UTAH GEOLOGICAL SURVEY

SURVEY NOTES

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URBAN GROWTH AND INCREASED HAZARD VULNERABILITY

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Design by Vicky Clarke

***Cover:** Salt Lake City skyline. Photograph by Frank Jensen, courtesy of the Utah Travel Council.*

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The Director's Perspective

by Richard G. Allis

Several articles in this issue of Survey Notes highlight the rapid urban growth along the Wasatch Front and the increased vulnerability from geologic hazards. Utah had the fourth highest population growth in the country last decade (29%), with most growth occurring along the Intermountain seismic belt. Because of this, the state has the seventh highest annualized earthquake loss rate ($51 million). The growth statistics for the 1990s highlight another trend – that of rapid urbanization occurring within the Wasatch Range, compared to the traditional growth areas along the valley floors and benches adjacent to the mountain fronts in northern and southern Utah. The county with the highest growth rate during the 1990s was Summit County (92%), with Park City being its largest city. This trend towards building in steeper terrain has increased the risk of forest fire hazards, and the associated subsequent risks of debris flows. Repeated droughts in recent years have compounded these risks, with several damaging debris flows occurring this year (see Rich Giraud's article on the Santaquin debris flow).

The UGS endeavors to warn and advise local governments and their city planners on the risks of geologic hazards as new subdivisions are being planned. Unfortunately geologic hazards are not always a high priority when all the other growth pressures are also taken into consideration. This year's debris flows near Alpine (just north of Provo), and at Santaquin (just south of Provo), demonstrated that people are most receptive to messages about geologic hazard vulnerability when damaging events actually occur. Provo City is now taking advantage of a grant from the Emergency Watershed Protection program of the NRCS to reduce the debris-flow hazard from Buckley Draw which also burned last summer, but fortunately missed experiencing any severe summer downpours. The Santaquin debris flows were not triggered by the storm of the century; the 0.27 inches of rain that fell in probably less than 15 minutes could occur anywhere along Wasatch Front once every few years. The UGS is currently working with the National Weather Service on compiling a package of educational materials based on the Santaquin debris flows to capitalize on the window of opportunity and increase the awareness of city planners and the public.

On another topic, starting January 1, 2003, anyone practicing geology before the public in Utah requires a professional geologist license. The "grandfather" period when the ASBOG exam is not required extends until January 1, 2004. During this time applicants still must meet educational and work experience standards to receive a license. Information about applying for licensure can be found at the State Division of Occupational and Professional Licensure website: http://www.dopl.utah.gov/licensing/geologist.html.

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New Maps Show Potential Geologic Effects of a Magnitude 7 Earthquake in the Salt Lake City Area

by Barry J. Solomon

Introduction

In 1860, essayist and poet Ralph Waldo Emerson wrote, "We learn geology the morning after the earthquake, on ghastly diagrams of cloven mountains, upheaved plains, and the dry bed of the sea." Human nature remains the same now as then—we often learn our geologic lesson after an earthquake, rather than plan in advance. The seismically active central Wasatch Front of Utah, with a population of about 1.7 million centered upon Salt Lake City, has the potential to be shaken by a strong (magnitude 7) earthquake. However, the region has not experienced a strong earthquake in historical time. To help understand earthquake risks and estimate losses in the region, we mapped geologic hazards posed by a magnitude 7 earthquake along the Salt Lake City segment of the Wasatch fault zone, a major active zone of normal faulting.

Federal, state, and private-industry partners cooperated in this study, partially funded by the U.S. Geological Survey's National Earthquake Hazards Reduction Program and with additional support and technical assistance from the Utah Division of Emergency Services and Homeland Security, URS Corporation, and Pacific Engineering & Analysis. Our hazard maps will provide the geologic basis for a comprehensive loss estimate using HAZUS computer software, which was developed for the Federal Emergency Management Agency for use in estimating losses and planning for emergency preparedness, response, and recovery.

The earthquake hazards we mapped include surface fault rupture, tectonic subsidence, earthquake ground shaking, liquefaction, and earthquake-induced landsliding. Most hazards were mapped by considering the thickness of unconsolidated deposits ("soil" to geologists and engineers), rock and soil properties, and the relationship of thickness and properties to effects observed in historical earthquakes worldwide.

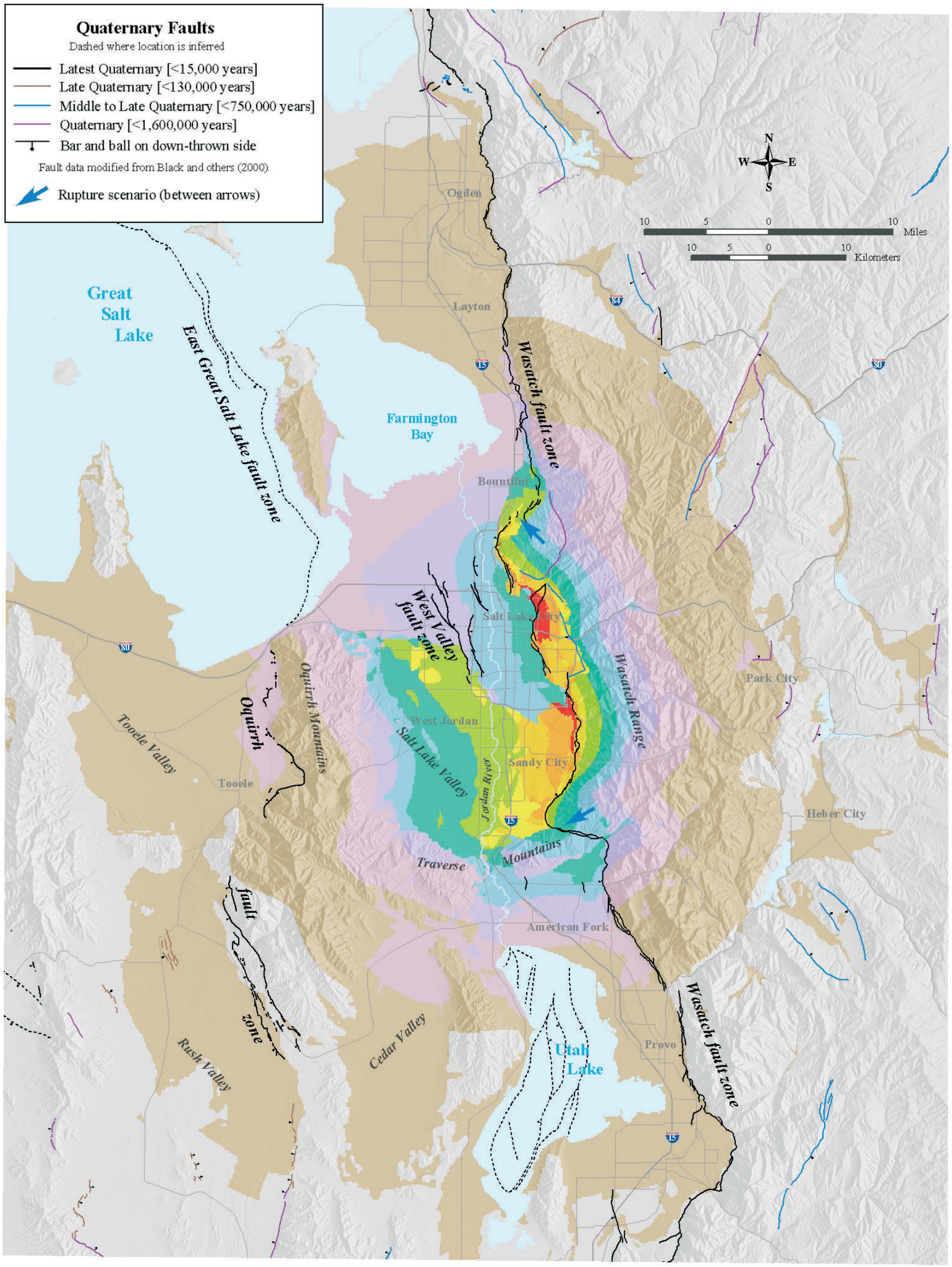
The Scenario Earthquake

The Wasatch fault zone trends north-south through the Wasatch Front and is divided into 10 segments, including the Salt Lake City segment. Geologic evidence indicates that the Salt Lake City segment generates large earthquakes (approximately magnitude 7) on average every 1,350 years, the most recent having been about 1,300 years ago. Because a large earthquake on the Salt Lake City segment will affect the greatest number of people and probably produce the greatest losses along the central Wasatch Front, we selected a magnitude 7 event on this segment as the scenario earthquake.

A strong earthquake in the Salt Lake City area may create a fault scarp similar to this, formed during the 1983 Borah Peak earthquake in Idaho.

Mapped Earthquake Hazards from the Scenario Earthquake

Surface fault rupture: Movement along faults deep within the earth generates earthquakes. In Utah, if the earthquake is strong enough, commonly greater than magnitude 6.5, the fault movement will break to the ground surface. Along the Wasatch fault zone, this surface fault rupture will form a near-vertical scarp as one side of the fault is uplifted and the other side is downdropped. We estimate an average scarp height of 6.1 feet where faulting occurs along the East Bench of Salt Lake Valley. This amount of displacement is capable of causing irreparable damage to any structure built across the scarp. A zone of additional deformation will likely accompany the main scarp on its downthrown side.



Peak Horizontal Acceleration (g)	Modified Mercalli Intensity	
< 0.1	I-V	Weak to moderate shaking - Very light damage at MM V.
0.1 - 0.2	VI	Strong shaking - Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster and damaged chimneys. Damage light.
0.2 - 0.3		
0.3 - 0.4	VII	Very strong shaking - Negligible damage in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or designed structures.
0.4 - 0.5	VIII	Severe shaking - Slight damage in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures.
0.5 - 0.6		
0.6 - 0.7		
0.7 - 0.8	IX	Violent shaking - Considerable damage in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse.
0.8 - 0.9		
0.9 - 1.0		
1.0 - 1.1		

Peak horizontal ground accelerations resulting from a M 7 scenario earthquake along the Salt Lake City segment of the Wasatch fault zone.

Tectonic subsidence: When earthquake faults break the ground surface in a geologic setting like the Wasatch Front, the adjacent valley floor may drop down and tilt towards the fault, creating a subsidence trough. The extent of tilting is controlled by the amount and length of surface fault displacement.

When the Salt Lake Valley floor tilts during the scenario earthquake, the shoreline of Farmington Bay in Great Salt Lake will shift to the southeast. Developed areas near the lake shore and in the northern Jordan River flood plain may be flooded if the level of Great Salt Lake is high when shifted. Subsidence may also cause localized ponding of shallow ground water east of the Jordan River in Salt Lake Valley.

Ground shaking: Ground shaking is the most widespread hazard resulting from the scenario earthquake. Normally, a building need only withstand the vertical force of gravity (assigned an acceleration value of 1 *g*) to support its own weight. However, during an earthquake a building is also subjected to horizontal accelerations from ground shaking. These accelerations have the potential to cause damage to weak structures (buildings not specifically designed to resist earthquakes) if they are greater than 0.1 *g*, and damage potential increases with the strength of ground motions.

During our scenario earthquake, potentially damaging ground motions extend north to Ogden and south to Provo at distances of 30 to 40 miles from Salt Lake City. The strength of ground motions rapidly decreases with increasing distance from the fault on its upthrown side in the Wasatch Range, although potentially damaging ground motions may occur in the mountain valleys. Potentially damaging ground motions are amplified in certain deposits of sand and gravel, particularly those present on the east side of Salt Lake Valley.

Liquefaction: Liquefaction occurs when ground shaking is strong enough to cause shallow, water-saturated, cohesionless soils (commonly sand) to lose their strength and ability to support the weight of overlying soil and structures. Liquefaction is one of the major causes of earthquake damage.

During our scenario earthquake, much of Salt Lake Valley and nearby areas has a potential for large lateral (possibly greater than 1 foot) and vertical (possibly greater than 8 inches) liquefaction-induced ground displacements. Research suggests that damage may be severe from ground displacements this large, and much of the damage may be irreparable. However, the extent of soils having the potential for large liquefaction-induced displacements is deceiving. Their widespread distribution is due to the high levels of ground shaking resulting from the scenario earthquake, which can cause large displacements even in soils that are not usually prone to liquefaction. Although possible, large displacements are unlikely in southern Salt Lake Valley, but are most likely in the densely populated northern part of the valley, the west Bountiful area, and the northern end of Utah Valley.

A landslide caused by the 1992 St. George earthquake destroyed this house in Springdale.

Landsliding: Another geologic hazard that may be caused by earthquake ground shaking is landsliding. Slopes considered unstable under normal conditions will be even less stable during moderate to strong earthquakes, and some slopes that are normally stable may also fail as a result of earthquake ground shaking, particularly if wet. Landslides can damage buildings, transportation routes, and utility lines by displacement of the ground, and cause flooding due to discharge of springs and damming of streams.

During our scenario earthquake, landsliding will likely be most severe on mountain spurs of the Wasatch Range adjacent to Salt Lake Valley, threatening downslope development in areas such as the East Bench. However, prehistoric landslide deposits are relatively rare on these slopes, suggesting that landslides have not commonly occurred during previous large earthquakes in Salt Lake Valley. Landsliding may also occur along steep banks of the Jordan River in southern Salt Lake Valley and, to a lesser extent, in the Oquirrh Mountains to the west, the Traverse Range to the south, and the Wasatch Range interior to the east. Because landsliding is more common under wet conditions, the hazard will be greatest from a springtime earthquake during snowmelt.

A Tool for the Future

Our geologic-hazard maps, available publicly later this year, demonstrate the widespread effects in the central Wasatch Front of the scenario earthquake. However, we don't have to wait until, as Emerson wrote, "after the earthquake" to learn our lesson. We hope that these maps provide a basis to better understand earthquake risks and encourage loss reduction in Utah before the next strong earthquake happens. Being prepared is a much better choice than waiting idly by for disaster to strike.

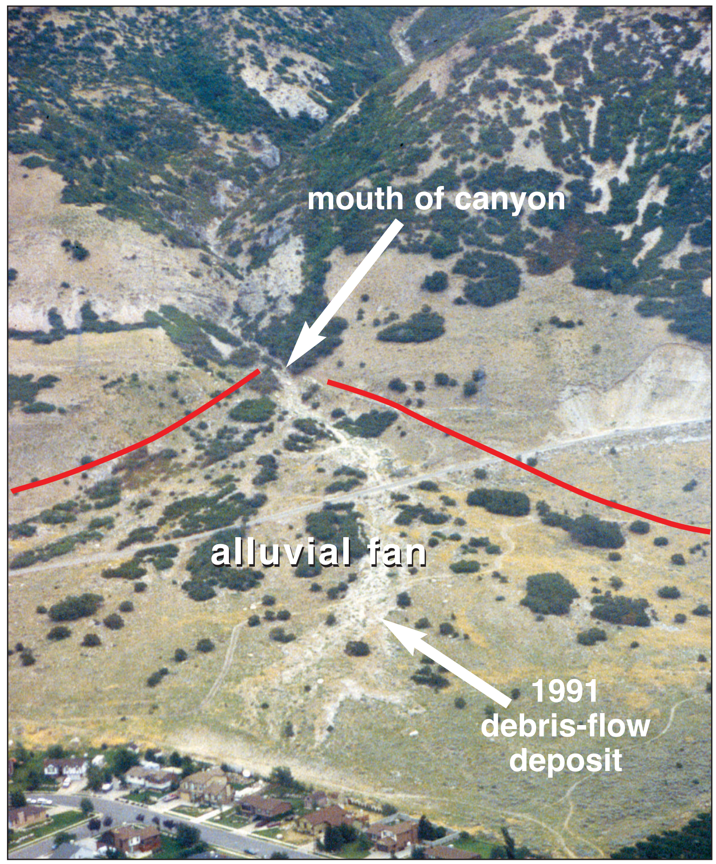
Debris Flows in Utah – New Guidelines for Hazard Evaluation

By Richard Giraud

Debris flows are fast-moving slurries of rock, mud, organic matter, and water that flow down steep mountain channels and then spread out and come to rest on alluvial fans. Debris flows are triggered by rapid snowmelt or intense thunderstorm rainfall. Alluvial fans at the mouths of mountain drainages have gentle slopes and are favored sites for housing and other development. However, when debris flows travel out onto alluvial fans they can be life-threatening and destructive because they can occur with little warning, cause flooding and burial by debris, and have impact pressures large enough to push houses off foundations and collapse walls. Large-volume, destructive debris flows on alluvial fans are best described as relatively low-probability, high-consequence events where the time period between debris flows is often a period of deceptive tranquility.

Since the state was settled by pioneers in 1847, debris flows in Utah caused 14 deaths and substantial property damage. One notable debris flow, the 1983 Rudd Canyon debris flow in Farmington, damaged 50 homes and caused $3 million in damage. Many areas of the Wasatch Front are particularly at risk from future debris flows, because a high population density exists on alluvial fans where no protective measures have been taken.

A debris-flow-hazard evaluation is necessary when developing on geologically young alluvial fans to ensure safe development. To help provide for consistent and systematic debris-flow-hazard evaluations, the Utah Geological Survey is preparing a report titled “Guidelines for the Geologic Evaluation of Debris-Flow Hazards on Alluvial Fans in Utah.” These guidelines will assist geologists in evaluating debris-flow hazards. The purpose of a debris-flow-hazard evaluation is to determine if a hazard exists and, if so, to provide geologic information needed to design risk-reduction measures. The guidelines focus the hazard assessment on two specific areas: the drainage basin and the alluvial fan. For most hazard assessments flow volume is the most important factor in addition to flow frequency, impact pressure, runout distance, and sediment burial depth.



Aerial view, looking northeast, of the September 7, 1991 Cameron Cove debris flow in North Ogden (photo taken in August 1996).

Debris flows start high in the drainage basin and increase in volume as they travel down channels, scouring and incorporating sediment. Geologists can estimate potential debris-flow volume by assessing the sediment-supply conditions in the drainage basin. Therefore, the hazard evaluation of the drainage basin focuses on the channel sediment supply, erosion conditions, and surface-water runoff conditions that ultimately determine the volume of material that reaches the alluvial fan. Study of historical debris flows indicates 80 to 90 percent of the debris-flow volume is eroded from channels; therefore, determining the volume of available channel sediment is critical to the hazard evaluation. The amount of sediment stored along channels is estimated by field surveys of channels in the

What About Great Salt Lake?

by Barry J. Solomon

Seiches (pronounced "sayshes") are oscillations of enclosed bodies of water, similar to the sloshing of water in a bathtub. The term was first used in 19th century Switzerland to apply to standing waves set up on the surface of Lake Geneva by wind and changes in barometric pressure. However, seiches often occur following an earthquake. Although strong ground shaking most commonly causes earthquake seiches, more dramatic seiching motion may be produced by a permanent vertical ground displacement beneath a water body, such as may be caused by surface faulting or tectonic subsidence. These waves are sometimes called "surges" to differentiate them from much milder but otherwise similar oscillations of closed water bodies caused by ground shaking.

Recent interest in possible seiches in Great Salt Lake results from the potential for lakeshore flooding associated with historically high lake levels in the early 1980s. Possible seiches were first discussed in this context by the University of Utah Seismograph Stations in an analysis of earthquake-design considerations for the inter-island diking project, which described accounts of waves generated in Great Salt Lake by the 1909 magnitude 6+ Hansel Valley, Utah earthquake. Although felt reports placed the location of the 1909 earthquake about 9 miles northeast of the north lake shore, the accounts of waves generated by this event suggested that the earthquake might actually have occurred beneath the lake and caused displacement of the laµke bottom, generating a surge. The larger 1934 magnitude 6.6 Hansel Valley earthquake apparently did not generate similar lake waves, consistent with instrumental location of the earthquake epicenter and with surface faulting located just northeast of the north lake shore.

The height of the wave generated by the 1909 Hansel Valley earthquake was later estimated at more than 12 feet using elevations of Great Salt Lake and the Lucin Cutoff railroad trestle, which was overtopped by the wave. However, this estimate did not consider the cause of the wave. The estimate is now believed to be an example of the potential for waves generated by differential subsidence of the lake floor associated with one of several active faults underlying the lake. Thus, when describing the consequences of an earthquake with a specified magnitude and location (a scenario earthquake), the mechanism of wave generation is important to consider and depends upon the relative locations of the lake, earthquake epicenter, and surface fault rupture. In the case of our scenario, neither a surge from displacement of the lake bed nor a seiche from ground shaking will be significant.

drainage basin.

Debris-flow deposits on alluvial fans provide a record of past flow volumes and runout. The hazard evaluation on alluvial fans follows the idea that the general areas where debris flows have deposited sediment in the recent geologic past are where they will likely deposit sediment again in the future. Alluvial fans are landforms composed of a mixture of debris-flow and stream-flow deposits. Geologists describe and analyze the debris-flow deposits exposed in subsurface excavations to understand past debris flows, including estimating how frequently debris flows occur, typical volumes of past flows, typical sediment burial depths, and runout distances on different parts of the alluvial fan. By understanding the behavior of past flows, geologists can estimate the hazard that future debris flows might present.

Wildfires in the drainage basin increase the debris-flow hazard through loss of vegetation and creation of water-repellent soil conditions that promote rapid runoff during thunderstorm rainfall or snowmelt. Recent wildfires that burned drainages above the Wasatch Front communities of Santaquin, Provo, and Springville required implementing emergency measures because debris-flow hazards had not been addressed in some residential developments below the burned areas. Fire-related debris flows have recently occurred in the following areas:

- Lake Point, Big Canyon debris flow, 8/23/00, Barrow Pit fire;
- Vivian Park/South Fork Provo River, South Fork debris flow, 8/31/00, Wasatch fire complex;
- Alpine, Preston Canyon debris flows, 8/21/01 and 9/6/02, Oak Hills fire; and
- Santaquin and Spring Lake, Dry Mountain debris flows, 9/12/02, Mollie fire (see related article in this issue).

The August 23, 2000, Big Canyon fire-related debris flow above Lake Point. Greg McDonald, a UGS geologist, is taking measurements to determine the volume of the flow on the alluvial fan.

Historical records of debris flows in Utah have shown the flows to be highly variable in terms of size, material properties, and runout distance; therefore, conservative design parameters must be used in risk reduction. The guidelines focus on obtaining geologic information to understand and describe the hazard to help hydrologists and engineers model the hazard and design risk-reduction measures.

Fire-Related Debris Flows Damage Houses in Spring Lake and Santaquin, Utah

by Richard Giraud and Greg McDonald

On the evening of September 12, 2002, intense thunderstorm rainfall on Dry Mountain, about 18 miles south of Provo, triggered fire-related debris flows that traveled down drainages and onto alluvial fans, damaging houses and property in Spring Lake and Santaquin east of Interstate 15. Fire-related debris flows are debris flows that start in areas burned by wildfires. Wildfires can produce conditions favorable for debris flows because they expose bare soil to erosion by burning vegetation and creating water-repellent soil conditions that promote rapid runoff. The September 12, 2002, fire-related debris flows started high in the drainages of Dry Mountain that burned in the 2001 Mollie wildfire, a human-caused fire that burned 8,000 acres between August 18 and September 1, 2001.

The storm was relatively short in duration, only dropping 0.27 inches of rain. However, it was preceeded by several days of light rain that kept soils wet and promoted runoff, triggering multiple debris flows on the west flank of Dry Mountain. Three debris flows deposited sediment in subdivisions built on alluvial fans in Spring Lake and Santaquin, and others deposited sediment in undeveloped areas. The debris flows were typical of other historical debris flows in Utah, occurring with little warning and traveling quickly down the channels and onto alluvial fans. Homeowners had little time to react. One flow in Spring Lake filled part of the High Line irrigation canal with sediment, causing flooding in addition to debris-flow damage.

Sediment deposited at the intersection of Lambert Avenue and Apple View Street in Santaquin. The debris flow moved cars and filled basements with sediment.

The debris-flow impact broke through the basement window of this house on Apple View Street in Santaquin.

The debris flow entered the front and garage doors of this house on Peach Street in Santaquin.

The debris flow broke through the back wall of this house on Peach Street in Santaquin.

The most damaging debris flow traveled through a subdivision in Santaquin that was evacuated immediately after the event. This debris flow moved and partially buried several vehicles, broke through a house wall, and entered other houses through broken basement windows and doors. Debris-flow impacts also tore gas meters from their mounts, causing gas leaks and a small fire. The majority of house damage was due to sediment and water flowing into houses. Sediment flow and burial on lots also damaged landscaping and property outside the houses. The flow did not follow city streets, but rather flowed around houses and through lots.

Following the Mollie fire in September 2001, an assessment of post-burn conditions on Dry Mountain by state and federal agencies, including the Utah Geological Survey, identified an increased debris-flow and flood hazard to the subdivisions on the alluvial fans. These agencies recommended that local communities perform a more detailed hazard evaluation to determine where emergency measures were necessary. These agencies also noted that debris-flow and flooding hazards existed in these areas before the fire, and that efforts to address the short-term hazards related to the fire should also consider the long-term potential of debris flows and floods. The homes and subdivisions apparently were constructed without regard to the debris-flow hazard. Because no emergency measures were taken to divert or contain flows to protect houses and property in response to recommendations in 2001, both short- and long-term debris-flow hazards remain. Local communities are now planning to take active defensive measures.

New Utah Minerals

By Carl Ege

Orthominasragrite, $V^{4+}O(SO_4)(H_2O)_5$

Orthominasragrite is a vanadium sulfate found at the North Mesa mine group in the Temple Mountain mining district, Emery County. The mineral is found as rounded aggregates approximately 0.002 mm across. Orthominasragrite is pale blue to bright blue with a pale blue streak. The mineral has a hardness of 1 and a density of 2.00 g/cm^3.

Orthominasragrite occurs in a fossilized log in the Shinarump Conglomerate Member of the Triassic Chinle Formation. The mineral is associated with pyrite, sulfur, minasragrite, and undescribed vanadium sulfate. Orthominasragrite is named for its relationship with the mineral minasragrite.

Oswaldpeetersite, $(UO_2)_2CO_3(OH)_2 \cdot 4H_2O$

Oswaldpeetersite is a basic uranyl carbonate found at the Jomac uranium mine in San Juan County. The mineral is found as prismatic crystals in radiating groups. Individual crystals are approximately 0.1 mm long and 0.01 mm wide. Oswaldpeetersite is canary yellow and has a pale yellow streak. The mineral has a hardness between 2 and 3 and a density greater than 4.10 g/cm^3. Oswaldpeetersite also occurs in the Shinarump Conglomerate in a fossilized log. The mineral is associated with gypsum, cuprite, goethite, antlerite, lepidocrocite, mbobomkulite, hydrombobomkulite, sklodowskite, and two undefined uranium minerals. Oswaldpeetersite is named for Maurice Oswald Peeters, a structural crystallographer and researcher at the University of Leuven, Belgium.

For more information:

Hawthorne, F.C., Schindler, M., Grice, J.D., and Haynes, P., 2001, Orthominasragrite, $V^{4+}O(SO_4)(H_7O)_5$, a new mineral species from the Temple Mountain, Emery County, Utah, U.S.A.: The Canadian Mineralogist, v. 39, p. 1325-1331.

Vochten, R., Deliens, M., and Medenbach, O., 2001, Oswaldpeetersite, $(UO_2)_2CO_3(OH)_2 \cdot 4H_2O$, a new basic uranyl carbonate mineral from the Jomac uranium mine, San Juan County, Utah, U.S.A.: The Canadian Mineralogist, v. 39, p. 1685-1689.

Survey News

Cheryl Ostlund has transferred to DNR Parks Northwest Region Office for an interesting change of scenery. Her position of Administrative Secretary has been assumed by **Jo Lynn Campbell** lately with the Geologic Information group.

Neil Storey has left the Hazards group to join CH2M-Hill as a GIS analyst. His position has been filled by **Justin Johnson**, formerly with the Division of Water Resources.

Pat Speranza, after 18 1/2 years as a cartographer in Editorial, has transferred her affections to Florida. Best of luck, Pat.

Energy News

Salt Lake City to Again Host the AAPG Annual Convention in 2003

by Tom Chidsey

ENERGY
OUR MONUMENTAL TASK
AAPG Annual Meeting
Salt Lake City, Utah
May 11-14, 2003

Editor's note: Tom Chidsey, General Chairman for the 2003 AAPG Annual Convention, is Manager of the Utah Geological Survey's oil and gas section. The Survey is an active AAPG supporter and welcomes the 2003 AAPG Annual Convention to Salt Lake City.

Introduction

"This is the right place!" proclaimed pioneer leader Brigham Young as he entered the Salt Lake Valley in 1847. One hundred fifty-five years later, Salt Lake City is still the right place…the place to join 6,000 geologists from around the world for the Annual Convention of the American Association of Petroleum Geologists (AAPG) and the Society of Sedimentary Geology (SEPM). This meeting is scheduled for May 11-14, 2003, and is hosted by the Utah Geological Association (UGA).

The convention slogan and logo, "Energy—Our Monumental Task," applies to the entire worldwide membership of AAPG. The backdrop depicts the famous Monument Valley, located in Arizona and Utah, which represents the need to balance preservation of the scenic open spaces of the American West with providing energy for a growing world economy. Utah assists with this monumental task of providing energy in an environmentally responsible way while consistently remaining in the top 15 oil- and gas-producing states.

Technical Program

Fifty oral sessions and 50 poster sessions will provide approximately 1,000 technical presentations during the three-day conference. The session topics are grouped into nine themes: (1) global energy resources, (2) the business side of petroleum, (3) technologies – new and proven, (4) reservoirs, (5) structure and tectonics, (6) stratigraphy, sedimentology, and paleontology, (7) petroleum systems and geochemistry, (8) environmental issues, and (9) student presentations. Sessions sponsored by AAPG and SEPM will cover a wide range of hot topics including new play concepts from the world's petroleum provinces, deepwater sequence stratigraphy and deposition, biostratigraphy, reservoir modeling, salt tectonics, lacustrine reservoirs, and emerging gas plays. Each of the AAPG divisions - Energy Minerals Division (EMD), Division of Environmental Geosciences (DEG), and Division of Professional Affairs (DPA) - is sponsoring specific sessions and forums on topics such as coalbed methane, carbon dioxide sequestration, remote sensing, methane hydrates, environmental best practices, and national security as it pertains to petroleum.

Field Trips

"The landscape everywhere . . . is of rock - cliffs of rock, tables of rock, plateaus of rock, terraces of rock, crags of rock - ten thousand strangely carved forms; rocks everywhere," was penned by Major John Wesley Powell on July 17, 1869, to describe what is now part of Canyonlands National Park. The rest of Utah also has rocks everywhere. The 23 field trips being offered at the Salt Lake City meeting will provide ample opportunity to witness spectacular displays of well-exposed geology.

The field trips will take participants to the classic Utah geology that serves so well as both modern and ancient outcrop reservoir analogs. These trips fit into the wide range of convention themes where participants can examine ancient and modern lake deposits, thrust and extensional faulting, salt tectonics, fluvial-deltaic sequences,

Continued on page 13...

Convention field trips will include classic geologic sites throughout Utah, such as Dead Horse Point. Photo courtesy of Utah Division of Parks and Recreation.

"Glad You Asked"

Are there glaciers in Utah's mountains?

by Sandy Eldredge

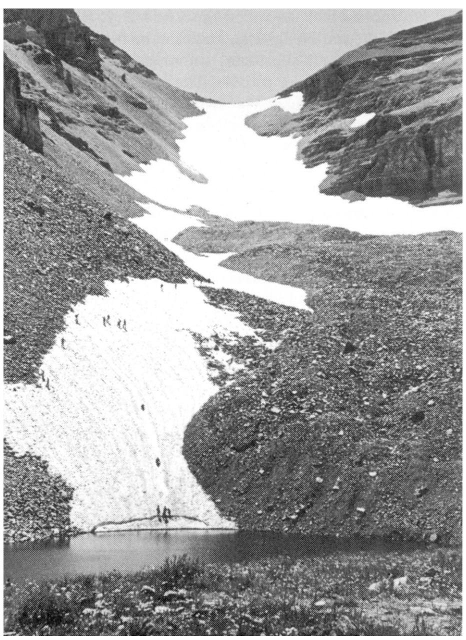
Patches of snow sometimes persist throughout most, if not all, of the year in Utah's areas of high elevation, such as on the east side of Mt. Timpanogos in Utah County. These patches of snow, often called snowfields, are not glaciers. Although we may currently be living in a time period called an ice age (albeit a warm interval within this time period)*, the glaciers in Utah disappeared thousands of years ago.

A glacier is a moving mass of ice and snow. When enough snow layers accumulate, the lower layers compact and recrystallize into ice. The heavy mass then slowly moves downslope by the force of gravity. The thick (for example, over 1,000 feet thick in some of Utah's mountain ranges) mass persists from year to year.

Snowfields, in contrast, do not move. Typically, the snow is not very deep either (for example, only several feet thick on parts of the Mt. Timpanogos snowfield). Sometimes, the snow may even completely melt out during the peak of high summer temperatures.

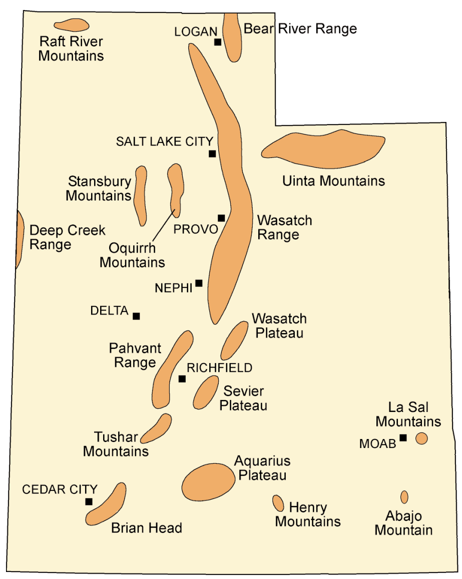
Glaciers have covered mountain ranges and high plateaus in Utah at various times in the past; the most recent glacial episode was approximately 30,000 to 10,000 years ago. At that time, the climate was colder (how much colder is up for debate, but some estimates are as much as 45° to 60°F colder) and wetter (again, up for debate, but possibly as much as 33 percent more precipitation). Great depths of snow accumulated, especially in basins over 10,000 feet in elevation, where glaciers would form. These great masses of ice eventually extended downslope to elevations as low as 5,000 feet in some areas.

*An ***ice age*** *is a long time interval (millions to tens of millions of years) when air temperatures are relatively cold and large areas of the Earth are covered by glaciers, both in the mountains (alpine or valley glaciers) and over continents (continental glaciers). The current ice age began between 2 and 3 million years ago. Because air temperatures fluctuate over the millions of years of an ice age, there are relatively colder times (glacial periods) and relatively warmer times (interglacial periods). Therefore, glaciers go through various stages of advancing and retreating and/or appearing and disappearing. The most recent glacial period probably peaked about 18,000 to 20,000 years ago. The climate has continued to more or less warm ever since, and we are probably now in a warm (interglacial) period within this ice age.*



Mt. Timpanogos snowfield on the east side of the mountain. Note the thin patches of snow.

Glacier on Kenai Peninsula, Alaska, shows the thick mass of ice and snow, which calves off (breaks and falls) into the ocean as it constantly moves downslope.



Glaciated areas in Utah included the mountain ranges and plateaus shown on this map. The Uinta Mountains claim the largest ice coverage at about 1,000 square miles, with some glaciers as long as 27 miles. The Wasatch Range was the next-largest glaciated area with over 60 glaciers, some descending as low as 5,000 feet in elevation. Another major glaciated area was over 50 square miles on the Aquarius Plateau. Glaciers retreated and advanced in response to climate fluctuations. The most recent warming trend caused the last glaciers to melt out of Utah's uppermost reaches about 8,000 to 7,000 years ago.

GeoSights

Pink Water, White Salt Crystals, Black Boulders, and the Return of Spiral Jetty!

by William F. Case

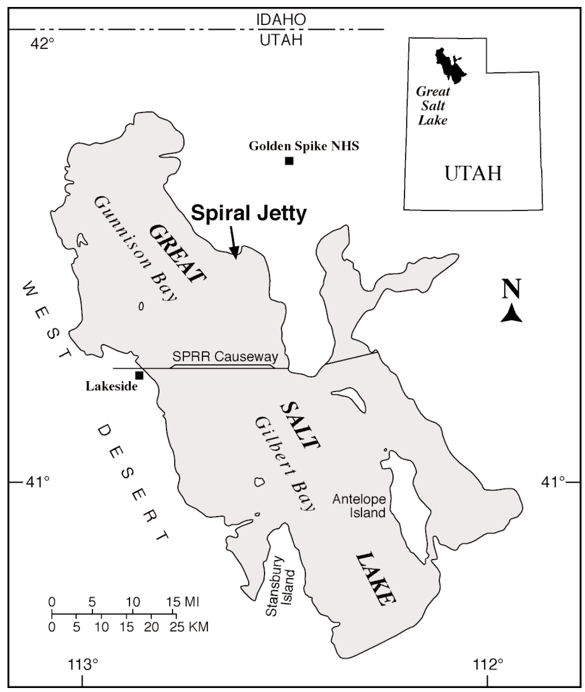
It's early September 2002 at Rozel Point in Gunnison Bay (the north arm) of Great Salt Lake about 16 miles (24 km) from the Golden Spike National Historic Site. A spiral form of salt-encrusted basalt boulders is just emerging from the pinkish water. Seldom-seen Spiral Jetty is visible again!

Artist Robert Smithson created Spiral Jetty in April 1970 and later donated the earthwork art to the Dia Center for the Arts in New York. Great Salt Lake's setting and the artistic contrast between the pink water, white salt crystals, and black basalt boulders evidently inspired Smithson. But perhaps the most intriguing aspect of Smithson's creation, which is 1,500 feet (457 m) long and 15 feet (4.6 m) wide, is that it is only visible when climate conditions cause the level of Great Salt Lake to drop below an elevation of 4,197.8 feet (1,280.2 m).

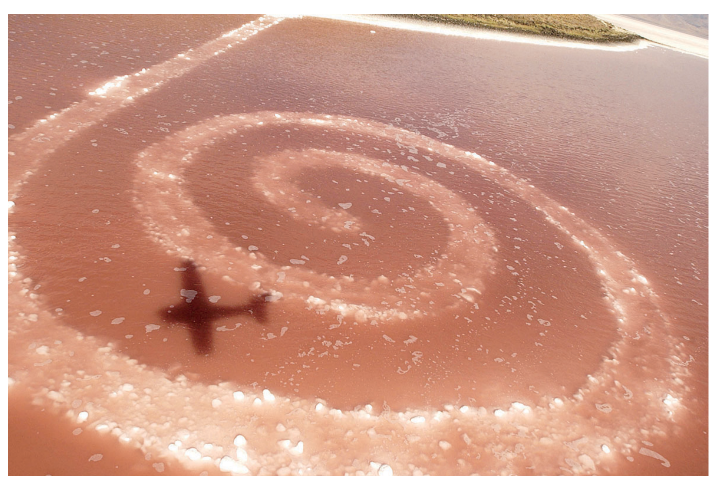
The water's pink color is due to a red pigment in the salt-tolerant bacteria and algae that survive in the north arm's extreme 27 percent salinity. Great Salt Lake was split into two parts by a rock causeway constructed across the lake by the Southern Pacific Railroad in 1959. Before the causeway was built, fresh water from the Bear, Weber/Ogden, and Jordan Rivers circulated throughout the entire Great Salt Lake. When the causeway was built, circulation became restricted and salt content of the north arm increased because most of the river water flows into Gilbert Bay (the south arm).

White salt crystals encrust almost any solid object in contact with north-arm water. The black basalt boulders Smithson took from the beach to construct Spiral Jetty are no exception; they are now covered with salt crystals. The basalt boulders are from local volcanic eruptions during Pliocene time, about 5 to 2 million years ago.

Spiral Jetty surfaced several times between 1970 and 2002. Throughout the lake-level fluctuations Spiral Jetty survived wave erosion; the hard salt crust probably cemented the boulders together and provided a protective layer on the jetty surface.



Location map for the Spiral Jetty.



Aerial view of Spiral Jetty showing pink salt water and black basalt boulders draped with a crust of white salt crystals. Lake level is 4197.3 ft. Copyright, Francisco Kjolseth, Salt Lake Tribune, August 28, 2002.

Spiral Jetty, September 15, 2002; lake level is 4197.2 ft. Copyright 2002, Bruce Thompson/Pingraphics, used by permission.

White salt encrusting black basalt boulders on the shore of Great Salt Lake near Spiral Jetty, September 14, 2002, lake level 4197.2 ft.

How to Get There

Drive to the Golden Spike National Historic Site (GSNHS), 30 miles (45 km) west of Brigham City, Utah by following signs on Utah State Route 83 through Corinne. Once at GSNHS take the gravel road leading west toward the West Side Drive approximately 6 miles (9 km) to an intersection that has a small white "Promontory Ranch" sign. Take the south (left) road from the "Promontory Ranch" sign intersection and continue south about 1 mile (1.5 km) to an intersection near a corral; veer right to the road that heads southwest and continue about 9 miles (13.5 km) to Great Salt Lake at Rozel Point. You will see an old, white, mobile home and rusted military amphibious vehicle, a linear jetty associated with past oilfield activity, and, if the water is low enough, the Spiral Jetty. A map and instructions are at www.nps.gov/gosp/tour/jetty_directions.htm.

Triggered Seismicity in Utah from the November 3, 2002 Denali Fault Earthquake

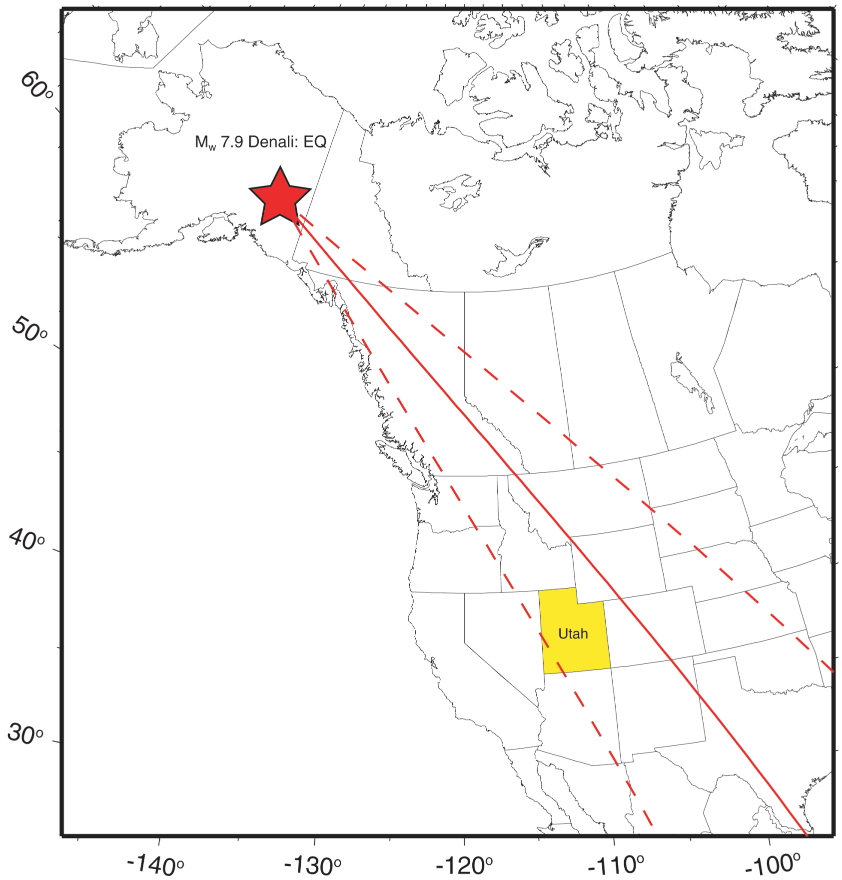
by K.L. Pankow, W.J. Arabasz, S.J. Nava, and J.C. Pechmann
University of Utah Seismograph Stations

On Sunday, November 3, 2002, at 3:12 p.m. (MST), a large (magnitude 7.9) earthquake occurred on the Denali fault in Alaska. Coincident with the arrival of the seismic waves in Utah around 3:28 p.m., the University of Utah's regional seismic network detected a marked increase in earthquake activity along the Intermountain seismic belt in Utah. The earthquakes were small-magnitude events (less than magnitude 3.3) generally concentrated in five clusters. With the exception of a cluster northeast of Nephi (cluster C in figure below), the events occurred in localities with repetitive prior seismicity. The first locatable triggered earthquake was a magnitude 2.6 shock about 12.5 miles east of Salt Lake City. It occurred a little before 3:30 p.m. In the 12 days following the Denali fault earthquake, the mean rate of earthquakes above magnitude 1.5 in the Wasatch Front area increased to almost triple the mean rate for the previous three years. Statistically it can be shown that this rate increase was not due to chance.

The first well-documented case of a large earthquake triggering small distant earthquakes was the 1992 magnitude 7.3 Landers, California earthquake. The Landers earthquake triggered small earthquakes up to 775 miles from the source. Researchers observed that the triggered earthquakes occurred (a) in the direction of earthquake rupture, (b) in areas where the seismic waves temporarily enhanced the stress field and (c) mostly in areas of recent volcanic or geothermal activity. Observations (a) and (b) similarly apply to the earthquake triggering in Utah, but not observation (c) (see below). The Denali fault earthquake ruptured in an east-southeastward direction along the Denali fault, and Utah is along a projection of this rupture direction (see figure). Using data from 44 recording sites in Utah, including 38 new strong-motion stations of the Advanced National

Seismic System and six broadband stations, we estimate that the temporary increase in the stress field was approximately 100 times greater than the daily stress variation associated with solid earth tides.

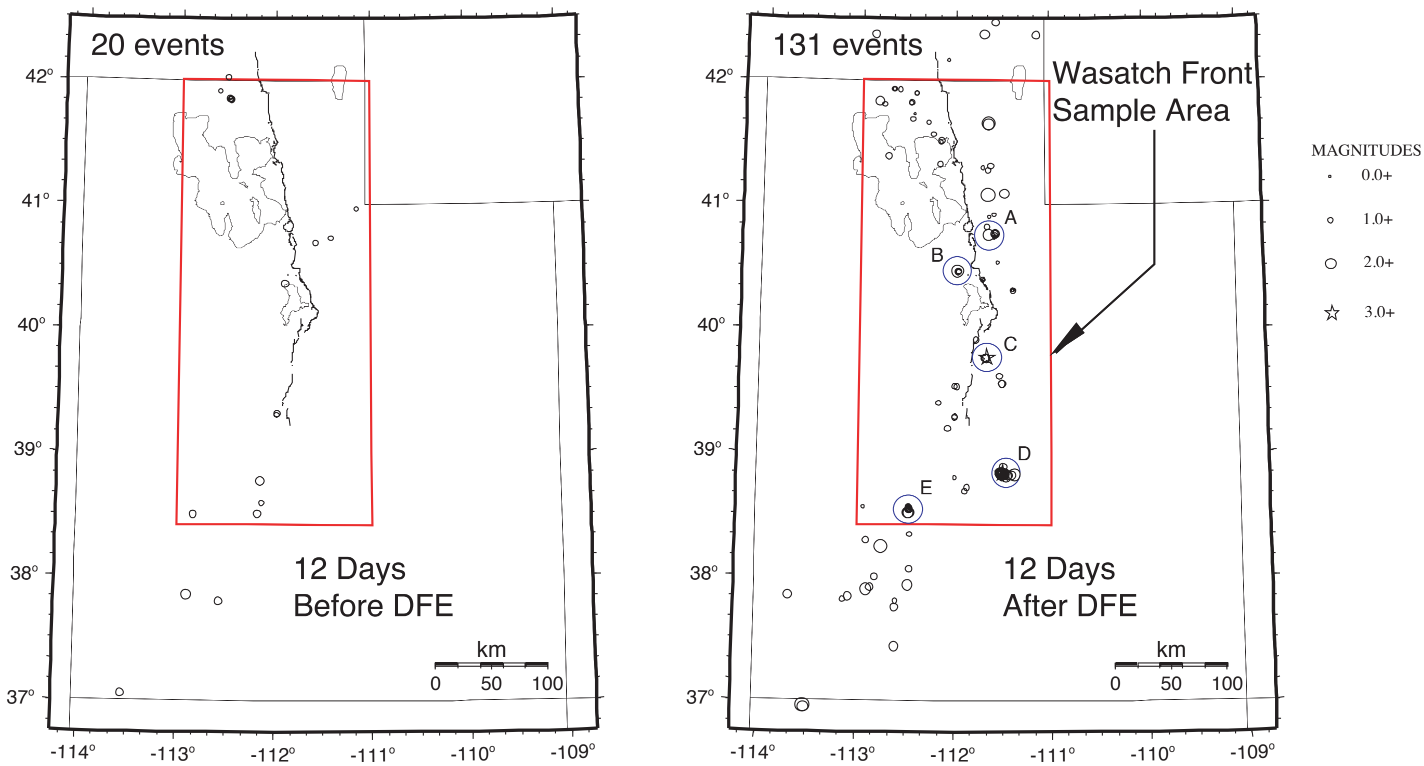
What makes the observation of triggered earthquakes in Utah distinct from earlier observations is the geologic setting and the large distance (more than 1,850 miles) from the Denali fault earthquake. Remotely triggered earthquakes in the past have been observed chiefly in regions characterized by recent volcanic or geothermal activity, such as Yellowstone National Park in Wyoming, The Geysers in northern California, and Long Valley caldera in eastern California. Further, many of the mechanisms proposed to generate the triggered earthquakes attribute the earthquakes to effects on fluids associated with recent volcanic or geothermal activity. The regions of earthquakes in Utah triggered by the Denali fault earthquake fall into neither of these two categories. By systematically studying these earthquakes, we hope to provide new clues into the dynamic triggering of distant earthquakes. For more information, go to http://www.seis.utah.edu/AGU2002/index.shtml.



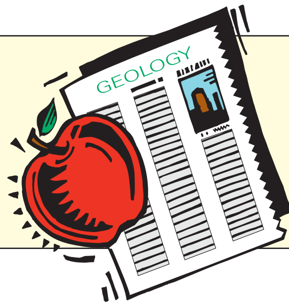
Projection showing Utah in relation to the rupture direction (solid line; dashed line ±10°) of the Denali fault earthquake (indicated by star).

UTAH EARTHQUAKES
October 23 ,2002 – November 3 (22:39), 2002

UTAH EARTHQUAKES
November 3 (22:39), 2002 – November 15, 2002



Comparison of earthquake activity in Utah immediately before and after the Denali fault earthquake (A-E represent clusters of earthquakes). Data from the University of Utah seismic network.



Teacher's Corner

Attention 4th- and 5th-grade teachers
Field trips and workshop offered May 10 and May 17, 2003
1 Hour Inservice Credit
Only $20.00

Saturday, May 10, 2003, teachers may choose one of two field trips.

(1) **Geology along the Wasatch Front** 8:00 a.m. – 4:00 p.m.

Teachers will learn about the local geology and geologic processes that have made today's landscape, and will see the three different rock types. Limit 40 teachers.

Lunch and transportation provided.

$10.00

(2) **Antelope Island and Great Salt Lake, Utah: A natural history view of Utah's un-dead sea and its biggest island** 8:00 a.m. - 4:00 p.m.

Teachers will learn about local geologic history from Antelope Island. Other topics include the dynamics of Great Salt Lake and Lake Bonneville. Limit 20 teachers.

Lunch and transportation provided.

$10.00

Saturday, May 17, 2003 8:30 a.m. - 4:00 p.m.

More! Rocks in Your Head, a nationally acclaimed workshop, will be offered to Utah teachers. The workshop covers core curriculum topics of rocks, minerals, fossils, and soil (4th); weathering and erosion (4th & 5th); geologic processes affecting Earth's surface (5th); and deposition of rock layers (5th). Teachers are guaranteed to walk away excited to share what they've learned with their students. All activities are hands-on and require little or no teacher preparation time. Teachers will receive:

- manual
- rock and mineral kit
- classroom-ready materials

Location: Department of Natural Resources
1594 W. North Temple
Salt Lake City, UT

Snacks and lunch provided

$10.00

These greatly reduced prices for teachers are due to the generous sponsorship by the American Association of Petroleum Geologists (AAPG) and ConocoPhillips. The AAPG national convention will be held in Salt Lake City the week of May 12, 2003.

Register early! Registration deadline is April 1, 2003.

For One Hour Inservice Credit, you must sign up for both a field trip and the workshop. Or just attend one Saturday to further your earth science understanding! For further information, please contact Sandy Eldredge at 537-3325, sandyeldredge@utah.gov or visit the Utah State Office of Education's website http://www.usoe.k12.ut.us/curr/science/.

...Continued from page 8

carbonate mounds, eolian facies, dinosaur fossils, the geology of coal and coalbed methane, and sequence stratigraphy. Many of these trips will take place in national parks, monuments, and recreation areas, such as Zion, Arches, Canyonlands, Lake Powell, and the Grand Canyon, that were set aside for their geology and scenic beauty.

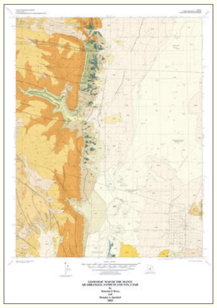
Short Courses

A variety of short courses (19) are being planned by the AAPG, its affiliated divisions, the SEPM, and the UGA. The short courses will emphasize the application of advanced technology to more efficiently find and develop oil and gas resources in the 21st Century. Topics include advanced risk analysis, coalbed methane, petroleum systems analysis, applied sequence stratigraphy, and the analysis and interpretation of subsurface pressures, as well as a Paradox Basin core workshop (sponsored by the Utah Geological Survey and the U.S. Department of Energy).

Note: One does not have to register for the convention to attend a field trip or short course. For more information contact the AAPG Convention Department at 1-800-364-2274.

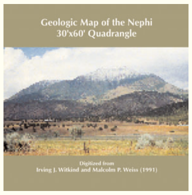
New Publications

Geologic map of the Tule Valley 30′ x 60′ quadrangle and parts of the Ely, Fish Springs, and Kern Mountains 30′ x 60′ quadrangles, northwest Millard County, Utah, by L.F. Hintze and F.D. Davis, 2 pl., 1:100,000, ISBN 1-55791-586-5, Map 186 . . . . **$8.90**



Geologic map of the Manti 7.5-minute quadrangle, Sanpete County, Utah by Malcolm P. Weiss and Douglas A. Sprinkel, 22 p., 2 pl., 1:24,000, ISBN 1-55791-588-1, 11/02, M-188 . . . . . **$9.45**

Ground-water sensitivity and vulnerability to pesticides, Utah and Goshen Valleys, Utah County, Utah, by Ivan D. Sanderson, Mike Lowe, Janae Wallace, and Jason L. Kneedy, 26 p., 2 pl., scale 1:100,000, 10/02, ISBN 1-55791-678-0, MP-02-10 . . . . **$12.45**

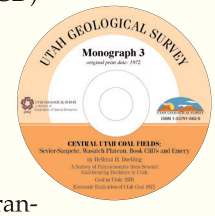


Witkind, I.J., and Weiss, M.P., 1991 (digitized 2002), Geologic map of the Nephi 30' x 60' quadrangle, Carbon, Emery, Juab, Sanpete, Utah and Wasatch Counties, Utah, scale 1:100,000 (digitized from U.S. Geological Survey Miscellaneous Investigations Map I-1937): CD-ROM, 11/02, ISBN 1-55791-589-X, Map 189DM **$24.95**

St. George dinosaur tracksite, 2 p., 9/02, PI-78 . . . . **free**

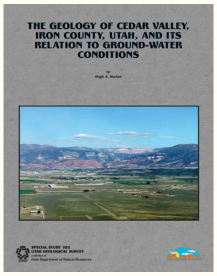
Interim geologic map of the San Rafael Desert 30' x 60' quadrangle, Emery and Grand Counties, Utah, by Hellmut H. Doelling, 1 pl., 20 p., 1:100,000, 10/02, OFR-404 . . . . . **$6.50**

October 2002 Publications list (paper and on CD)



Central Utah coal fields: Sevier-Sanpete, Wasatch Plateau, Book Cliffs and Emery, by Hellmut H. Doelling, 1972 (reprint, 2002, CD-ROM), 333 p., ISBN 1-55791-682-9, MO-3 . . . . **$14.95**

Interim geologic map of the Cedar Fort quadrangle, Utah County, Utah, by Robert F. Biek, 16 p., 1 pl., 1:24,000, 10/02, OFR-403 . . . . **$3.00**

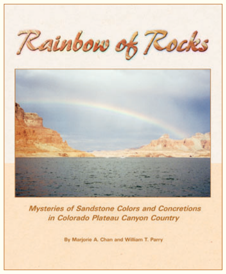


The geology of Cedar Valley, Iron County, Utah, and its relation to ground-water conditions, by Hugh A. Hurlow, 74 p., 2 pl., 1:100,000, 9/02, ISBN 1-55791-672-1, SS-103. . . . . **$22.50**

Interim geologic map of the Saratoga Springs quadrangle, Utah County, Utah, by Robert F. Biek, 16 p., 1 pl., 1:24,000, 10/02, OFR-402 . . . . . **$3.00**

Interim geologic map of the Veyo quadrangle, Washington County, Utah, by Janice M. Higgins, 17 p., 1 pl., 1:24,000, 10/02, OFR-401 . . . . **$3.00**

Coal Studies: reprints of Bulletin 112, Special Study 49, and Special Study 54 on CD, 6 papers, 236 p., 7 pl. **$14.95**



Rainbow of rocks, mysteries of sandstone colors and concretions in Colorado Plateau canyon country, by Marjorie A. Chan and William T. Parry, 17 p., 10/02, ISBN 1-55791-681-0, PI-77 . . . . **$2.00**

Available for free while supply lasts. Two CDs of U.S. Department of Energy's oil fluvial-dominated and shallow-shelf carbonate recovery studies. 22 papers total, including UGS's Uinta and Paradox Basin studies.

Natural Resources Map & Bookstore

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