UTAH GEOLOGICAL SURVEY

SURVEY NOTES

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Cover: *View to the southeast of the main scarp of the Wasatch fault at Bells Canyon in southeastern Salt Lake Valley (inset: view from the air of the Wasatch fault zone traversing glacial moraine at Bells Canyon).*

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The Director's Perspective

by Richard G. Allis

Several articles in this isssue of Survey Notes discuss earthquake hazards along the Intermountain seismic belt through Utah. Estimates from cumulative geologic slip rates along the major faults of the eastern boundary of the Basin and Range suggest east-west extension at a long-term rate of several millimeters per year (mm/yr). Monitoring confirms at least this rate of movement during the 1990s (compare this rate with tenths of mm/yr in the central Basin and Range, or with tens of mm/yr along the plate boundary in California). Utah experiences a magnitude 7 earthquake once every several hundred years, and a magnitude 5.5 or larger earthquake on average once every 10 years. Economic loss estimates for a magnitude 7 earthquake in Salt Lake County are in the range of billions to more than 10 billion dollars. These figures should be well-known to the Utah earth science community, but the implications for disaster preparedness of the wider community are not well recognized. How many of us have actually taken precautions in our own houses and offices to minimize the damage of a big shake?

The ongoing challenge for the UGS and other state agencies such as the Utah Division of Comprehensive Emergency Management is to increase awareness of the local geologic hazards, and to encourage mitigation measures, including recovery planning for the inevitable occurrence of damaging events. Recent collaborative work by URS Corporation, UGS, and the University of Utah has produced a series of earthquake ground-shaking maps for the Salt Lake Valley (Ivan Wong and others, in preparation as a UGS publication). We hope these maps, one set of which shows the variation in intensity of ground motion in the event of a major earthquake on the underlying Wasatch fault, will stimulate interest and awareness (and action!) of the potential damage. These maps will be published later this year and will be accessible on our web site. We are now working on a larger, Wasatch Front set of maps (Provo – Ogden, which should be available next year) for a scenario of a Wasatch fault earthquake.

Recent improvements in the University of Utah's strong motion seismic network around the Wasatch Front allow maps showing levels of ground shaking (called ShakeMaps) to be generated within minutes of an earthquake. The enhanced network had its first test in July with a magnitude 3.4 earthquake beneath northwest Salt Lake City (see article on p. 8 about effects felt at the UGS office). The ShakeMap can be seen at http://www.seis.utah.edu/shake. These maps allow emergency response teams to immediately focus on the worst-affected areas. We hope that the ShakeMaps for modern earthquakes, and the ground-shaking scenario maps for future large events, will increase the awareness of planners, decision makers, and the general public on preparing for the effects of large earthquakes in Utah.

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New Mapping of Earthquake Hazards along the Wasatch Front

by Barry J. Solomon

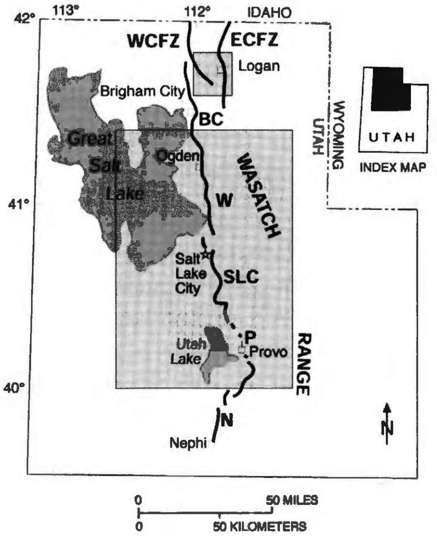
Introduction

Large earthquakes can disrupt lives with devastating effects on communities and individuals. The effects of large earthquakes throughout the world draw our attention when reported by the media, and elicit strong emotions of fear and sympathy. But many recent earthquakes occurred in distant and exotic locations—Turkey, India, Taiwan, and El Salvador. These earthquakes resulted in costly tragedies, but are they really relevant to residents of the Wasatch Front or other parts of Utah? Should we be that concerned with earthquakes after facing anxieties related to massive freeway reconstruction and preparation for the upcoming Olympics? The answer to these questions may be more obvious once we consider large earthquakes occurring in urban areas closer to home—San Fernando, 1971 (near Los Angeles); Loma Prieta, 1989 (near San Francisco); Northridge, 1994 (near Los Angeles); and Nisqually, 2001 (near Seattle). These earthquakes caused billions of dollars in damage and claimed many lives. Now consider this—the Federal Emergency Management Agency recently released a report that ranks Utah among states that face the highest earthquake risk in the nation. The report, *HAZUS99 Estimated Annualized Earthquake Losses for the United States*, ranks Utah seventh in the nation for absolute earthquake risk (the annual average earthquake loss) and sixth for relative risk (the ratio of the annual average earthquake loss to the replacement value of building inventory). These are sobering statistics. Although the size, timing, and location of future earthquakes are difficult to predict, variations in soil behavior and damage during earthquakes are controlled largely by mappable geologic and geotechnical site conditions. The Utah Geological Survey (UGS) is presently involved in evaluating these conditions to assess the potential for earthquake hazards in two areas along the seismically active Wasatch Front: the central Cache Valley of northern Utah, and the central Wasatch Front region.

> Should we be that concerned with earthquakes after facing anxieties related to massive freeway reconstruction and preparation for the upcoming Olympics?

Our evaluations, partially funded by the U.S. Geological Survey National Earthquake Hazards Reduction Program (NEHRP), will lead to the production of maps of earthquake hazards such as amplified earthquake ground motion, surface fault rupture, liquefaction, and earthquake-induced slope failure. Such maps are valuable tools for government officials and land-use planners to (1) guide safe and responsible development through incorporation into a land-use plan or zoning ordinance, (2) prepare earthquake-planning scenarios and loss estimates, (3) require site-specific investigations, or (4) increase earthquake awareness, education, and training. Geologists and engineers may use technical information on the maps to devise plans for addressing the hazards.

The primary purpose of our studies is to map earthquake hazards in specific areas. However, our studies also serve as pilot projects to test Geographic Information System (GIS) mapping techniques for use elsewhere in Utah. A GIS is a computerized system that allows users to access and manage varied sets of geographically related information. Information



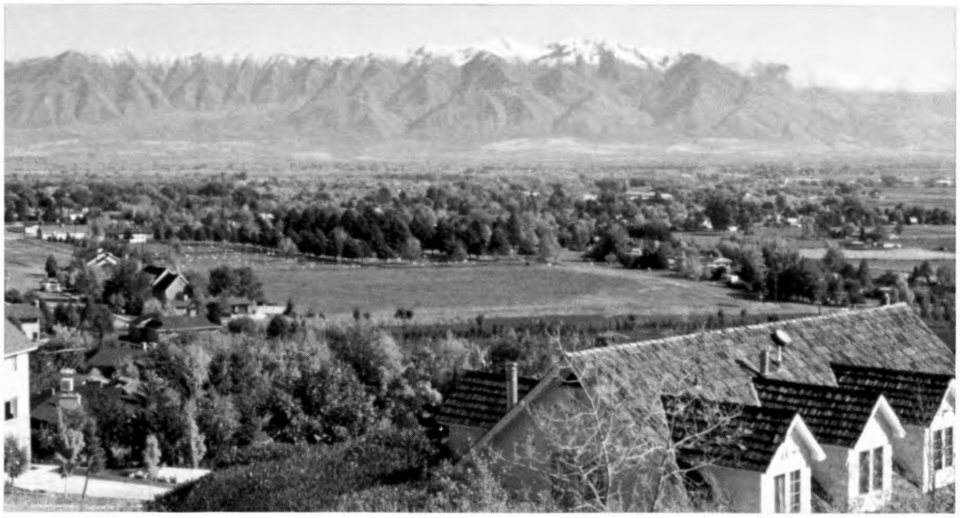
Earthquake-hazard study locations (shaded). Active faults include several segments of the Wasatch fault zone (BC-Brigham City, W-Weber, SLC-Salt Lake City, P-Provo, N-Nephi), the West Cache fault zone (WCFZ), and the East Cache fault zone (ECFZ).

related to earthquake hazards includes soil and rock properties as well as earthquake and fault characteristics. Prior to the advent of GIS, manipulating this information was a laborious, error-prone process. GIS technologies facilitate data management and map production.

Earthquake Hazards of the Central Cache Valley

In our first project we mapped earthquake hazards in the central Cache Valley of northern Utah. This area contains Utah's tenth-largest city (Logan) as well as the smaller communities of Hyde Park, Hyrum, Mendon, Newton, North Logan, Millville, Providence, Smithfield, and Wellsville. Three active fault zones nearby (the Wasatch, West Cache, and East Cache fault zones) pose a significant threat to the region, which was the site of the most damaging earthquake in Utah's history. A magnitude 5.7 earthquake occurred on August 30, 1962, near Richmond, about 10 miles north of Logan. Over three-fourths of the houses in Richmond were damaged, and landslides and rock falls blocked highways and canals. Several large buildings in Logan and Richmond suffered structural damage, and the total estimated earthquake loss was about $1 million (1962 dollars). The consequences of a similar earthquake today would be much more severe given the development that has occurred in the intervening 39 years, resulting in increased population and property values.

Earthquake-hazard mapping is most effective for hazard reduction when conducted prior to development. Cache Valley is largely rural but experiencing rapid growth as population expands from urban areas. Thus, our mapping will be available to reduce the exposure of new development to earthquake hazards in the central Cache Valley. However, earthquake-hazard mapping requires the interpretation of existing geotechnical data to determine the characteristics of underlying soils and their response to earthquakes. Because of the rural nature of the central Cache Valley, geotechnical data from boreholes are clustered in population centers and are sparse elsewhere. Boreholes are also typically drilled to shallow depths, so the meager geotechnical data from deeper soils are insufficient to assess certain earthquake hazards. To supplement geotechnical data, we relied upon information derived from abundant water wells. In contrast to the limited depth and irregular distribution of geotechnical boreholes, water wells in the central Cache Valley are typically deeper and are widely and uniformly distributed. For our study, we analyzed data from 182 geotechnical boreholes and 1,032 water wells, as well as information from existing surficial-geologic maps.



Development in the central Cache Valley extends westward from Logan (in the foreground) into largely rural areas at the base of the Wellsville Mountains (in the distance).

Earthquake-hazard mapping is most effective for hazard reduction when conducted prior to development.

Although results of our study have not yet been published by the UGS, a report was submitted to the U.S. Geological Survey. A copy of the report (*Seismic Hazards Mapping of the Central Cache Valley, Utah—a Digital Pilot Project*, by J.P. McCalpin and B.J. Solomon) is available for inspection in the Utah Department of Natural Resources Library. The report includes a discussion of analytical techniques, step-by-step procedures for GIS mapping of earthquake hazards, and hazard maps at a scale of 1:24,000. Mapped earthquake hazards include amplified earthquake ground motion, surface fault rupture, liquefaction, and earthquake-induced slope failure. The hazard maps, most developed from recently published mathematical relationships between characteristics of geologic materials and their observed association with historical earthquakes worldwide, show the relative degree of hazard.

Although the potential for each hazard is largely independent of the others, certain areas of the central Cache Valley are at greater risk from combinations of earthquake hazards. The greatest hazard is generally in the center of the valley where relatively thick clay, deposited by Lake Bonneville between about 14,000 and 24,000 years ago, is locally overlain by more recent saturated, sandy alluvium. The clay contributes to greater amplification of certain types of earthquake ground motions, whereas the alluvium contributes to a higher potential for liquefaction and liquefaction-induced lateral spreading. Much of the remainder of the valley floor and the mountains bordering the valley are subject to low and moderate earthquake hazards, although more severe hazards exist locally. Most

Contorted beds are possible evidence of prehistoric liquefaction in Lake Bonneville deltaic sands near the mouth of Green Canyon, North Logan.

> . . . as development proceeds into currently undeveloped areas, extending from both valley margins into the center of the valley and into the mountains, exposure to earthquake hazards will increase.

development in the central Cache Valley is along the valley margins, which have generally lower earthquake-hazard potentials. However, as development proceeds into currently undeveloped areas, extending from both valley margins into the center of the valley and into the mountains, exposure to earthquake hazards will increase.

An Earthquake Scenario for the Salt Lake City segment, Wasatch Fault Zone

Our hazard maps of the central Cache Valley reflect the response of susceptible geologic materials to earthquakes in the region, regardless of the earthquake source. Another technique for mapping earthquake hazards, however, reflects the risk posed by a specific earthquake. This type of analysis begins with defining the size and location of the earthquake (the scenario earthquake), calculating its associated ground motions, and mapping the geologic effects such as ground deformations due to ground failure (for example, liquefaction and landsliding). The resultant earthquake-hazard maps showing geologic effects can then be used to generate an estimate of the consequences to a region of the scenario earthquake. The estimate will describe the scale and extent of damage and disruption, including quantitative estimates of casualties and costs for repair and replacement of damaged buildings and facilities, losses of function for critical facilities, and the extent of induced hazards such as fire, flood, or contamination by hazardous materials. A similar estimate at a national scale was prepared for the HAZUS99 report cited above.

In our second project, we are mapping geologic effects of a scenario earthquake in the populous region of the central Wasatch Front, centered upon the Salt Lake City metropolitan area. This region lies astride the Wasatch fault zone, one of the longest and most active normal-slip faults in the world. The fault zone is divided into ten segments, each capable of generating strong earthquakes. The Salt Lake City segment is one of the more active segments, having generated four surface-faulting earthquakes in the past 6,000 years. These earthquakes have occurred on average every 1,350 years; the most recent one occurred between about 1,100 and 1,550 years ago. Geologic studies indicate that the magnitude of a surface-faulting earthquake on the Salt Lake City segment is 7, the size of our scenario earthquake. An earthquake of this size centered in the Salt Lake City area would place more than 1.3 million people at risk, with preliminary estimates of human fatalities of 7,600 and damages of about $12 billion.

Significant effects of our scenario

THE UGS RESPONSE TO A MAJOR EARTHQUAKE

When an earthquake occurs, emergency-response activities are complex and involve many private and public organizations. The UGS plays a key role in this emergency response as the lead state scientific agency responsible for understanding, documenting, and responding to geologic hazards. These activities will be most effective with advance planning. To that end, the UGS has prepared the Utah Geological Survey Earthquake-Response Plan and Investigation Field Guide to direct the UGS response to significant earthquakes in Utah. This document updates our previous plan and incorporates lessons learned from recent significant earthquakes elsewhere.

The plan defines criteria for selection of earthquakes to be investigated, delineates roles of UGS personnel during response, and outlines investigation objectives and procedures. The plan is designed to facilitate the role assigned to state geological surveys specified in the program of post-earthquake investigations conducted under the auspices of the National Earthquake Hazard Reductions Reauthorization Act of November 16, 1990.

The plan recognizes the critical need for documenting geologic effects of earthquakes, and for advising public officials managing response and recovery. Lessons learned can be incorporated into standards and practices for future hazard reduction. Providing a timely forum for information exchange among geoscientists and engineers is a key element of this plan, which includes provisions for a "post-earthquake information clearinghouse" with nightly meetings during the response period to help coordinate information gathering and availability.

earthquake may be felt within a large area of northern Utah, extending north-south from Ogden to Provo and east-west from Park City to Tooele. Because of this large area, we will map earthquake hazards at a scale of 1:250,000. Mapped hazards will include those mapped for the central Cache Valley, and will be based on similar relationships between the nature of geologic materials and their historical response to earthquakes elsewhere. We will also incorporate the results of previous studies of other geologic hazards to ensure comprehensive consideration of the effects of important hazards in the loss estimation. These other hazards include tectonic subsidence (tilting of the valley floor toward the surface fault rupture), flooding due to dam failure, and flooding due to a seiche (an earthquake ground-shaking-generated wave causing a sudden rise in water level) in Great Salt Lake.

Hazard Maps and Risk Reduction

Mapping earthquake hazards is an interesting geological exercise, but the maps have very practical applications. Earthquake-hazard maps focus our attention on important issues regarding earthquake risk reduction.

Earthquake **hazards** along the Wasatch Front are relatively great because of the presence of the Wasatch fault zone and other active faults in the region. However, the distribution of earthquake hazards is not uniform. For example, saturated flood plains along valley bottoms may pose a high liquefaction hazard but a low hazard for slope failure. Landslides pose a greater hazard on steep valley and mountain slopes, where the potential for liquefaction may be negligible. Earthquake-hazard maps illustrate the distribution of hazards based upon the physical characteristics of geologic materials.

Earthquake **risks** along the Wasatch Front are relatively high because of the level of development within seismically active, high-hazard areas. However, the level and age of development are also not uniform. Earthquake risk is greatest where development concentrated in seismically hazardous areas is old and prone to earthquake damage. By mapping earthquake hazards along the Wasatch Front in a Geographic Information System, the UGS provides a mechanism for estimating earthquake risk. This can be analyzed in a GIS by overlaying geologic-hazard map layers with relevant building and infrastructure information, such as transportation routes, utilities, and the location of critical facilities. Analyses can then be used to make informed decisions on hazard-reduction and emergency-response policies, priorities, strategies, and funding levels. Rehabilitating older buildings in hazardous areas and applying appropriate seismic codes to the design and construction of new buildings can reduce earthquake losses. Effective planning for emergency response can direct resources toward communities most subject to risk. The earthquake-hazard maps show the relative hazard to help us prepare for earthquakes prior to their occurrence, rapidly and effectively respond once an earthquake happens, and improve our understanding of our interaction with the geologic environment.

Geocaching - Treasure hunting with a high-tech twist

by Mark Milligan

Tired of hunting for lost Spanish mines in the Uinta Mountains and finding nothing but sore feet? Fed up with panning for gold in the West Desert and discovering nothing but sand? Ready to give up that metal detector and your prized pile of rusted tin cans and nails it took you three weekends under the hot sun to uncover? Geocaching may be for you! New technology has inspired a new breed of weekend treasure hunters - adventurers armed with a Global Positioning System (GPS) receiver.

Like a scavenger hunt, geocaching entails looking for a cache of hidden "treasure" using a GPS receiver and a provided set of coordinates. Other geocachers place all sorts of goodies in a coffee can, ammunition can, or similar container and hide it. The person hiding the cache records the site's latitude and longitude, then posts the coordinates on the Internet. Geocaching is a fun way to get out while learning and using navigation skills.

The Geologic Information and Outreach Program's geocache

In celebration of national Earth Science Week (October 8 - 12) the Geologic Information and Outreach (GIO) Program will hide a geocache on Monday, October 8. Like others on the Internet, our geocache has two simple rules: (1) if you take an item, then you must leave something in its place; and (2) record your visit in the cache's log book. Often caches have a theme. Our theme is minerals and rocks (of course) and that is just what you will find in the coffee can that contains our cache. Not just driveway gravel, but fun and interesting specimens (real keepers!). The coordinates for our geocache are: N 40° 46′ 38.0″ and W 111° 56′ 01.2″. (Hint: we did not venture more than a few blocks from our office.) So jump on the geocache band wagon and find some treasure.

For other caches and more information on geocaching, including advice on setting up your own cache, enter the key word "geocache" in your favorite Internet search engine.

Investigating Past Earthquakes on the Hurricane Fault

by William R. Lund

INTRODUCTION

The Utah Geological Survey (UGS) and the Arizona Geological Survey are cooperators on a study of the Hurricane fault, one of the longest and most active of several large, geologically young faults in southwestern Utah and northwestern Arizona. In Utah, the Hurricane fault trends north, dips west, and displaces the nearly flat-lying rocks of the Colorado Plateau down-to-the-west. The purpose of the study is to evaluate the Hurricane fault's potential for producing future large earthquakes.

Extending from Cedar City, Utah, to south of the Grand Canyon, the 160-mile-long Hurricane fault has produced thousands of feet of vertical displacement over the past approximately five million years. In more recent geologic time, the fault has displaced middle Quaternary (600,000 to 1,000,000 year old) basalt flows several hundred to more than a thousand feet and late Quaternary (<125,000 years old) alluvium and colluvium up to several tens of feet.

Although the Hurricane fault has not ruptured the ground surface in historical time, the area does have a well-documented record of seismicity. Southwestern Utah has experienced at least 20 earthquakes greater than magnitude (M) 4 over the past 100 years, the largest events being the M 6.3 Pine Valley earthquake in 1902 and the M 5.8 St. George earthquake in 1992. The largest historical earthquake in northwestern Arizona was the 1959 M~5.7 Fredonia earthquake.

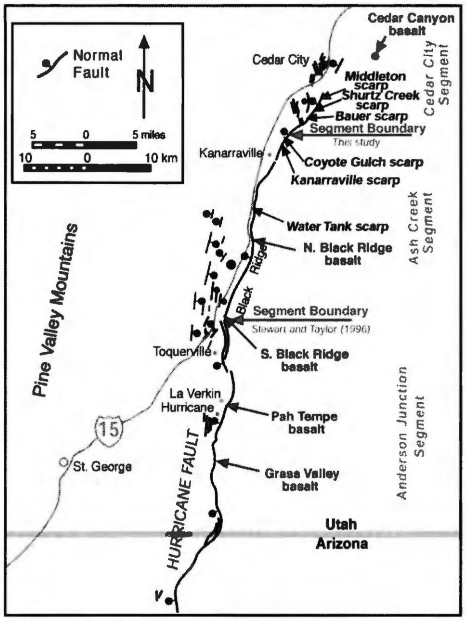
Considering its length, the Hurricane fault almost certainly consists of several independent segments. Bends and other complexities in the fault trace are likely locations for boundaries between possible rupture segments. Previous workers have proposed two fault segments on the Utah portion of the Hurricane fault, the Ash Creek segment on the north and the adjacent Anderson Junction segment to the south.

UTAH INVESTIGATION

Trenching

There are six sites on the Hurricane fault in Utah where fault scarps are formed on unconsolidated deposits. The UGS considered all six locations for trenching and selected the site at Coyote Gulch as our preferred study location. However, that site is on private property and is unavailable for trenching. Consequently, we decided to trench a large scarp at Shurtz Creek instead. Once trenching commenced, we quickly encountered numerous large boulders in the subsurface and were unable to expose the fault zone. We decided not to trench any of the four remaining locations because we had already selected what we considered to be the most favorable alternate site, and the other sites had similar geologic constraints or access problems.

Dating Stream Alluvium and Alluvial-Fan Deposits



Hurricane fault in southwestern Utah showing sites with scarps on unconsolicated deposits, locations of displaced basalts that can be correlated across the fault, and proposed segment boundaries.

Lacking a viable trench site on the north end of the fault, we decided to date geologically young alluvial deposits where they overlie the fault zone at the Middleton, Bauer, and Coyote Gulch sites. At the Middleton and Bauer sites the alluvium is not faulted, but at Coyote Gulch surface faulting has displaced young alluvial-fan sediments. Dating the deposits allows us to bracket the timing of the most recent surface-faulting earthquake at the north end of the fault. Stream cuts at all three sites expose the sediments of interest. We had bulk soil samples analyzed for grain-size distribution and total carbonate content, and to identify datable organic material. We submitted charcoal recovered from each site for ^{14}C dating.

The ages of the Middleton and Bauer charcoal are 1,530-1,710 years and 435-525 years, respectively. They bracket the age of the charcoal from Coyote Gulch, which is 1,055-1,260 years. These results show that the most recent surface-faulting earthquake at Coyote Gulch is younger than 1,055-1,260 years, since the faulting must be younger than the deposits it displaces. The unfaulted deposits at Middleton show that the surface faulting at Coyote Gulch did not extend north to the Middleton site, indicating the likely presence of a previously unrecognized rupture segment boundary between the two sites. Based on the geometry of the fault, we believe the boundary is at a pronounced right bend in the fault just north of Coyote Gulch. We have named the proposed new northern segment the Cedar City segment.

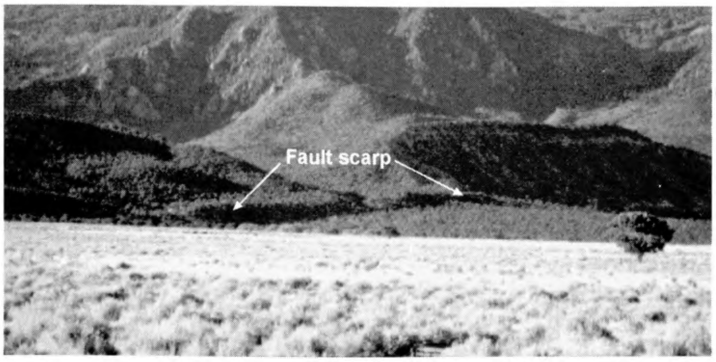
Developing Long-Term Fault-Slip Data from Displaced Basalt Flows

Fault slip rates (net fault displacement divided by time) allow us to study the behavior of faults over several earthquake cycles. The higher the slip rate, the more active and potentially hazardous is the fault. Where it is possible to determine slip rates for a variety of time intervals, we can evaluate changes in the fault's behavior through time. Knowing if a fault is slowing down or speeding up is important when evaluating earthquake hazards. The Hurricane fault provides a rare opportunity to develop long-term slip rates from displaced basalt flows along its length. We used detailed geochemical data to correlate the displaced flows, and paleomagnetic data and new geologic mapping to evaluate the extent of near-fault deformation adjacent to the fault. We then calculated the net slip across the fault, and dated the correlated basalts to determine the time period over which the slip occurred.

We identified four locations in Utah where displaced basalts can be correlated across the Hurricane fault (see table below). We also identified a fifth site east of Cedar City in Cedar Canyon where a basalt flow occupies the ancestral channel of Coal Creek high on the north wall of the canyon. When the basalt flowed down the channel of Coal Creek, it forced the stream to find a new path. Coal Creek has since re-established its channel and left the basalt stranded high above the present stream. Because Coal Creek is graded to Cedar Valley and crosses the Hurricane fault at the mouth of Cedar Canyon, movement on the fault controls the base level of the stream and the stream incision rate. Therefore, the rate of stream incision is a proxy for slip on the fault. The following table shows the net slip across the fault at each of the five basalt locations, the ages of the correlated basalts, and the resulting slip rate.

Location	Net Slip (meters)	Basalt Age (million years)	Slip Rate (mm/yr)
Grass Valley	440	1.0	0.44
Pah Tempe	73	0.353	0.21
S. Black Ridge	368	0.81	0.45
N. Black Ridge	476	0.86	0.55
Cedar Canyon	335	0.63	0.53

Long-term slip rates developed from displaced Quaternary basalt flows in Utah.



Looking southeast at the Shurtz Creek fault scarp where the UGS attempted to trench the Hurricane fault. The scarp is about 40 feet high.

The Hurricane Cliffs looking northwest from near the Utah/Arizona border. The Hurricane fault is at the base of the cliffs; strati graphic displacement across the fault is more than 2,000 feet.

The table and figure show that slip on the Hurricane fault increases from south to north. Additionally, although the data are sparse, slip rates appear to increase incrementally across a suspected segment boundary at South Black Ridge, lending credence to the idea that a seismogenic boundary exists at that location. Although little change in long-term slip rate is apparent north of South Black Ridge, slip rates determined for segmented faults elsewhere in the western United States indicate that a seismogenic boundary could still be present between the proposed Ash Creek and Cedar City segments.

STUDY CONCLUSIONS

Results of this study show that the Hurricane fault in Utah likely consists of three rupture segments, rather than two as previously thought. The newly proposed segment at the north end of the fault has been named the Cedar City segment. Of the three segments, the Cedar City segment has gone the longest without a surface-faulting earthquake. The single slip rate available for the new Cedar City segment closely approaches that of the Ash Creek segment to the south, which has had a surface-faulting earthquake in recent geologic time. Therefore, given its high long-term record of activity and because it has gone the longest without a surface-faulting earthquake, the Cedar City segment is considered the most likely location for a large earthquake on the Hurricane fault in Utah.

Energy News

GEOTHERMAL RESOURCES OF UTAH-2001

A Digital Atlas for Utah's Geothermal Resources

by Robert E. Blackett and Sharon I. Wakefield

In response to increasing interest in national renewable energy sources, the Utah Geological Survey (UGS), in cooperation with the Utah Energy Office, is completing work on a new, interactive, digital publication based upon geographic information system (GIS) technology. *Geothermal Resources of Utah-2001*, which will be published on compact disk (CD), contains data from publicly available reports and data sets available through 2000. The CD contains technical information for scientists and engineers, but its interactive, menu-driven reports, tables, and maps make it suitable for general public use.

The CD replaces a geothermal resource map of the state of Utah produced as part of a U.S. Department of Energy/UGS cooperative geothermal program in the late 1970s. Published in 1980, the *Geothermal Resources of Utah* map presented geothermal and water-resource data at a scale of 1:500,000. Although the information presented on the map was of a general nature, it showed locations of thermal wells and springs and listed individual source temperatures, water-quality data, and flow rates. The map also outlined areas of prospective value for geothermal resources, and provided descriptive information about individual geothermal areas. It was published through the U.S. National Oceanic and Atmospheric Administration and is now out of print.

The 1980 map needs replacing because it is out of date and available only in a few libraries, at a time when interest in renewable energy resources and technology is increasing. Since publication of the 1980 map, various workers completed a number of geothermal-related studies, the result of federal, state, and privately funded research. In addition to regional and statewide resource assessments, the studies also involve detailed analyses of individual geothermal areas. Inclusion of the data from these studies makes the new CD superior to the 1980 map.

The CD will contain (1) Adobe Acrobat® portable document format (PDF) documents describing geothermal resources of Utah and specific geothermal areas; (2) digital PDF maps of Utah and individual geothermal areas; (3) a 3,000-record database of thermal wells and springs; (4) geothermal, geologic, geographic, cultural, and infrastructure-related spatial data (ArcView®) files; (5) documentation and description of data sources and accuracy (metadata); (6) image files; and (7) software (ArcExplorer®) to construct and view various GIS themes, maps, images, and reports. Readers of Survey Notes may refer to the article and map in vol. 32, no. 3 to note some of the complexity.

The PDF documents, spatial data, metadata, image files, and software are organized into six subfolders:

Docs: PDF documents containing reports on geothermal resources and heat flow in Utah, data tables of thermal wells and springs, a comprehensive geothermal bibliography of Utah, and user guides for the CD and the freeware.

Geoth_db: A database containing nearly 3,000 records of thermal wells and springs in Utah.

Images: GIS-generated geothermal maps of Utah (PDF) and photos of Utah geothermal sites.

Menu: Applications for driving the CD-ROM menu system.

Shapes: Spatial data layers (as ArcView® shapefiles) containing base maps and infrastructure data, as well as updated geothermal well and spring data and heat-flow data for Utah. Metadata files that document the GIS layers are also included.

Software: ArcExplorer® and Adobe Acrobat® Reader freeware. ArcExplorer® enables users to retrieve and manipulate a variety of maps using the ArcView® shapefiles. Adobe Acrobat® Reader allows users to view PDF documents.

With the documents, databases, and software on the CD, users will be able to create individual GIS maps at varying scales containing any number of data layers. Data layers could include geothermal resources, land use, cultural, demographic, land grid, geologic, geographic, infrastructure, and other information as needed. GIS users can also import new or updated data layers from the Utah Automated Geographical Reference Center website (http://agrc.its.state.ut.us/) and elsewhere.

The Geothermal Resources of Utah-2001 CD is scheduled for publication near the end of 2001 and will be available through the Utah Department of Natural Resources Bookstore.

DNR Gets a Shaking from July's Magna Earthquake

by Jo Lynn Campbell, Michael D. Hylland, and Gary E. Christenson

At about 7:56 a.m. MDT on Sunday, July 8, the northwestern part of the Salt Lake Valley was shaken by a magnitude 3.4 earthquake. The epicenter was 2.7 miles north-northeast of Magna and about 7.5 miles west of the Department of Natural Resources (DNR) building. No significant damage was reported in the area; however, despite the small magnitude, the earthquake had things moving and shaking at DNR.

UGS employee Bill Case was working in his office, on the third floor, when the earthquake occurred. He said, "I felt a small jolt in my office and an unfamiliar noise at about 7:56 a.m. It was followed a few seconds later by a stronger jolt, like a truck hitting the building." When Brian Martin reported for work in the DNR Bookstore on Monday morning, he saw that publications were strewn all over as a result of the previous morning's earthquake. (Ironically, most of the publications were from the Geologic Hazards display.)

The earthquake was an early test of the new strong-motion monitoring network being installed along the Wasatch Front by the University of Utah Seismograph Stations using funding from the U.S. Geological Survey. One of the aims of the new "real-time" network is to generate automatically, within minutes after an earthquake, computer maps showing ground-shaking levels (ShakeMaps) that can be used particularly by emergency responders to determine where damages and injuries are likely to be greatest. (The new system will not be fully automated before this fall, so the ShakeMaps for the Magna earthquake were created manually a few hours after the earthquake.) The "intensity" ShakeMap for the small Magna quake shows that the maximum expected intensity was classified as "light," cor-

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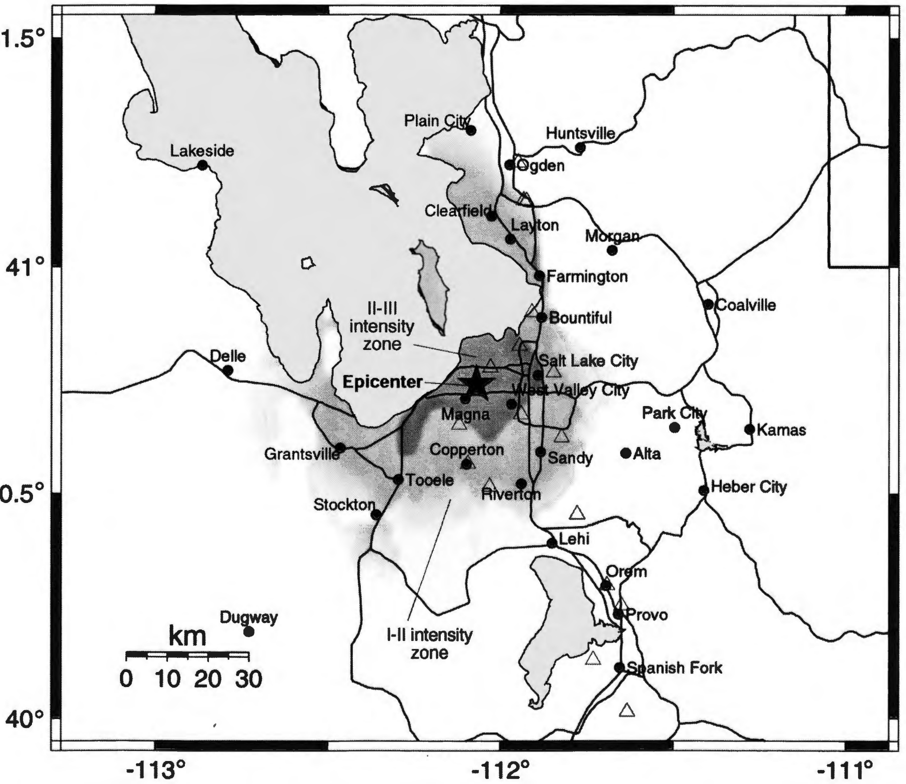
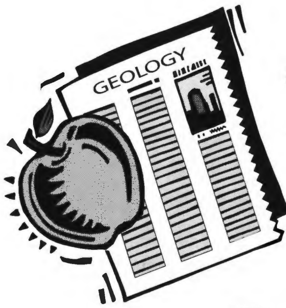


UUSS Rapid Instrumental Intensity Map for event: 01070813552
Sun Jul 8, 2001 07:55:51 AM MDT M 3.4 N40.74 W112.07 ID:01070813552

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very Light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC. (%g)	<.17	.17 - 1.4	1.4 - 3.9	3.9 - 9.2	9.2 - 18	18 - 34	34 - 65	65 - 124	>124
PEAK VEL. (cm/s)	<0.1	0.1 - 1.1	1.1 - 3.4	3.4 - 8.1	8.1 - 16	16 - 31	31 - 60	60 - 116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+



Teacher's Corner

Celebrate Earth Science Week

October 7-13, 2001

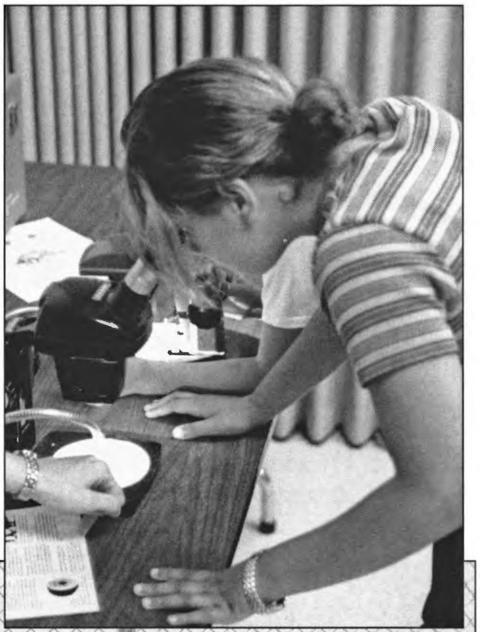
During the second week of October, Utah will join other states across the nation in celebrating the fourth annual Earth Science Week. Initiated in 1998 by the American Geological Institute, the focus of the week's activities is to help people understand the importance of the earth sciences in their lives.

Proclamations signed by governors of many states, including Utah, recognize that geology and the earth sciences are fundamental to society and to our quality of life. A common thread in the proclamations is that an understanding of geology and the earth sciences can help citizens make wise decisions for land management and use, is crucial to addressing environmental and ecological issues, and provides the basis for preparing for and mitigating natural hazards.

To encourage our young people to learn more about the earth and environmental sciences and to consider pursuing careers in these fields, the UGS will offer activities and demonstrations at the Utah Core Research Center during the week. School groups and others will be able to spend 1 1/2 hours learning about rocks, minerals, and dinosaurs. Included in the sessions are hands-on activities to investigate rock and mineral properties, gold panning, and watching how fossils are excavated for study. Participants will take home their own treasures of rock and mineral specimens, as well as a plaster cast of a fossil.

Utah Core Research Center
240 North Redwood Road
Salt Lake City
October 9 - 12 (Tuesday - Friday)
8:00 a.m. - 5:00 p.m.

To reserve a time, please call Carolyn Olsen at 537-3359.



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responding to an instrumental intensity of IV. A companion ShakeMap (not shown) for technical users indicates that the earthquake produced non-damaging peak ground accelerations (a measure of the strength of shaking at the ground surface, expressed as a percentage of gravitational acceleration, g) in the range of 0.04 g.

Utah seems to be having its share of small earthquakes lately, raising awareness of earthquake dangers in the state. Information on earthquakes, as well as other geologic hazards, can be obtained from the Natural Resources Map & Bookstore, 1594 West North Temple, Salt Lake City (www.maps.state.ut.us; 801-537-3320), or by calling the Utah Geological Survey at 801-537-3300. Information on specific earthquakes and the new ShakeMap system can be obtained from the University of Utah Seismograph Stations (www.quake.utah.edu; 801-581-6274).

"Glad You Asked"

by William F. Case

Why is the Wasatch Front "blessed" with the abundant sand, gravel, and rock that were so useful for the "Olympian" Interstate 15 project?

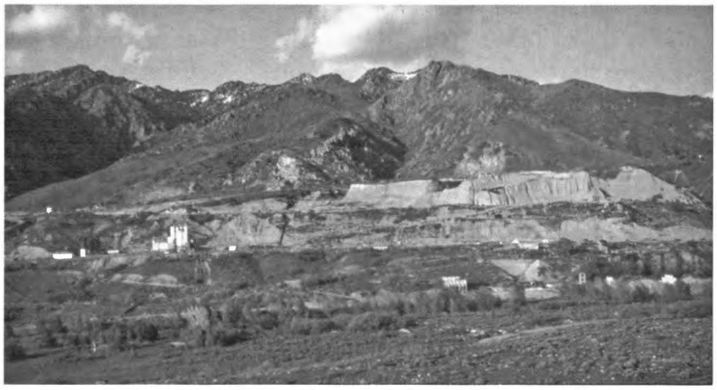
The Utah Department of Transportation's May, 2001 publication, *Interstate 15 User Guide On the Road Again Map*, reports that 7 million cubic yards of sand and gravel fill and 2.5 million square yards of concrete using crushed rock aggregate were used in the reconstruction of Interstate 15 through the Salt Lake Valley. Most of this material came from local Wasatch Front sources.

Why is the Wasatch Front blessed with so much sand, gravel, and rock so close to construction sites? In a word, it's because of Utah's geology!

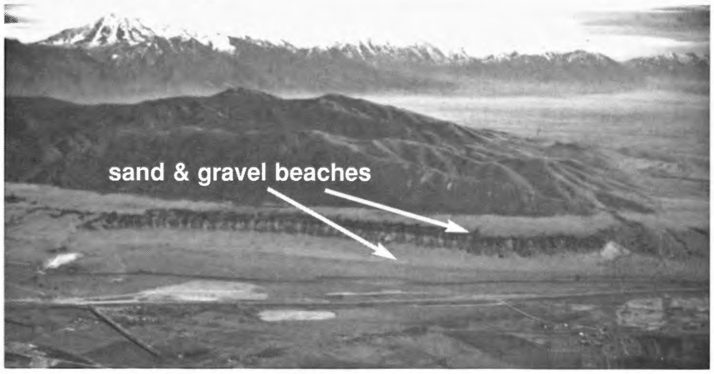
The abundance of these resources along the Wasatch Front is a result of up to a billion years of geological processes including (1) deposition of limestone and sandstone in shallow oceans, (2) uplift of mountain ranges, (3) fracturing and erosion of rock, and (4) transport and deposition of sand and gravel by streams, debris flows, glaciers, and lake processes.

Most of the sandstone and limestone was deposited on beaches and in lagoons of oceans that lapped back and forth across what is now the Wasatch Front, one billion to 160 million years ago. These rocks are now exposed by the uplift of the Wasatch Range along the Wasatch fault. In approximately 15 million years the Wasatch Range moved up at least 1 mile (1.5 km), relative to the down-dropping of the Salt Lake Valley. Continued weathering and erosion of the mountains gradually turns big rocks into little ones (sand and gravel). The sand and gravel was transported to the canyon mouths by streams, glaciers, and debris flows.

Basins in western Utah were once occupied by Lake Bonneville, an Ice Age lake as large as Lake Michigan. It began filling about 25,000 years ago when the climate became cool and wet. Snow and glacial ice accumulated in the Wasatch Range, reaching a maximum about 19,000 years ago. Glacial ice flowed down-valley as far as the mouth of Little Cottonwood Canyon during this maximum. Lake Bonneville rose to its highest elevation about 15,000 years ago and then overflowed into the Snake River drainage in Idaho; the lake level dropped over 300 feet (100 m) within a few months and then stayed at this elevation for at least 500 years. The climate became warmer and drier and Lake Bonneville evaporated leaving small lakes, including Great Salt Lake.



Sand and gravel pit at the mouth of Big Cottonwood Canyon, Salt Lake County. (photo 1991)



View south showing gravel deposits, Traverse Range and Point of the Mountain, Salt Lake County.

Vigorous canyon streams carrying large amounts of sand and gravel deposited deltas where they flowed into Lake Bonneville. Currents and waves of Lake Bonneville redeposited the sand and gravel along the shoreline as beaches that make up the familiar "bathtub rings" around the Wasatch Front. Occasionally, if the lake's shoreline currents were strong and carried a lot of sand and gravel, they would deposit a bar across a narrow gap in a valley; the Point of the Mountain at the south end of the Salt Lake Valley is such a bar.

The deltas, beaches, and bars deposited when Lake Bonneville was at the same elevation for 500 years or so are particularly large. Not surprisingly, these are where most of the sand and gravel pits are located. Mother Nature has indeed blessed the Wasatch Front with extensive sand and gravel deposits to use for construction and growth.

GeoSights

by Carl Ege

Paul Bunyans Woodpile, Juab County, Utah

Geologic information: Born from volcanic activity approximately 30 million years ago, Paul Bunyans Woodpile is a unique geologic feature in Juab County, central Utah. Looking like a series of colossal woodpiles stacked up neatly by a giant (in this case Paul Bunyan), this site is a relic of Utah's volcanic past. A volcano, similar to the large composite or stratovolcanos of the modern Cascade Range in the Pacific Northwest, was active in the vicinity of Paul Bunyans Woodpile. This volcano became inactive and later collapsed, forming a caldera or a large hole approximately 8.5 miles in diameter and more than 3,000 feet deep. After a brief period of dormancy, the volcano became active within the caldera for a brief period of time. Recent work conducted by Brigham Young University indicates that the Woodpile may be a series of numerous dikes, probably the result of this later volcanic activity. Dikes are composed of an igneous rock and are oriented vertically. They form when magma is injected into preexisting cracks or fissures and later cools under the ground surface.

View of Paul Bunyans Woodpile (looking northeast)

The Woodpile is a classic example of columnar jointing where the rock fractures in prismatic patterns, producing parallel columns. These columns form when cooling magma within the dike contracts, forming cracks similar to those on the surface of a cooling cake. Once a crack forms, it continues to grow from subsurface cooling, thereby forming longer and longer columns. Each column at Paul Bunyans Woodpile is approximately 1 foot in diameter and up to 15 feet in length. The columns are three to seven sided depending on slight variations in how the lava cooled. These columns are oriented horizontally and give the appearance of having been tilted on their sides. Normally, columnar jointing is associated with lava flows, and the joints are oriented vertically. However, the horizontal orientation here appears to be the result of subsurface cooling from the sides inward to the middle of the dikes.

The Woodpile is also home to an arch. This arch was created by a process known as frost action, which involves expansion and contraction associated with repeated cycles of freezing and thawing. In this process, water enters cracks in the rock and freezes; the expanding ice creates separation along the cracks. Eventually the rock will break off, creating holes in a rock outcrop. The estimated span of the arch is 20 feet long by 4 feet high. This arch can be seen by hiking farther up the trail and viewing the Woodpile from the side.

How to get there: From Salt Lake City, travel south on I-15 to Santaquin (exit 248). Turn right (west) at the end of the off ramp onto U.S. Route 6. Travel west and then south on U.S. Route 6 for 35.7 miles to a sign indicating Paul Bunyans Woodpile turnoff. Turn left (east) and proceed up the road for 3.2 miles to the trail head to the Woodpile. This stretch of road can be quite rough so proceed with caution. Do not attempt when the road is wet. Once at the trail head, proceed through the gate and hike approximately 0.5 miles to the Woodpile. Make sure you close the gate after you. The trail is well marked and a relatively easy hike. Bring plenty of water and sunscreen.

Useful maps: Lynndyl 1:100,000-scale topographic map, Tintic Mountain 1:24,000-scale topographic map, and a Utah highway map. Topographic maps can be obtained from the Natural Resources Map & Bookstore, 1594 West North Temple, Salt Lake City, UT, (801) 537-3320.

Web Highlights

What to visit on our web site www.ugs.state.ut.us

by Christine Wilkerson

The Utah Geological Survey's web site consists of hundreds of pages of content. So unless you're looking for something specific, how do you know what not to miss while visiting our site. Let me introduce you to some of our more visually interesting and informative pages (in other words, those pages that contain numerous graphics and that both non-geologists and geologists can enjoy).

Great Salt Lake: One of our most popular hard-copy brochures, Commonly Asked Questions About Utah's Great Salt Lake and Ancient Lake Bonneville, is also online. This online brochure can answer the age-old questions, why is the Great Salt Lake salty?, what lives in the lake?, and more importantly what makes the lake stink? It also contains many photos taken around the lake including the West Desert pumping plant, the historic Saltair resort, the Bonneville Salt Flats, and close-ups of oolites and brine shrimp. What are oolites? Visit our web site and this online brochure will tell you. (Hint: some of the most beautiful beaches around Great Salt Lake are composed of oolitic sand.) Web address: www.maps.state.ut.us/online/pi-39/index.htm

Utah Geological Survey - Public Information Series
Commonly Asked Questions About Utah's Great Salt Lake and Ancient Lake Bonneville
Page 10

What activites/industries exist in and near Great Salt Lake?

The Great Salt Lake and its environs have been used by swimmers, boaters, bikers, hikers, and hunters for recreational purposes from the mid-1800s to the present. Long-term water-level fluctuations, both high and low, have adversely affected lake recreation over the years, however. Nearly a dozen resorts have either been flooded or left high and dry. The most famous resort, Saltair, was built in 1893 and destroyed by fire in 1971. The lake and and its three state parks, Great Salt Lake Saltair Beach, Antelope Island, and Willard Bay, attracted over a million tourists in 1994.

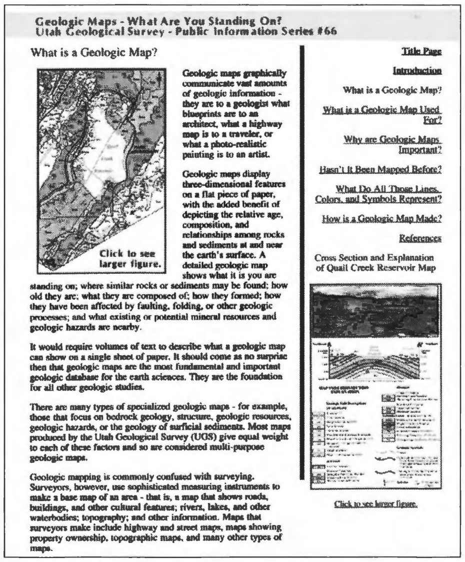
Famous resort, Saltair, built in 1893 and destroyed by fire in 1971. Photo courtesy of the Utah State Historical Society.

from the lake started in the mid-1800s and continues to be an important part of the State's economy. Other products, including magnesium metal, chlorine gas, sodium and potassium sulfate, and magnesium chloride, have been extracted since the early 1960s. Oil occurs in natural seeps on the north shore of the lake, and drilling in the late 1970s disclosed additional oil beneath the bed of the lake. The brine-shrimp industry harvests brine-shrimp eggs, for use as fish food, and exports them world wide. Eight state waterfowl management areas and one federal migratory bird refuge dot the southern, northern, and eastern shores of the lake. Established during the early 1900s, these areas serve as important resting, feeding, and nesting areas for millions of ducks, geese, grebes, shorebirds, and other water-dependent birds. Visitors are always welcome, and hunting is generally allowed during the regular waterfowl hunting season.

Oil occurs in natural seeps on the north shore of the lake, and drilling in the late 1970s disclosed additional oil beneath the bed of the lake.

This online brochure answers the many questions you may have about Great Salt Lake. www.maps.state.ut.us/online/pi-39/index.htm

Geologic Maps: Have you ever looked at a geologic map and wondered what all those colors, lines, and symbols meant? (No, not all those dark lines are new roads.) Here is your chance to discover what a geologic map is, how to read them, how geologists make them, and why we need them, by clicking on our online brochure, Geologic Maps - What Are You Standing On? Web address: www.maps.state.ut.us/online/pi-66/index.htm



Geologic Maps - What Are You Standing On?
Utah Geological Survey - Public Information Series #66

What is a Geologic Map?

Geologic maps graphically communicate vast amounts of geologic information - they are to a geologist what blueprints are to an architect, what a highway map is to a traveler, or what a photo-realistic painting is to an artist.

Geologic maps display three-dimensional features on a flat piece of paper, with the added benefit of depicting the relative age, composition, and relationships among rocks and sediments at and near the earth's surface. A detailed geologic map shows what it is you are standing on; where similar rocks or sediments may be found; how old they are; what they are composed of; how they formed; how they have been affected by faulting, folding, or other geologic processes; and what existing or potential mineral resources and geologic hazards are nearby.

It would require volumes of text to describe what a geologic map can show on a single sheet of paper. It should come as no surprise then that geologic maps are the most fundamental and important geologic database for the earth sciences. They are the foundation for all other geologic studies.

There are many types of specialized geologic maps - for example, those that focus on bedrock geology, structure, geologic resources, geologic hazards, or the geology of surficial sediments. Most maps produced by the Utah Geological Survey (UGS) give equal weight to each of these factors and so are considered multi-purpose geologic maps.

Geologic mapping is commonly confused with surveying. Surveyors, however, use sophisticated measuring instruments to make a base map of an area - that is, a map that shows roads, buildings, and other cultural features; rivers, lakes, and other waterbodies; topography; and other information. Maps that surveyors make include highway and street maps, maps showing property ownership, topographic maps, and many other types of maps.

Title Page
Introduction
What is a Geologic Map?
What is a Geologic Map Used For?
Why are Geologic Maps Important?
Hasn't It Been Mapped Before?
What Do All Those Lines, Colors, and Symbols Represent?
How is a Geologic Map Made?
References

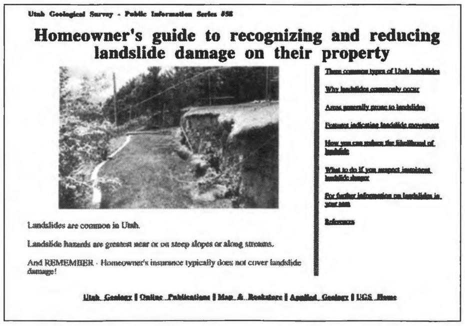
Cross Section and Explanation of Quail Creek Reservoir Map

Click to see larger figure.

What is a geologic map? Find out here: www.maps.state.ut.us/online/pi-66/index.htm

Utah Dinosaurs: Do you want to know more about dinosaurs than your five-year-old? Then our informative dinosaur fact sheets are just the thing for you. These pages contain information about the different dinosaurs discovered in Utah and small graphics of what most of the dinosaurs might have looked like. With sharper teeth and a more graceful build, which dinosaur rivals Tyrannosaurus rex as the supreme meat-eater of the Mesozoic age? (Hint: it's Utah's state fossil.) Web address: www.ugs.state.ut.us/utahgeo/dinofossil/index.htm

Landslide Guide: Homeowners frequently inquire about potential geologic hazards at their residence. Our online brochure, Homeowner's Guide to Recognizing and Reducing Landslide Damage on Their Property, will tell you what areas are generally prone to landslides and what to look for at your home that might indicate landslide movement. Web address: www.maps.state.ut.us/online/pi-58/index.htm



Utah Geological Survey - Public Information Series #58

Homeowner's guide to recognizing and reducing landslide damage on their property

Three common types of Utah landslides
Why landslides commonly occur
Areas generally prone to landslides
Features indicating landslide movement
How you can reduce the likelihood of landslide
What to do if you suspect imminent landslide danger
For further information on landslides in your area
References

Landslides are common in Utah.

Landslide hazards are greatest near or on steep slopes or along streams.

And REMEMBER - Homeowner's insurance typically does not cover landslide damage!

Utah Geology | Online Publications | Map & Bookstore | Applied Geology | UGS Home

Recognize features indicating possible landslide movement around your home. www.maps.state.ut.us/online/pi-58/index.htm

Salt Lake City Building Stones: Have you ever wondered what stones were used for the interior and exterior of Utah's Capitol and where they came from? Or what building stones cover the outside of the American Stores Tower and how ancient they are? Or what unique limestone was used for the Hansen Planetarium/Old Salt Lake City Public Library building and how it formed? (Hint: think oolites again.) Even if these questions have never even crossed your mind before, you can still get the answers by visiting our online brochure, Building Stones of Downtown Salt Lake City. Web address: www.maps.state.ut.us/online/pi-60/index.htm

These are just a few of the fascinating pages located on the Utah Geological Survey's web site. Other pages include issues of Survey Notes; fault, liquefaction, and radon maps; rock, mineral, and fossil collecting localities; mineral activity summaries; ongoing petroleum studies; educational resources; Utah's geologic history, and more. Please visit our site at www.ugs.state.ut.us.

Survey News

UGS loses its "new" energy team. With the reassessment of the Energy Office needs, we'll lose **Tom Brill, F.R. Jahan Bani**, and **Glade Sowards**. Ah well, office shuffleboard strikes again.

Nicole King (receptionist) resigned at the end of July to have a baby. **Neil Storey** has accepted the GIS analyst position for the Hazards program. **John Alexander** is our new paleontologist/preparator in the Paleontology section of the Environmental program. A senior geologist position is currently being advertised. We are looking for someone with remote sensing skills as well as familiarity with information base management and web technologies to enhance access to this information. These skills will complement in-house expertise and will provide opportunities for the UGS to seek federal funds in this area (e.g., NASA is looking for linkages with state geological surveys to promote applications and use of their satellite data.)

New Publications from UGS

Utah Geological Survey 2001, 6 p., 8/01, PI-73 .... Free
This latest brochure gives a working introduction to the UGS and its services.

Delineation of drinking water source protection zones for Covered Bridge Canyon public water supply well, Utah County, Utah, by Charles E. Bishop, 37 p., 8/01, RI-247 .... $4.30

Evaluation of potential geologic sources of nitrate contamination in ground water, Cedar Valley, Iron County, Utah, with emphasis on the Enoch area, by Mike Lowe and Janae Wallace, 50 p., 1 pl., 1:48,000. 8/01, SS-100 .... $9.95

Utah Geological Survey earthquake-response plan and investigation field guide, by Barry J. Solomon, 24 p. + 32 p. appendix, 7/01, OFR-384 .... $3.50

Natural Resources Map & Bookstore

1594 W. North Temple
Salt Lake City, UT 84116
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Fax: (801) 537-3395
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www.maps.state.ut.us

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$ 90.01 - $110.00	$10.50

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	Utah residents add 6.6% sales		
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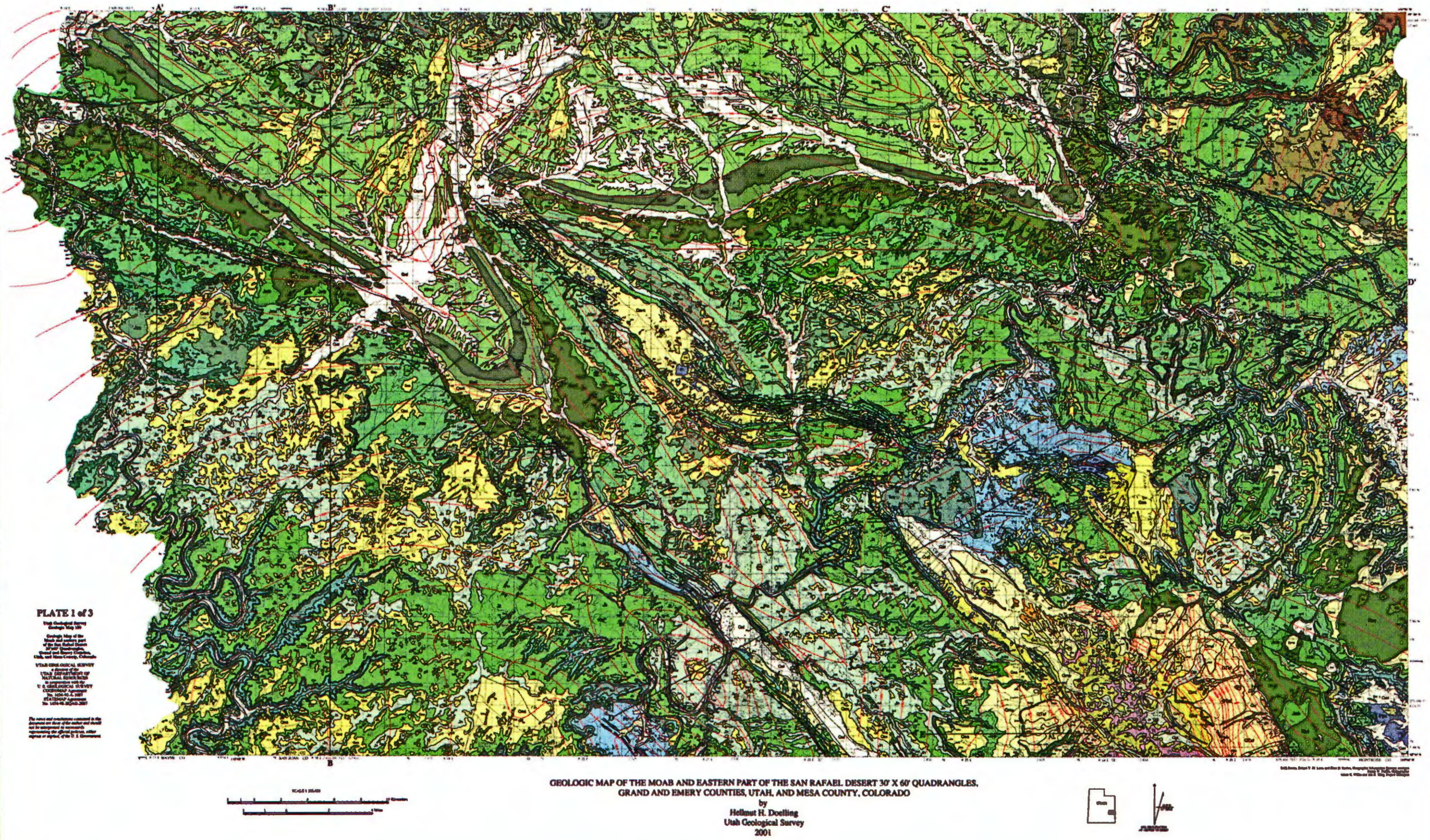
☐ Charge Card	**TOTAL**		

Geologic map of Moab



Geologic map of the Moab and eastern part of the San Rafael Desert 30' x 60' quadrangles, Grand and Emery Counties, Utah, and Mesa County, Colorado, by Hellmut H. Doelling, 3 plates, scale 1:100,000.

This full-color 42" x 25" map covers all of the south half of Grand County, home of the Paradox oil field, Arches National Park, and Deadhorse Point State Park. The mapping has taken over a decade to complete and represents a significant contribution to understanding the geology of this vast area. $36.50

This map and other products are available at the Natural Resources Map & Bookstore, 1594 West North Temple, Salt Lake City (www.maps.state.ut.us).

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