UTAH GEOLOGICAL SURVEY

SURVEY NOTES

Volume 40, Number 2

May 2008

Geologic Hazards of the St. George–Hurricane area

CONTENTS

Design: *Stevie Emerson*
Cover: *A historical slope failure in the Petrified Forest Member of the Chinle Formation and overlying unconsolidated deposits has severely damaged a road and threatens nearby homes in the St. George–Hurricane area.*

The Director's Perspective

by Richard G. Allis

This issue highlights the fact that Utah's residents live in a geologically hazardous state. Rapid urban growth in many parts of the state is causing pressure for development in areas having the potential for damage from floods, landslides, unstable soils, rock falls, and earthquakes. The article on geologic-hazard and adverse-construction-condition maps for the St. George–Hurricane area (page 1) shows how the UGS is providing Geographic Information System tools for planners and other local-government officials to identify potential hazard areas, and consequently where detailed site-specific studies are needed prior to development.

The rapid-growth areas of Utah are not the only concern to the UGS from the standpoint of geologic hazards. The magnitude (M) 6.0 earthquake in Wells, Nevada, on February 21 was a graphic reminder that ground shaking from earthquakes can cause considerable damage to unreinforced masonry (URM) buildings (see article on page 7). Such buildings, typically brick, are common in older sections of most Utah towns and cities. Not until about 1975 were building codes in Utah significantly upgraded to reduce the potential for life-threatening damage from ground shaking. In fact, a recent study estimates that there are 185,000 URMs in the Wasatch Front area (Bob Carey, unpublished tax-assessor data, Division of Homeland Security). Most of these are residences, but a significant number are public facilities such as schools and commercial buildings. Earthquakes in the M 5–6 range or larger have historically occurred every 5–30 years in Utah. The last earthquake with a magnitude of greater than 5 occurred in 1992 (St. George, M 5.8) and was the second-most damaging earthquake in Utah's history. We are due for a moderate-sized earthquake, but how prepared are we? For more information about the earthquake threat refer to our Web site (geology.utah.gov/utahgeo/hazards/eqfault/index.htm) and to the publications listed on page 7.

One of the outcomes of the Governor's Geologic Hazards Working Group that met during 2006 and 2007 was a recommendation for improved geologic-hazard information (see *Survey Notes* article, September 2007, page 7; and for copy of report: geology.utah.gov/ghp/geohaz_workgroup/pdf/ghwg_report.pdf). Both developers and regulators agree that contentious issues could be reduced if the potential for hazards was known prior to developments being designed and major financial investments being committed. A request from the UGS to the Governor and subsequently to the Legislature for funding to support two new geologic-hazard specialists was approved during the 2008 session. A priority for the new positions will be updated and improved Wasatch Front geologic-hazard maps. In a joint resolution (H.J.R. 7), the legislature urged the Utah Seismic Safety Commission to compile an inventory of public URM buildings in the state to quantify the extent of vulnerability in an earthquake. The Legislature also passed a bill that defines geologic hazards, and provides a process for adjudicating disputes between developers and the regulating authority (House Bill 177, sponsored by Representative Morley). Prior to the legislative session, the Utah League of Cities and Towns and the UGS provided input for the bill, and during the session the bill received widespread bipartisan support. This bill may be a sign of increasing public awareness that we live in a hazardous state, which means we must reduce risks, and in some cases, avoid building in some areas. In light of the Wells, Nevada, earthquake, we are also reminded to take precautions in our homes and offices to reduce the potential for damage from earthquake ground shaking.

Survey Notes is published three times yearly by Utah Geological Survey, 1594 W. North Temple, Suite 3110, Salt Lake City, Utah 84116; (801) 537-3300. The Utah Geological Survey provides timely scientific information about Utah's geologic environment, resources, and hazards. The UGS is a division of the Department of Natural Resources. Single copies of *Survey Notes* are distributed free of charge within the United States and reproduction is encouraged with recognition of source. Copies are available at *geology.utah.gov/surveynotes*
ISSN 1061-7930

Geologic-Hazard and Adverse-Construction-Condition Maps for the St. George–Hurricane Area, Washington County, Utah

by W.R. Lund, T.R. Knudsen, G.S. Vice, and L.M. Shaw

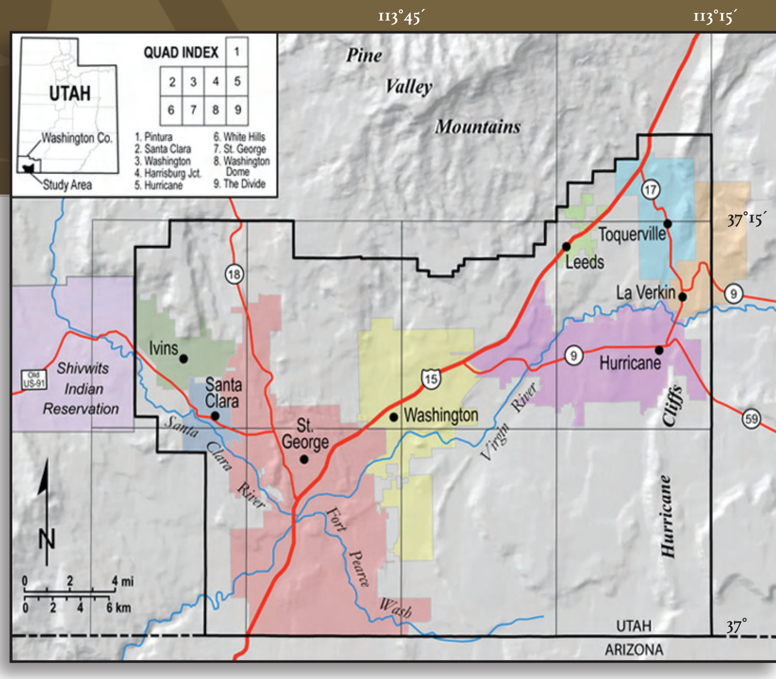
Southwestern Utah's warm climate and beautiful scenery have made the St. George–Hurricane area one of Utah's fastest growing regions for more than two decades. As land well-suited for development becomes increasingly scarce, urbanization has moved into less favorable areas where geologic hazards and adverse construction conditions become more of an issue for development. In these areas, timely geologic information early in the planning and design process is critical to avoiding or mitigating geologic hazards and other geology-related construction problems. The Utah Geological Survey (UGS) is nearing completion of a Geographic Information System (GIS)-based study of the St. George–Hurricane area that will help planners and other local-government officials determine where geologic hazards and/or adverse construction conditions may exist, and consequently where detailed, site-specific studies are needed prior to development.

This study encompasses 366 square miles in Washington County. We established the study-area boundary in consultation with Washington County, the Five County Association of Governments, and cities and towns in the study area. The study area includes most remaining developable land in the St. George–Hurricane area, including large tracts of vacant land that will undoubtedly be developed in the future. Principal communities in the study area are Hurricane, Ivins, La Verkin, Leeds, Santa Clara, St. George, Toquerville, and Washington. Growth in these communities over the past six years has been phenomenal.

Population data for principal communities in the St. George–Hurricane area

Community	Estimated 2006 Population	2000 Census Population	Percent Increase
St. George	69,831	49,663	41%
Washington	16,280	8186	99%
Hurricane	11,740	8250	42%
Ivins	7491	4450	68%
Santa Clara	6644	4630	43%
La Verkin	4619	3392	36%
Toquerville	1231	910	35%
Leeds	860	547	57%
Total	118,696	80,028	48%

Population information provided by Five County Association of Governments (2006).



Principal cities and towns, major transportation routes, and drainages within the 366-square-mile study area (black outline).

The principal products of this study are 14 geologic-hazard and adverse-construction-condition maps (1:24,000 scale) with accompanying text documents. Each map covers a different hazard or adverse construction condition, and the text documents provide background information on the data sources used to create the maps, the nature and distribution of the hazards or adverse construction conditions, and possible mitigation measures. An additional text document discusses earthquake-induced ground shaking; however, data are insufficient at this time to prepare a ground-shaking-hazard map.

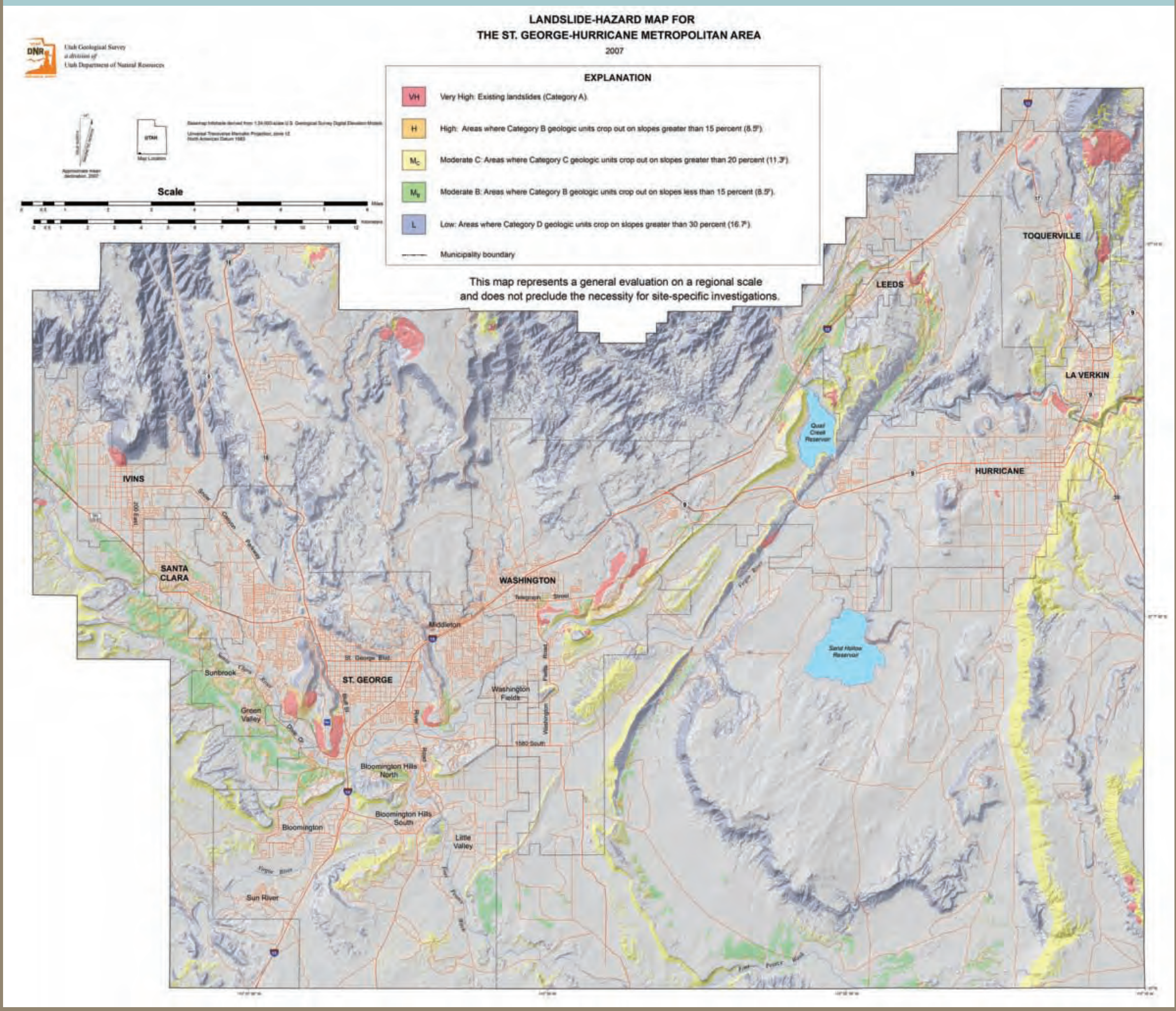
The UGS and Utah Automated Geographic Reference Center developed a new GIS search application for this project. The GIS format permits the powerful organizational and analytical features of computer-based databases and maps to be used in the identification, characterization, and mitigation of geologic hazards and adverse construction conditions. The application allows the user to quickly search the maps to identify geologic hazards and adverse construction conditions, and then create a custom map and explanatory text for a particular area. The user can search by property tax ID number, by specifying a point defined by latitude and longitude or Universal Transverse Mercator (UTM) coordinates and then defining a radius around that point, by clicking on an individual parcel, or by drawing a polygon around an area of interest.

Although we compiled data for this study from many sources, the chief sources of information were nine new digital 1:24,000-scale geologic quadrangle maps covering the St. George–Hurricane area prepared by the UGS Geologic Mapping Program. These maps provide the basic geologic data necessary to derive geologic-hazard and adverse-construction-condition maps. This new geologic information allowed us to update and expand on an earlier 1983 UGS geologic-hazard report for the St. George area, both in terms of the number and kinds of hazards and adverse construction conditions considered and the extent of the area covered.

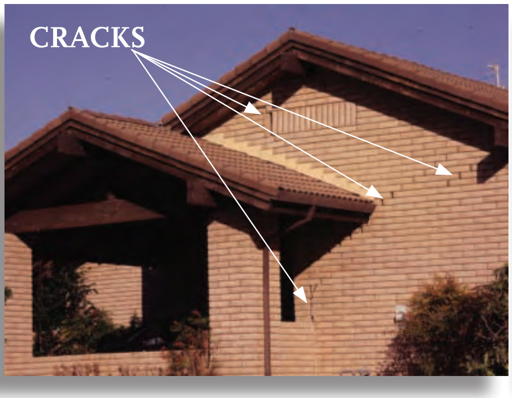
On an annual basis, the most widespread and damaging geologic hazard in southwestern Utah is flooding, and the most troublesome construction condition is expansive soil and rock. The devastating floods of January 2005 on the Santa Clara and Virgin Rivers provided ample evidence of the destructive power and life-threatening nature of flooding in the area. Many buildings and other structures throughout the area have experienced cracked foundations and walls, as well as other kinds of structural, architectural, and landscape damage from expansive soil and rock. Because of their wide distribution, frequent occurrence, and damage potential, floods and expansive soil and rock will remain the principal geology-related issues with which planners, developers, and residents must contend in the future.

Landslides and rock falls are of increasing concern as land well-suited for building in lowland areas becomes scarce and development moves near or onto hillsides. Some clay-rich bedrock in the area is weak and susceptible to landslides, especially when wet. The close correlation of existing landslides with weak bedrock units provides ample warning that development on slopes underlain by landslide-susceptible bedrock must proceed with caution. Southwestern Utah has a history of damage to buildings and other facilities from rock falls, and favorable conditions for rock fall are widespread in the study area. Rock-fall damage is likely to increase as development moves into those areas unless effective mitigation measures are implemented.

Although large, damaging earthquakes are rare in southwestern Utah, active faults capable of producing earthquakes as large as magnitude 7 exist in the area. Hazards associated with such earthquakes (ground shaking, surface fault rupture, landslides, rock falls, and liquefaction) have the greatest potential for catastrophic property damage, economic disruption, and loss of life of any geologic hazard in the area. Because of their great destructive potential, the effects of large earthquakes must be reduced through land-use planning, adoption and enforcement of modern seismic building codes, and disaster preparedness



Example of a geologic-hazard map derived from new 1:24,000-scale geologic information available for the St. George–Hurricane area.



Left: Expansive soil and rock that was not adequately considered during construction has produced cracks in the walls of this house in Santa Clara.

Right: Flooding in January 2005 resulted in extensive damage to homes along the Santa Clara River.

planning and drills. Moderate earthquakes similar to the magnitude 5.8 St. George earthquake in 1992 must also be considered because they are more common than large earthquakes, are capable of doing significant property damage, and may be life threatening.

The remaining geologic hazards and construction conditions addressed in this study are typically localized in nature, and while the problems associated with them are rarely life threatening, they are potentially costly when not recognized and properly considered in project planning and design.

Geologic hazards and adverse construction conditions included in the report.
Geologic Hazards
Surface Fault Rupture
Earthquake Ground Shaking *
Liquefaction
Flooding
Landslide
Rock Fall
Adverse Construction Conditions
Expansive Soil and Rock
Collapsible Soil
Gypsiferous Soil and Rock
Shallow Bedrock
Caliche
Wind-Blown Sand
Breccia Pipes and Paleokarst
Soil Piping and Erosion
Shallow Ground Water
**Text document only, no map prepared.*

About the Authors

William Lund has 36 years of experience as an engineering geologist—7 years with geotechnical consulting firms in Arizona, California, and Oregon, and 29 years with the UGS. He is a former deputy director of the UGS, presently is the Geologic Hazards Program Senior Scientist, and is manager of the UGS' Southern Regional Office in Cedar City. He is a Licensed Professional Geologist in Utah, Registered Geologist in Arizona, and Certified Engineering Geologist in Oregon, and is a past president of the Intermountain Section of the Association of Engineering Geologists, Utah Geological Association, and Dixie Geological Society. In addition to the geologic-hazards mapping project described in this article, other recent projects include seismic-hazard evaluations of the Hurricane, Sevier, and Washington faults.

Tyler Knudsen is a geologist with the UGS Geologic Hazards Program in Cedar City. His principal responsibilities are to identify, investigate, and publish information on Quaternary faults, landslides, and other potential geologic hazards in southwestern Utah. Tyler has been instrumental in the completion of the comprehensive St. George–Hurricane geologic hazards mapping project and is currently studying the seismic potential of the Washington fault near St. George. Upcoming projects include ArcGIS Geographic Information System-based geologic hazards mapping in Zion National Park and the Cedar City–Parowan Valleys. Prior to joining the UGS in early 2006, Tyler worked for a St. George-based geotechnical consulting firm, and completed a master's degree in geology at the University of Nevada, Las Vegas.

Lucas Shaw is a GIS Analyst for the Geologic Hazards Program. Since signing on with the UGS in 2004, he has worked to get GIS technologies and information into the hands of expert and novice alike. His work for the Hazards Program includes landslide susceptibility analysis, emergency response preparedness, and custom GIS application development. He has also improved the GIS administration, data management, and GIS integration with Internet map services at the UGS.

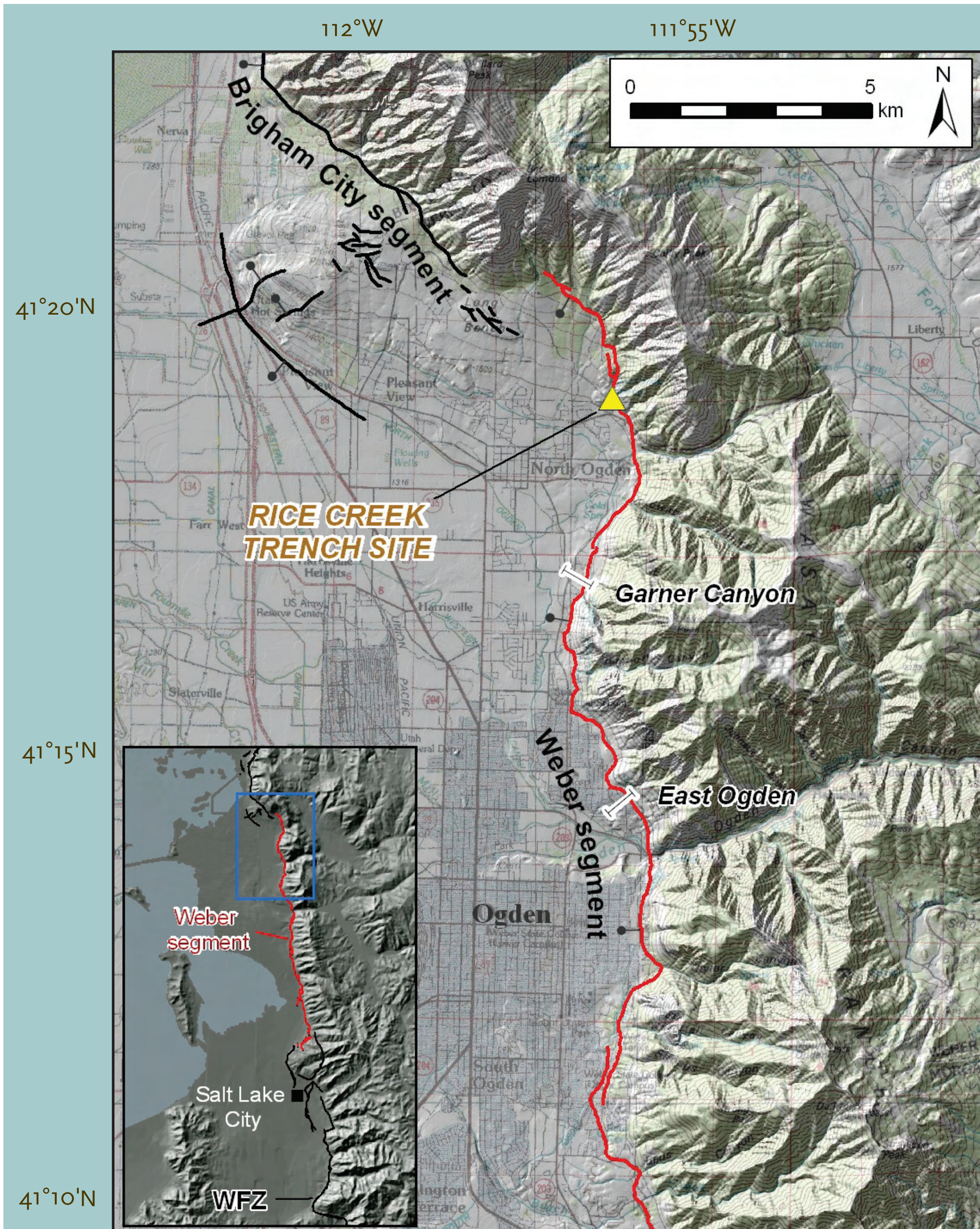
Garrett Vice was formerly a geologist for the UGS. He worked as a co-investigator on the St. George–Hurricane geologic hazards project for several months prior to attending graduate school at the University of Nevada, Reno. Garrett will graduate from UNR in June with a master's degree in geology, and is looking forward to a promising career in the oil industry.

UGS Excavates New Fault Trenches on the Weber Segment of the Wasatch Fault Zone

by Christopher B. DuRoss and Greg N. McDonald

During the spring of 2007, the Utah Geological Survey (UGS) and U.S. Geological Survey (USGS) continued a cooperative program of studying prehistoric earthquakes on the Wasatch fault zone (WFZ) by excavating trenches on the northern part of the Weber segment. The WFZ is Utah's most prominent and active fault, extending over 210 miles (340 km) from southern Idaho to central Utah and capable of producing earthquakes in the range of magnitude 7. The fault puts the populated Wasatch Front at risk as it traverses east bench communities at the base of the Wasatch Range. Although the WFZ has not produced a historical surface-faulting earthquake, detailed paleoseismic data gathered from fault-trench excavations indicate that 21 large-magnitude, surface-faulting paleoearthquakes have occurred on the central part of the fault in the past 6100 years (on average one earthquake every 300 years). These earthquakes did not rupture the entire 160-mile (250 km) length of the central part of the WFZ, but rather broke along individual fault segments, each spanning a 20- to 40-mile-long (30-60 km) section of the fault. The most recent large-magnitude earthquake on one of the central WFZ segments occurred about 350 years ago on the Nephi segment.

Recently, interest in the paleoseismology of the WFZ has renewed, as the fault is an ideal laboratory for studying the frequency and magnitude of surface-faulting earthquakes in the Basin and Range Province. The most recent paleoseismic research on the WFZ includes studies of the Nephi, Provo, and Salt Lake City segments. Our current research focuses on the Weber segment, which extends about 40 miles (60 km) from North Ogden to North Salt Lake. The reasons for trenching the Weber segment include (1) a poorly constrained history of surface-faulting earthquakes from earlier trench studies, (2) large uncertainties in earthquake correlation and recurrence, fault displacement, and slip rate resulting from the limited data, (3) evidence for anomalously large- and small-displacement earthquakes on the segment, and (4) limited opportunities for investigating Holocene (past 11,500 years) earthquakes on the segment due to extensive development.



Northern Weber segment of the Wasatch fault zone (WFZ), showing locations of the Rice Creek trench site and previous trench investigations ("I" shapes). Red line indicates trace of the Weber segment; ball and bar on downthrown side.

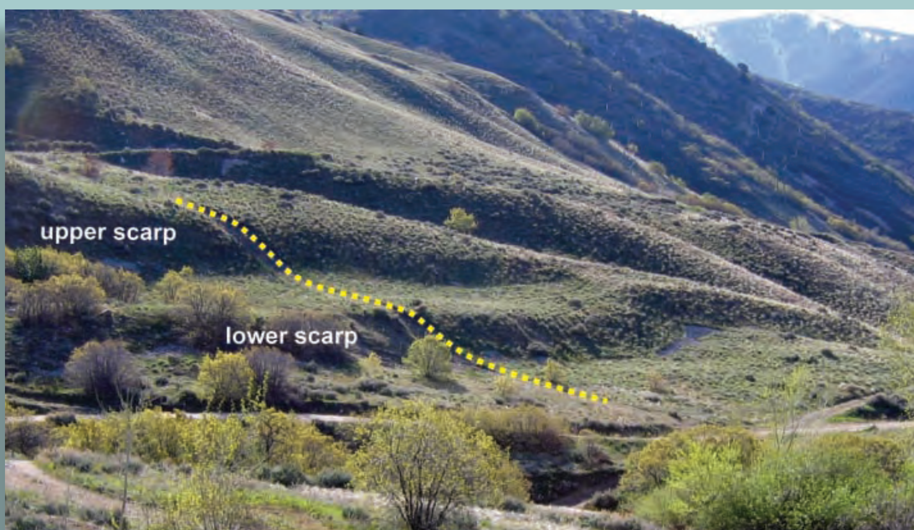
We excavated two trenches across fault scarps formed on Holocene alluvial-fan deposits in eastern North Ogden City at Rice Creek Springs. One trench across two main fault scarps about 20 and 30 feet (6 and 10 m) high revealed two zones of complex surface faulting.

Faulted alluvial-fan deposits and fault-scarp-related colluvium (soil and sediment that has collapsed and been eroded from the scarp face shortly after an earthquake) exposed in the trenches indicate that at least four Holocene surface-faulting earthquakes have occurred on this part of the WFZ. The earliest paleoearthquake occurred during the late stages of active alluvial-fan deposition, as indicated by a fault zone buried by fan sediments. We infer later surface-faulting events from the presence of scarp-derived colluvium deposited after alluvial-fan deposition ceased at the site. The alluvial fan at the Rice Creek site postdates abandonment of the Bonneville shoreline about 16,800 years ago, and comparison with the morphology and position of other fans along the segment suggests a young, possibly early- to mid-Holocene age. These preliminary results indicate that the Rice Creek trench site provides a record of Weber-segment paleoseismicity that is comparable with previous studies of the Weber-segment near East Ogden (four events in 3000–5000 years) and Kaysville (three events in about 6000 years). At the Rice Creek site, we interpret at least four earthquakes in a presumably similar time period (about the past 5000–10,000 years).

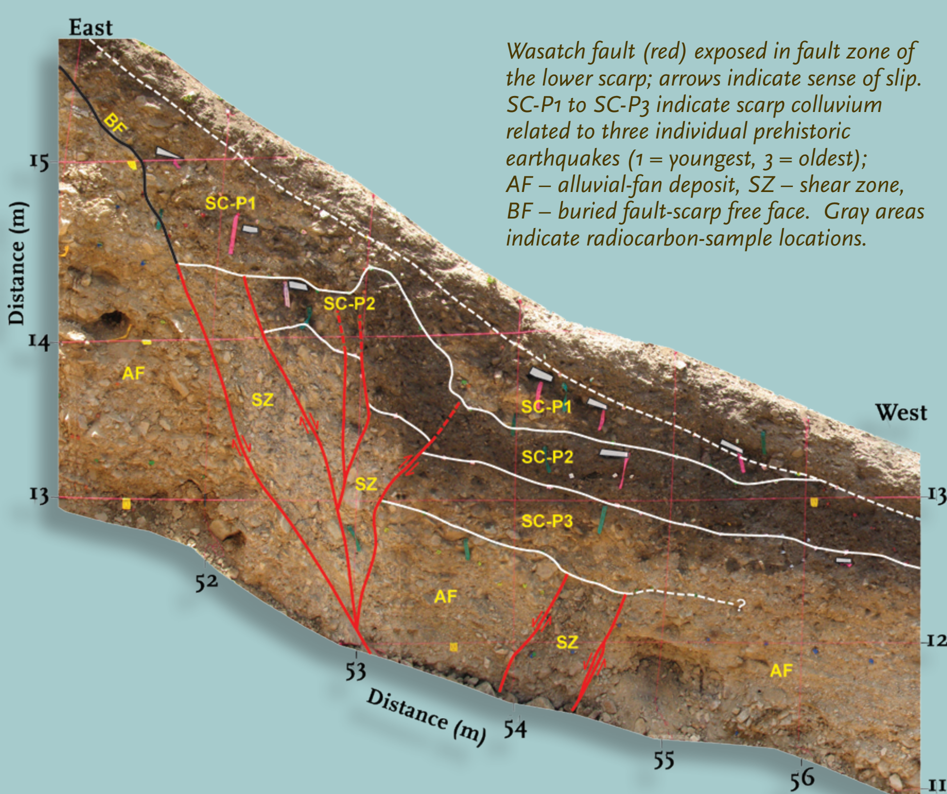
To refine the Holocene earthquake history and overall rate of activity of the Weber segment, we submitted material for radiocarbon and luminescence dating. Radiocarbon dating of charcoal fragments will help constrain the timing of individual paleoearthquakes. Luminescence dating, which establishes when sand grains were last exposed to sunlight (presumably during deposition), will help constrain the age of the youngest alluvial-fan deposits at the site, provide a maximum time limit for all paleoearthquakes inferred from the trench investigation, and provide a time component for average slip-rate calculations.

To complete our ongoing study, we plan to develop a chronology of surface-faulting earthquakes at the site; determine a revised earthquake-correlation scheme among all trench sites for the Weber segment; refine estimates of fault displacement, slip rate, and earthquake recurrence; and compare our results with paleoseismic information for the adjacent Salt Lake City and Brigham City segments. Ultimately, these data are essential to understanding the segmentation of the northern WFZ, updating probabilistic ground-shaking-hazard maps for the region (e.g., the USGS National Seismic Hazard Maps), and revising seismic-design provisions in building codes.

This work was partly funded by the USGS National Earthquake Hazards Reduction Program; the USDA Forest Service and a private landowner granted land access. Collaborators on the trenching project include USGS geologists Anthony Crone, Stephen Personius, David Lidke, and Michael Machette; Utah State University student Stephanie Davi; and UGS geologists William Lund and Tyler Knudson. A final report of the investigation is planned for publication by the UGS in late 2008.



Fault scarps at the Rice Creek trench site. Yellow dotted line indicates approximate location of main trench; view is to the southeast.

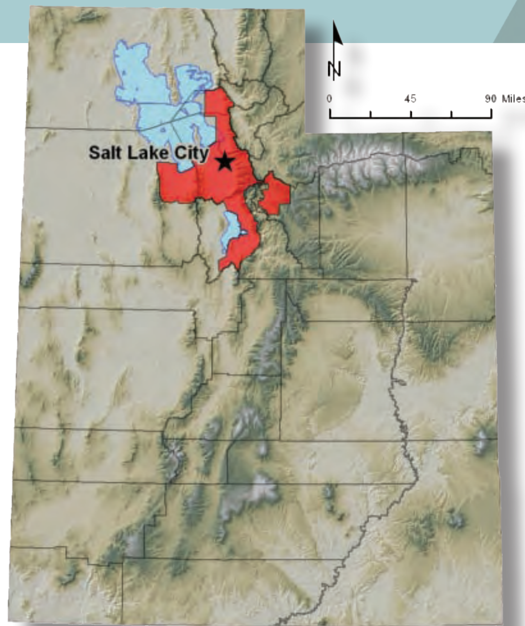


Wasatch fault (red) exposed in fault zone of the lower scarp; arrows indicate sense of slip. SC-P1 to SC-P3 indicate scarp colluvium related to three individual prehistoric earthquakes (1 = youngest, 3 = oldest); AF – alluvial-fan deposit, SZ – shear zone, BF – buried fault-scarp free face. Gray areas indicate radiocarbon-sample locations.

UGS Compiles GIS Database Showing Geologic-Hazard Special-Study Areas for the Wasatch Front

by Gary E. Christenson and Lucas M. Shaw

From 1988 to 1995, the Utah Geological Survey (UGS) and Wasatch Front County Hazards Geologists completed geologic-hazard special-study-area maps for the urban parts of Davis, Salt Lake, Tooele, Utah, Wasatch, and Weber Counties. These maps presently exist in a variety of formats ranging from modern Geographic Information System (GIS) digital databases to hard-copy mylar overlays. Recent work by the UGS addresses a long-term need to compile these maps into a uniform GIS database to enhance their utility to their wide range of potential users.



Area covered by the Wasatch Front GIS database compilation.

The 1:24,000-scale hazard maps show areas where surface-fault-rupture, landslide, and debris-flow/alluvial-fan-flooding special studies are recommended prior to development. These maps were originally compiled as mylar overlays. Similarly, Utah State University and the consulting firm Dames and Moore completed a series of liquefaction-potential maps in 1982–90 for much of northern Utah at a scale of 1:48,000 as hard-copy mylar maps. Local governments typically use these maps in geologic-hazard ordinances for land-use planning and regulation, and state and local government agencies also use them in developing pre-disaster mitigation plans and critical lands maps. The maps can also be used by homeowners, homebuyers, real-estate agents, and others to assess potential risks at particular sites of interest.

Working from the geologic-hazard and liquefaction-potential maps, we compiled four separate GIS datasets corresponding to surface-fault-rupture, liquefaction, landslide, and debris-flow/alluvial-fan-flooding hazards. These four hazards have relatively uniform map data throughout the area covered by the GIS database. Data for other hazards (e.g., rock fall, stream flooding, problem soils) exist in some but not all areas. Because of the spotty data coverage, we did not compile GIS datasets for these other hazards.

The new GIS database will be the starting point for implementation of the Governor's Geologic Hazards Working Group's recommendation to update and improve existing Wasatch Front geologic-hazard maps (see article in the September 2007 issue of *Survey Notes*, and UGS Circular 104). Many new geologic maps and geologic-hazard reports have been completed since the original special-study-area maps were compiled, so the GIS database will facilitate formal updates. For ready access, the GIS database will be made available on compact disk from the UGS and posted on the UGS and Utah Automated Geographic Reference Center Web sites.

Layton City Director of Community Development Scott Carter (brown shirt, at left) and UGS Senior Geologist Richard Giraud (white jacket, far left) discuss Layton's Sunset Drive landslide with Governor Huntsman and the Governor's Geologic Hazards Working Group following the Seprember 25th public meeting in Layton.

Governor's Geologic Hazards Working Group Completes its Final Report

The Governor's Geologic Hazards Working Group presented its final report entitled *A Plan to Reduce Losses from Geologic Hazards in Utah* to Governor Jon M. Huntsman, Jr., at a meeting in Layton on September 25, 2007, followed by a public meeting and field visit to the Sunset Drive landslide in east Layton. A summary of the working group's activities and recommendations appears in the September 2007 issue of *Survey Notes* (v.39, no.3, p.7). The final report is published as UGS Circular 104 and is now available on the UGS Web site at geology.utah.gov/ghp/geohaz_workgroup/index.htm.

UGS Responds to the Magnitude 6.0 Wells, Nevada, Earthquake

Unreinforced masonry buildings in the historic district of Wells were severely damaged in the earthquake.

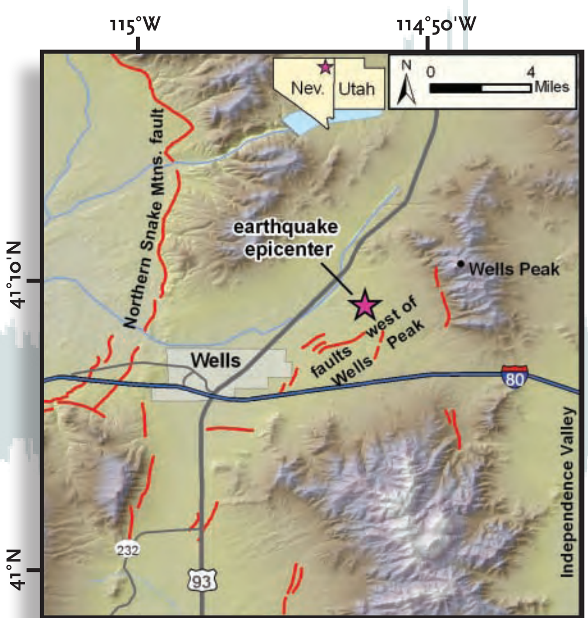
by Christopher B. DuRoss

The magnitude 6.0 Wells earthquake occurred in the early morning of February 21, 2008. The earthquake epicenter is about 6 miles northeast of Wells, Nevada, near the Utah border about 50 miles northwest of Wendover. Wells is located in the Basin and Range Province, a seismically active region that includes most of Nevada and western Utah. Wells and neighboring rural areas experienced strong ground shaking from the earthquake, which was felt as far as several hundred miles away from the epicenter, including along the Wasatch Front. Earthquake-related losses in Wells consist mostly of heavily damaged buildings in the historic part of downtown, and ruptured underground utilities including water pipes and fuel lines.

The Wells earthquake has several important implications for the earthquake hazard in Utah. First, the earthquake likely occurred on a fault that, based on geological evidence, does not have a high level of activity (i.e., long periods of time pass between large earthquakes). This demonstrates that less active faults in the Basin and Range Province are still significant sources of large earthquakes. Dozens of similar faults are mapped throughout Utah. Second, ground shaking from the earthquake caused considerable damage to unreinforced masonry buildings, whereas buildings designed to modern building codes showed minimal damage. Utah has a large number of similar unreinforced masonry buildings along the Wasatch Front (see The Director's Perspective in this issue of *Survey Notes*), and is likely to experience ground shaking stronger than that of the Wells earthquake. Finally, the Wells earthquake provided an opportunity to consider Utah's readiness to respond to a large earthquake. The Utah Geological Survey (UGS), Utah Division of Homeland Security, and University of Utah Seismograph Stations all assisted Nevada agencies with a quick response to the earthquake, but an event of similar or larger magnitude along the Wasatch Front would tax our resources and have more catastrophic and disruptive effects.

The UGS Geologic Hazards Program sent a team of geologists to assist the Nevada Bureau of Mines and Geology (NBMG) with the scientific response to the earthquake. The purpose of the UGS field investigation was to (1) look for surface faulting or ground cracking associated with mapped Quaternary faults (i.e., faults that have produced large earthquakes in relatively recent geologic time); (2) document geologic evidence of strong ground shaking such as liquefaction (loss of strength in water-saturated soils), ground cravcks, rock falls, and landslides; and

(continued on page 17)



Location of the magnitude 6.0 Wells, Nevada, earthquake epicenter. Quaternary faults (red) from the U.S. Geological Survey Fault and Fold Database of the United States.

General Information on Earthquake Hazards in Utah

Homebuyers guide to earthquake hazards in Utah, by S.N. Eldredge, 1996, Utah Geological Survey Public Information Series 38, 27 p., online at **www.ugs.state.ut.us/online/pdf/pi-38.pdf.**

Earthquakes & Utah, by S.N. Eldredge, 1997, Utah Geological Survey Public Information Series 48, 6 p., online at **www.ugs.state.ut.us/online/pdf/pi-48.pdf.**

Utah natural hazards handbook for public and government awareness, S.N. Eldredge, editor, 1992, Utah Division of Comprehensive Emergency Management, 62 p.*

** The Utah Division of Homeland Security is preparing an updated edition of the* Utah Natural Hazards Handbook. *Also, the UGS is contributing material for a new publication of the Utah Seismic Safety Commission entitled* Putting Down Roots in Earthquake Country—Your Handbook for Earthquakes in Utah. *Watch for announcements of the release of these publications in* Survey Notes *and on our Web site.*

GLAD YOU ASKED...

So you think you have found a meteorite! Now, how can you verify your find?

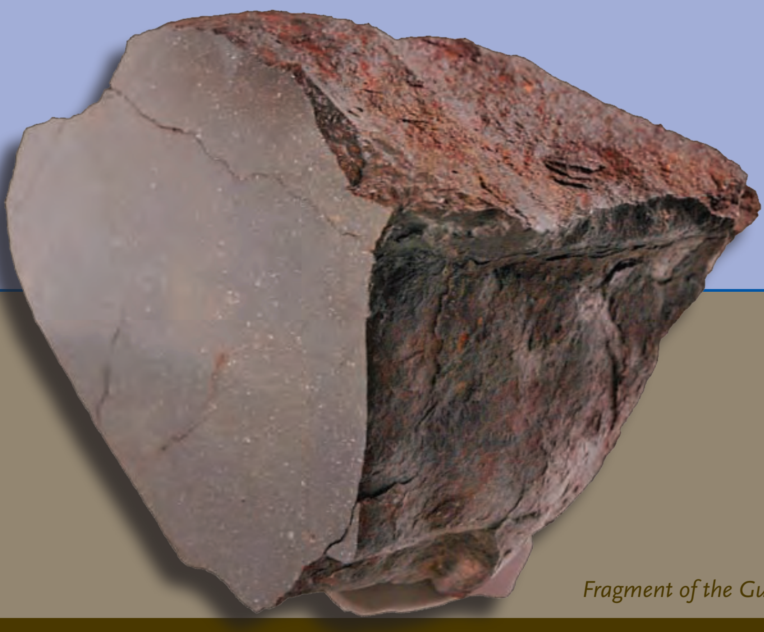
by William F. Case

You found a strange rock. It is heavy, dark colored, and magnetic, so you are thinking it must be a meteorite from outer space. You visualize it falling through the air in a blaze and landing right where you can find it. You are going to be rich!

A meteorite is a solid object that has traveled through the solar system and landed on the Earth's surface. The odds of finding a meteorite are slim even if you see it fall. Many objects initially thought to be meteorites turned out to be space or aircraft junk, and even metallic pieces of wood chippers.

The more than 50 meteorite types are grouped into three broad categories: stony, iron, and stony-iron. Most meteorites come from the asteroid belt. The remainder includes rocky debris from the heads of comets that have melted and broken apart, and rock fragments originating from the Moon and Mars. Stony meteorites closely resemble Earth sandstones or conglomerates, iron meteorites are obviously metallic, and stony-irons have metallic and non-metallic components.

Meteorite identification is frustrating because almost all the identification rules have exceptions. The following guidelines may help you determine if you have a meteorite.



Fragment of the Gunlock Meteorite (see next page).

1. Does the rock have a *fusion crust*? As meteorites descend through the Earth's atmosphere, they burn and form a thin crust of melted rock. The crust's color is usually dark brown to black. If the meteorite has been on the Earth's surface for some time, weathering turns the meteorite surface to more of a rusty brown color.

2. How does the *appearance* of the rock compare with surrounding rocks? Meteorites are black or dark brown, rather smooth, with no gas holes; often, meteorites look very different from the other rocks lying nearby.

3. Is the rock *magnetic*? If the answer is no, then it is probably not a meteorite. Almost all meteorites (even stony) will be attracted to a magnet due to their iron content. Because some Earth minerals are also magnetic, this test is not conclusive.

4. Is the rock *heavy* compared to other rocks of the same size? Meteorites are dense and feel heavy due to their metal content.

5. Does the rock surface have *shiny spots* that look like untarnished silver? Meteoritic iron doesn't tarnish or rust because it forms in an oxygen-free environment.

6. Does the rock have a *streak*? Streak is the color of the powder produced when the rock is rubbed on white unglazed porcelain such as the bottom of a coffee cup or ceramic tile. For example, magnetite (a magnetic, iron-bearing mineral common in igneous rocks on Earth) has a black streak. Meteoritic iron does not have a streak unless it has been lying exposed on the Earth's surface for a long time.

If your rock has passed most of the guidelines then the next step is to visit the following Web sites for more information leading to verification by experts:

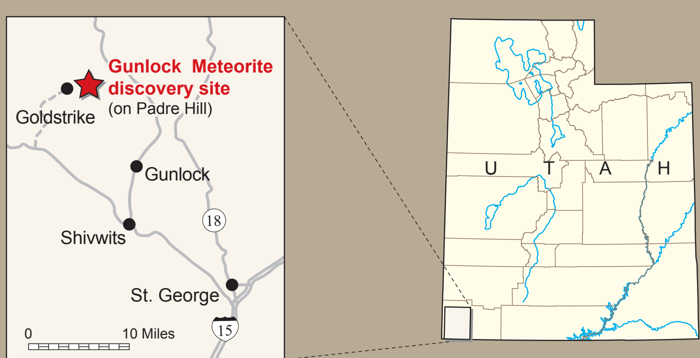
- **meteorites.wustl.edu/more_info_nonlunar.htm**
  Randy Korotev. Washington University
- **meteorites.asu.edu/identification/index.htm**
  Arizona State University
- **meteorite-identification.com/verification.html**
  Meteorite testing and classifying institutions

The Gunlock Meteorite Finds a New Home at the Utah Geological Survey

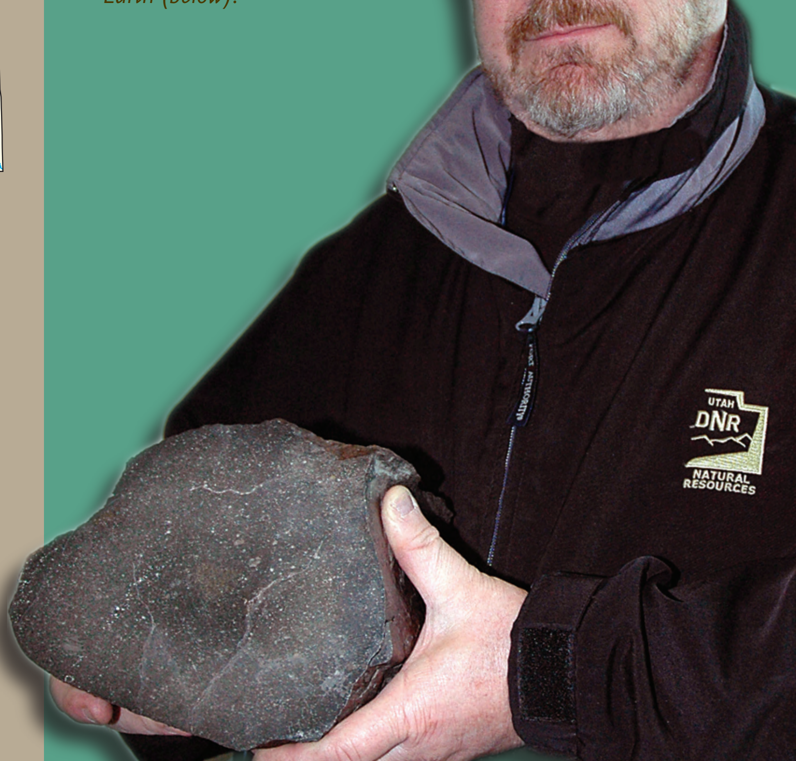
by Michael Laine

The Gunlock Meteorite was discovered in 1982 in southwestern Utah. One of only 18 meteorite samples known from Utah (see geology.utah.gov/surveynotes/gladasked/gladmeteorites.htm),the Gunlock Meteorite is an extremely rare and valuable find. Now, after 26 years in a private collection, a 18-pound piece of the Gunlock Meteorite has returned to Utah and found a new home at the UGS.

Meteorites are important because they are samples of asteroids, comets, or planets and are among the only rocks that provide geologists with "ground truth" information about the nature of solar-system bodies other than the Earth. The Gunlock Meteorite is a chondrite, a particular group of stony meteorites that derives its name from the Greek word for "seeds." The name alludes to the meteorites' distinctive texture characterized by small grains called chondrules. Current theories concerning the origin of chondrites suggest they are related to the



birth of the sun in a contracting disk of spinning interstellar dust and gas clouds called a solar nebula. As the sun ignited, interstellar dust in the nebula melted and condensed into droplets or chondrules of silicate minerals like olivine and pyroxene, which are also found in many igneous rocks on Earth. As soon as the chondrules started forming they began clumping together with the remaining dust and gas in the solar nebula, forming a primitive cosmic sediment of silicate minerals, metals like iron and nickel, and simple organic compounds, as well as diamond dust and heavy elements seeded into the nebula by nearby exploding stars or novas. In time, this cosmic sediment grew from pebble-sized rocks to boulders, asteroids several hundred miles

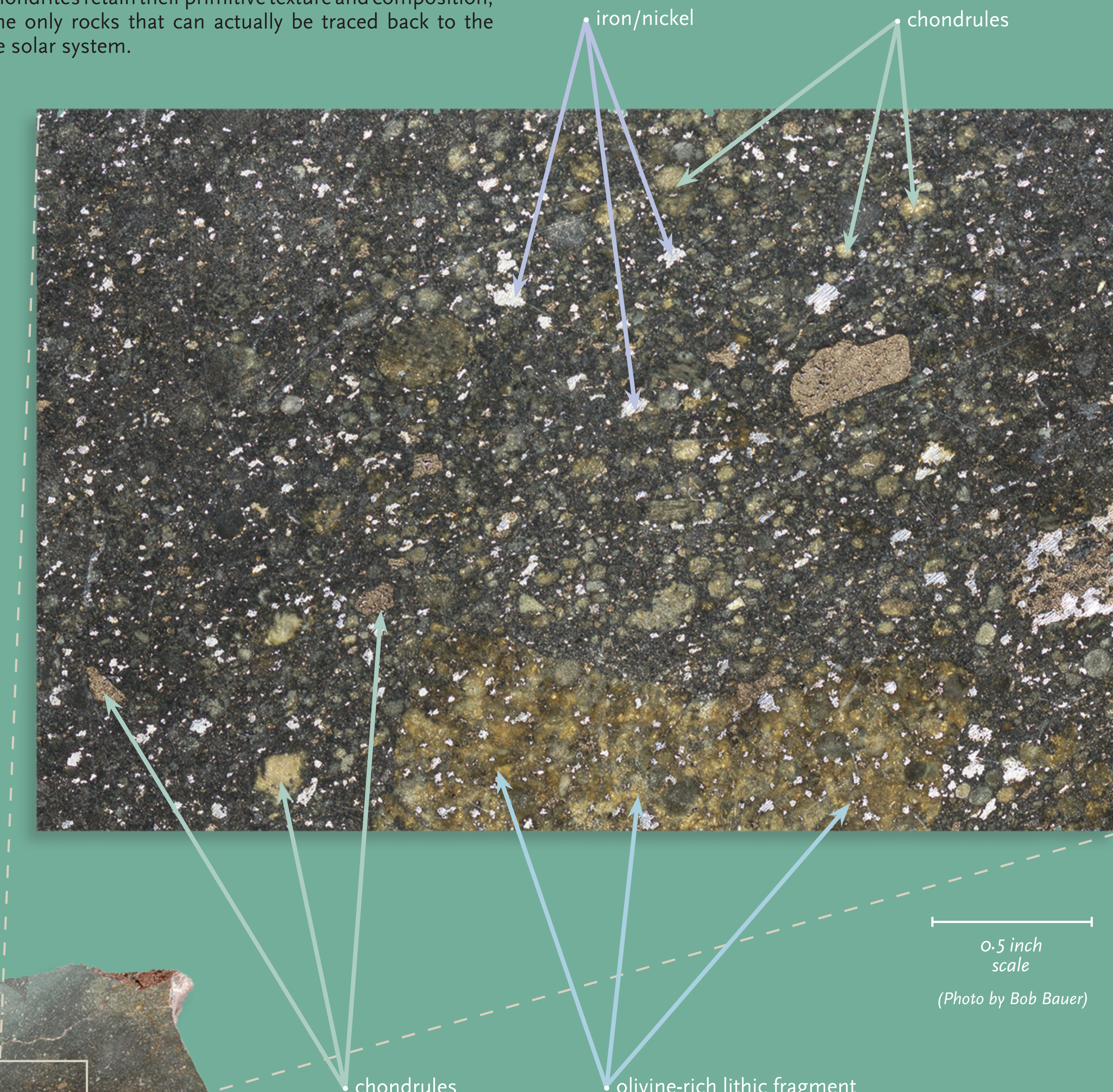


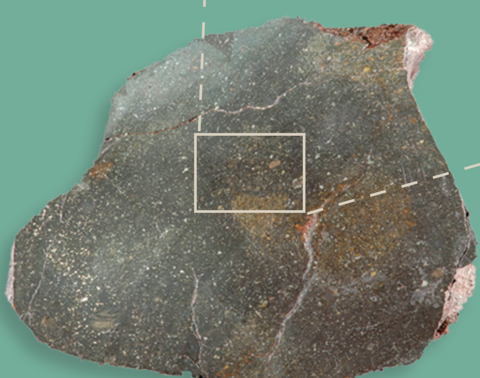
The Gunlock Meteorite, held by Michael Laine, displays the characteristic fusion crust formed during entry into the Earth's atmosphere (above). The polished slice through the football-sized meteorite reveals it's distinctive chondritic texture and fractures possibly due to impact with the surface of the Earth (below).

across, and occasionally into even larger objects like planets. The present-day asteroid belt between Mars and Jupiter is a collection of leftover chondritic material that did not become part of a larger planet. Collisions between asteroids knock off pieces that occasionally fall to Earth as chondritic meteorites.

Chondritic meteorites are among the most exciting rocks available for scientific study. The age of chondrites, determined by the radioactive decay of constituent elements, is an amazing 4.5 billion years—older than any other known rocks on Earth. Although Earth probably formed about the same time, geologic processes have constantly recycled the rocks on its surface. Because chondrites retain their primitive texture and composition, they are the only rocks that can actually be traced back to the birth of the solar system.

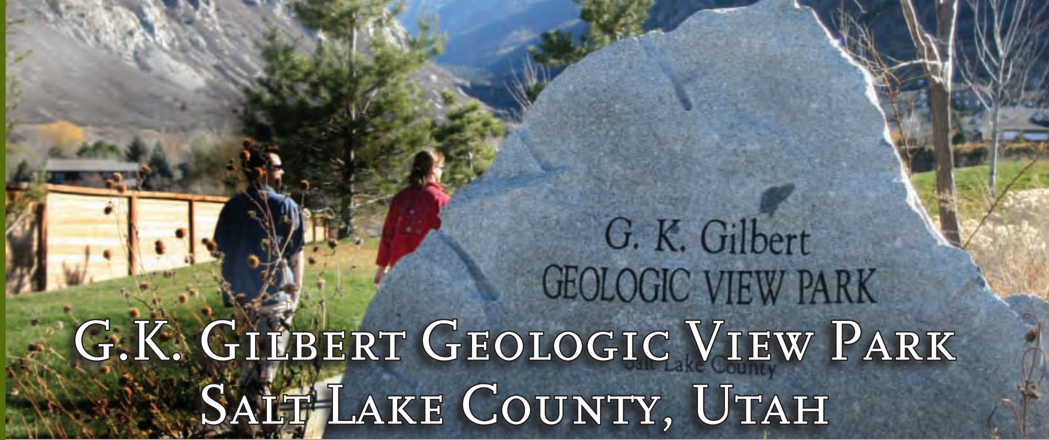
Mr. Don Adair, of Boise, Idaho, discovered the Gunlock Meteorite on June 22, 1982, while mapping the geology of the Goldstrike mining district in Washington County. A quick survey of Padre Hill, where the meteorite was found, yielded a second meteorite fragment about 150 feet away. The two fragments fit together, indicating they were originally one piece. This past winter, Mr. Adair graciously donated one of the fragments to the UGS where it can be seen on permanent display in the Natural Resources Map & Bookstore.





(Photo by Bob Bauer)

Close-up of the Gunlock Meteorite showing typical chondritic texture: a poorly sorted collection of silicate-rich chondrules, olivine-rich lithic fragments, and iron/nickel (white reflections) in a dark matrix of fine-grained silicate minerals, simple organic compounds and diamond dust. This is the cosmic sediment from which all the planets of the solar system were formed.



G.K. Gilbert Geologic View Park
Salt Lake County, Utah

by Sandy Eldredge

The boulder at the park entrance is quartz monzonite of the Little Cottonwood stock and was originally from the Temple Quarry in Little Cottonwood Canyon. The drill holes along the left side of the boulder were made in the late 1800s by quarry workers using sledgehammers and hand-held drill bits.

Park information: Utah has a new geologic park! Located near the mouth of Little Cottonwood Canyon southeast of Salt Lake City, the park showcases several world-class examples of geologic features and has long been a destination for thousands of people on educational field trips. Five geologic interpretive signs were installed in November 2007 and park dedication will take place on May 7, 2008.

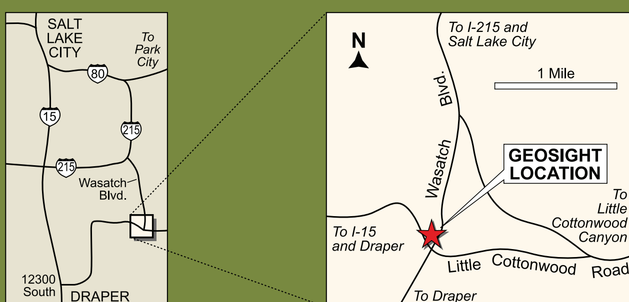
Geologic information: The interpretive signs provide information on a variety of geologic features that can be viewed from the park, including several rock formations in the Wasatch Range, scarps of the Wasatch fault, landforms and deposits associated with Ice Age glaciers, and evidence of past gold mining. The signs also supply additional information about Lake Bonneville and past quarrying activities.

In the immediate vicinity of the park, the three visible rock formations are the metamorphic Little Willow and Big Cottonwood Formations and the igneous Little Cottonwood stock. The Little Willow Formation consists primarily of contorted quartz schist and gneiss; at 1.7 billion years old, it is the oldest rock in the Salt Lake City area. The Big Cottonwood Formation is a thick unit of alternating shale/slate and quartzite beds originally deposited in a tidal/shoreline environment 1 billion to 800 million years ago. In contrast, the Little Cottonwood stock is a relatively young 31-million-year-old intrusive igneous rock called quartz monzonite (generally known as granite).

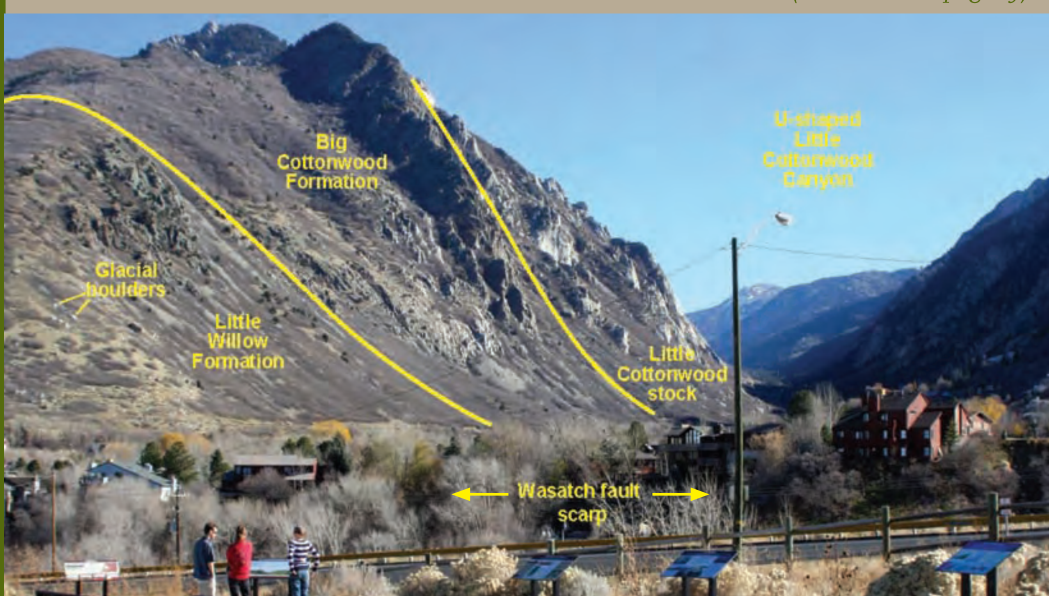
(continued on page 15)

How to get there:

From the north: **From I-15, take exit #304 onto I-80 East and after 5 miles bear right at exit #128 onto southbound I-215. Travel 5.9 miles, take exit #6 at 6200 South and turn left (east). Within 1 mile the road becomes Wasatch Boulevard near a gravel pit. Travel 1 more mile to a stoplight and continue straight (south). In 2.1 miles, turn right at a stoplight to continue on Wasatch Boulevard. In 1.1 miles is the junction with Little Cottonwood Road (9800 South); the park is northwest of this junction. Go right (west) to reach the park entrance.**



From the south: **From I-15, take exit #291 and go east on UT-71/12300 South towards Draper. In 1.2 miles, the road becomes Draper Parkway. Continue 0.6 miles, then turn left (north) onto 1300 East. In 3.6 miles, turn right (east) onto UT-209/9400 South. Travel 3 miles to the park entrance on the left (north) side of road just before the junction with Wasatch Boulevard.**



Interpretive signs at the G.K. Gilbert Geologic View Park show a panoramic overview highlighting geologic features and provide information about the Wasatch fault, Lake Bonneville, glaciers, bedrock geology, and mining activity.

GEOSIGHTS

The Green Pond Landslide

Imperceptibly Moving Ground

By Francis X. Ashland

Green Pond trail sign—hike on moving ground.

About a mile west of Trappers Loop Road (State Route 167) along the road to the Snowbasin ski resort (State Route 226) is the Green Pond trailhead. Most people who use the nearby trails to hike, bike, or ride horses may not appreciate that they are recreating on moving ground. The edge of the Green Pond landslide, one of the largest landslides in the area, is just a few feet southeast of the trailhead parking area. The signs of ongoing landslide movement are subtle, however, and likely noticed by only the most careful observer.

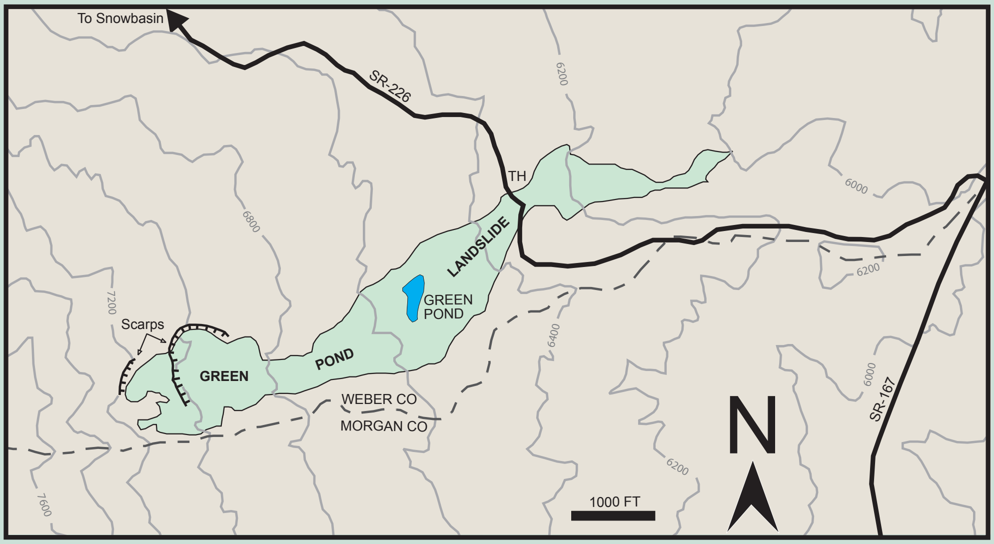
Some indication of the very slow, imperceptible movement of the Green Pond landslide is revealed by the condition of State Route 226, which crosses a narrow part of the slide. Constructed to provide access to the ski resort for the 2002 Olympic Games, the pavement is currently cracked at the edges of the slide, and the original lane stripes have been slightly offset and subsequently repainted.

Beginning in late 2005, the Utah Geological Survey (UGS) began monitoring the movement of the landslide using a survey-grade Global Positioning System instrument. Between October 2005 and August 2007, the landslide moved about 5 inches.

The Green Pond and other landslides in the surrounding area, including some that have damaged houses in Mountain Green, are underlain by a weak geologic unit known as the Norwood Tuff. Weathering of volcanic rock layers in the unit has formed some of the weakest clays in Utah on which overlying layers and shallow surficial deposits slide.

The large slides in the Norwood Tuff like the Green Pond landslide have probably existed for over 10,000 years, but remain active today. Most of these landslides typically move very slowly. However, recent geologic investigations by the UGS of the large landslides in the area have revealed that parts of these slides have moved more dramatically, likely several feet or more in a single year, in the recent past. One focus of our research is to try to understand what conditions control the movement of landslides in the Norwood Tuff, perhaps enabling us to predict when more dramatic movement may occur in the future.

Road cracks across State Route 226 define the edge of the Green Pond landslide. Arrow is on slide and shows general movement direction.



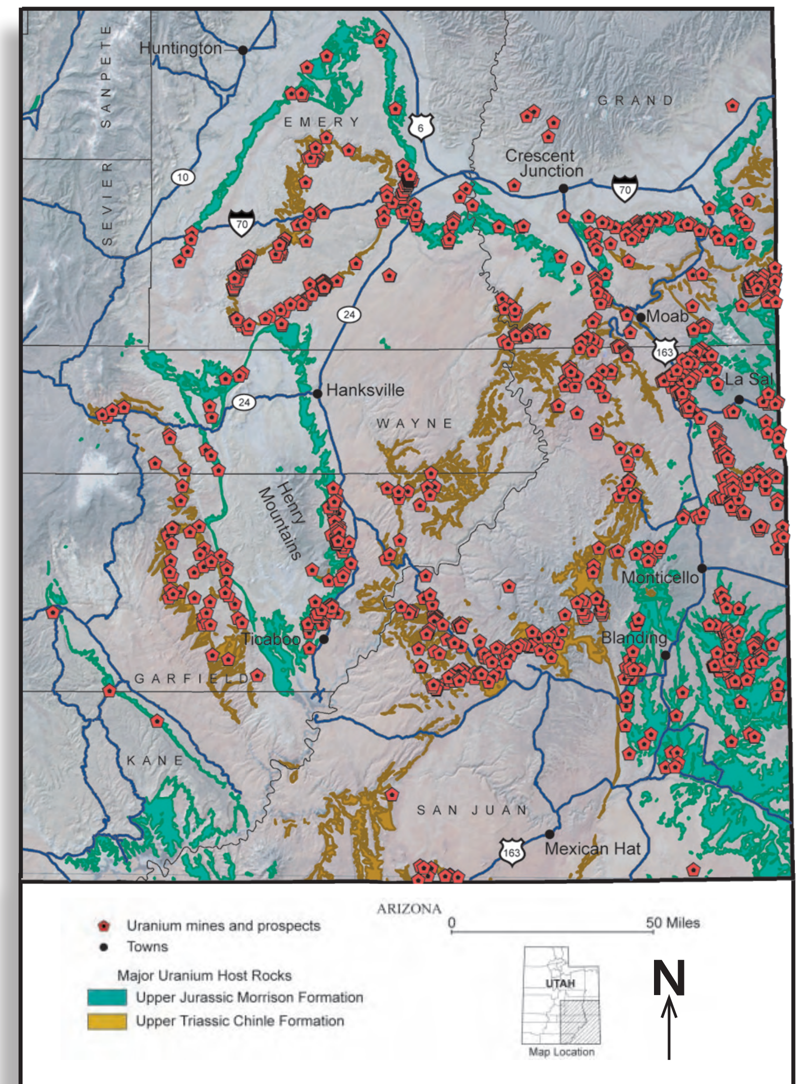
Location of the Green Pond landslide along State Route 226. Approximate location of trailhead (TH) parking area shown.

ENERGY NEWS

A New Uranium Boom?

by Ken Krahulec

Utah is the third-largest uranium-producing state in the U.S., having a cumulative production of about 130 million pounds of uranium oxide (U_3O_8). Production came to a halt in the early 1990s due to low uranium prices, but a resurgence in the market may be bringing a new period of uranium exploration and production to Utah.



Uranium mines and prospects in southeast Utah.

The vast majority of Utah's uranium production has come from small, low- to moderate-grade, sandstone-hosted uranium deposits in the Colorado Plateau of southeastern Utah. These ore bodies typically occur in curvilinear trends along favorable ancient stream channels developed in continental basins. The principal sedimentary ore hosts in Utah are fluvial sandstones of the Upper Jurassic Morrison Formation and Upper Triassic Chinle Formation. Sandstone-hosted deposits typically average 0.1 to 0.6 percent U_3O_8.

Utah's first uranium boom began in 1948 when the U.S. Atomic Energy Commission (AEC) set a guaranteed price and bonus schedule for domestic uranium ore, driven by the requirements of nuclear weapons production. Subsequently, the AEC set up six uranium ore-buying stations scattered across Utah. Utah's uranium production grew rapidly during the late 1940s and on into the mid-1950s, peaking in 1958 at 8.9 million pounds of U_3O_8 from 392 small underground mines. Production then declined into the 1960s.

A second uranium boom began in the early 1970s with the development of the nuclear power industry. This phase of uranium development peaked in 1981—about 4.5 million pounds of U_3O_8 produced from an estimated 100 mines. Since the mid-1980s, Utah's mines have had difficulty competing with lower-cost foreign operations, resulting in rapidly declining production. By 1991, uranium prices were so low that Utah's operations were no longer economic (about \$40 to \$50 per pound U_3O_8 in 2007 dollars) and all production ceased, followed a few years later by the idling of other underground uranium mines in the U.S.

The U_3O_8 price continued to decline through the 1990s and finally bottomed out in 2001 at about \$8 per pound. During this period of low prices (1992 to

2003), few companies were actively exploring for uranium in Utah, and most of the old mines and associated facilities were closed and reclamation had begun. The most notable pending reclamation effort is the U.S. Department of Energy's planned relocation of 10.5 million tons of old uranium mill tailings from along the Colorado River just north of Moab to a permanent disposal site 30 miles north near Crescent Junction.

Since 2001, the uranium spot price has rapidly escalated to over $70 per pound (April 2008). This price increase resulted from a lack of uranium mine development over the past couple decades, compounded by the recent increases in demand. The new higher uranium price has encouraged renewed exploration and development in Utah and may lead to the beginning of a third uranium boom.

Currently, all of Utah's old uranium mines remain closed except for the Pandora mine near La Sal in eastern San Juan County and the Tony M mine near Ticaboo in southeastern Garfield County. The Pandora mine renewed operations in December 2006 and is currently producing at a rate of about 100 tons of ore per day. The Tony M mine is being redeveloped for production at a rate of about 350 tons per day in 2008. Both mines are owned by Denison Mines Corporation, the owner of Utah's lone, active uranium processing plant—the White Mesa uranium-vanadium mill near Blanding, which is fully licensed by the U.S. Nuclear Regulatory Commission for ore processing and permanent tailings disposal.

The exploration and rehabilitation of several other old uranium mines is ongoing. The Whirlwind mine (Energy Fuels Inc.), on Beaver Mesa along the Utah-Colorado border about 28 miles northeast of Moab, is scheduled to begin production in 2008. This is an interesting operation because, while much of the underground mining occurs in Utah, the portal and surface facilities are a mile to the east in Colorado. A second plant, the Shootaring uranium mill at Ticaboo (Uranium One Inc.), is on standby but is pursuing operating permits and licenses.

Unmined uranium mineral resources remain at many known properties; the largest resource is the roughly 20 million pounds of U_3O_8 remaining in the Tony M–Bullfrog deposits in the southern Henry Mountains northwest of Ticaboo. Most of the current exploration and development work in Utah is focused on the Henry Mountains, La Sal, and Lisbon Valley (south of La Sal) areas. The Lisbon Valley mining district is Utah's largest uranium district, having produced nearly 54 million pounds of U_3O_8.

The major issue affecting the future of uranium mining in Utah is whether nuclear power will ultimately be accepted as a clean, safe, and economical fuel producing substantial power with very low "greenhouse gas" emissions, or will it continue to be perceived as a potential environmental and safety hazard. Whereas the international community, led by France, Canada, India, and China, is rapidly adopting the more favorable view, the U.S. generally has not. If the new, international vision of uranium as a clean, "low-greenhouse gas" power source is adopted, Utah's third uranium boom could last longer than its predecessors.

Here are some important references on the geology of uranium deposits in Utah available from the Natural Resources Map & Bookstore (mapstore.utah.gov).

Uranium and vanadium map of Utah, by R.W. Gloyn, R.L. Bon, S. Wakefield, and K.A. Krahulec, 2005, Utah Geological Survey Map 215DM. *(This CD contains both GIS shape files and a PDF file of the state's uranium prospects, mines, mining districts, and favorable geological strata.)*

Uranium/vanadium publications of the Utah Geological Survey – a collection of reprints, Utah Geological Survey Open-File Report 462. *(This CD contains 14 previously published reports with over 1400 pages on uranium in Utah.)*

GEOSIGHTS

(continued from page 11)

The Wasatch fault, Utah's longest and most active fault, exhibits some of its largest fault scarps at this site. Reaching more than 100 feet high, these scarps formed during repeated large earthquakes that displaced the ground surface.

This is one of only a few localities in the world where mid-latitude alpine glaciers met lakes during the last Ice Age 30,000 to 10,000 years ago. The glaciers in Little Cottonwood Canyon and Bells Canyon (to the immediate south) extended into Lake Bonneville, the Ice Age lake that covered much of western Utah. Glacial features at this site include the classic U-shaped canyon of Little Cottonwood Canyon (caused by glacial scouring), moraines, and scattered glacial boulders.

More than a century ago, gold was mined in the Little Willow Formation, and mine dumps are evident near the canyon mouth where the former town of Gold City was located. Out of view in the lower canyon is the famed Temple Quarry, where granite of the Little Cottonwood stock has been quarried at various times since the 1860s to construct several prominent buildings in Salt Lake City.

SURVEY NEWS

Employee News

UGS Employee of the Year

Congratulations to **Kent Brown** who was named the 2007 UGS Outstanding Employee of the Year. He is a GIS Analyst in the Geologic Mapping Program and has been with the UGS for 25 years. It is largely through Kent's efforts and leadership that the UGS is recognized as one of the leaders in using digital technology. Kent has, through his own efforts, stayed at the cutting edge of technology, and is able to solve almost any computer-related problem. He has spent many hours training other staff on the latest GIS techniques and helping geologists incorporate new computer software and hardware into their field mapping (see feature articles in the January 2008 issue of *Survey Notes*). Kent's expertise has also been recognized outside the UGS, and he has helped both Brigham Young University and the Nevada Bureau of Mines and Geology set up digital photogrammetry systems. We are proud to recognize Kent for his outstanding contributions and service to the UGS.

Gary Christenson retired in March after 27 years of service to the UGS. He joined in 1981 as a site investigations geologist, and in 1988 became manager of the Applied Geology Program (currently the Geologic Hazards Program) and continued in that role until retirement. One of Gary's most recent achievements was chairing the Governor's Geologic Hazards Working Group, which produced a report for the Governor containing numerous recommendations (*A Plan to Reduce Losses From Geologic Hazards in Utah,* 2007, UGS Circular 104). One outcome of the working group's activity and recommendations was the first increase in general funding for the Geologic Hazards Program in more than 10 years. Gary's knowledge and expertise, long respected by the engineering-geology community, will be missed. Fortunately, he is staying in the Salt Lake City area, and we can expect to find him on a nearby golf course!

Donald T. McMillan

Donald Theodore McMillan, State Geologist and director of the Utah Geological and Mineral Survey (UGMS) from 1974 to 1981, passed away in Tucson, Arizona, October 27, 2007, at the age of 91.

Donald T. McMillan was born in Scarsdale, New York, in 1916, and raised near New York City. As a boy, he developed a lifelong affinity for the outdoors, which propelled him to his future career as a geologist. He received his bachelor's degree from Williams College in Massachusetts and a master's degree in geology from the Montana School of Mines in 1939. With jobs scarce, his first paycheck came from working as a miner for Anaconda Company in the copper mines of Butte, Montana.

Immediately after Pearl Harbor, Don enlisted in the Army Air Corps. On the day he got his wings, he married Elizabeth Keefe. He flew in the Pacific Theater, and after Japan's surrender, led the first American planes onto Japanese soil to bring supplies to the country's citizens. He retired with the rank of Lieutenant Colonel in the USAF Reserve.

Don returned to Butte after the war and started his career as a professional geologist. He moved his family throughout the West, including stints in Zacatecas, Mexico, where he became bilingual, and Tucson, Arizona, the city he would return to later in life. In the 1960s he worked for Strauss Exploration, becoming Vice President of Exploration, and traveling to places such as Panama, Colombia, Peru, and Ghana.

In 1974 he was appointed director of the UGMS, becoming Utah's third State Geologist. In seven years with the Survey, he oversaw expansion of the Applied Geology Program, increasing the Survey's role investigating geologic hazards and performing engineering-geology work. During this time he often assisted with engineering-geology investigations, a notable one being his evaluation of the loss of salt from the Bonneville Salt Flats between the 1960s and 1970s. In 1976 Don moved the UGMS from its cramped quarters on the University of Utah campus to the University's Research Park.

After retiring from the UGMS in 1981, Don returned to Tucson. Along with a love of travel, Don's favorite activities were skiing and sailing, passions he passed on to his children. He is survived by his wife Betty, his sister Helen Routh, four daughters, five grandchildren, and six great-grandchildren.

Sources: Obituary in Mining Enginering, Society for Mining Metallurgy and Exploration, February 2008, page 97.
Retirement article, Survey Notes, vol. 15, no. 2, Utah Geological and Mineral Survey, May 1981.

Steve Bowman replaces Gary Christenson as the new manager of the Geologic Hazards Program. Steve comes to us from Reno, Nevada, where he worked for Terracon Consultants. He has a Ph.D. in Geoengineering from the University of Nevada, Reno.

Sandow "Mark" Yidana has joined the Ground Water and Paleontology Program as a ground-water modeling specialist. Mark has a Ph.D. in Environmental Management from Montclair State University, New Jersey, and received his B.S. from the University of Ghana.

Phil Powlick, manager of the State Energy Program since late 2005, has been appointed as the new director of the Utah Division of Public Utilities. Congratulations Phil!

Jason Berry replaces Phil Powlick as the new State Energy Program manager. Jason has been the renewable energy coordinator at the UGS for the last two years.

Welcome to **Stevie Emerson**, our new graphic designer. Stevie has a Bachelor of Fine Arts from Weber State University and is already a great asset to the Editorial Section.

Sonja Heuscher has filled the geologist position in the Energy and Minerals Program. Sonja has an M.S. in geology from the University of Utah and comes to us from the Utah Department of Environmental Quality.

The Ground Water and Paleontology Program bids farewell to paleontologist **Jennifer Cavin** who accepted a position with the Nebraska Highway Salvage Program. Best of luck, Jennifer, in your new endeavor.

(Wells continued from page 7)

(3) provide geologic information to emergency response teams as necessary. In general, Basin and Range earthquakes smaller than magnitude 6.5 are not associated with surface faulting, but earthquakes close to this magnitude, such as the Wells event, may produce minor cracking at the ground surface. Finding these features (if present) is important for relating mapped Quaternary faults to large earthquakes in the Basin and Range Province and estimating future ground motions in the region.

The UGS field investigation focused on several mapped Quaternary faults near Wells and Independence Valley, but did not reveal any evidence for surface faulting or ground cracking. In Wells, UGS geologists searched for, but did not observe, any geologic effects of strong ground shaking, such as liquefaction or landslides. However, field observations were limited by impassible roads and frequent snowfall, which may have masked minor earthquake-related features. The NBMG plans to resume the search for these features in spring 2008.

The Wells earthquake is a reminder that Utah lies in a geologically hazardous area and that prudent planning and preparedness are essential to reduce the risk to life and property.

For more technical information on the Wells earthquake or UGS field investigation, visit the NBMG earthquake clearinghouse at www.nbmg.unr.edu/WellsEQ/ch/index.html.

New Publications

Surficial geologic map of the Levan and Fayette segments of the Wasatch fault zone, Juab and Sanpete Counties, Utah, by Michael D. Hylland and Michael N. Machette, 37 p., 1 pl., scale 1:50,000, ISBN 1-55791-791-4, **M-229**..***$13.50***

Delineation of drinking water source protection zones for public-water-supply springs in western Cache Valley, Cache County, Utah—North Fork, Big Birch, Little Birch, Garner, Sparks, Thompson, Goodey, Myler, City Creek, Buttars, Loosle, Lower, and Upper Springs, by Charles E. Bishop, CD (189 p.), ISBN 1-55791-769-8, **RI-256**..***$14.95***

Delineation of drinking water source protection zones for the Mountain Green public-water-supply well, Morgan County, Utah, by Charles E. Bishop, CD (7 p. + 9 p. appendices), ISBN 1-55791-781-7, **RI-261**..***$14.95***

Paleoseismology of Utah, Volume 16: Paleoseismic reconnaissance of the Sevier fault, Kane and Garfield Counties, Utah, by William R. Lund, Tyler R. Knudsen, and Garrett S. Vice, CD (27 p. + 4 p. appendices), ISBN 1-55791-787-6, **SS-122**..***$14.95***

Geologic map of the lower Escalante River area, Glen Canyon National Recreation Area, eastern Kane County, Utah, by Hellmut H. Doelling and Grant C. Willis, CD (8 p., 1 pl., 1:100,000 [contains GIS data]), ISBN 1-55791-767-1, **MP-06-3DM**................................***$24.95***

Geologic map of the Logan 30' x 60' quadrangle, Cache and Rich Counties, Utah, and Lincoln and Uinta Counties, Wyoming, by J.H. Dover (digitized from U.S. Geological Survey Miscellaneous Investigations Series Map I-2210 [1995]), CD (2 pl., scale 1:100,000 [contains GIS data]), ISBN 1-55791-790-6, **MP-06-8DM**................................***$24.95***

Large mines in Utah, 2008, compiled by Roger L. Bon and Sharon Wakefield, 4 p., 1 pl., 1:700,000, **OFR-515**....................................***$6.00***

Geologic map of the Skinner Peaks quadrangle, Juab and Sanpete Counties, Utah, by Tracey J. Felger, Donald L. Clark, and Michael D. Hylland, CD (2 pl., 1:24,000), ISBN 1-55791-762-0, **M-223**..***$19.95***

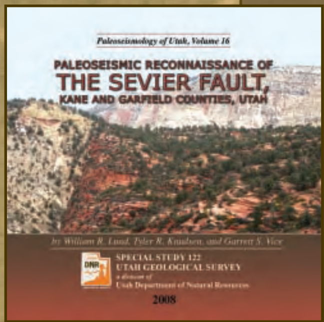
Geologic map of the Abajo Mountains area, San Juan County, Utah, by I.J. Witkind, assisted by H.T. Cantor, P.C. Griffin, D.R. Tuttle, and G.R. Marshall (digitized from Plate 1 of U.S. Geological Survey Professional Paper 453 [1964]), CD (2 pl., scale 1:31,680 [contains GIS data]), ISBN 1-55791-759-0, **MP-06-7DM**................................***$24.95***

New insights into the structural geology of the Gilson and northern Canyon Mountains, central Utah, by Sanghoon Kwon and Gautam Mitra, CD (31 p., 1 pl.), ISBN 1-55791-778-7, **MP-07-4**....................................***$14.95***

Landslide susceptibility map of Utah, by Richard E. Giraud and Lucas M. Shaw, DVD (11 p., 1 pl., 1:500,000 [contains GIS data]), ISBN 1-55791-780-9, **M-228** ***$19.95***

The preliminary landslide history database of Utah, 1850–1978, by Ashley H. Elliott and Michael J. Kirschbaum, CD, **OFR-514**......................................***$14.95***

Paleoseismology of Utah, Volume 17: Paleoseismic investigation of the northern strand of the Nephi segment of the Wasatch fault zone at Santaquin, Utah, by Christopher B. DuRoss, Greg N. McDonald, and William R. Lund, CD (30 p. + 3 p. appendix, 1 pl.), ISBN 1-55791-789-2, ***SS-124***..***$14.95***

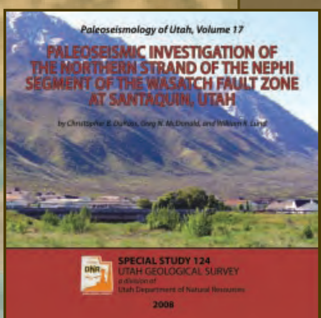


PALEOSEISMIC RECONNAISSANCE OF THE SEVIER FAULT, KANE AND GARFIELD COUNTIES, UTAH

by William R. Lund, Tyler R. Knudsen, and Garrett S. Vice

This CD contains a 28-page report and appendices that characterize the relative level of activity of the Sevier fault in southwestern Utah. The Sevier fault (known as the Toroweap fault in Arizona) trends generally north-south through southwestern Utah and northern Arizona. This study used aerial-photograph analysis, field reconnaissance, detailed mapping of selected areas, and new geochemical analyses and $^{40}Ar/^{39}Ar$ radiometric ages for volcanic rocks displaced by the fault. Paleoseismic results of this study include estimates of geologic slip rates and surface-faulting recurrence intervals at two critical locations in Utah, and identification of two possible seismogenic segment boundaries along the Utah portion of the fault.

Special Study 122 ....$14.95



PALEOSEISMIC INVESTIGATION OF THE NORTHERN STRAND OF THE NEPHI SEGMENT OF THE WASATCH FAULT ZONE AT SANTAQUIN, UTAH

by Christopher B. DuRoss, Greg N. McDonald, and William R. Lund

This CD contains a 30-page report, appendix, and plate for a UGS paleoseismic investigation of the Nephi segment of the Wasatch fault zone. This study, which characterizes the relative activity of the northern strand of the Nephi segment, presents the results of fault-trench excavations near Santaquin, Utah, and includes a discussion of (1) previous paleoseismic investigations on the Nephi segment, (2) the geology of the Santaquin trench site and excavations, (3) paleoseismic results including the timing of the most recent surface-faulting earthquake, fault displacement and slip rate, and surface-faulting-earthquake recurrence and magnitude, and (4) implications for segmentation of the southern Wasatch fault zone.

Special Study 124 ....$14.95

SURFICIAL GEOLOGIC MAP OF THE LEVAN AND FAYETTE SEGMENTS OF THE WASATCH FAULT ZONE, JUAB AND SANPETE COUNTIES, UTAH

by Michael D. Hylland and Michael N. Machette

This map and accompanying 37-page booklet provide essential data for a variety of earthquake-hazard parameters related to the Levan and Fayette segments of the Wasatch fault zone, including surface-rupture length, vertical ground-surface displacement, prehistoric-earthquake timing, and slip rate. Encompassing the south end of the Wasatch fault zone between the towns of Nephi and Fayette, the map completes a series of relatively detailed (1:50,000 scale) geologic maps by the UGS and U.S. Geological Survey that now cover the entire length of the Wasatch fault zone having evidence for one or more large, surface-faulting earthquakes in recent geologic time (past 10,000 years). In addition to addressing earthquake hazards, the map also shows the distribution of geologic deposits associated with other geologic hazards, including alluvial-fan flooding, debris flow, landsliding, rock fall, and expansive soil.

Map 229 ....$13.50

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