UTAH GEOLOGICAL SURVEY

SURVEY NOTES

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Geologic Hazards in Utah

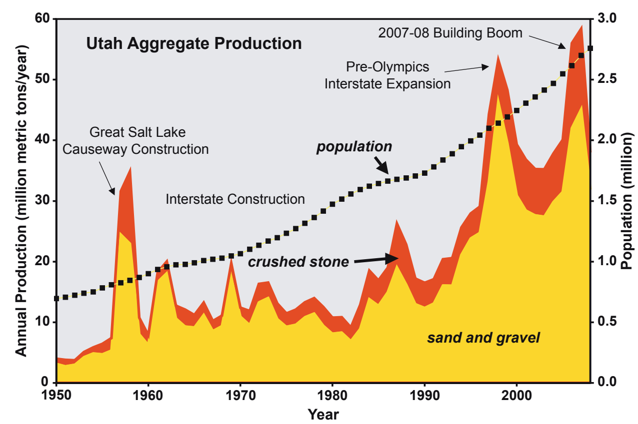
The Director's Perspective

by Richard G. Allis

This "Perspective" deals with two issues that arose during the month prior to writing. One addresses the Logan landslide and canal collapse, and the other was triggered by a query from a county about potential sand and gravel resources near the Wasatch Front. Both issues highlight the importance of detailed geologic mapping, particularly that which emphasizes Quaternary geology and geologic hazards.

The tragic landslide and associated canal collapse that occurred in Logan during July (see page 16) highlights how it often takes a catastrophe to stimulate changes in public policy to mitigate geologic hazards. Although the cause of the landslide has not been determined, the event has triggered public debate about whether Utah's canals are safe, especially where they traverse above urban areas. Many canals were built decades ago, and urban areas have typically expanded around them. The Utah Geological Survey has noticed that in some urban areas the ground-water levels rise to a peak in late summer due to overwatering of lawns, and this can make hillsides vulnerable to failure. The issue of whether canals are safe is therefore complicated, and includes geologic factors such as the slope, strength, and stability of the underlying formations; hydrological factors such as temporal variations in the water levels and their causes; and engineering factors such as the canal design and maintenance, and slope modification that may have occurred below the canal during urban growth. Utah has over 5000 miles of canals, and some canals are over 100 years old. Geologic maps will be an important component of assessing which sections of canals could pose a hazard to residents living downslope.

Another value of geologic maps is their use in identifying potential sand and gravel resources. Utah has many examples of where sand and gravel pits that were once outside of towns have become surrounded by development, and continued operation of the pits is no longer tolerated. Growth and development require construction commodities such as aggregate (sand, gravel, and crushed stone) so there is an ongoing need in Utah for access to new deposits. The historical pattern of aggregate use depicts fluctuations in construction activity, including the building boom in 2007 and 2008 and its subsequent collapse (see graph below). During this recent peak, total aggregate use reached a record 58 million metric tons/year. However, when population growth is also considered, this peak in use amounted to only 20 tons per person per year in 2007–08, compared to 25 tons/person/year during the pre-Olympics construction boom in 1998, and 40 tons/person/year in the late 1950s when the rail causeway across Great Salt Lake was constructed. Another trend that is occurring is increasing use of crushed stone (mostly limestone) as a construction material. The cost of aggregate has remained remarkably constant over the last 40 years when adjusted for inflation ($4–6/ton). The peak production in 2008 amounted to $350 million in revenue at the quarry gate, so this is an important part of Utah's economy.



Contents

Design: *Richard Austin*
Cover: *Rock-fall boulder measuring 20'x 15'x 13' and weighing approximately 250 tons, near Croydon, Morgan County, Utah, March 2004. Photo by Greg McDonald.*

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 Printed on recycled paper

NEW GEOLOGIC HAZARDS MAPPING IN UTAH

by Steve D. Bowman, Jessica J. Castleton, and Ashley H. Elliott

Introduction

Development in urban areas along the Wasatch Front is proceeding at a rapid pace; in many areas geologic hazards have not been mapped to meet the needs of new and evolving geologic-hazard ordinances. As land well suited for development becomes scarce in many areas, development occurs in areas with more exposure to geologic hazards. To address this issue, the Utah Geological Survey created the Geologic Hazards Mapping Initiative in 2008, with funding from the Utah Legislature. The need for the initiative was highlighted during meetings of the Geologic Hazards Working Group, formed in 2006 by Governor Jon M. Huntsman, Jr. as the result of numerous landslides during 2005 and 2006 and related issues with the development approval process in Utah. The initiative will provide planners, local officials, property owners, developers, engineers, geologists, design professionals, and the interested public with information on the type and location of critical geologic hazards that may affect existing and future development. This information will be presented as geologic-hazard maps for use in land-use and development planning, regulation, and design in Utah.

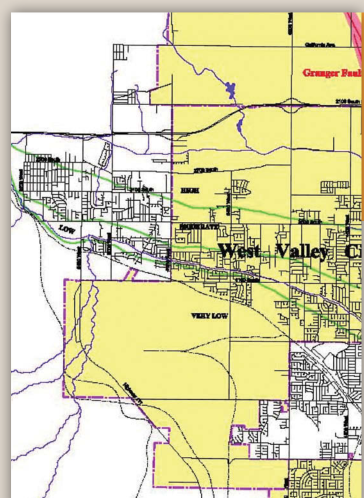
We have begun geologic-hazard mapping in areas of high projected growth where recent Quaternary geologic mapping has been completed, specifically the western part of Salt Lake Valley, where the growth rate is estimated to be 41% from 2005 to 2020. Geologic-hazard mapping planned for 2009–2010 is anticipated to continue in Salt Lake and Utah Counties. Additional hazards mapping is planned in Davis, Weber, Wasatch, Summit, and Uintah Counties.

Geologic-Hazard Maps

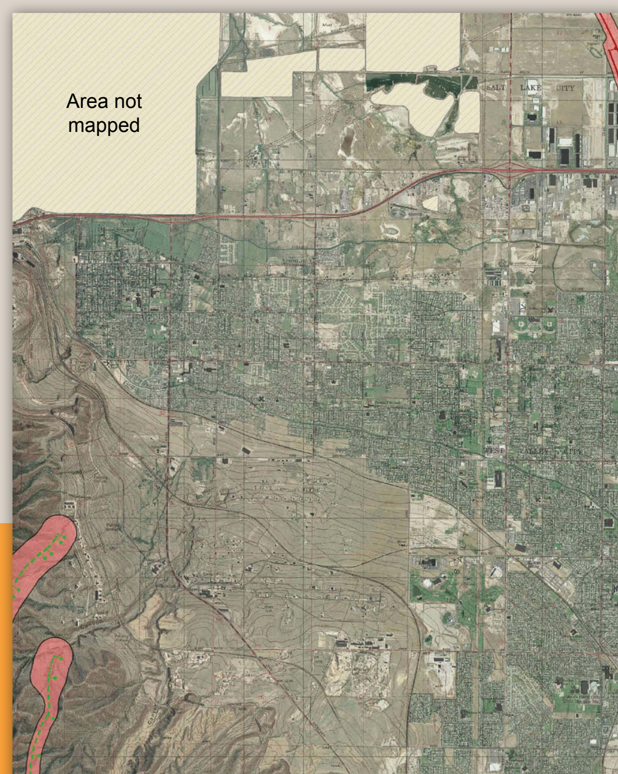
Our final product will be sets of geologic-hazard maps that are created on U.S. Geological Survey 7.5-minute quadrangle topographic base maps enhanced using aerial photography from the 2006 National Agriculture Imagery Program and/or hillshading to show topographic relief. The maps are being prepared by compiling a geographic information system (GIS) database incorporating available Natural Resources Conservation Service (NRCS) soil maps, previous geotechnical and/or geologic-hazard studies, geologic maps, and other field data. Depending upon the specific area and availability of data, the hazard map sets will include maps showing earthquake, landslide, flood, problem soil and rock, indoor radon, and shallow ground-water hazards. In addition, a map showing slope angles may be included for use with local ordinances pertaining to buildable areas.

The earthquake-hazard maps will address potential surface fault rupture, ground shaking, and liquefaction. The maps illustrate these hazards by showing areas of mapped active (Quaternary) faults (those faults with evidence of movement within the past 1.8 million years) with applicable special-study zones, site classes for use with the International Building and Residential Codes, and areas where saturated sandy soils may liquefy and lose strength in an earthquake, respectively.

The landslide-hazard maps delineate areas prone to landslides and rock falls. These maps illustrate landslide and rock-fall susceptibility by taking into account geology and slope angle. The maps also show areas of known, existing landslides and rock fall.



Existing Salt Lake County Planning and Development Services map of surface-fault-rupture (in red) and liquefaction potential (green boundaries) special-study areas, clipped to approximate Magna quadrangle boundary.



New, preliminary surface-fault-rupture-hazard map (one of 11) of the Magna quadrangle, based upon recent geologic mapping by the UGS. Map shows two new surface-fault-rupture special-study zones (in red) in lower left corner. Base mapping includes 2006 NAIP imagery and USGS topographic information.

Encroaching development along the western part of Salt Lake Valley extends into areas having multiple geologic hazards, including landslides, collapsible and expansive soil, flooding, and earthquake hazards.

The flood-hazard maps show areas susceptible to flooding by creeks, rivers, and other drainages; flash floods; sheetflow; and debris flows. The maps are based on the geologic conditions of various mapped units, such as depositional environment and age. For example, geologic units deposited by floods and debris flows typically have a higher flood hazard than other units. Our maps are intended to supplement other flood-hazard maps already used in land-use planning and regulation. For example, Flood Insurance Rate Maps produced by the Federal Emergency Management Agency show creek and river flooding, but they generally do not show flooding by sheetflow and debris flows.

The problem-soil-and-rock-hazard maps delineate areas of expansive soil and rock, collapsible soil, shallow bedrock, soil piping and erosion, and wind-blown sand. Expansive soil and rock results from the presence of clay minerals that undergo changes in volume; these deposits shrink/swell in response to changes in moisture content. Collapsible-soil hazards are typically present on geologically young alluvial fans near mountain fronts that contain soils with void spaces that may collapse when the soils become wet, resulting in the settlement of the ground surface.

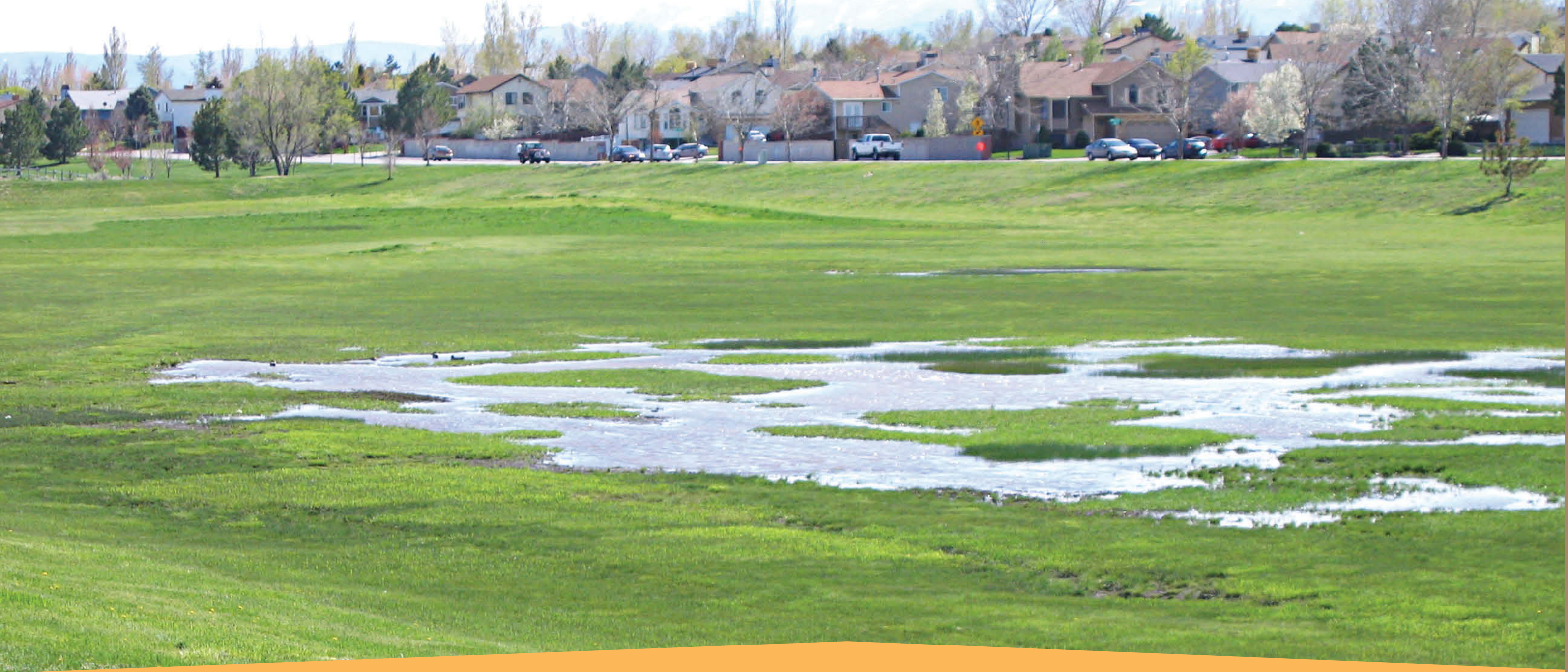
The other hazard maps will illustrate indoor radon potential and shallow ground-water hazards. Indoor radon potential is a function of source materials (rock and soil) containing uranium, such as shale and granite, and soil permeability that allows radon gas to flow toward building foundations and basements. Shallow ground water may be present in areas near lakes and streams, shallow bedrock, and/or low-permeability soils and can cause problems with wet crawlspaces and basements, foundation and utility excavations, or buried structures.

Conclusion

While site-specific geotechnical investigations should be performed for all development, our new maps will identify areas where additional, specialized geologic-hazard investigations are necessary prior to development. In Utah, licensed Professional Geologists and Professional Engineers perform these investigations. The maps will also provide information that may be used for emergency planning and community risk assessment for existing home and business owners.

The Utah Geological Survey will provide copies of the published maps to local governments within the study areas, and will work

Damage to a home in northern Utah from an active landslide. The home was constructed before geologic-hazard and geotechnical investigations were required by city or county governments. Photo by Francis Ashland.



Shallow ground water exposed within an engineered basin designed for drainage control in the surrounding development. Identification of shallow ground water is critical in the design of structures to prevent damage from wet crawlspaces and basements.

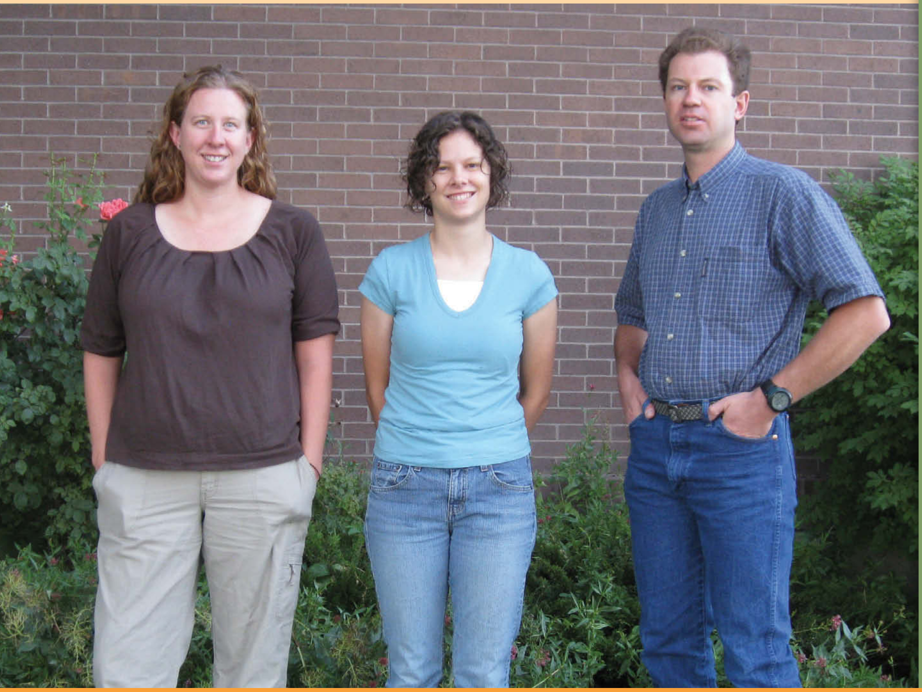
with communities as requested to help prepare geologic-hazard ordinances. City and county government agencies will find the geologic-hazard maps useful in land-use planning and regulation, and for development of their own infrastructure. State and federal government agencies (such as the Utah School and Institutional Trust Lands Administration, U.S. Forest Service, and Bureau of Land Management) will find the maps useful in land management activities, permit application reviews, and development of their own infrastructure. The private sector, including property owners, developers, planners, consultants, and the general public, will find the maps useful in development project planning and design, real estate transaction due-diligence, and other activities.

FOR MORE INFORMATION:

Geologic Hazards Program (GHP): http://geology.utah.gov/ghp

Geologic Hazard Resources for Consultants and Design Professionals: http://geology.utah.gov/ghp/consultants

Geologic Hazard Resources for Homebuyers and Real Estate Agents: http://geology.utah.gov/utahgeo/hazards/realtors.htm



ABOUT THE AUTHORS

Steve Bowman (right) has 14 years of experience as a geological engineer, nine of which were on projects throughout the western United States for geotechnical consulting firms. He is presently the Geologic Hazards Program Manager with the UGS. Steve is a Licensed Professional Geologist in Utah, Professional Geological Engineer in Nevada, Professional Geotechnical Engineer in Oregon, and certified as a LEED Accredited Professional. In addition to the geologic-hazard mapping project described in this article, other recent projects include historical aerial photography compilations, landslide inventory mapping, and geologic data preservation.

Jessica Castleton (left) and **Ashley Elliott** (center) are geologists with the UGS Geologic Hazards Program. Ashley has worked for the UGS since 2006. Her primary responsibilities are geologic-hazard mapping in western Salt Lake Valley and completing a landslide inventory for Utah. In addition, she is currently involved in several long-term landslide monitoring projects using survey-grade GPS equipment. Ashley is a co-recipient of the 2008 Arthur L. Crawford Award for outstanding contributions to Utah's geology. Jessica joined the UGS in 2008. Her principal duties include geologic-hazard mapping and monitoring. Jessica currently serves as the secretary/treasurer for the Intermountain Section of the Association of Engineering Geologists and actively participates in the Geological Society of America and the Salt Lake Chapter of the Association of Women Geoscientists.

LANDSLIDE INVENTORY MAPPING IN TWELVEMILE CANYON, CENTRAL UTAH

by Richard E. Giraud

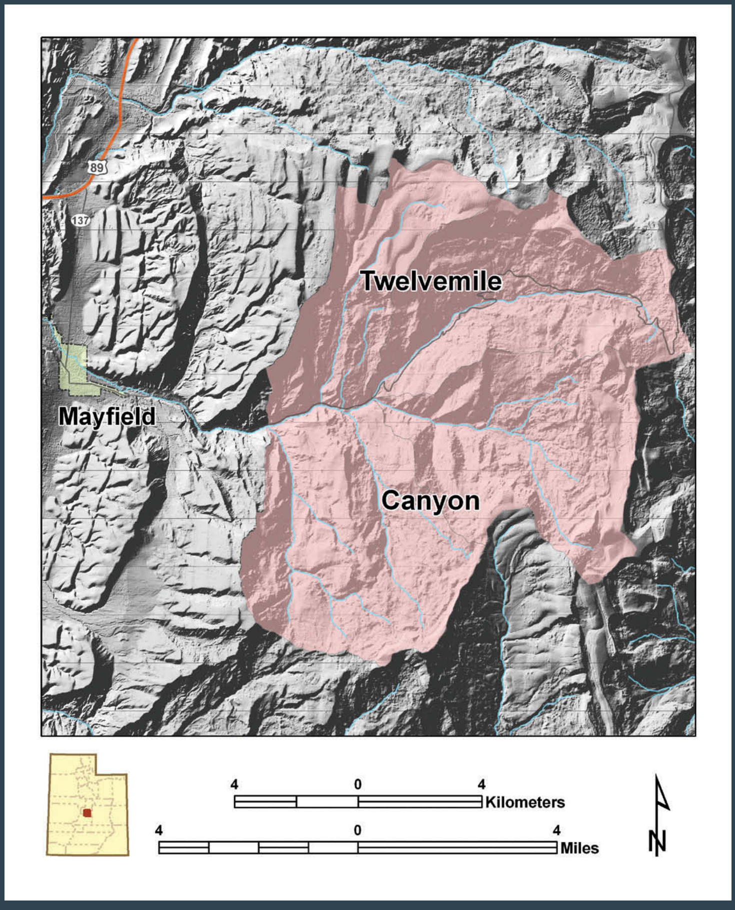
Twelvemile Canyon, east of Mayfield, Utah, contains large, historically active damaging landslides. Widespread landsliding in 1983 resulted in road relocations, drainage of a water reservoir, and a permanent campground closure. In 1998, a landslide deposited material in a creek causing a significant increase in the creek's sediment load. To address ongoing problems the Utah Geological Survey (UGS) and Manti-La Sal National Forest began a cooperative project in 2008 to prepare a landslide-inventory map and database of the canyon. The purpose of the map and database is to show individual landslides and their characteristics, and to provide Manti-La Sal National Forest with information to manage landslide problems.

The landslide inventory map and database show landslide location and provide specific landslide information. We are using a geographic information system (GIS) to capture, store, analyze, and display the data collected for each mapped landslide. The GIS can show which landslides affect or threaten streams, reservoirs, and other features of interest.

Landsliding in Twelvemile Canyon is associated with weak, landslide-prone rock, particularly the Tertiary-Cretaceous (about 65 million years old) North Horn Formation. The North Horn is composed mostly of shale that weathers to clay and produces many of the largest landslides in central Utah. The North Horn is overlain by the Tertiary Flagstaff Formation and underlain by the Cretaceous Price River Formation, both of which contain shale and produce landslides.

One of the largest landslides in Twelvemile Canyon is the 1983 Twelvemile landslide which is 2.5 miles long. The Twelvemile landslide temporarily blocked a creek; when ponded water eventually overtopped the landslide dam, the rapid release of water created a debris flow (a debris flow is a rapidly moving landslide composed of water, sediment, and rock having a consistency that is similar to wet concrete). The debris flow traveled 2.4 miles down South Fork Twelvemile Creek before burying part of Pinchot Campground. The campground was permanently closed following the debris flow. Also in 1983, two other landslides were moving into Twelvemile Creek. These landslides did not block the creek, but erosion of the landslides by the creek greatly increased the creek's sediment load. In 1998 a landslide 1.2 miles long traveled downslope and collided with the 1983 Twelvemile landslide. Continued 1998 movement in this landslide caused the lower part to detach and travel 1.8 miles down South Fork Twelvemile Creek, depositing landslide material in the creek and again increasing its sediment load. In addition to these historical landslides, Twelvemile Canyon has evidence of prehistoric landslides that have blocked and deflected creeks.

Our landslide inventory mapping project covers 60 square miles in Twelvemile Canyon on the west side of the Wasatch Plateau. The mapping makes use of several different dates of aerial photography; aerial photos from 1940 through 2006 provide a 66-year history



Twelvemile Canyon landslide inventory map area east of Mayfield, Utah.

View looking up the 2.5-mile-long 1983 Twelvemile landslide (the area without trees). Landslide movement in 1983 killed most of the trees on the landslide. The upper landslide was moving slowly in 2008.

of landsliding in the canyon. The photography documents the approximate times of major landslide movement and shows how often some landslides move. The landslide inventory mapping process includes mapping each landslide boundary and recording landslide characteristics including:

- area,
- material,
- movement type,
- name,
- movement activity,
- thickness,
- movement direction,
- movement dates
- bedrock underlying the landslide, and
- confidence in mapped landslide boundaries.

All landslide information is stored in a GIS database. The database can be queried to show relationships between landslides and other land-management elements such as streams, reservoirs, roads, bridges, trails, campgrounds, and timber sale areas.

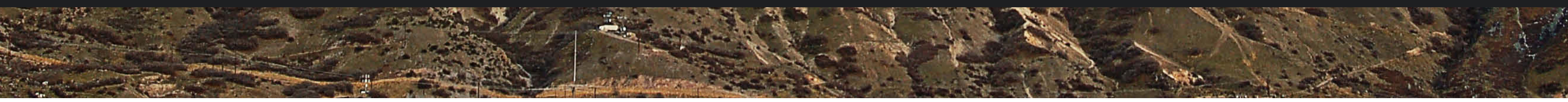
Our mapping shows that most of the landslides are reactivations of pre-existing landslides. Some of these landslides have moved very slowly, inches or less per year, while others have moved rapidly and traveled miles. We observed evidence that suggests at least parts of some landslides were moving slowly in 2008.

A landslide inventory is generally an initial step in managing landslide problems in a large area like Twelvemile Canyon. Since most active landslides are reactivations of existing landslides and an inventory map shows landslide locations, the map can be used to identify future potential landslide problem areas. Landslide susceptibility maps and landslide risk maps can also be derived from a landslide inventory, and these derivative maps can assist in managing landslide problems. When completed, our landslide inventory will benefit Manti-La Sal National Forest in managing forest lands, downstream water users impacted by high sediment loads, and all those who use forest resources or recreate in Twelvemile Canyon.

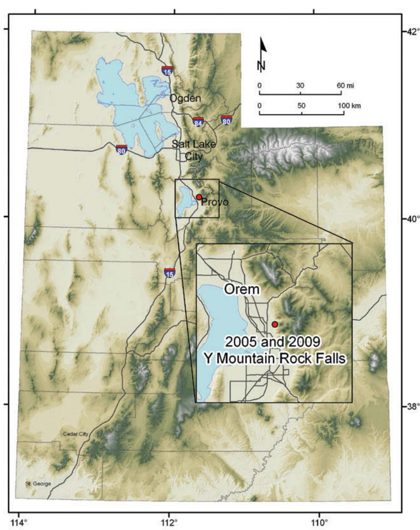
The 1983 debris flow that partially buried Pinchot Campground is the light-colored deposit above the dark brown layer (an organic-rich soil developed on the former ground surface). A concrete post is visible in the debris-flow deposit near the upper left corner. South Fork Twelvemile Creek is at bottom of the photo.

2ND Damaging Y Mountain Rock Fall In Four Years

by Ashley H. Elliott and Richard E. Giraud



For the second time in four years, a rock fall damaged a neighborhood on the eastern edge of Provo, Utah. Around 11:30 a.m. on April 11, 2009, a large rock-fall boulder severely damaged a vacant house at 1496 North 1550 East, and another, smaller boulder damaged the outside of a playhouse on the adjacent lot to the north. The April 11 rock fall damaged a house one lot north of where a rock fall on May 12, 2005, damaged a guest house that was later demolished.



Location of the 2005 and 2009 Y Mountain rock falls.

Both the 2009 and 2005 rock falls occurred on the steep west face of Y Mountain, named for the large white "Y" on its slope that has become a nationally recognized symbol of nearby Brigham Young University. The 2009 rock fall likely occurred in response to recent weathering and erosion of a limestone cliff band by freeze-thaw action (a process in which water seeps into a crack and expands the crack as it freezes) and spring storm precipitation. One spring storm on April 8–9 dropped 1.5 inches of precipitation in less than 18 hours at the nearby Cascade Mountain climate data site (3 miles southeast of the rock-fall source area). The cliff band where the rock fall originated is approximately 2500 vertical feet above the houses and consists of Mississippian-age limestone. Impact craters (bounce marks) and tracks through vegetation on the slope below the cliff band indicate several rocks were involved in the initial rock-fall release. Several of these rocks traveled an estimated one mile downslope, and likely achieved high velocities as they bounced and rolled. At 1496 North 1550 East, a boulder bounced over the 6-foot-high back fence and through the back of the house. Inside the house, the boulder damaged the ceiling and crashed through a wall before falling through the floor into the garage below, breaking the garage door. At 1522 North 1550 East, a boulder bounced over the back fence and hit the edge of a playhouse before it came to rest on a fence delineating the property line between this lot and 1496 North.

Limestone cliff source area for the 2005 and 2009 rock falls.

Numerous boulders from prehistoric and historical rock falls scattered throughout the neighborhood and on the hillside above indicate the high rock-fall hazard of the area. The rock-fall source area consists of tall limestone cliffs capable of producing large rock-fall boulders. Steep mountain slopes below the cliffs act as an accelerator for detached boulders, sending them speeding to the houses below. The cliff and steep slopes are part of a drainage basin that funnels detached boulders toward the neighborhood. Rock-fall impact craters of varying ages on the hillslope above the neighborhood indicate that the area has long been, and continues to be, an active rock-fall area.

Following the 2005 and 2009 rock falls, the UGS provided Provo City with geologic information about the rock-fall hazard to the subdivision. In the study, the UGS recommended that nearby residents be informed they are in a rock-fall-hazard area. In addition, residents may wish to hire a geotechnical consultant to investigate the continued risk from rock falls to the neighborhood or to individual homes, and to recommend risk-reduction measures.

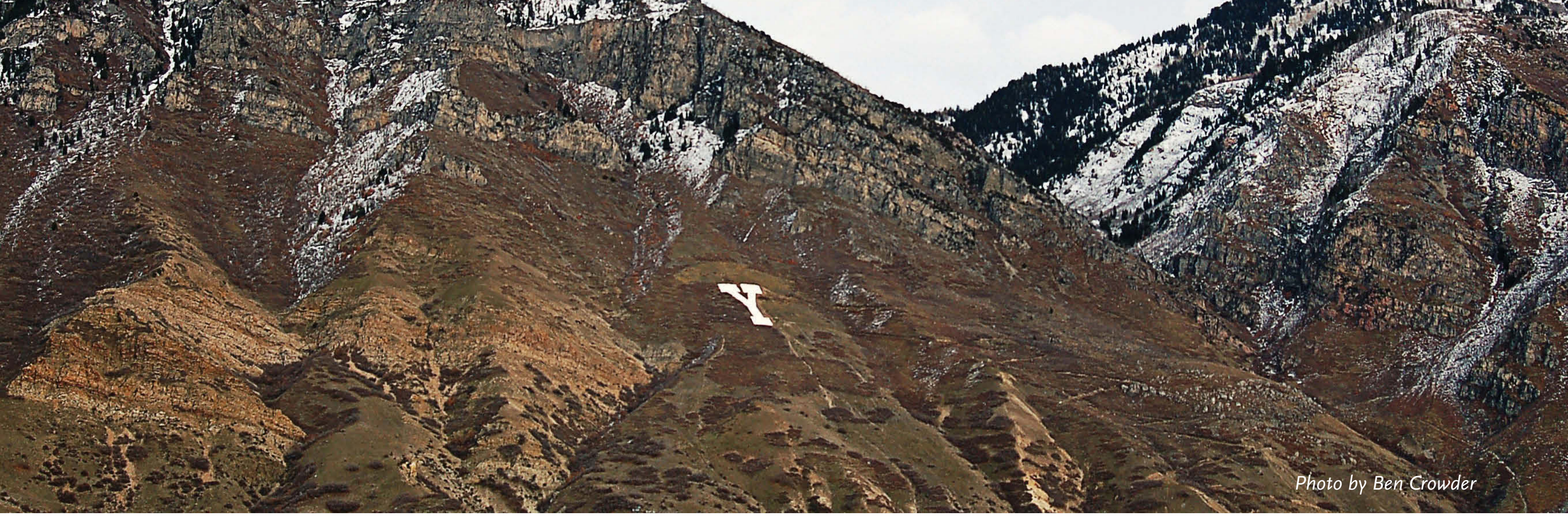
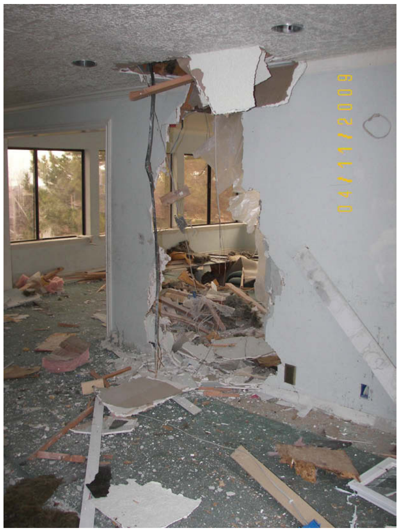


Photo by Ben Crowder



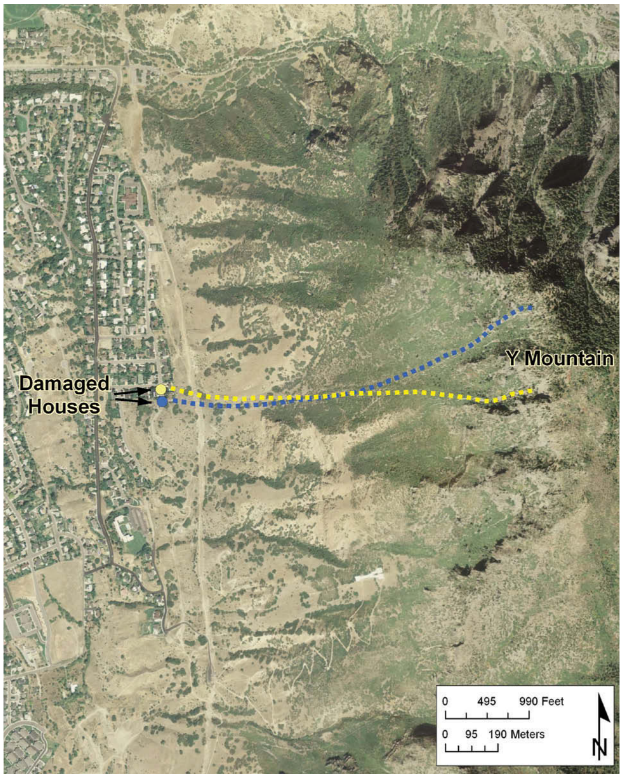
Above: *Boulder from the 2009 rock fall came to rest in the garage of the house at 1496 North 1550 East. Boulder is estimated to be 4 x 5 x 4 feet. Photo courtesy of the Provo Fire Department.*

Above left: *A rock-fall boulder hit the red pole, bending it, before bouncing over the fence and into the back of the house at 1496 North 1550 East. Photo courtesy of the Provo Fire Department.*

Above middle: *Inside the house at 1496 North 1550 East showing where the boulder hit the ceiling and went through a wall. Photo courtesy of the Provo Fire Department.*

Bottom left: *A rock-fall boulder that damaged the outside of this playhouse at 1522 North 1550 East, lies on a damaged fence.*

Bottom right: *The 2005 (blue) and 2009 (yellow) rock-fall paths, and damaged houses.*



LARGE ROCK FALL

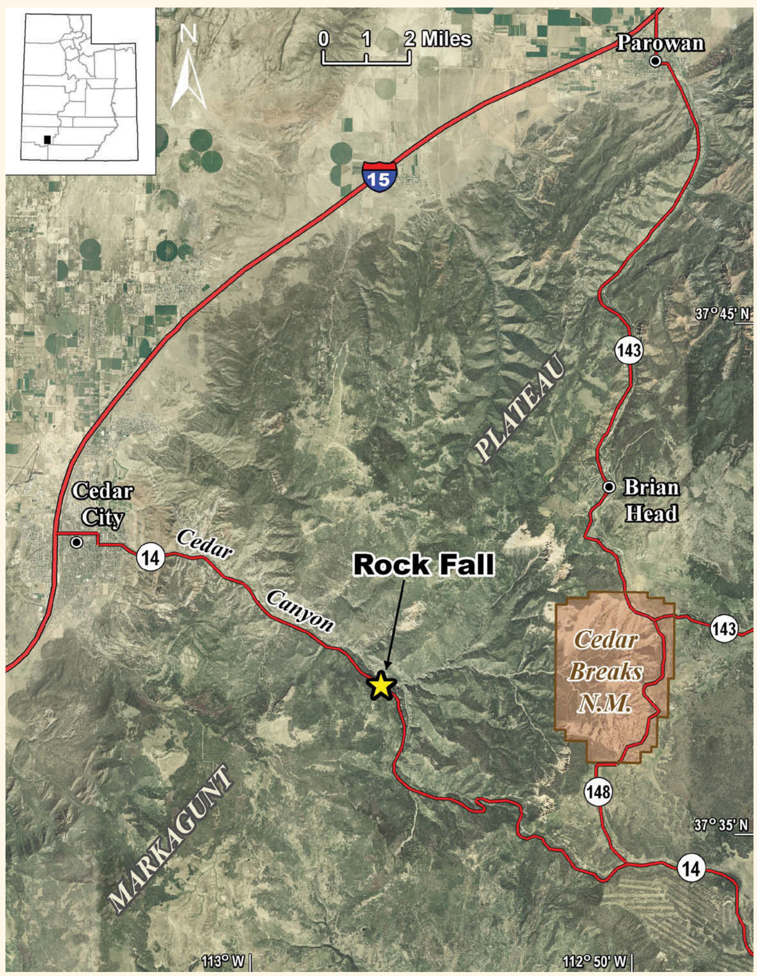
closes highway near Cedar City, Utah

by William R. Lund, Tyler R. Knudsen, and Keith E. Brown

On Monday, January 5, 2009, at approximately 6:00 p.m., a large rock mass detached from a cliff on the south side of Cedar Canyon about 8 miles east of Cedar City, Utah. The rock mass fell, bounced, and rolled downslope while disintegrating into tens of individual large boulders and hundreds of smaller ones before burying an approximately 750-foot-long section of Utah State Route 14 (SR-14). SR-14 is an important transportation link between Interstate 15 at Cedar City and U.S. Highway 89 at Long Valley Junction to the east. The triggering mechanism for the event was likely recurring freeze-thaw cycles and ice wedging in bedrock joints. Fortunately, there were no motorists on the affected section of the highway when the rock fall occurred. The Utah Department of Transportation (UDOT) estimated the rock-fall volume at 60,000 cubic yards. The largest boulder observed had dimensions of approximately 18 x 18 x 24 feet and weighed an estimated 600 tons. SR-14 remained closed while UDOT blasted the largest boulders, cleared the highway right-of-way with heavy equipment, and repaved the damaged road surface. Geologists from the Utah Geological Survey Southern Region Office inspected the rock fall on the morning of January 7, 2009, while UDOT cleanup activities were underway.

Cedar Canyon incises the western margin of the Markagunt Plateau at the transition between the Basin and Range Province and Colorado Plateau. Deformed Mesozoic sedimentary strata in the transition zone are exposed in the lower several miles of the canyon; however, at the rock-fall site, the canyon is in the Colorado Plateau proper, and rock units there are largely undeformed, dipping a few degrees to the east. The stratigraphic section at the rock-fall site includes the cliff-forming Tibbet Canyon Member of the Straight Cliffs Formation, which sourced the rock fall, and the underlying slope-forming Tropic Shale and Dakota Formation, all Cretaceous in age. The 600-foot-thick Tibbet Canyon Member is chiefly fine- to coarse-grained, limey sandstone; the 30-foot-thick Tropic Shale is sandy mudstone and muddy sandstone; and the greater than 600-foot-thick Dakota Formation is chiefly interbedded mudstone and sandy mudstone with thin sandstone horizons.

About a half mile west of the rock fall, SR-14 leaves the bottom of Cedar Canyon and begins climbing the steep, south canyon wall toward the top of the Markagunt Plateau. The Tropic Shale and Dakota Formation are exposed in the lower part of the canyon wall and are susceptible to landsliding. At the rock-fall location, SR-14 crosses a large rotational landslide, which has been intermittently active for many years and has frequently damaged the roadway. The rock fall detached from the overlying Tibbet Canyon cliff and fell onto the landslide below. Examination of the site showed no evidence of renewed movement of the landslide either prior to or



Rock-fall location along SR-14, 8 miles east of Cedar City, Utah.

following the rock fall when the landslide surface was suddenly loaded with the weight of the fallen rock.

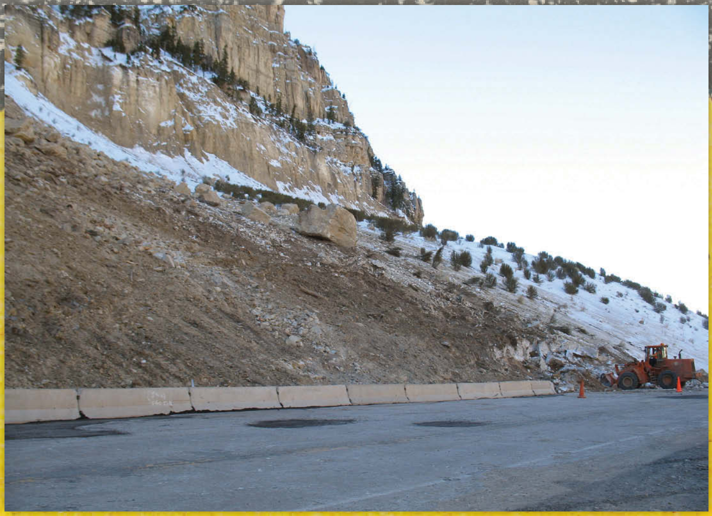
The University of Utah Seismograph Stations (UUSS) recorded a magnitude 1.7 earthquake on January 5 at 6:04 p.m. in Cedar Canyon—11 minutes before the Iron County Sheriff's dispatch received notification of the rock fall from a passing motorist who backtracked 3 miles to make the phone call. UUSS stated that this earthquake may have been triggered by the rock fall. The seismic waveforms are atypical for a local tectonic earthquake (emergent compressional-wave arrivals and the absence of clear shear-wave arrivals), and large depth uncertainty allows for a surface origin. A final determination of the source of the earthquake will require further study. However, because of the small size of the earthquake, the available data are of marginal quality. Other than earthquake timing, the only other constraints on timing of the rock fall are a UDOT snowplow that passed through the area at 5:30 p.m. prior to the event and the 911 call received at 6:15 p.m. following the event.

UDOT immediately began clearing and repair of SR-14. Originally estimated to require two weeks of work, UDOT reopened SR-14 six days after the event. In addition to clearing and repairing the roadway, remedial work included installation of concrete Jersey barriers to reduce the potential for boulders remaining on the slope above the road to reach the roadway in the future. UDOT plans further remedial work to reduce the rock-fall hazard from large boulders remaining on the slope above the highway.

The largest boulder to reach the canyon floor measured 18' x 18' x 24' and weighed an estimated 600 tons. (Photo taken January 7, 2009.)

UDOT crew clearing rock-fall debris from the roadway on January 7, 2009. Several of the largest boulders required blasting before they could be removed.

The source of the rock fall was the cliff-forming Tibbet Canyon Member of the Cretaceous Straight Cliffs Formation. The Tibbet Canyon Member is underlain by the slope-forming Tropic Shale and Dakota Formation. View looking southeast (photo taken January 7, 2009, by Mel Aldrich).



Rock-fall debris was cleared, the road surface repaired, and the highway reopened for traffic in six days. UDOT installed concrete Jersey barriers along the edge of the roadway to provide rock-fall protection. Slope above the roadway was originally contoured as part of a landslide remediation project in 1989 (photo taken January 14, 2009).

Deadly Landslide Along Canyon Road in Logan, July 11, 2009 *by Francis Ashland*

Shortly before noon on July 11, 2009, a landslide occurred on the lower part of the Logan bluff, directly south of Utah State University and U.S. Hwy. 89, destroying a house and killing three people—a mother and her two children. The residents were in the process of evacuating the house they rented along the north side of Canyon Road on the advice of their landlord, and were likely gathering some of their belongings when the house collapsed and was partly overridden by landslide debris.

Based on eyewitness accounts and photographs, the landslide initially occurred between the bottom of the bluff and the Logan Northern Canal farther up the slope, rapidly destroying the access road along the south edge of the canal and the southern part of the canal, which caused some of the water in the canal to spill directly onto the top of the slide. Within about forty minutes of the initial failure, upslope enlargement of the landslide completely destroyed the remainder of the canal. Canal water cascaded onto the east side of the landslide causing flooding and sedimentation, partly burying a house directly to the east of the collapsed house.

The July 11 landslide is the second destructive landslide on the bluff in four years. A landslide in September 2005, just a short distance to the east, occurred on the slope directly above the canal, temporarily blocking flow in the canal, and sending debris and water into a house below the canal. The timing of both landslides in the second half of the year is not typical for landslides in northern Utah, which usually occur in the spring.

Above: *View across the upper part of the landslide at 12:37 p.m. on July 11, 2009, about forty minutes after the initial movement. A section of the canal has been completely destroyed by upslope enlargement of the landslide. Photograph by Dustin Auman.*

Below: *Main scarp of the landslide on July 11, 2009.*

Teacher's Corner

Earth Science Week
October 5 – 8 (Monday – Thursday), 2009
9:30 a.m. – 3:30 p.m.

Hands-on activities for school groups

Come celebrate Earth Science Week with your 4th or 5th grade class. The Utah Geological Survey will once again be offering hands-on science activities.

Earth Science Week is celebrated throughout the world to increase public understanding and appreciation of Earth sciences and to engage in responsible stewardship of the Earth. Launched in 1998 by the American Geological Institute (AGI), efforts have grown on local, national, and international levels to highlight the vital role Earth sciences play in society's use of resources and interaction with the environment.

The hands-on activities include gold panning, observing erosion and deposition on a stream table, identifying rocks and minerals, and learning how Utah's dinosaur discoveries are excavated and prepared. For more information, please visit our Web site at **geology.utah.gov/teacher/esweek.htm**.

Call 801-537-3300 to make reservations and ask to speak with Sandy Eldredge or Jim Davis. Groups are scheduled for 1½-hour sessions.

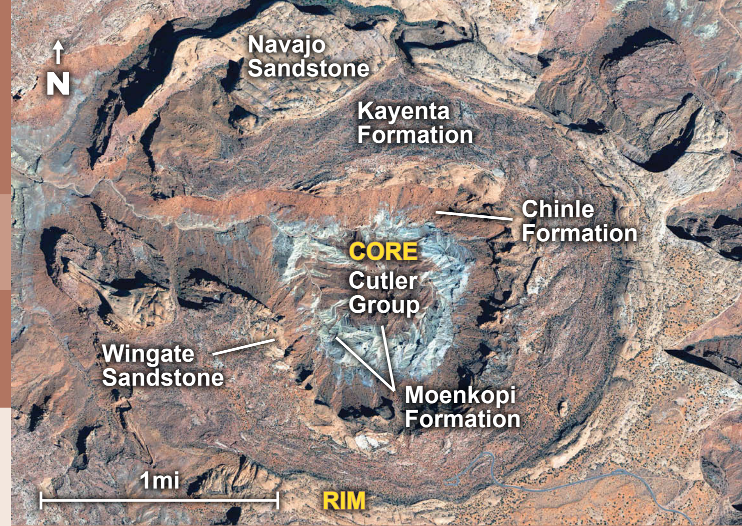
Teachers Note! National contests, including photography, visual arts, and essay contests are conducted by the AGI. The theme of the 2009 Earth Science Week is "Understanding Climate." All mailed submissions must be postmarked no later than Friday, October 16, 2009, and all electronic submissions must be received by 5 p.m. EST, Friday, October 16, 2009. Please visit the AGI's Earth Science Week Web site (www.earthsciweek.org/index.html) to find out more.

Investigating stream erosion and deposition.

GeoSights

Utah's Belly Button, Upheaval Dome

by William Case



Geologic formations of Upheaval Dome.

	Geologic formations exposed at the surface of Upheaval Dome						Subsurface geologic formation containing salt beds
Geologic Formation	Navajo Sandstone	Kayenta Formation	Wingate Sandstone	Chinle Formation	Moenkopi Formation	Cutler Group • White Rim Sandstone • Organ Rock Shale	Paradox Formation
Geologic Age	JURASSIC 200–145 million years ago			TRIASSIC 250–200 million years ago		PERMIAN 300–250 million years ago	PENNSYLVANIAN 318–300 million years ago

Upheaval Dome in Canyonlands National Park, Utah, is a colorful circular "belly button," unique among the broad mesas and deep canyons of the Colorado Plateau. The rim of Upheaval Dome is 3 miles across and over 1000 feet above the core floor. The central peak in the core is 3000 feet in diameter and rises 750 feet from the floor. Since the late 1990s, the origin of the Upheaval Dome structure has been considered to be either a pinched-off salt dome or a complex meteorite impact crater; in other words the "belly button" is either an "outie" (dome) or "innie" (crater).

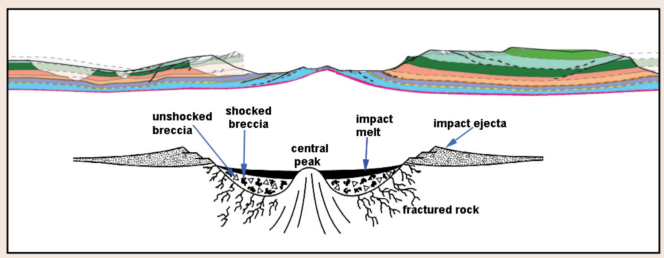
Both origin hypotheses account for the overall structure of Upheaval Dome, assuming approximately a mile of overlying rock has been eroded. The main differences between the two hypotheses are the amount of time and the pressures needed to produce the structure.

A salt dome is produced when a subsurface layer of salt (originally deposited when a large body of saline water evaporated) is eventually squeezed upward because of the weight of overlying rock. At Upheaval Dome, the upward flow would have to have been "pinched off" by rock that fell into voids left by salt dissolved by surface water.

The pinched-off salt dome hypothesis assumes that up to 20 million years of moderate pressures produced the feature, compared to only a few minutes of extremely high to low pressure changes for the impact crater hypothesis.

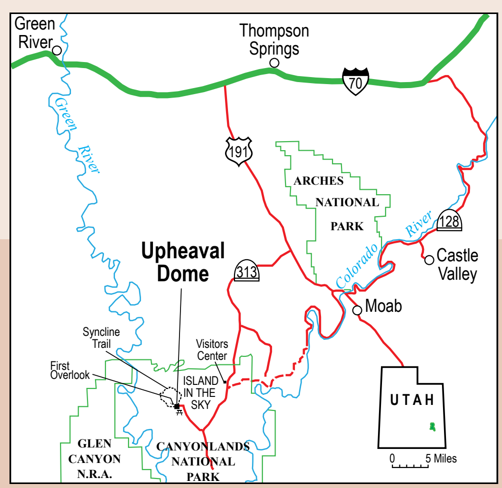
Until recently, "smoking gun" evidence for either origin was absent because of erosion. No remnant pieces of salt or related rocks and minerals have been found to support the pinched-off salt dome hypothesis; neither were formerly molten rocks, ejected and crushed rock, or minerals altered by high pressure found to support the impact crater hypothesis. Then, in 2007, German scientists Elmar Buchner and Thomas Kenkmann reported finding quartz crystals that were "shocked" by the high pressure of a meteorite impact. Many geologist now consider the mystery of Upheaval Dome's origin to be solved (and it's an "innie"!).

The core consists of the oldest rock formations at Upheaval Dome. The Organ Rock Shale and White Rim Sandstone of the Permian Cutler Group, and Triassic Moenkopi Formation were injected and pushed upward in a chaotic jumble. The Triassic Chinle Formation, Triassic-Jurassic Wingate Sandstone, and Jurassic Kayenta Formation and Navajo Sandstone are stacked, oldest to youngest, from the core to the rim.



Comparison of a geologic cross section across Upheaval Dome (top) and an idealized cartoon of a complex meteorite impact crater (bottom). Except for a few "shocked" quartz grains, no impact-crater-formed rocks have been found at Upheaval Dome, evidently because they were removed by erosion. Geologic profile modified from Jackson and others (1998, Geological Society of America Bulletin); impact crater cartoon from NASA Web site (solarsystem.nasa.gov/multimedia/display.cfm?IM_ID=788).

How to get there: Upheaval Dome is in Canyonlands National Park. From I-70 at Crescent Junction follow U.S. 163/191 south for 20 miles to Utah S.R. 313. Head west along S.R. 313 to the Canyonlands National Park entrance station and visitor center, continue to Island in the Sky, and then bear right to Upheaval Dome, a distance of about 30 miles. Enjoy the picnic ground at Upheaval Dome and take the short but steep overlook trails, or, if you are an experienced, well-prepared hiker with about eight free hours, take the Syncline Valley trail. There is signage with trail directions and mileage.



Glad You Asked

What should you do if you find a fossil? Can you keep it? Should you report it?

by Carole McCalla and Sandy Eldredge

Fossils—remains, traces, or imprints of past plant and animal life—are widely found throughout Utah. Depending on land ownership, some fossils can be collected for personal non-commercial use. However, vertebrate fossils (see description below) may not be collected on any federal or state lands. Whether you can keep a fossil or not depends on (1) the type of fossil, and (2) who owns or manages the land where the fossil was found.

Types of fossils

Vertebrate fossils are from animals that have a backbone. The fossils include bones, teeth, skin impressions, footprints, tail drags, and other traces of activity. Vertebrates found in Utah include dinosaurs, fish, turtles, and mammals such as mammoths and musk oxen.

Dinosaur footprint

Mammoth tusk

Invertebrate fossils refer to animals that do not have a backbone, such as trilobites, ammonites, clams, snails, coral, shellfish, and insects.

Ammonite

Brachiopod

Plant fossils are any remains or traces of ancient plants, including pine cones, impressions of leaves and stems, and petrified wood.

Leaf Impression

Petrified Wood

Land status in Utah

Federal lands are managed by a federal government agency: the Bureau of Land Management (BLM), U.S. Forest Service (USFS), National Park Service, Bureau of Reclamation, Department of Defense, U.S. Fish and Wildlife Service, or Bureau of Indian Affairs. Of these agencies, only the BLM and USFS allow some fossil collecting.

State lands are mostly managed by the School and Institutional Trust Lands Administration (Trust Lands).

Private lands are held by private owners (including local governments and Indian tribes).

Steps to take

1. Determine ownership of the land you intend to visit. Consult surface-management-status maps (sold by various agencies and outlets including the UGS and BLM).

2. Become familiar with the regulations that apply to collecting on the various lands. Refer to the UGS flier Publication Information Series 23, *Rules and Regulations Regarding Rock, Mineral, and Fossil Collecting in Utah*, which is available at the UGS Natural Resources Map & Bookstore or online at geology.utah.gov/online/pdf/pi-23.pdf.

3. Contact the appropriate land manager/owner to inquire about any specific regulations.

Some general fossil collecting rules in Utah

- **Vertebrate fossils may not be collected on any federal or state lands** except under permits issued to accredited institutions.
- Invertebrate and plant fossils may be collected (in reasonable amounts if collection is for personal, non-commercial purposes) on BLM, USFS, and state-administered Trust Lands.
- Some BLM lands may be closed to collecting for various reasons. Inquire at the appropriate local BLM office.
- Collecting permits are required on USFS lands and may vary per district. Contact the applicable USFS district.
- Collecting on state-administered Trust Lands requires a permit and payment of an annual fee. Permits may be obtained at Trust Lands offices and at the UGS Natural Resources Map & Bookstore.
- Permission is required to collect on private lands. Always check with the landowner before removing any fossils.
- Private landowners have the right to keep any fossils found on their property. They are urged to report any fossil finds to the UGS (see below).

Report your fossil find!

Many fossil finds end up in private collections, depriving the public and scientists of vital opportunities for research, education, and display. Therefore, no matter where you find a fossil or what the fossil is, the UGS strongly encourages you to report your find to the State Paleontologist or other paleontology staff at the UGS (801-537-3300). Then, the site of your discovery will be documented for scientific purposes!

Illegal fossil collecting in Utah puts man in jail.

A fossil hunter who in 2001 found a site on BLM land filled with dinosaur bones was removing and selling the bones illegally on the black market. Fortunately, once he discovered parts of a distinctive dinosaur neck, he turned the site over to paleontologists. The site revealed thousands of bones from babies to adults that were identified as being from a very significant new dinosaur species—*Falcarius utahensis*. Convicted of theft of government property, the individual served a five-month prison term and paid a $15,000 fine.

The fossilized skeleton of Falcarius utahensis *is on display at the Utah Museum of Natural History.*

Couple gets a dinosaur leg bone named after them for reporting their discovery.

In 2007, John and Brenda Bell stumbled across a 4-foot-long fossilized bone while hiking near Arches National Park. Although not experts, the Bells were sure the bone was from a dinosaur and wisely left it undisturbed and then notified the State Paleontologist at the UGS. The next week, they returned to the site with UGS staff and volunteer assistants. The Bells helped excavate the bone, which was identified as the tibia (shin bone) from one of the largest (up to 90 feet in length) long-necked, long-tailed dinosaurs—the *Diplodocus*. The couple's discovery is unofficially named "Bell's Bone." Had it been a new dinosaur species, it might have been officially named after them.

John and Brenda Bell with their discovery, "Bell's Bone."

ENERGYNEWS

Geologist measuring fracture orientation in the Jurassic Morrison Formation at Aneth oil field.

Carbon Dioxide Sequestration Demonstration Project Underway in Utah!

by Stephanie Carney

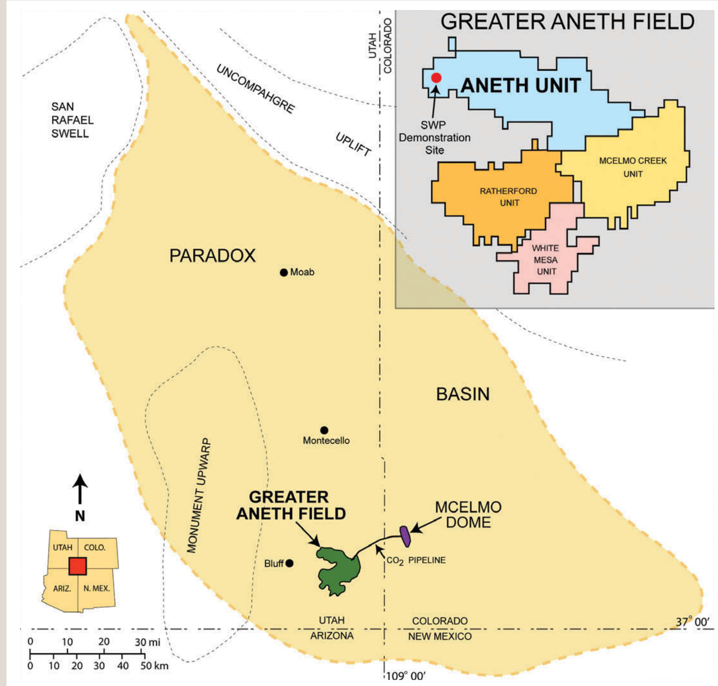
Climate change, caused by elevated levels of greenhouse gases such as carbon dioxide (CO_2) in the atmosphere, is a growing national concern. The U.S. Department of Energy has established seven regional partnerships across the nation to research and develop technology, infrastructure, and regulations to store (or sequester) large volumes of CO_2 that would otherwise be released into the atmosphere. Geo-sequestration—long term storage in underground geologic formations—is one proposed way to reduce CO_2 levels in the atmosphere. In 2005, the Utah Geological Survey (UGS) joined the Southwest Regional Partnership (SWP) for Carbon Dioxide Sequestration, which consists of several partners from industry, university, and federal and state agencies. The SWP has developed three geo-sequestration research sites, one of which is at Greater Aneth oil field in southeastern Utah.

Greater Aneth oil field, which is the state's largest, has produced over 450 million barrels of oil since its discovery in the 1950s and continues to produce today. As production has declined over the years, operators have employed enhanced oil recovery (EOR) techniques to recover as much oil as possible from the producing rock layers, or reservoir. Such techniques include injecting water and gases like CO_2 into the reservoir to mobilize and push remaining oil out of the reservoir. The Aneth Unit site, part of Greater Aneth field, was chosen by the SWP for a demonstration project because this technique was already in practice in other parts of the field, and a pipeline system was in place that supplies CO_2 from a nearby, naturally occurring source in southwest Colorado (McElmo Dome). The goals of the demonstration project are to inject CO_2 into an area of the reservoir where EOR has not been undertaken before, monitor where and how the gas moves, determine whether the reservoir at Aneth Unit and others like it are safe sequestration sites, and demonstrate that CO_2 can be sequestered while increasing production in a mature oil field.

Before injection of CO_2 began, the UGS performed several field analyses to help determine whether the project area was geologically suitable for sequestering CO_2. One main objective was to determine if any faults or other fractures occur in strata of the Aneth Unit area, as they can be potential migration pathways for CO_2 to leak from the reservoir to the surface. First we mapped the surface geology to determine if any faults or fracture systems are present within surface formations. We then mapped subsurface formations focusing on ground-water aquifers, the oil reservoir, and the reservoir seal to determine if any faults are present at depth. The reservoir seal is an impermeable layer above the reservoir that keeps reservoir fluids from migrating to the surface. If any surface faults link with subsurface faults cutting the reservoir seal or reservoir, then CO_2 could migrate or leak to the surface. Or, if any faults connect the reservoir to the ground-water aquifers, then this could lead to CO_2 contamination of aquifers that are critically important to the local communities of Montezuma Creek and Aneth.

Our work shows that no major faults occur in the area. We did, however, find several thousand fractures in surface rocks. These fractures, called deformation bands, are small and are confined to the sandstone units of the Morrison Formation. We observe no evidence of these fractures penetrating into the subsurface. Based on these results, migration or leakage of CO_2 from the reservoir to the surface along faults is unlikely and there are no fault or fracture connections between the reservoir and ground-water aquifers, so CO_2 contamination of the aquifers is unlikely.

Injection and monitoring at the Aneth Unit demonstration well site began February 1, 2008, but injection for EOR elsewhere at Aneth Unit began in the fall of 2007. As of March 2009, about 28 billion cubic feet (BCF) of CO_2 has been injected into the Aneth Unit site, with approximately 0.7 BCF injected into the SWP demonstration well. The operator at Aneth Unit, Resolute Natural Resources, reports an overall increase in oil production at the unit indicating a successful start for their EOR project, and no CO_2 leaking or contamination has been detected. The SWP CO_2 sequestration demonstration project is on schedule, and monitoring will continue through the end of this year. Injection of CO_2 for EOR will continue at Aneth Unit after the SWP sequestration project ends, but from our demonstration project, we hope to gain insight into the fate and long-term storage effects of CO_2 in mature oil reservoirs.



Location of Greater Aneth oil field and the natural CO_2-producing McElmo Dome field within the Paradox Basin. Inset shows units of the Greater Aneth field and the approximate location of the SWP demonstration site.

SURVEY NEWS

Through the American Recovery and Reinvestment Act, the Utah State Energy Program (USEP) was awarded a $35.5 million formula grant by the U.S. Department of Energy in late June. USEP is gearing up by hiring additional staff to develop and administer new programs and projects. Many of the new USEP programs got under way in August 2009, with additional programs starting soon after. For additional information on funding opportunities and updates, contact us at energyrecovery@utah.gov, or visit our Web site at geology.utah.gov/sep/stimulus.

In May, the UGS received a Nevada Earthquake Safety Council (NESC) 2009 Award in Excellence for rapid field reconnaissance and assistance with posting information on the Web after the 2008 Wells, Nevada, earthquake. The award was presented at a joint meeting of the NESC and Utah Seismic Safety Commission in Wells.

The UGS won several awards at the recent Utah Geographic Information Council conference in Midway, Utah. Congratulations to **Rich Emerson** for first place in the Professional Poster Competition for *Evaluation of Sources of Poor Quality Ground Water*, to **Buck Ehler** for first place in the Professional Map competition for *Geologic Map of the Hite Crossing–Lower Dirty Devil River Area*, and to **Tyler Knudsen** and **Bill Lund** for an Honorable Mention in the Professional Map Competition for *Natural Hazards in Zion National Park*.

UGS Hosts Association of American State Geologists 101st Annual Meeting

The Utah Geological Survey hosted the four-day conference, held in June in Park City, Utah. In attendance were many present and former state geologists from across the country. Also attending were over 20 scientists from the U.S. Geological Survey who met with the state geologists to discuss national geologic policy issues.

Pre-, mid-, and post-conference fieldtrips featuring Utah's scenic geology were the highlight of the conference for many participants. The UGS has since received numerous e-mails and letters complimenting UGS staff for an outstanding conference.

Pictured at the Snowbird Tram Plaza are Rick Allis, current Utah State Geologist, and former Utah State Geologists Lee Allison (1989–1999) and Genevieve Atwood (1981–1989).

The Expanded Utah Core Research Center: Open for Business

by Michael D. Laine, Curator

The Utah Geological Survey's Utah Core Research Center (UCRC) offers researchers access to Utah's most comprehensive collection of geologic specimens for petroleum-industry research, workshops, and short courses; academic research; and a variety of UGS/industry cooperative projects. The newly remodeled UCRC now provides the benefits of the most significant improvements to the center since its initial construction in 1997. In the planning stage for three years, the reconstruction began with groundbreaking in August 2008 and was completed in April 2009 with the addition of expanded and more modern laboratory, office, and classroom space.

The newly remodeled UCRC offers the benefits of the most significant improvements to the center since its initial construction in 1997.

The original office and classroom end of the UCRC was rearranged and enlarged to improve the quality and capacity of all the industry and academic research operations that take place at the UCRC. Improvements include a new 75-seat-capacity classroom; new permanent microscopy, digital imaging, and water-well cuttings laboratories; new office for the curator; and an office for visiting scientists that also doubles as a small conference room. Other significant additions include a reception and geotech area, new storage room, and radiant heat for the core viewing area.

New digital imaging laboratory increases the efficiency and quality of core photography.

To reduce construction costs, many components of the original building, including the whole front of the building and most of the doors and windows, were reused in the new construction. Lighting fixtures, ceiling tiles, and other structural items were also reused where possible.

The new UCRC can now accommodate significantly larger workshops and classes (three times the previous capacity) as well as other geologic meetings and events. In addition, the new laboratories will improve the efficiency and quality of all UGS, industry and academic research, imaging, and sampling projects conducted at the facility.

Crawford Award

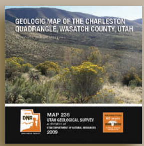
The Utah Geological Survey awarded its prestigious Crawford Award to UGS geologist Hugh Hurlow in recognition of the outstanding geologic publication *Geology and Ground-Water Chemistry, Curlew Valley, Northwestern Utah and South-Central Idaho—Implications for Hydrogeology* (UGS Special Study 126). The presentation was made at the annual UGS awards picnic on July 9, 2009.

UGS geologist Hugh Hurlow, winner of the prestigious Crawford Award.

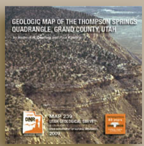
Hugh's work was a comprehensive study of the geology and hydrogeology of the Curlew Valley drainage basin, including new geophysical, geochemical, and isotopic data that greatly improved understanding of the ground-water system that contributes to the flow of Locomotive Springs, a large spring complex at the north end of Great Salt Lake. The study better delineates the subsurface structure of the ground-water basin and better defines the ground-water flow systems contributing to Locomotive Springs. The work shows that the decrease in flow at Locomotive Springs can be attributed to ground-water pumping up-gradient of the springs. The Division of Water Rights has praised the study and noted that the work will help them delineate future policy in the area.

The Crawford Award was established in 1999 to commemorate the 50-year anniversary of the Utah Geological Survey. The award recognizes outstanding achievement, accomplishments, or contributions by a current UGS scientist to the understanding of some aspect of Utah geology or earth science. The award is named in honor of Arthur L. Crawford, first director of the UGS.

NEW PUBLICATIONS

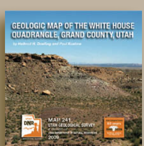


Geologic map of the Charleston quadrangle, Wasatch County, Utah, by Robert F. Biek and Mike Lowe, CD (28 p., 2 pl., 1:24,000), ISBN 1-55791-815-5, **M-236**........ **$14.95**



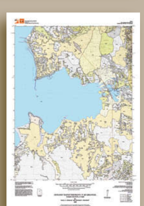
Geologic map of the Thompson Springs quadrangle, Grand County, Utah, by Hellmut H. Doelling and Paul Kuehne, CD (2 pl., 1:24,000) ISBN 1-55791-812-0, **M-239**........ **$14.95**

Geologic map of the Sagers Flat quadrangle, Grand County, Utah, by Hellmut H. Doelling and Paul Kuehne, CD (2 pl., 1:24,000) ISBN 1-55791-811-2, **M-240**........ **$14.95**

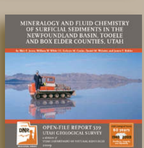


Geologic map of the White House quadrangle, Grand County, Utah, by Hellmut H. Doelling and Paul Kuehne, CD (2 pl., 1:24,000) ISBN 1-55791-813-9, **M-241**........ **$14.95**

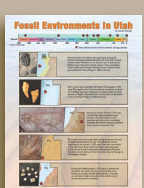
Rock-fall hazards in Utah, by Jessica J. Castleton, 4-page brochure, **PI-94**........ **FREE**



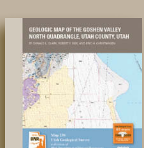
Geologic map of the Provo 7.5' quadrangle, Utah County, Utah, by Barry J. Solomon and Michael N. Machette, 2 pl., scale 1:24,000, ISBN 1-55791-799-X, **M-233**........ **$11.95**



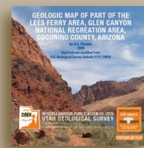
Mineralogy and fluid chemistry of surficial sediments in the Newfoundland Basin, Tooele and Box Elder Counties, Utah, by Blair F. Jones, William W. White III, Kathryn M. Conko, Daniel M. Webster, and James F. Kohler, CD (53 p. + 43 p. appendices), **OFR-539**........ **14.95**



Fossil environments in Utah, by Carole McCalla, 1 p. (2 sided) flyer, **PI-93**........ **FREE**



Geologic map of the Goshen Valley North quadrangle, Utah County, Utah, by Donald L. Clark, Robert F. Biek, and Eric H. Christiansen, CD (2 pl., 1:24,000), ISBN 1-55791-782-5, **M-230**........ **$14.95**

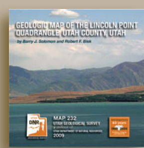


Geologic map of part of the Lees Ferry area, Glen Canyon National Recreation Area, Coconino County, Arizona (digitized and modified from plate 1 of U.S. Geological Survey Bulletin 1137), by D.A. Phoenix, CD (2 pl., 1:24,000 [contains GIS files]), ISBN 1-55791-809-0, **MP-09-2DM**........ **$24.95**

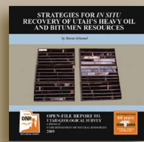
Geologic map of the West Mountain quadrangle, Utah County, Utah, by Donald L. Clark, 3 pl., 1:24,000, ISBN 1-55791-784-1, **M-234**........ **$15.95**

Interim Geologic map of the Seep Ridge 30' x 60' quadrangle, Uintah, Duchesne, and Carbon Counties, Utah, and Garfield and Rio Blanco Counties, Colorado, by Douglas A. Sprinkel, 3 pl., 1:100,000, contains GIS data, **OFR-549DM**........ **on UGS Web site only**

Geologic map of the Soldiers Pass quadrangle, Utah County, Utah, by Robert F. Biek, Donald L. Clark, and Eric H. Christiansen, CD (3 pl., 1;24,000), ISBN 1-55791-803-1, **M-235**........ **$14.95**



Geologic map of the Lincoln Point quadrangle, Utah County, Utah, by Barry J. Solomon and Robert F. Biek, CD (2 pl., 1:24,000), ISBN 1-55791-798-1, **M-232**........ **$14.95**



Strategies for *in situ* recovery of Utah's heavy oil and bitumen resources, by Steven Schamel, CD (113 p.), **OFR-551**........ **$14.95**

These and other publications are available from:

Natural Resources Map & Bookstore

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Soldiers Pass quadrangle, Map 235

West Mountain quadrangle, Map 234

Goshen Valley North quadrangle, Map 230

Provo 7.5' quadrangle, Map 233

Lincoln Point quadrangle, Map 232

Geologic maps of the central and southern Utah Lake area, Utah County, Utah

The UGS has released a block of five 1:24,000-scale geologic maps of the Provo, Lincoln Point, Soldiers Pass, Goshen Valley North, and West Mountain quadrangles. These detailed maps cover parts of Utah and Goshen Valleys, the Lake Mountains, and West Mountain in north-central Utah. Geologic maps are used by scientists, engineers, land-use planners, academics, and others, and provide basic scientific data for a multitude of derivative studies. These five maps are also the basis for part of an intermediate-scale geologic map of the Provo 30' x 60' quadrangle, which will be released by the UGS in the near future.

See page 17 for information on purchasing these maps.

Visit the new UGS blog

for the latest information from the Utah Geological Survey Web site, including new publications and maps, news releases, and other articles of geologic interest.

geology.utah.gov/blog