UTAH GEOLOGICAL SURVEY

SURVEY NOTES

Volume 45, Number 3 September 2013

FIRE-RELATED DEBRIS-FLOW HAZARD ON THE WASATCH PLATEAU

The Director's Perspective

by *Richard G. Allis*

The hazards theme of this *Survey Notes* issue is a reminder that we live in a geologically hazardous state. The hazards that concern us vary from infrequent, large magnitude events such as major earthquakes to smaller magnitude, frequent events such as debris flows, rock falls, and landslides. This spring, a major failure occurred in the sidewall of Kennecott's open-pit Bingham Canyon Mine. The resulting landslide flowed into the pit; the total distance between the main scarp and the toe was 1.5 miles. Within days, Kennecott had posted high-resolution photos of the slide on the web, and provided some details about the scale of the slide. The mass of rock in the slide was estimated at 165 million tons, equivalent to about 100 million cubic yards of rubble. Unusual deformation in the pit wall had been monitored for several months prior to the landslide, and Kennecott had moved equipment out of the likely path of the impending slide. Even so, twelve 330-ton haul-trucks that were parked on a far-side bench several hundred feet above the bottom of the pit were engulfed by the slide (visible in photo at the toe of the slide). Kennecott has stated that production from the mine this year could be halved compared to past years. The mine produces about 25 percent of U.S. copper production each year, and also produces significant amounts of molybdenum, gold, and silver.

Various blogs and press reports have subsequently commented that the Bingham Mine slide is probably one of the largest human-caused landslides in the world, and Kennecott has suggested it is probably one of the largest mining-related slides. Up to now, the 1983 Thistle landslide in central Utah has been known as this nation's most costly landslide, with $200 million in direct reconstruction costs, and over $100 million in indirect costs largely due to the disruption to railroad business[1]. In today's dollars, this amounts to about $700 million. That landslide was estimated at 50 million tons and was just over a mile in length. Kennecott has not stated what the cost of returning the mine to full production will be, but some mineral analysts have speculated that it will be at least $1 billion; if so, this event will earn the dubious title as the nation's most costly landslide.

Bingham Canyon Mine landslide. Photo courtesy of Kennecott Utah Copper.

These two landslides highlight how the costs and impacts of large hazard events can rapidly escalate. The paleoseismic record from trenches across the Wasatch fault demonstrates that magnitude 7 earthquakes recur on average about every 300 years somewhere along the fault. In addition to many lives lost and collapsed buildings, the reconstruction costs from such an earthquake are expected be in the range of $10–30 billion (refer to "Director's Perspective" in the May 2013 issue of *Survey Notes*).

[1] "Flooding and Landslides in Utah: An Economic Impact Analysis" Report by Bureau of Economic and Business Research, University of Utah, December 1984.

Thistle landslide, 1983.

Contents

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Cover: *September 1, 2012, fire-related debris flow deposit on the Mill Canyon alluvial fan following the 2012 Seeley fire. Photo by Richard Giraud.*

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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

Damaging Debris Flows Prompt Landslide Inventory Mapping for the 2012 Seeley Fire, Carbon and Emery Counties, Utah

by Richard Giraud and Greg McDonald

Utah Department of Transportation snow plow clearing the July 7, 2012, fire-related debris flow deposit from State Route 31 in Huntington Canyon (photo courtesy of Emery County Sheriff's Department).

The 2012 Seeley fire was a lightning-caused fire that burned 75 square miles (48,050 acres) on the Wasatch Plateau in central Utah. The fire, which started on June 26 and was contained on July 18, was approximately 15 miles northwest of Huntington and about 12 miles east of Fairview. Thunderstorm rainfall on July 7, 2012, produced fire-related debris flows and flooding, causing damage to State Route (SR) 31 and Huntington Creek in Huntington Canyon. Additional thunderstorm rainfall in 2012 produced debris flows and flooding on July 16, July 30, July 31, and September 1, 2012. To date in 2013, rainfall produced debris flows and flooding on July 16 and 18. These rainstorms show how prone the steep, burned slopes are to generating debris flows and flooding.

The Utah Geological Survey (UGS) and the Manti–La Sal National Forest (MLSNF) modified an existing cost-share agreement to focus on landslide inventory mapping of the Seeley fire burn area. The map and accompanying geographic information system (GIS) geodatabase show and characterize landslides (including debris flows) within the burn area to provide information to manage potential post-fire landslides and to prioritize areas where risk-reduction measures are needed.

Debris flows are the most common type of landslide following a wildfire and are triggered when intense thunderstorm rain falls on steep, burned slopes. Debris flows are mixtures of water and sediment, and in the Seeley fire area, the sediment consists of boulders, gravel, sand, mud, burned tree trunks, partially burned organic matter, and ash. Some flows contain more water than sediment and are fluid, having a consistency similar to a dilute milkshake. Other flows contain more sediment than water and are more viscous, having a consistency similar to wet concrete. Fire-related debris flows occur when wildfires leave bare ground and little vegetation to intercept intense thunderstorm rainfall, increasing surface-water runoff. The runoff water concentrates in stream channels where it erodes and incorporates loose channel sediment to form debris flows. The debris flows continue to erode channel sediment and increase in volume as they flow down steep mountain channels until they reach an alluvial fan at the channel mouth and spread out, depositing sediment.

Debris flows are one of the most dangerous post-fire hazards because they can be life threatening, move rapidly, and strike with little warning. Debris flows are generally more damaging than water floods because of their destructive power. Debris-flow density, thickness, and velocity can combine to produce large impact pressures, and flows can destroy buildings, campgrounds, roads, bridges, culverts, and other infrastructure in their path. Thirteen of Utah's fifteen debris-flow fatalities occurred in campgrounds at night, where fast-moving debris flows struck with little warning and left victims with no time to move to a safe location. The UGS worked closely with the MLSNF during and after the Seeley fire, providing fire-related debris flow hazard information to understand risks and potential impacts. The MLSNF put closure notices and travel restrictions into place for debris-flow areas and other post-fire hazards (such as flooding, falling and rolling trees, and falling rocks) to protect public safety.

The fire and intense thunderstorm rainfall that followed, transformed the area into a landscape that produced debris flows and floods that damaged SR 31, other roads, trails, recreation sites, fisheries, and water sources for power generation and local irrigation systems. The Seeley fire occurred within a popular recreation area notable for its scenic viewing, camping, hiking, fishing, and hunting. The area is also tied financially to several local industries including coal mines, coal-fired electrical power generation, livestock production, and natural gas wells and distribution pipelines. SR 31 through Huntington Canyon is a National Scenic Byway and the highway is the only paved route across the Wasatch Plateau.

We prepared the landslide inventory by analyzing and interpreting 11 sets of stereo and orthophoto aerial photography acquired periodically from 1938 through 2011, which provide a 73-year history of landsliding in the burn area. The characteristics of each historical and prehistoric landslide are recorded in the GIS geodatabase. The Seeley fire area has fewer landslides than other areas of the Wasatch Plateau because the rock units underlying the steep areas are stronger and therefore produce fewer landslides. Rock units in the burn area consist of the Mancos Shale, Star Point Sandstone, Blackhawk Formation (shale, siltstone, sandstone, and coal), Castlegate Sandstone, Price River Formation (sandstone and shale), and North Horn Formation (shale). Elsewhere on the Wasatch Plateau, numerous landslides occur in the North Horn Formation, but within the burn area, only a small area of North Horn is present, mostly on gentle slopes that do not produce many landslides. To date our mapping indicates a minimum of 32 fire-related debris flows in 2012 and 2013 (following the fire), in addition to many potential debris-flow areas.

The potential for fire-related debris flows is highest immediately after a fire and will decrease as vegetation is reestablished. For the Seeley fire the potential for debris flows and flooding will persist until the regrowth of vegetation stabilizes burned hillslopes, intercepts rainfall, and buffers runoff. Most fire-related debris flows in Utah and the Intermountain West occur within two or three years following the fire. Drought conditions can limit vegetation regrowth and result in a longer recovery. The UGS landslide inventory map will help the MLSNF manage the post-fire potential for debris flows and other landslides as vegetation recovers in the Seeley fire burn area.

Sandstone boulders, logs, and wood debris deposited in Nuck Woodward Canyon by a July 18, 2013, fire-related debris flow.

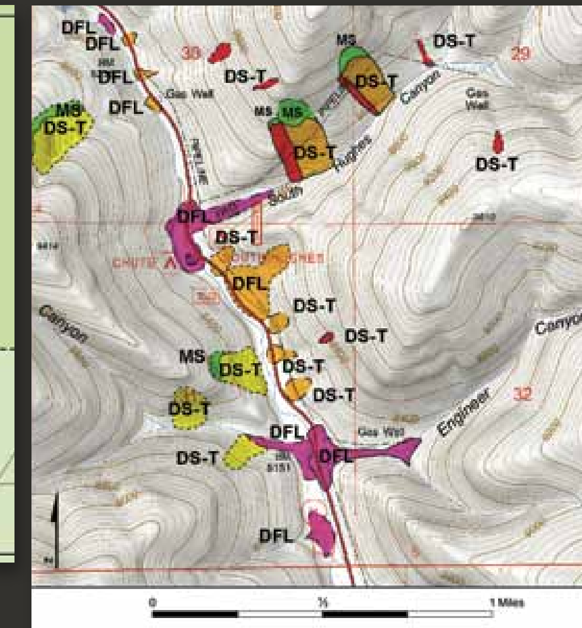
A September 1, 2012, fire-related debris flow covered most of the Mill Canyon alluvial fan and deposited sediment into Huntington Creek. State Route 31 is at the bottom of the photograph (photo courtesy of Emery County Sheriff's Department).

For more information:
Preliminary Landslide Inventory Map of the 2012 Seeley Fire Area, Carbon and Emery Counties, Utah, Utah Geological Survey Open-File Report 612:
http://geology.utah.gov/online/ofr/ofr-612.pdf

For information on the UGS Geologic Hazards Program: **http:/geology.utah.gov/ghp**

For information on fire-related debris flows: **http://geology.utah.gov/online/pi/pi-90.pdf**

For MLSNF information about the Seeley fire, potential hazards, closure notices, and travel restrictions:
http://www.fs.usda.gov/detail/mantilasal/home/?cid=STELPRDB5385573



LEFT *Location of the Seeley fire (in orange).*

RIGHT *Part of the landslide inventory map in Huntington Canyon shows different types of landslides. The pink areas show alluvial fans where 2012 and 2013 fire-related debris flows deposited sediment, red areas are landslides with historical movement, orange areas are dormant or slow moving landslides, and yellow areas are dormant eroded landslides. Map labels for landslide types: DFL – debris flow, DS-T – debris slide with translational movement, and MS – landslide main scarp.*

About The Authors

Richard Giraud has been a geologist with the UGS since 1997 and has worked on a variety of landslide projects with the Geologic Hazards Program. He specializes in debris flows and has a specific interest in fire-related debris flows. Current work involves landslide inventory mapping on the Wasatch Plateau.

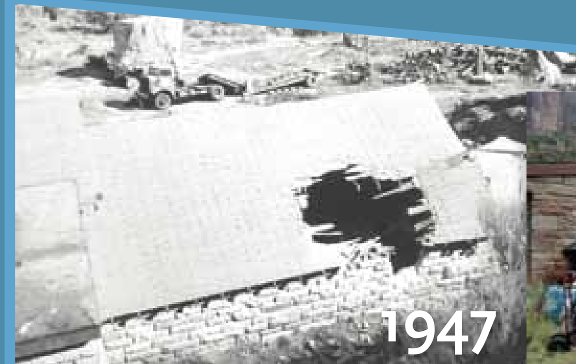
Greg McDonald has been a geologist with the UGS Geologic Hazards Program since 1998, and has been primarily mapping landslides in the Manti-La Sal Forest on the Wasatch Plateau since 2008. Greg has also worked on a variety of projects including several paleoseismic studies, many debris-flow, landslide, and rock-fall investigations, geologic-hazard and surficial-geologic mapping, and earthquake ground-shaking-related studies.

ROCK FALL:

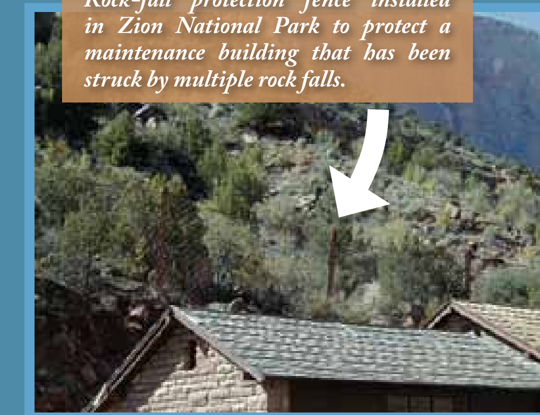
An Increasing Hazard in Urbanizing Southwestern Utah

by William R. Lund

Southwestern Utah's combination of steep slopes capped by resistant cliffs and ledges of bedrock makes rock fall the region's most common form of slope failure. Rock fall is the dislodging and rapid downslope movement of rocks and small rock masses; rock fall is a safety hazard because falling or rolling rocks can damage property and cause injury or even loss of life. In recent years as development in southwestern Utah has encroached into rock-fall hazard areas, rock-fall strikes have become increasingly common, damaging property in St. George, Rockville, and Zion National Park, crushing a water pipeline in Parowan Canyon, and closing State Route 14 in Cedar Canyon for almost two weeks. Additionally, a rock fall in January 2013 seriously injured the occupant of a home in St. George.



Rock falls 63 years apart in 1947 and 2010 strike the same maintenance building in Zion National Park in almost the same spot. Photos courtesy of the National Park Service.



Rock-fall protection fence installed in Zion National Park to protect a maintenance building that has been struck by multiple rock falls.

Ledge of the well-jointed, resistant Shinarump Conglomerate Member of the Chinle Formation overlying a slope composed of the softer upper red member of the Moenkopi Formation. The Shinarump Conglomerate has generated numerous large rock-fall boulders that in the past rolled down slope into a now-developing area of Rockville, Utah. This area is mapped by the UGS as having a high rock-fall hazard.

Rock falls occur where a source of rock exists above slopes steep enough to allow rapid downslope movement of rocks by falling, rolling, and bouncing. Gravity is the ultimate cause of rock falls, and most rock falls occur with little or no warning. However, sometimes there is a discernible triggering event such as a rainstorm, freeze/thaw cycle, rapid snow melt, or erosion below a cliff or ledge. Earthquakes often cause rock falls, and the 1992 magnitude 5.8 St. George earthquake resulted in numerous rock falls in southwestern Utah. Additionally, slope modifications such as road cuts, building pads, or clearing slope vegetation for development, can heighten or create local rock-fall hazards.

Early recognition and avoidance of rock-fall-prone areas is the most effective way to reduce rock-fall hazard and risk. Because rock falls typically occur repeatedly where conditions for them are most favorable, southwestern Utah residents can often identify rock-fall hazard areas by the accumulation of rock-fall boulders on and at the base of susceptible slopes. The presence of these boulder accumulations is evidence of a rock-fall hazard, and provides a clear warning that rock-fall-mitigation measures are required if development is to take place in those areas. When avoidance is not an option, numerous techniques are available to reduce potential rock-fall damage.

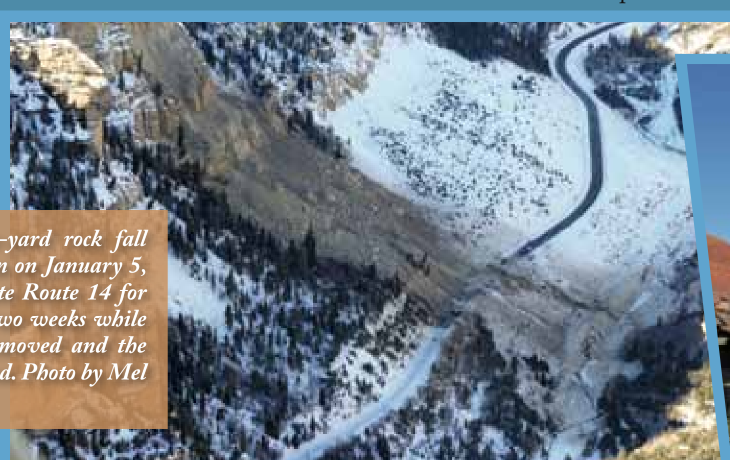
For more than a decade, geologists in the Utah Geological Survey's (UGS) Southern Regional Office have been mapping rock-fall and other geologic hazards in southwestern Utah. Geographic-information-system-based hazard map folios are now available for the 366-square-mile St. George–Hurricane metropolitan area, and the 154-square-mile highest visitation portion of Zion National Park. Additionally, the UGS will soon release a hazard map folio for the 97-square-mile State Route 9 scenic corridor between the communities of La Verkin and Springdale. The UGS provides copies of its hazard maps to communities within the study areas, so planners and public officials have accurate, easily available information on rock-fall and other hazards in their jurisdictions as they plan for and manage future growth. The St. George and Zion National Park hazard maps are also available to the public on the UGS website at http://geology.utah.gov/maps/geohazmap/washington.htm. The State Route 9 maps will be placed on the website when the report is published.

In addition to showing where rock-fall hazards may occur, the maps include recommendations for conducting investigations to reduce risk to property and life safety. In some instances, a site-specific assessment may only require a field geologic evaluation to determine if a rock-fall source is present. If a source is identified, additional work is required to assess the hazard. Parameters that must be evaluated include rock type, joints and other fractures, bedding planes, and potential maximum rock size. Slopes below a source should be evaluated for slope angle, aspect, surface roughness, vegetation, and distribution and size of past rock-fall boulders. Additionally, the distance to which rocks may run out beyond the base of the slope requires careful evaluation.

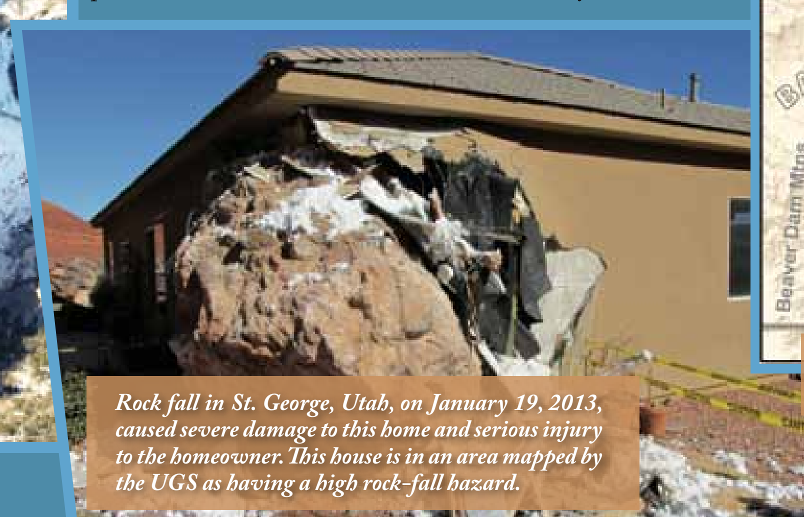
Once a rock-fall hazard has been identified and characterized, a geotechnical consultant experienced in rock-fall-hazard mitigation should provide design or site-preparation recommendations to reduce the hazard. The map recommendations have a particular urgency because all recent damaging rock falls in the three UGS study areas have occurred in locations mapped as having a high rock-fall hazard, but where mitigation measures were not implemented.

In summary, rock falls happen on a daily basis somewhere in southwestern Utah, and while the majority occur in remote areas or cause no damage or injury, damaging and life-threatening rock-fall strikes are becoming more common as development continues to move into areas subject to rock-fall hazard. The next damaging rock fall in southwestern Utah is simply a matter of time, and if the recent past is the key to the future, it won't be a very long time. That is why the UGS continues to actively map rock-fall and other geologic hazards in southwestern Utah, and to work with communities and the public to reduce rock-fall hazard and risk.

Additional information about rock-fall hazards in Utah is available on the UGS website at http://geology.utah.gov/utahgeo/hazards/landslide/index.htm, and in Washington County specifically at http://geology.utah.gov/maps/geohazmap/washington.htm



A 60,000 cubic-yard rock fall in Cedar Canyon on January 5, 2005, closed State Route 14 for approximately two weeks while the rock was removed and the roadway repaired. Photo by Mel Ashcroft.



Rock fall in St. George, Utah, on January 19, 2013, caused severe damage to this home and serious injury to the homeowner. This house is in an area mapped by the UGS as having a high rock-fall hazard.

Boundaries of the three study areas in southwestern Utah for which the UGS has prepared GIS-based geologic-hazard map folios that include rock-fall hazard maps.

New Geologic Data Resources for Utah:

Aerial Imagery, Geologic Hazard Documents, and Geologic Maps

by Steve D. Bowman

Recognizing the value and importance of physical and digital geology-related resources, the Utah Geological Survey (UGS) in partnership with the U.S. Geological Survey (USGS) started a Geologic Data Preservation Project in 2007, to collect, inventory, preserve, and manage geologic data of value for future use by industry, government, academia, and the public. These data are an important resource for those involved with land-use planning and management; geologic, geotechnical, and environmental investigations; mineral and resource exploration; real estate due-diligence activities; environmental protection; academic research; and teaching. Making these data easily available will significantly enhance these activities by providing more complete background data. In addition, end-users of data held by the UGS may realize cost savings from not having to acquire the data directly themselves. As part of this project, the UGS has inventoried, archived, and made available to the public a variety of geologic data, including aerial photography covering Utah and surrounding areas, engineering geology and geologic-hazard reports, and geologic maps.

Annotated 1970 low-sun-angle aerial photograph of Lower Bells Canyon Reservoir and the Salt Lake City segment of the Wasatch fault, which crosses the photo from top (north) to bottom (south). This photograph was taken in the afternoon so west-facing scarps are illuminated and east-facing scarps are shadowed. Low-sun-angle photographs from this aerial project were used to highlight fault scarps along the Wasatch Front and are used for fault-characterization and geologic-mapping purposes today.

The UGS Aerial Imagery Collection contains aerial photography of Utah dating from 1935 to the present, with about half of the collection dating before 1960. The collection includes over 120,000 frames (individual photographs, of which over 75,000 have been scanned and entered into a database) and associated indexes, orthophotomaps (semi-controlled orthophotos), and other materials. Various federal government agencies originally acquired most of these frames for agricultural management purposes, and this photography is now integral to many geologic projects, such as geologic mapping and geologic-hazard investigations. Prior to this project, the majority of the pre-1955 federally acquired Utah aerial photography was only available as a copy from the National Archives at a significant per-frame cost. Most of the frames acquired are in stereoscopic mode, such that successive frames overlap, creating stereo pairs that provide a three-dimensional image when viewed with a stereoscope. A small percentage of the frames are low-sun-angle photographs acquired during the morning or afternoon when shadows highlight certain topographic features. The UGS developed a database system to manage the collection and store associated information (metadata) that can be accessed through a web-based search and download application available at http://geology.utah.gov/databases/imagery/.

The UGS has collected unpublished reports, maps, memorandums, field notes, consultant reports, and other geologic-hazard and engineering-geology documents since the formation of the Site Investigation Section (now Geologic Hazards Program) in 1980. Few copies were ever produced of most of the documents in the collection. The new UGS GeoData Archive System compiles Utah geology-related scanned documents, photographs (except aerial), and other digital materials from our files and those gathered from other agencies or organizations into one easy-to-use web-based system. Resources available to general users are in the public domain and may contain reports submitted to state and local governments as part of permit reviews. Each resource is searchable by metadata describing each resource, along with spatial searching for resources that are local or site-specific in nature. Resources representing counties, regions, or other large areas are not spatially searchable at this time and require text-based metadata searches. Not all resources may be available to all users due to copyright and/or distribution restrictions. Upon searching for specific materials, users may view them directly or download them to their local device. Documents are predominately in text-searchable PDF format and photographs in JPEG format. The UGS GeoData Archive System is available online at http://geodata.geology.utah.gov.

The UGS Geologic Map Database (MAPBIB) contains approximately 2,850 geologic maps covering various parts of Utah, dating from about 1890 to present, that vary from published USGS and UGS Map and Bulletin Series maps, to informal consulting reports and internal unpublished "sketch" maps. Over 1000 maps in the database were either produced in only limited numbers, are completely out of print, are in remote libraries, or are limited-distribution, informally published literature that is difficult to locate. For a few hundred of the maps, only a single copy may exist. Our long-term goal is to locate the best possible copy of all Utah geologic maps, and to produce and archive a high-resolution digital scan of each map in the MAPBIB database. Since 2009, the UGS has inventoried, cleaned, and scanned 918 geologic maps covering various parts of Utah. The UGS has spatially referenced each map with 16 points (if possible) to create JPEG and GeoTIFF images of each map, and created a footprint for each map for future spatial indexing and locating. Many of these maps are available online at http://geology.utah.gov/maps/geomap/interactive/index.htm.

This and other geologic data preservation projects will allow data held by the UGS to become more readily available to the public through inventorying, creating metadata, and developing creative information delivery methods, such as enhanced Internet information products (UGS GeoData Archive System, web mapping applications, and others) and continued collaboration with the Utah Automated Geographic Reference Center and other organizations.

Annotated 1937 aerial photograph of Salt Lake City from the earliest known aerial-photograph data set of Salt Lake Valley, showing the state Capitol building and urbanization that occurred in the early part of the last century.

ENERGY NEWS

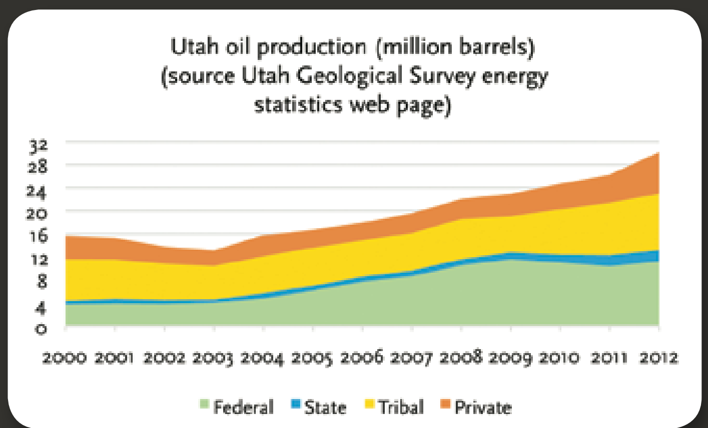
Are Ownership and Production Patterns of Utah Petroleum Resources Related?

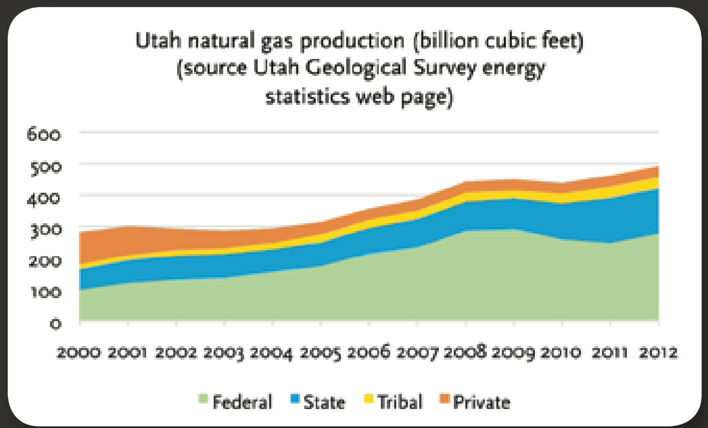
by David E. Tabet

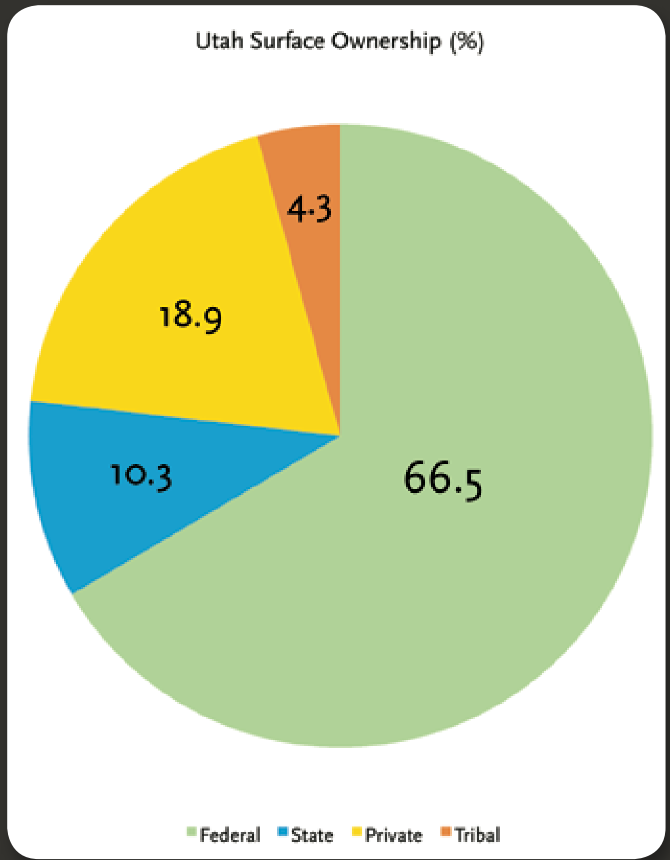
Much news has recently been written about how improved technology has led to rising U.S. oil and gas production, and whether the U.S. will become energy independent in the future. Since at least 2003, Utah has been a part of this increasing oil and gas production pattern.

In Utah, ownership of the land with petroleum potential is divided into four major categories: federal, state, tribal, and private. According to a February 2012 Congressional Research Service report, about two-thirds of the state's surface area is owned by the federal government. The remaining third is split between private, state, and tribal ownership.

Utah Geological Survey (UGS) fossil fuel production records for the period from 2000 to 2012 show that while annual gas and oil production was mostly increasing overall since 2001, production by various owners showed some differing trends. Interestingly, production of natural gas from federal lands grew in absolute and relative terms until 2009, when the percentage produced from federal lands was about 66 percent, or approximately proportional to the percentage of federal land ownership in Utah. Since 2009, gas production from federal lands has generally declined or been flat. In 2012, only 47 percent of Utah's gas production was from federal lands, indicating gas production from federal lands is no longer proportional to the percentage of federal land ownership.







For oil production, all ownership categories generally followed an overall decreasing production trend from 2000 to 2003, and then had increases through 2012. However, only federal oil production recorded recent drops in both 2010 and 2011 of about 5 percent each year, but rebounded slightly in 2012. Total Utah oil production has historically been strongly influenced by tribal areas since Utah's largest fields, Greater Aneth and Altamont-Bluebell, which combined have produced about half of the state's oil, are found mainly on Navajo and Ute tribal lands, respectively. Whether the amount of oil produced by Utah's various land owners will ever be proportional with the amount of land held by these owners is unclear, but recently the percentage of oil produced from federal lands has dropped, from a high of 50 percent in 2009 down to 37 percent in 2012.

What is the significance of these production trends by ownership? Since the federal government controls about two-thirds of Utah, if petroleum production from federal lands continued to drop, Utah's overall petroleum production would eventually be pulled back into a declining trend. Increased oil and gas development on the non-federal one-third of Utah alone cannot sustain long-term high levels of statewide production when federal lands are not also participating in a similar increasing trend. Thus, if Utah's federal lands do not renew absolute and proportional increases in petroleum production, over the long term jobs and revenues from Utah petroleum production should decrease.

Come celebrate Earth Science Week with the Utah Geological Survey this year at the Utah Core Research Center. We will be offering hands-on activities (especially relevant to 4th- and 5th-grade classes) including panning for "gold," 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 website at http://geology.utah.gov/teacher/esweek.htm.

To make reservations, contact Jim Davis or Sandy Eldredge at 801-537-3300. Groups are scheduled for 1½-hour sessions.

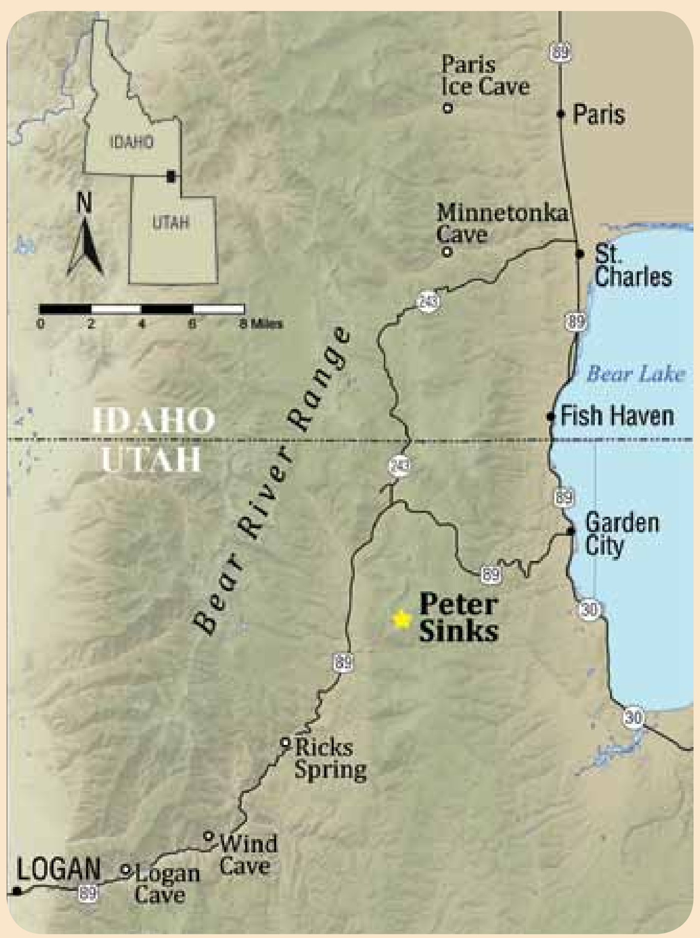
TEACHER'S CORNER

Earth Science Week 2013 | October 7–10, 2013 | 9:20 am–2:10 pm

Hands-on Activities for School Groups

GLAD YOU ASKED

BY JIM DAVIS



Where is the Coolest Spot in Utah?

Among all the cool places in Utah, the coolest by far is Peter Sinks. High in the Bear River Range in Cache County, Peter Sinks is frequently the coldest place in the United States in wintertime, even colder than anywhere in Alaska. Peter Sinks holds the second-place record—less than half a degree shy of the all-time record at Rogers Pass, Montana—for coldest recorded temperature in the contiguous United States at -69.3°F set on February 1, 1985. Separate readings were taken by automated instrumentation and two Utah State University students using alcohol thermometers (mercury freezes at about -38°F). Summer at Peter Sinks can be chilly, too; a low of 3°F was noted in June 2001. Peter Sinks also has had extraordinary ranges of temperature—swings of nearly 80°F in a few hours, and more than a 28°F change in nine minutes.

Why is a place nearly 500 miles south of Canada so unduly cold? The cause is a combination of high elevation, dry air, and topography. Peter Sinks is a collection of sinkholes, a product of the underlying geology, that form a bowl-shaped depression surrounded by ridges hundreds of feet higher than the low point. Peter Sinks creates its own microclimate due to the concentration and retention of cold air. Cold, dry air is the heaviest kind of air. It pours into and ponds in the bowl, with nowhere to escape until the air spills over the lowest lip of the ridgeline of the topographic depression. As long as there is no wind to mix the atmosphere, cold air fills Peter Sinks. This condition is called "cold-air pooling," an occurrence all too familiar to residents of the Wasatch Front and Cache Valley, who endure intense winter temperature inversions when colder air fills the valleys, trapping in air pollution.

Peter Sinks is two connected depressions, an upper bowl and a lower bowl, forming an elongated basin about 2 miles long and half a mile wide perched 2,000 feet above upper Logan Canyon. Grasses, shrubs, and herbs grow on the floor of Peter Sinks where it is too cold for trees to grow, yet trees grow farther up on the sides and rim of the bowl, an example of an "inverted treeline." This is because temperatures are much higher along the sides and rim of Peter Sinks, particularly at night.

Karst **is a term used to describe the characteristic topographic features created through chemical weathering via mildly acidic rainfall and groundwater dissolving rocks, in particular limestone (calcium carbonate) and dolomite (calcium magnesium carbonate). Limestone and dolomite are widespread in the Bear River Range. Terrain here resembles Swiss cheese in places, with pits, caverns and caves, and numerous springs that discharge from the system of underground passages pervading the rock. Many celebrated karst-type landforms are found in the Bear River Range: Ricks Spring (a reappearing underground stream), Logan Cave (4,290 feet in length), Wind Cave (really arches and alcoves rather than a true cave), Paris Ice Cave (with ice formations present throughout the year), and Minnetonka Cave (with many classic cave formations such as stalactites and stalagmites).**

Ricks Springs, Cache County, Utah.

Peter Sinks, oblique view to the southwest. Note the "inverted treeline" where the bottom of Peter Sinks is devoid of trees; however, trees grow higher up on the sides and rim of the basin. Google Earth image. Scale varies in this perspective. Vertical exaggeration 1.5x.

Rock type, tectonics, and chemical weathering are responsible for numerous sinkholes in the Bear River Range. These sinkholes form when the ground surface caves in above underground voids dissolved out of the carbonate rocks. Past compressional and ongoing tensional forces have played a role in forming the Bear River Range and the high, elevated, fault-bounded basins that the sinks occupy. These basins, lacking a surface drainage outlet, enhance chemical weathering of the rock through the concentration and retention of water at topographic low areas (analogous to cold-air pooling). Water drainage out of the sinks is subterranean.

The U.S. record low temperature may yet fall to Peter Sinks. Utah State University's Utah Climate Center, with support from Campbell Scientific of Logan, installed a monitoring station in 2009 as part of the Peter Sinks Temperature Monitoring Project (information found online at http://twdef.usu.edu/Peter_Sinks/Sinks.html). The station provides continuous temperature and wind speed data at the bottom of the sinks and higher up on the rim of the sinks. Previously, the sinks had only sporadic measurements, so now an accurate portrayal of temperature patterns and extremes of Peter Sinks will soon come to light.

ELEVATION	LOCATION
8,120 feet	N 41° 54' 46"; W 111° 31' 08"

GeoSights

The Goosenecks of the San Juan River, San Juan County, Utah

by Marshall Robinson

View looking south from the Goosenecks State Park parking lot.

What in the world is a gooseneck? When it comes to describing a landform, fowl play (pun intended) may seem apparent. Even when you are standing in front of one, the answer is not obvious. Not until you get a look from above does this name start to make sense. In geology, "goosenecks" is a term used for sinuous canyons and valleys that resemble the curved neck of a goose.

The world-famous 180-degree bends of the deeply entrenched San Juan River are a must-see vista for landscape photographers. The San Juan River, named after San Juan Bautista (Saint John the Baptist), flows nearly 5.5 miles through its meandering channel while only covering 1.3 miles as the crow flies. In total, the San Juan snakes 383 miles from the San Juan Mountains of southeastern Colorado to Lake Powell in southern Utah. Image from Bing Maps.

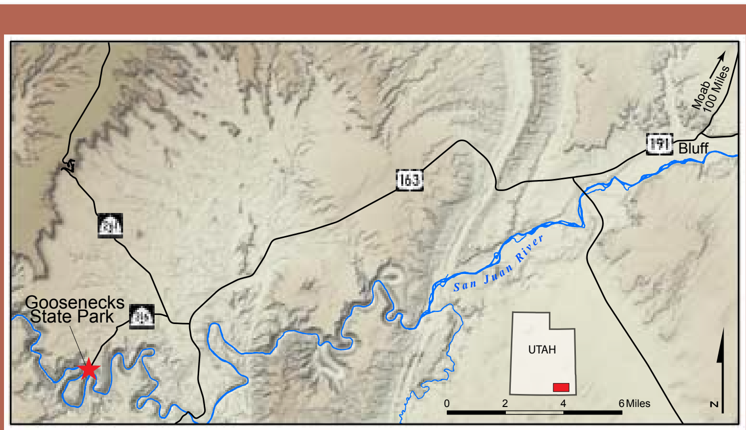
The Goosenecks of the San Juan River have rightfully earned themselves a state park designation. Goosenecks State Park is, in essence, a parking lot perched at the edge of a precarious 1,000-foot cliff. This abrupt cliff, however, provides a panoramic view of the winding canyon holding the San Juan River below.

Geologic Information: The lower and upper cliffs that line the San Juan River are composed of more than 300-million-year-old rocks known as the Paradox and Honaker Trail Formations, respectively. The Halgaito Formation overlies the Honaker Trail Formation, and blankets the desert landscape along the road to the state park, while also providing a foundation for the parking lot. Limestone, siltstone, sandstone, and shale beds constitute these cliff and slope-forming rocks. These rocks have their origins in an ancient marine environment where sea level alternately rose and fell before eventually receding, leaving behind a largely flat terrain. The ancestral San Juan River meandered across this gentle landscape, literally setting its path in stone.

Meandering streams similar to the ancient San Juan River flow throughout the world; however, specific conditions must be met for them to cut such deep, winding canyons called *entrenched meanders*. This brings up a bit of irony because meandering streams twist and turn as they do because of a low gradient, which in itself is the reason why they also do not typically cut deep canyons. On the other hand, rivers with high gradients flow faster, giving them the erosive power to cut deep canyons; however, high-gradient streams also typically cut straight channels.

So, how did the San Juan River cut 1,000 feet into the ground when it had such a low gradient? It was able to do so because long after the San Juan River's sinuous course was set, its headwaters slowly began to rise along with the rest of the Colorado Plateau (approximately 15 to 20 million years ago, although the timing of this event remains a subject of debate among the geologic community), concurrently increasing the river's gradient, flow velocity, and downcutting rate. Since the San Juan had already set its path in its earlier stages, this new rapid downcutting overcame the river's determination to change its course, thus allowing it to continue along this path while slicing deeper and deeper into the canyon's rocks.

The Goosenecks of the San Juan are not alone, as there are other entrenched meanders in the western United States and elsewhere. Capitol Reef National Park's Sulphur Creek in Wayne County is another textbook example, as well as parts of the Snake River Canyon in southern Idaho. Many others can be found throughout the Colorado Plateau, but none are so tightly wound and deeply incised as the San Juan River's goosenecks.



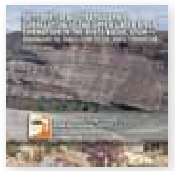
How to Get There:

Goosenecks State Park is located at the southern dead end of Utah State Route 316 approximately 270 miles southeast of Salt Lake City. From Moab, drive south on U.S. Highway 191 for approximately 100 miles to Bluff (where the highway turns into U.S. Highway 163). Continue west on U.S. 163 for 17 miles and turn right on Utah State Route 261, then after one mile turn left on SR 316 and continue about 3.5 miles to the parking lot. The state park is free to visitors, and camping is available without a reservation year-round. Tent camping, however, is for those who are truly adventurous as this area can become extremely windy.

New Publications

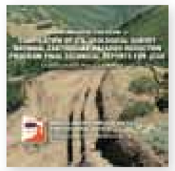
Geologic map of the George Mountain quadrangle, Garfield and Kane Counties, Utah, by Robert F. Biek, CD (2 pl. [contains GIS data]), scale 1:24,000, ISBN 978-1-55791-877-2, **M-262DM..........................$24.95**

Geological characterization of the Birds Nest aquifer, Uinta Basin, Utah: Assessment of the aquifer's potential as a saline water disposal zone, by Michael D. Vanden Berg, Danielle R. Lehle, Stephanie M. Carney, and Craig D. Morgan, CD (47 p., 31 pl. [contains GIS data]), ISBN 978-1-55791-874-1, **SS-147..$39.95**



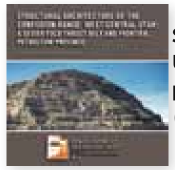
Outcrop chemostratigraphic correlation of the upper Green River Formation in the Uinta Basin, Utah—Mahogany oil shale zone to the Uinta Formation, by Dave Keighley, CD (30 p.), ISBN 978-1-55791-875-8, **MP-13-1..$14.95**

Preliminary isostatic gravity map of the Grouse Creek and east part of the Jackpot 30´ x 60´ quadrangles, Box Elder County, Utah, and Cassia County, Idaho, by V.E. Langenheim, H. Willis, N.D. Athens, B.A. Chuchel, S.M. Kraushaar, N.E. Knepprath, J. Rosario, J. Roza, A.I. Hiscock, and C.L. Hardwick, CD (3 p., 1 pl., 4 data files), ISBN 978-1-55791-876-5, **MP 13-2...........$14.95**



Paleoseismology of Utah, Volume 23—Compilation of U.S. Geological Survey National Earthquake Hazards Reduction Program Final Technical Reports for Utah, compiled by Steve D. Bowman and William R. Lund, DVD (9 p. + 56 reports), ISBN 978-1-55791-878-9, **MP 13-3...................................$14.95**

Preliminary landslide inventory map of the 2012 Seeley fire area, Carbon and Emery Counties, Utah, by Greg N. McDonald and Richard E. Giraud, CD (1 pl. [contains GIS data]), scale 1:24,000, **OFR-612........................$19.95**



Structural architecture of the Confusion Range, west-central Utah: a Sevier fold-thrust belt and frontier petroleum province, by David C. Greene and Donna M, Herring, CD (22 p., 6 pl.), **OFR-613...$19.95**

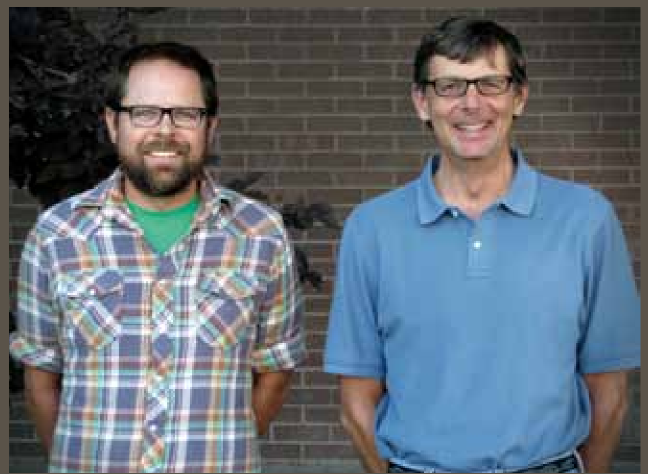
Mapping tool to show trends in groundwater nitrate concentrations in Utah, by Janae Wallace and Paul Inkenbrandt, 23 p., **OFR-610..................................$8.00**

Survey News

2013 Crawford Award

The prestigious 2013 Crawford Award was presented to UGS geologists **Rich Giraud** and **Greg McDonald** in recognition of their work on the outstanding geologic publication *Landslide Inventory Map of Twelvemile Canyon, Sanpete County, Utah* (UGS Map 247DM). The publication includes a 1:24,000-scale landslide inventory map and geodatabase for Twelvemile Canyon in central Utah. The map covers 59 square miles on the west side of the Wasatch Plateau. The purpose of the map and database is to show landslide deposits and their characteristics to provide information to the U.S. Forest Service and the general public for managing landslide problems.

The Crawford Award recognizes outstanding achievement, accomplishments, or contributions by a current UGS scientist to the understanding of some aspect of Utah geology or Earth science. Awardees are selected by the UGS Board. The award is named in honor of Arthur L. Crawford, first director of the UGS.



UGS geologists Greg McDonald and Rich Giraud.

Employee news

The Editorial Section welcomes **Nikki Simon** as the new graphic designer. Nikki relocated to Utah from Bozeman, Montana, and has a Bachelor of Fine Arts degree from Montana State University. **Zach Anderson** joined the Mapping Program as a GIS analyst. Zach has a Master of Science degree in Geology from Northern Arizona University, with a strong emphasis on GIS techniques. Welcome to Nikki and Zach! **Rebecca Medina** resigned as secretary for the Groundwater and Paleontology Program after nine years of service.

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2014 Calendar of Utah Geology

Featuring scenic photographs highlighting Utah's geologic diversity. The photographs were taken by UGS employees who are often on assignment in some of the state's most interesting and unique locations. Pictures are accompanied by geologic descriptions and location information. The calendar is available at the Natural Resources Map & Bookstore, so order now and don't miss out.

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