $200 million (in 1983 dollars), making Thistle the most expensive landslide to date in U.S. history.

Thistle landslide and "Thistle Lake," 1983.

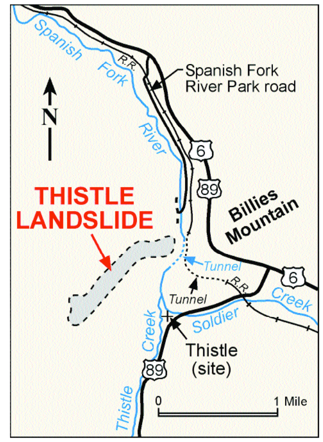


Thistle landslide, February 2005. View to the west from pullout on U.S. Route 6/89. Note railroad tunnel at bottom center (constructed after the landslide buried the original railroad grade).

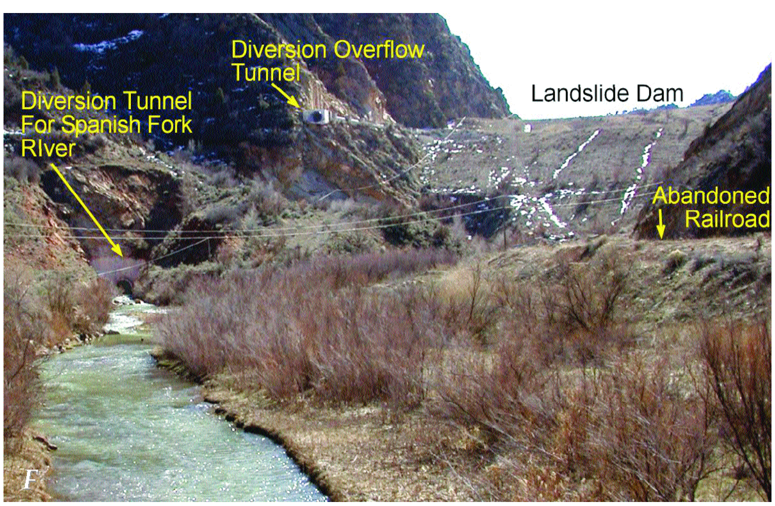


Thistle landslide, 2001. View to the west from pullout on U.S. Route 6/89.

The 1983 landslide consisted of detritus from the North Horn and Ankareh Formations that moved along a trough-shaped depression in deeper bedrock (a paleovalley). Landslides in Spanish Fork Canyon are nothing new. In fact, the area of the 1983 landslide has undergone repeated historical and prehistoric movement. Furthermore, the Thistle Landslide and immediate area has continued to move intermittently since the 1983 wet year. Minor mudslides (earth flows) periodically occur near its flanks and head. Following a wet winter, almost the entire slide (except for the "dam" section) moved in spring of 1998. This 1998 reactivation also enlarged the head of the slide by an area about the size of several football fields.



How to get there: Travel on I-15 towards the town of Spanish Fork. Take exit 261 and head east on U.S. Route 6/89. To view the landslide from the downstream side, turn right onto Spanish Fork River Park road after approximately 11 miles; otherwise, continue approximately 12.7 miles (from I-15) and turn right into the large pullout immediately before a massive double road cut. This pullout provides an excellent overview and interpretive signage. Approximately 1.5 miles past the pullout, turn right onto U.S. Route 89 and travel approximately 1.5 miles to the ruins of the town of Thistle and more interpretive signage.



A. Thistle's old red schoolhouse (circa 1893) just before inundation by "Thistle Lake" in 1983.

B. Today's remnants of Thistle's old red schoolhouse.

C. Though apparently intact, this house was buried to the eaves while inundated by "Thistle Lake" and recently re-flooded by Thistle Creek. Over 15 feet of sediment was locally deposited during the brief five months that the lake existed. Located on the west side of U.S. Route 89, just south of Thistle's old red schoolhouse ruins.

D. With the rise of "Thistle Lake," roofs became rafts, now randomly strewn along the former shoreline. Located on the east side of U.S. Route 89, just south of Thistle's old red schoolhouse ruins.

E. Landslide dam and shorelines of "Thistle Lake." View to the north from U.S. Route 89.

F. View to the south (upstream) of the Thistle landslide dam and Spanish Fork River diversion tunnels.

"Glad You Asked"

by William F. Case

What is Utah's State Soil?

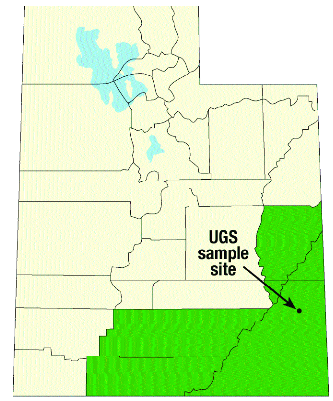
The Mivida (mee vee duh) soil is Utah's unofficial state soil. Although not legislatively established, the Mivida is listed by the Natural Resources Conservation Service (NRCS) as Utah's representative soil.

Soil is a complex product of (1) mechanical and chemical breakdown, erosion, and transport – by moving water, ice, or wind - of rocks and minerals (parent material), (2) leaching and deposition of chemicals and nutrients, and (3) organic growth and decomposition. Soils generally consist of 25% water, 25% air, 45% rock and mineral pieces, and 1-5% organic material. Aside from water and air, soil is our most important natural resource. Soil offers physical support, minerals, and a home for billions of microbes (mostly fungi and bacteria) that convert minerals to nutrients for crops.

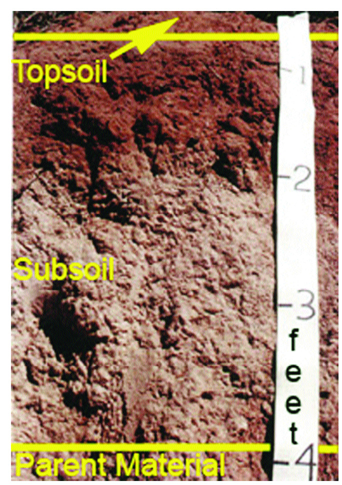
The Mivida soil is widespread across southeastern Utah; its parent material is sand derived from the lower Mesozoic sandstone so prevalent in southern Utah's famous parks and monuments. According to the NRCS, the Mivida soil consists of fine sandy loam (mostly sand, with a small amount of silt and clay) that has a yellowish-red topsoil and pinkish-brown subsoil. It covers over 200,000 acres of rangeland, irrigated cropland, wildlife habitat, and recreational land on cuestas and benches in southeastern Utah. It forms in wind-deposited sheets of sand eroded from Quaternary (0 to 1.8 million years old) dunes and Mesozoic sandstone. The soil is present at elevations between 5000 and 5400 feet. Precipitation of only 8 to 13 inches per year limits native vegetation to grasses, Mormon tea, saltbush, and sagebrush. A small sample of the Mivida soil (topsoil) is available from the Geologic Information and Outreach Program Staff, Utah Geological Survey, 801-537-3300.

For more information on soils, see the Natural Resources Conservation Service web site: http://soils.usda.gov/

Figures and Mivida soil description from:
ftp://ftp-fc.sc.egov.usda.gov/NSSC/StateSoil_Profiles/ut_soil.pdf



Mivida soil occurrence in Utah.



Representative soil profile of Mivida soil.

UGS Mivida soil sample site.

Teacher's Corner

St. George Teachers Enthused about Geology

"It was fantastic – we need more science inservices like this!"

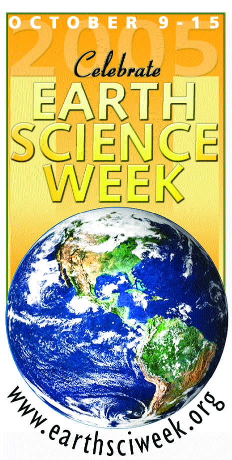
In February, three Utah Geological Survey staff led a two-day *Geologic Processes Change the Earth's Surface* workshop in St. George for 18 fifth-grade teachers. With support from the Utah Seismic Safety Commission, University of Utah Seismograph Stations, and Utah Division of Emergency Services, teachers were able to receive valuable teaching materials and resources.

The workshop entailed (1) a field trip to look at earthquake faults, volcanos, inverted topography, weathering, erosion, and deposition, and (2) classroom activities to investigate geologic processes and features in more depth.

With their enhanced geologic knowledge base, most participants plan to take their students on a geology field trip and allocate several extra weeks to teach this exciting science unit of their curriculum.

For teachers interested in attending a similar workshop in other areas of Utah, please contact Sandy Eldredge at sandyeldredge@utah.gov, 801-537-3325.

Teachers investigate modern and ancient sand dunes, as well as evidence of volcanic activity in Snow Canyon State Park.



Utah Geological Survey Announces
Earth Science Week 2005 Poster Contest

Contest supported by the Utah Geological Association

Earth Science Week is an international event that takes place every second full week of October. It offers a great opportunity for teachers and students to learn about the Earth and its resources. To encourage teacher and student involvement, the Utah Geological Survey (UGS) will institute a poster contest generously supported by the Utah Geological Association.

Check our web site for updated information or please contact us:

http://geology.utah.gov
Sandy Eldredge, 801-537-3325, sandyeldredge@utah.gov
Nancy Carruthers, 801-537-3346, nancycarruthers@utah.gov

Details:

- Announcements will be sent to local 4th-grade teachers in early August.
- Entries (one per classroom) must be postmarked no later than September 22, 2005.
- Winners will be announced September 28, 2005.

Awards:

- Sixteen winning classrooms will be awarded a reserved spot to attend the 2005 Earth Science Week activities at the UGS Utah Core Research Center, October 11-14.
- The top three entries will be awarded paid bus fare to attend the activities at the UGS.
- Winning posters will be displayed during Earth Science Week at the UGS.

New Publications

The Oil and Gas Fields Map of Utah has been updated to February 2005 (originally released 7/04) with an additional field and new ArcView project; M-203DM rev, CD (1 plate, scale 1:700,000) $24.95

Geologic map of the Saratoga Springs 7.5' quadrangle, Utah County, Utah, by Robert F. Biek, 2 pl. 1:24,000, ISBN 1-55791-707-8, 12/04, M-201 (with M-202)

Geologic map of the Cedar Fort 7.5' quadrangle, Utah County, Utah, by Robert F. Biek, 2 pl. 1:24,000, ISBN 1-55791-708-6, 12/04, M-202 . . . . $11.95 for both maps.

Ground-water sensitivity and vulnerability to pesticides, eastern Box Elder County, Utah, by Mike Lowe, Janae Wallace, Neil Burk, Matt Butler, Anne Johnson, and Rich Riding, CD (24 p., 2 pl., 1:120,000), MP-05-1, 1/05 . . . . $19.95

Preguntas comunes acerca de Gran Lago Salado de Utah y de Antiguo Lago Boneville (Spanish version of "Commonly asked questions about Utah's Great Salt Lake") by J. Wallace Gwynn, 22 p., PI-86, 1/05 . . . . $2.25

Hydrogeologic setting of the Snake Valley Hydrologic Basin, Millard County, Utah, and White Pine and Lincoln Counties, Nevada – Implications for possible effects of proposed water wells, by Stefan Kirby and Hugh Hurlow, CD (39 p.), 1/05, RI-254 . . . . $19.95

Progress report geologic map of the east part of the Provo 30' x 60' quadrangle, Utah (year 4 of a multi-year project), by Kurt N. Constenius and James C. Coogan, 22 p., 1 pl. 1:62,500, 12/04, OFR-439 . . . . $7.50

Geologic map of Westwater 30' x 60' quadrangle, Grand and Uintah Counties, Utah and Garfield and Meas Counties, Colorado, by J.L. Gualtieri, (digitized from U.S. Geological Survey Miscellaneous Investigations Series Map I-1765 [1988]), scale 1:100,000, OFR-441DM, 12/04 [CD contains GIS data] $14.95

Interim geologic map of Virgin quadrangle, Washington County, Utah, by Janice M. Hayden, 2 pl., 1:24,000. 1/05, OFR-442 . . . . $7.95

Interim geologic map of the lower San Juan River area, eastern Glen Canyon National Recreation Area and vicinity, San Juan County, Utah, by Grant C. Willis, scale 1:50,000, OFR-443DM, 12/04 [CD contains GIS data] . . . . $14.95 (paper copy $15.00)

Interim geologic map of the Mills quadrangle, Juab County, Utah, by Charles G. Oviatt and Lehi F. Hintze, 5 p., 1 pl, 1:24,000, 2/05, OFR-445 . . . .$5.00

Investigation of the potential of Interferometric Synthetic Aperture Radar (InSAR) to detect land subsidence in SW Utah, by Richard R. Forster, 21 p., 1/05, OFR-446 . . . .$14.95

Geologic map of the Washington Dome quadrangle, Washington County, Utah, by Janice M. Hayden, 29 p., 2 pl., 1:24,000, 4/05, M-209 . . . .$10.80

Proceedings volume, Basin and Range Province Seismic-Hazards Summit II, edited by William R. Lund, CD (20 papers, 64 abstracts, 10 posters), ISBN 1-55791-725-6, 4/05, MP-05-2 . . . .$14.95

Provisional structural geologic map of the Jericho quadrangle, Juab County, Utah, by Sanghoon Kwon and Gautram Mitra, 2 pl. 1:24,000, 4/05, OFR-444 . . . .$8.00

Available at:

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