UTAH GEOLOGICAL SURVEY

SURVEY NOTES

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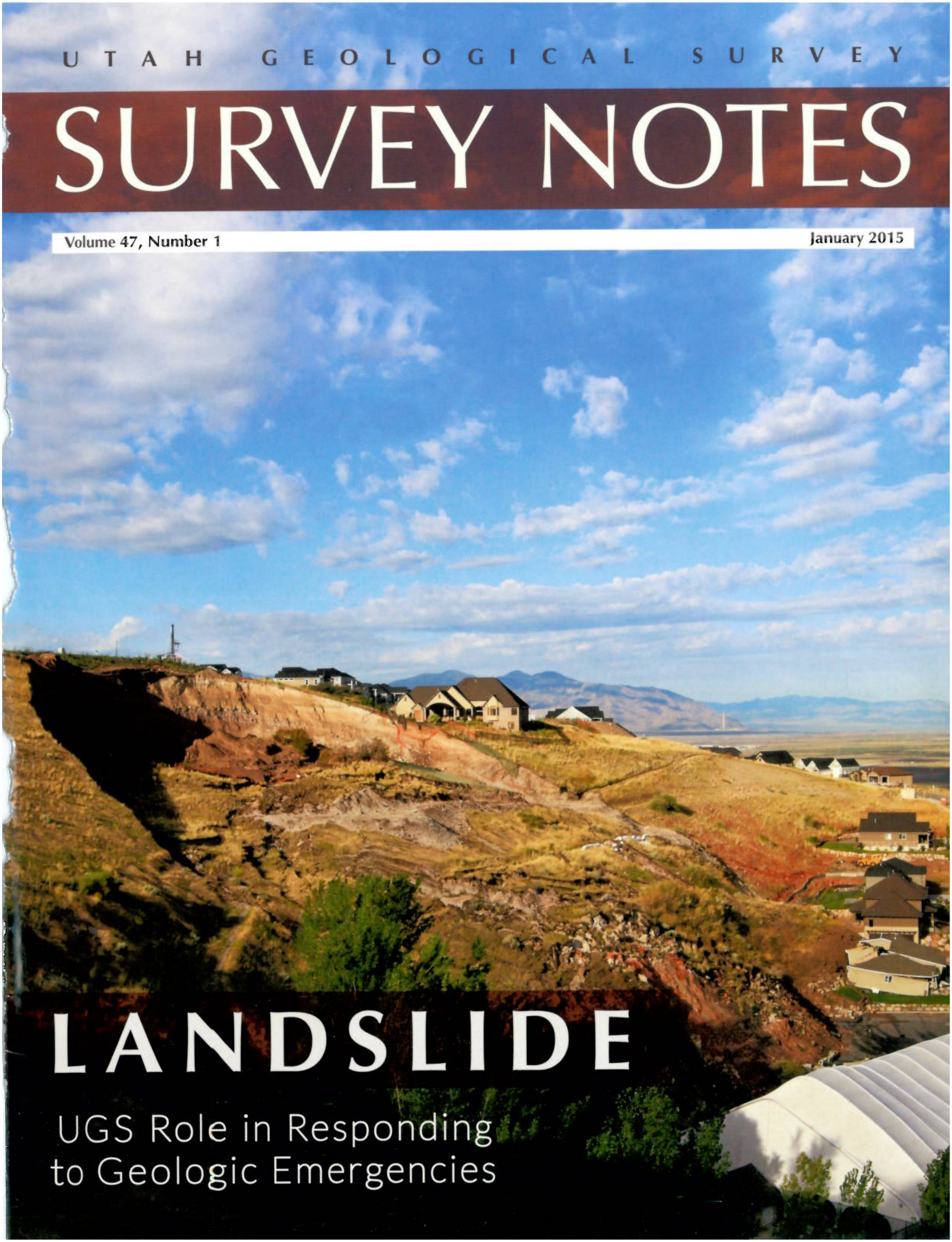

LANDSLIDE

UGS Role in Responding to Geologic Emergencies

Contents

Design | *Nikki Simon*

Cover | *Parkway Drive landslide, North Salt Lake, Utah, August 14, 2014. The landslide damaged the Eagle Ridge Tennis and Swim Club (white tent structure), and severely damaged one house (directly above the tent structure in photo) (photo courtesy of Gregg Beukelman).*

THE DIRECTOR'S PERSPECTIVE

by Richard G. Allis

Utah's population is predicted to almost double by 2050, adding about 2.5 million residents. Inevitably, significant population growth brings potential impacts on quality of life. A recent survey of "Quality of Life and State Priorities" conducted by Envision Utah confirms overall perceptions of a high quality of life in Utah ("2014 Values Study Results," Envision Utah, October 16, 2014). One of the performance factors evaluated by this survey was Utah's "preparation for disasters," and this ranked as average, marginally below factors such as healthy living, natural lands, arts and culture, and slightly above factors such as agriculture, transportation, and healthcare.

One of the challenges in evaluating societal priorities as we plan for growth is that high-impact but low-frequency events tend to be undervalued. An obvious example is our preparedness for damaging earthquakes. About 75 percent of Utah's population resides within 50 miles of the Wasatch fault, where magnitude (M) 7 earthquakes occur on average about every 300 years on the central part of the fault, and it has been about 200 years since the last major earthquake. Sophisticated damage models based on building codes and damage from earthquakes elsewhere predict hundreds of fatalities, over 100,000 households displaced, and an economic impact of at least $50 billion for an M7 earthquake on the Salt Lake City segment of the Wasatch fault. However, human nature is such that it frequently perceives other issues as more important and pressing when comparing the possibility that a very hazardous event may or may not occur in the next few decades.

Much can be done to improve a community's resilience to natural disasters as growth occurs. Geologic hazard maps that get incorporated into local government planning, and adherence to appropriate building and development codes, can minimize impacts from the inevitable hazard events. The recent Parkway Drive landslide in North Salt Lake described in this issue (page 1) highlights the risks to life and property when development occurs in geologically hazardous areas. In this case, no lives were lost, but one house was destroyed, another home's backyard was destroyed, and an adjacent tennis club suffered significant damage. The Utah Geological Survey (UGS) had identified unstable ground in this area 10 years ago, and in a similar geologic setting 0.6 miles away, the slow-moving Springhill Drive landslide resulted in 12 houses being demolished between 1998 and 2013 (http://geology.utah.gov/utahgeolhazards/landslide/springhill/index.htm). In December 2013, two fatalities occurred when a large rock demolished a house in Rockville. The UGS had identified this house, and many others in Rockville, as being in the high-hazard zone for rockfalls, but unfortunately most development here occurred decades earlier. Geologic-hazard maps are most useful when completed prior to development, and local government zoning restrictions can optimize investment and land-use according to the hazard. The UGS continues to prioritize our limited funds for geologic hazard mapping in areas of highest population growth.

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Emergency Response and the Utah Geological Survey

What role do we serve and what services are provided?

BY **STEVE BOWMAN**

Part of the mission of the Utah Geological Survey (UGS) as defined in state code, is to "determine and investigate areas of geologic and topographic hazards that could affect the safety of, or cause economic loss to, the citizens of the state." This includes responding to geology-related emergency events, such as landslides, rockfalls, debris flows, earthquakes, and other hazards, by assisting local governments and the Utah Division of Emergency Management (UDEM). When a geologic-related emergency occurs, local emergency managers and first responders need clear, unbiased scientific information related to the initial safety of the site. This leads to a few questions:

- Is the site likely safe for first responders and others to enter and work?
- What geologic information is needed to reduce the risk?
- Is geologic monitoring needed to increase safety?
- Is another event likely to occur within a short time frame?
- Are other nearby areas at risk from geologic hazards?

The UGS Geologic Hazards Program has experienced engineering geologists who are available to provide assistance at any time to local governments and the UDEM when a geologic emergency occurs. For particularly significant emergency events, responses are managed from the UGS Emergency Operations Center (EOC) at the Utah Department of Natural Resources Building in Salt Lake City, in conjunction with the state UDEM EOC at the Utah State Capitol, the State Hazards Mitigation Team, various local governments, and other agencies. Where or when mobile and/or landline phone communication is unavailable, the UGS can use radio communication between the various EOCs and field staff throughout the central Wasatch Front.

Since 1850, at least 36 fatalities from geologic hazards have been documented in Utah, and a significantly higher but undetermined number of injuries, along with billions of dollars of economic losses, have occurred. In addition to numerous small geologic-hazard events, several notable events have prompted emergency response activities by the UGS in the past several years. These include the August 2014 Parkway Drive landslide in North Salt Lake, the December 2013 rockfall in Rockville, and the 2012 Seeley Fire debris flows on the Wasatch Plateau.

On the morning of August 5, 2014, a large landslide occurred above Parkway Drive in North Salt Lake. The Parkway Drive landslide (estimated at 300,000 to 400,000 cubic yards) severely damaged a house and a tennis and swim club, and threatens other houses and a nearby natural gas pipeline. The landslide involved an engineered slope that had been part of a gravel pit in the 1990s, but has since been reclaimed and partially developed into the Eaglepoint subdivision. The slope is underlain by Lake Bonneville sands and gravels and Tertiary-age (44 to 49 million years ago) tuffaceous sediments (volcanic deposits that commonly weather to clay). UGS personnel had documented small, shallow landslides at the base of this slope in the mid-2000s. As part of the Parkway Drive landslide emergency response, the UGS quickly started mapping the landslide boundaries and documenting landslide movement

UGS engineering geologist monitoring movement of the Parkway Drive landslide with GPS equipment (photo courtesy of Ben Erickson).

See cover for photo of the North Salt Lake landslide. Caption on inside cover.

and features using precision GPS equipment and photographs the day of the main movement event, and provided that information to North Salt Lake and UDEM. The UGS continues to routinely monitor the landslide and assist local homeowners and others with questions about the landslide.

On December 12, 2013, a large rock mass detached from a cliff above the town of Rockville and then rolled and bounced downslope and impacted a house, killing the two occupants inside. This rockfall occurred in an area where the UGS had mapped a high rockfall hazard the previous year. The cliff from which the rockfall initiated is approximately 375 feet above the house, and the boulders traveled approximately 750 feet before destroying the house. The two largest boulders to reach the site weighed an estimated 490 and 520 tons, respectively, and several other boulders were estimated to weigh well in excess of 20 tons. The rockfall occurred just before dark, and geologists from the UGS Southern Utah Regional Office in Cedar City responded at first light the next morning. The geologists performed a reconnaissance of the rockfall source area to determine the relative safety for emergency responders in the damaged area below, including the demolished house and garage, and provided information to the Springdale Chief of Police, who managed the emergency as the Incident Commander.

In June and July 2012, the Seeley Fire burned 75 square miles in central Utah, and rainfall triggered fire-related debris flows during and immediately after the fire. The UGS was already mapping landslides in an adjacent area of the Manti–La Sal National Forest as part of a long-term mapping project, and was familiar with the landslide and debris-flow potential of the area. The UGS and U.S. Forest Service (USFS) quickly modified an existing agreement so that landslide and debris-flow reconnaissance and mapping could be funded for the burned area (see article by Richard Giraud and Greg McDonald in the September 2013 issue of *Survey Notes*, v. 45, no. 3, p. 1). Mapping of the fire area provided valuable information to the USFS so that informed decisions could be made about public access, including road, campground, and picnic area closures, as many of these areas and facilities were directly impacted or were in the path of possible future debris flows. The USFS faced significant pressure by the public and others to keep forest facilities open, and the mapping information was critical to effectively determine which facilities faced high enough risk to justify temporary or permanent closure. Several campgrounds that the USFS closed were later impacted by fire-related debris flows, so potentially many injuries and even loss of life may have been prevented as a result of UGS recommendations. Additionally, the provided information was used in the planning process for constructing debris basins to contain future debris flows, for the siting of temporary weather stations used for storm debris-flow potential warnings by the National Weather Service, and for reducing the risk to other infrastructure in the area, including the PacifiCorp Huntington power plant.

After the initial emergency response, local governments are often left with uncertainty regarding what to do about the emergency event over time, how to minimize the impact to residents and others, how to reduce the risk of future events, and whether other areas are at risk and what can be done to reduce the risk. The UGS provides geologic advice to local governments and the public after an event to help them make informed decisions on the potential for additional, future events; possible mitigation measures to reduce risk (what to consider in the project, known problematic geologic conditions, what qualifications are needed by professional consultants, etc.); and on restricting public access to specific areas, if warranted, to protect public safety.

As no Utah local governments have engineering geologists experienced with geologic hazards on staff (a few local governments have a private consulting geologist on contract), the services provided by the UGS are critical during and after geologic-hazard events. As a non-regulatory scientific agency, the UGS provides unbiased, objective geologic information to local governments and the public, so informed decisions can be made to protect the public and others from geologic hazards, including life safety, injury, and economic impacts.

For More Information

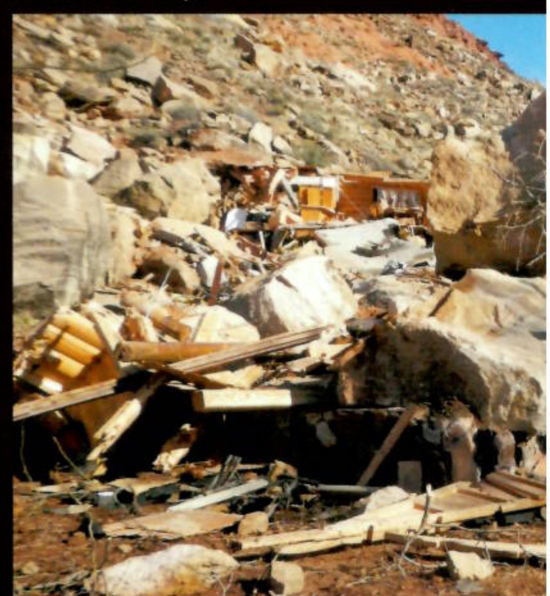
Geologic Hazards Program: http://geology.utah.gov/ghp/

Utah Division of Emergency Management: http://publicsafety.utah.gov/emergencymanagement/

Parkway Drive landslide data: http://geology.utah.gov/utahgeo/hazards/landslide/parkwaydrive/index.htm and http://geodata.geology.utah.gov/pages/search.php?search=!collection108&bc_from=themes

Rockville rockfall report: http://geology.utah.gov/online/ri/ri-270.pdf

Landslide inventory map of the 2012 Seeley Fire: http://geology.utah.gov/online/ss/ss-153.pdf



A fire-related debris flow carrying large boulders and logs flowed through the Bridges Campground in 2014. Fortunately, the campground was unoccupied, as it had been closed after the 2012 Seeley Fire (photo courtesy of Richard Giraud).

ABOUT THE AUTHOR

Steve Bowman has 17 years of experience as a geological engineer/engineering geologist, 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 and Engineer in Utah, a Professional Geological Engineer in Nevada, and certified as a LEED Accredited Professional. Recent projects include coordinating the Basin and Range Province Seismic Hazards Summit III and the Utah Earthquake Working Groups, LiDAR data planning and acquisition, geologic data preservation, landslide inventory mapping, and historical aerial photography compilations.

December 12, 2013, fatal rockfall in Rockville, Utah. Two people perished when their house was struck by the rockfall.

UGS engineering geologists inspecting landslide features and monitoring landslide movement with GPS equipment at the Parkway Drive landslide, North Salt Lake (photo courtesy of Adam Hiscock).

Geologic-Hazard Information Available on the UGS Website

A wide variety of geologic-hazard-related information is available on our website for use in hazard mitigation and other projects (http://geology.utah.gov/ghp/consultants/index.htm), and should be considered when planning new development or infrastructure. This information includes guidelines for conducting geologic-hazard investigations; geologic-hazard maps showing the mapped location and relative magnitude of various hazards; geologic maps showing bedrock and Quaternary (soil) geology; various reports describing specific hazards, investigations, and/or emergency events; scanned aerial photographs that may visually show various hazards and can be used to document the location and past timing of specific hazard events, such as landslides and rockfall; and scanned unpublished files, reports, and photographs collected by the UGS documenting various geologic hazards and specific locations. Often, the long-term economic impact of geologic hazards to local governments, landowners, and the public is not adequately addressed in development and infrastructure planning; geologic information provided by the UGS can help address this issue and reduce the uncertainty associated with and lack of awareness of geologic hazards.

LiDAR

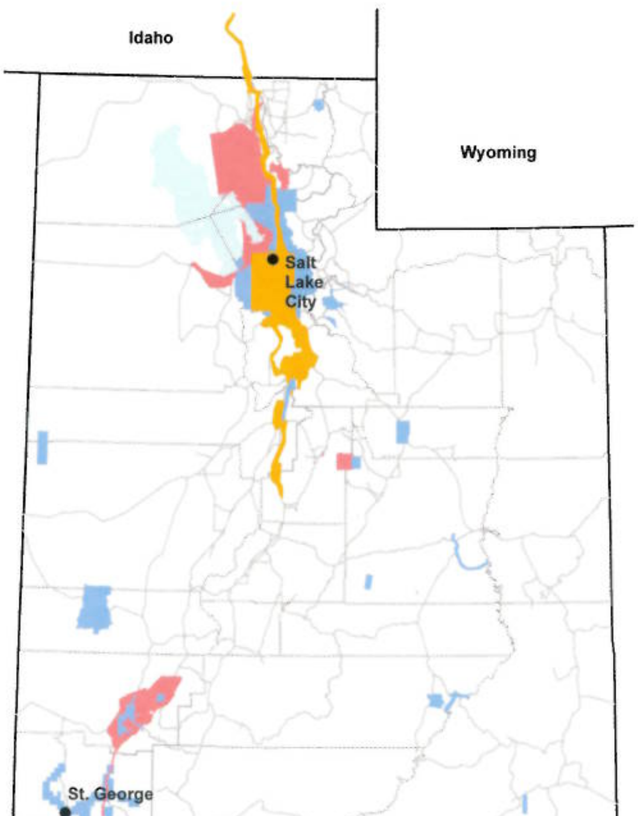
Valuable Tool in the Field Geologist's Toolbox

BY STEVE BOWMAN, ADAM HISCOCK, MIKE HYLLAND, GREG MCDONALD, AND ADAM MCKEAN

LiDAR (Light Detection and Ranging) has become one of the most valuable tools for geologists studying the Earth's surficial processes and landforms. LiDAR is a technique of transmitting laser pulses and measuring the reflected returns to determine the distance to an object or surface. LiDAR data are commonly collected by means of an aerial survey, where a LiDAR instrument mounted on the floor of an aircraft sends pulses at a rapid rate (typically billions of pulses for a project) to determine ground-surface elevations. Computer processing of the raw LiDAR data, including digital "removal" of vegetation, results in highly accurate, bare-earth digital elevation models (DEMs) of the ground surface. Landslides, small fault scarps, and other geologic features that are difficult to detect visually in the field or on aerial photographs can often be clearly shown on LiDAR-based imagery, allowing for very detailed surficial geologic mapping.

For analyzing large areas, LiDAR has several advantages over traditional surveying methods. The high point-spacing density of LiDAR results in much higher resolution, and the ability to digitally manipulate the data in different ways maximizes the topographic information that can be obtained. LiDAR data can be used to create a hillshade image, which simulates a three-dimensional representation of the ground surface "illuminated" as if the sun was shining on it from a particular location in the sky. The location of the "sun" (both its azimuth, or compass direction, and its vertical angle above the horizon) can be selected to highlight topographic features having a particular trend across the landscape. Other LiDAR-derived images useful for mapping landforms include slopeshade images, which indicate slope steepness, and surface-contour (topographic) maps, where the contour interval (vertical distance between adjacent contour lines) can be selected to best illustrate the topography. In addition to surficial geologic mapping, the versatility of LiDAR data lends itself to numerous other applications such as watershed analysis, vegetation analysis, wetlands mapping, land-use planning, and others.

The Utah Geological Survey (UGS) and its various partners have been acquiring high-resolution LiDAR data across Utah in support of geologic mapping and other research projects, including 1-meter data in 2011 and 0.5-meter data in 2013–14. We are also working toward acquiring additional 0.5-meter LiDAR data in areas of northern Utah in 2015. Several UGS projects highlight the utility of the recently acquired LiDAR data. These include geologic mapping of the Salt Lake City North quadrangle, fault trace mapping along the Wasatch fault zone, and landslide mapping on the Wasatch Plateau.

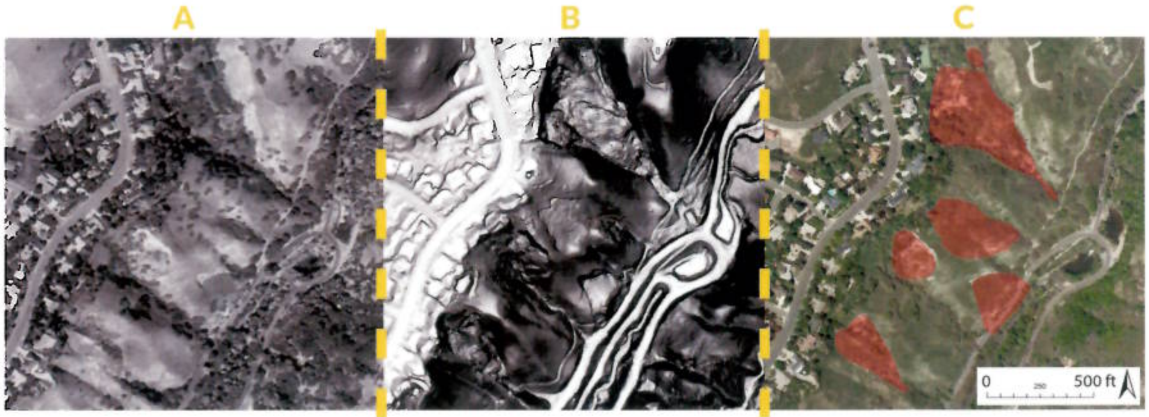


Approximately 1,902 square miles of 1-meter LiDAR data was acquired in 2011 for the Cedar and Parowan Valleys, Great Salt Lake shoreline/wetland areas, Hurricane fault zone, Lowry Water area, Ogden Valley, and North Ogden (red), and 1,422 square miles of 0.5-meter data was acquired in 2013–14 for the entire Wasatch fault zone from north of Malad City, Idaho, south to near Fayette, Utah, and most of Salt Lake and Utah Valleys (orange). Other areas of available LiDAR data shown in blue.

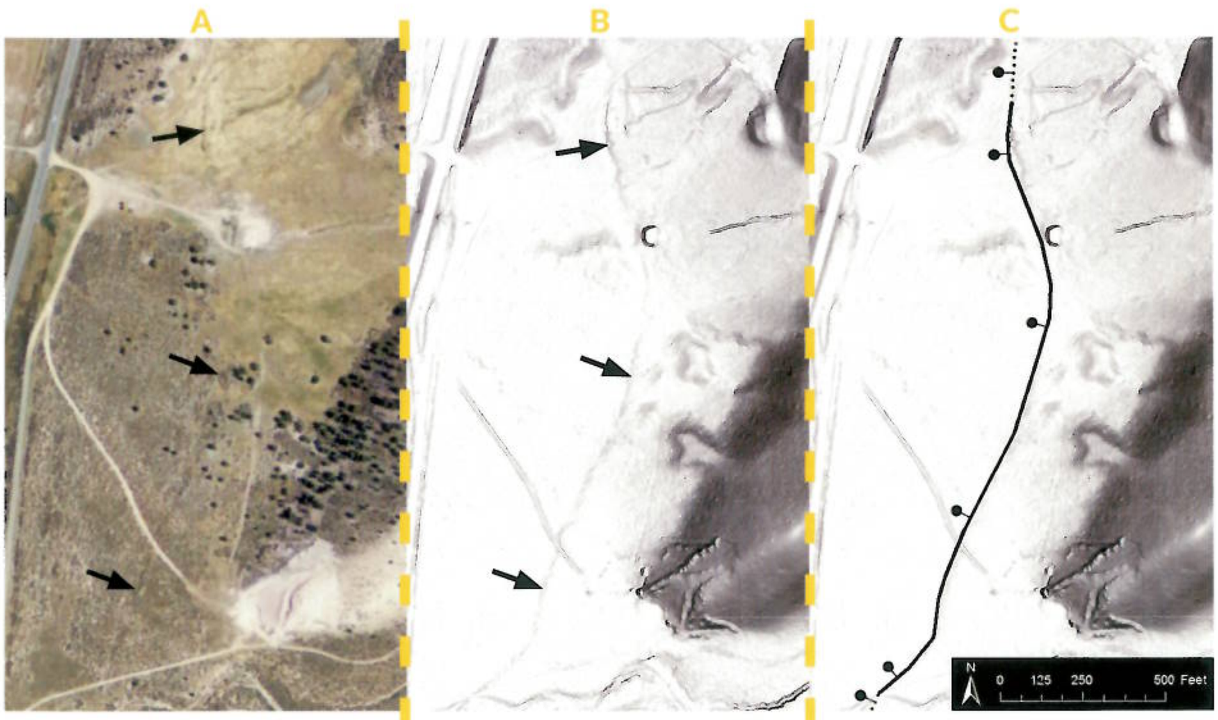
Geologic Mapping of the Salt Lake City North Quadrangle

New geologic mapping of the Salt Lake City North quadrangle used two vintages of LiDAR data to map landslides in City Creek Canyon: 2-meter data acquired in 2006 and 0.5-meter data acquired in 2013–14. LiDAR-derived hillshade and slopeshade images were particularly effective tools for enhancing and identifying landslide geomorphology.

Landslide terrain appears on hillshade and slopeshade images as a rough ground surface relative to the comparatively smooth surface of the adjacent undisturbed ground. Previous geologic maps of the City Creek



Three views of the historically active City Creek landslides that lie between Capitol Boulevard and the City Creek Canyon floor. (A) In the 1990s aerial photograph, the landslides are obscured by brush on the canyon wall, whereas in the new (B) 0.5-meter 2013–14 LiDAR slopeshade map the landslides and their geomorphology are clearly visible. (C) The newly remapped landslides are shown in red on the 2009 aerial photograph.



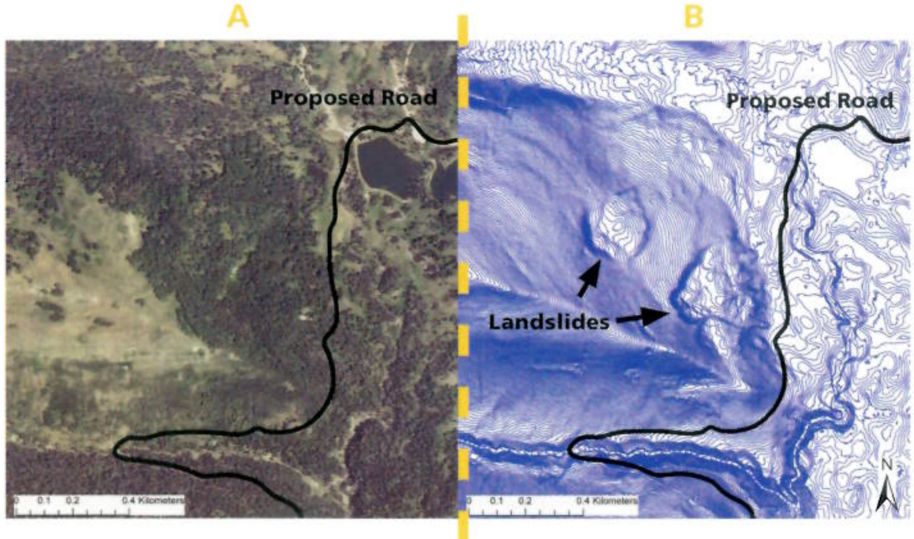
Example of fault scarp mapping on the Levan segment of the Wasatch fault zone in central Utah. (A) Subtle expression on 2011 aerial photograph of a very small fault scarp (scarp location indicated by arrows). (B) The scarp shows clearly on the 2013–14 LiDAR slopeshade map. (C) Annotated slopeshade shows mapping of the west-facing fault scarp (bar and ball symbol on down-dropped side).

area only showed the main City Creek landslide, a historically active landslide that lies between Capitol Boulevard and the City Creek Canyon floor. The 2-meter LiDAR data helped to identify seven additional landslides in the immediate vicinity, but some of the landslide boundaries remained uncertain even after field checking. Hillshade and slopeshade images created from the new 0.5-meter LiDAR data clarified the landslide boundaries and allowed for more detailed landslide mapping and a high degree of confidence.

In addition to landslide mapping, LiDAR data contributed to more detailed and accurate mapping of traces of the Warm Springs fault of the Wasatch fault zone and Granger and Taylorsville faults of the West Valley fault zone in the Salt Lake City North quadrangle, as well as surficial geologic mapping of the quadrangle as a whole.

Fault Trace Mapping along the Wasatch Fault Zone

LiDAR data are being used to generate new fault trace maps along the Wasatch fault zone, Utah's largest and most hazardous fault zone. The 0.5-meter LiDAR data acquired in 2013–14 are serving as the primary tool for this mapping, in



Area of proposed USFS road reroute near Potters Ponds. Landslides on tree-covered slope above proposed road are difficult to discern on 2011 aerial photograph (A), but are clearly evident on 1-meter contour map generated from high-resolution LiDAR (B).

addition to historical aerial photography and on-the-ground field checking. Over the course of this project, many previously unmapped fault traces have been identified thanks to the high resolution of the new LiDAR data.

In the past, low-sun-angle aerial photography had become a standard tool for mapping fault scarps. In this technique, photographs are taken from an aircraft during morning or evening hours depending on whether the fault scarps are dominantly west- or east-facing, respectively; the low angle of the sun results in steep scarp faces appearing as linear shadows. LiDAR-derived slopeshade and hillshade images have the advantage of being able to manipulate the DEM to maximize the digital "shadow" effect, which is extremely helpful for mapping very small scarps and those having a trend that varies from north-south. Using a combination of these viewing methods, as well as LiDAR-derived surface contour maps, fault scarps can be mapped with high accuracy.

The very high resolution of the 0.5-meter LiDAR data has allowed us to more accurately map traces of the Wasatch fault zone, even in areas of dense vegetation, and has helped us identify many additional traces of the fault that cross areas of potential future development.

Landslide Mapping on the Wasatch Plateau

LiDAR data acquired in 2011 included a roughly 64-square-mile area in the Manti–La Sal National Forest in the central part of the Wasatch Plateau, within the area of a multi-year landslide mapping project by the UGS in cooperation with the U.S. Forest Service (USFS). The 1-meter data were acquired in an area of planned landslide inventory mapping where the geology, vegetation types and densities, and topography are highly variable. This landslide inventory mapping served as a test case to compare the LiDAR-based surficial geologic mapping with more traditional mapping methods, including stereo aerial-photograph interpretation, topographic map examination, and field mapping.

The high-resolution LiDAR data have proven to be very beneficial for mapping landslides on the Wasatch Plateau. Notably, LiDAR enhances surficial mapping abilities on heavily vegetated slopes. Within the LiDAR acquisition area, several landslides were easily identifiable on tree-covered slopes that were otherwise difficult or impossible to observe by traditional methods. A good example of where LiDAR proved beneficial is an area near a proposed USFS road relocation southwest of Potters Ponds. On aerial photographs, a forested slope adjacent to the proposed road alignment shows no clear evidence of landsliding, and potential landslide features are difficult to discern. However, a LiDAR-derived contour map shows landslide geomorphology very clearly, including internal landslide features and areas of younger, inset landsliding.

In general, LiDAR enabled more detailed mapping of landslides in the Wasatch Plateau landslide inventory area, and the 1-meter resolution improved mapping accuracy and efficiency over traditional mapping methods.

Conclusions

Overall, LiDAR is proving to be an extremely useful tool that enhances our surficial geologic mapping capabilities. In a few cases, LiDAR did not improve mapping of problematic areas where visibility on aerial photographs was relatively good. Like any mapping tool, LiDAR should not be relied on alone, and detailed fieldwork remains indispensable for a full understanding of the geology specific to an area. But, while a compass, stereoscope, aerial photography, rock hammer, and hand lens are still essential tools, LiDAR is a great addition to any geologist's toolbox.

LiDAR data in Utah can be accessed through the following links:

Utah Geological Survey – *http://geology.utah.gov/databases/lidar/lidar.htm*

Utah Automated Geographic Reference Center – *http://gis.utah.gov/data/elevation-terrain-data/*

OpenTopography – *http://opentopography.org/*

ENERGY NEWS

DEVELOPMENT OF NEW MARKETS FOR UINTA BASIN CRUDE VIA RAIL

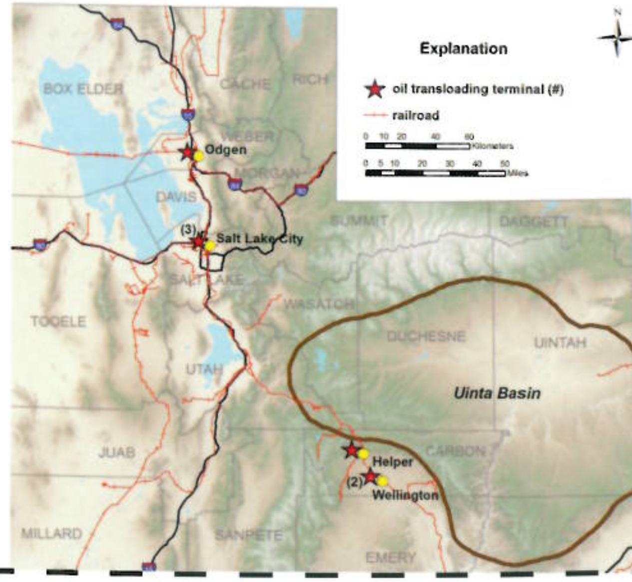
BY DAVID TABET

From 2006 to 2013, U.S. annual oil production increased over 48 percent from 1,830 million barrels (bbls) to 2,716 million bbls. Similarly over the same period, Utah's annual oil production jumped 59 percent from 22 million bbls to 35 million bbls, mainly from the Uinta Basin of northeastern Utah. This rapid increase in Uinta Basin oil production has taxed the ability of its typically sole market at Salt Lake City refineries to absorb the extra oil. Another problem is that Uinta Basin crude is "waxy" and solidifies at normal outside temperatures to the consistency of shoe polish, which makes transport via pipeline impossible unless the pipeline is heated and insulated. To find new out-of-state markets for Uinta Basin crude oil, producers there have recently started shipping their product to other states in heated and insulated rail tank cars.

The transport of Uinta Basin crude oil by rail to markets outside Utah started significantly in 2013, when a temporary shut-down of a Salt Lake City refinery briefly caused a local glut of oil. Uinta Basin oil producers such as Berry/Linn Petroleum, Crescent Point Energy, Newfield Exploration, and Ultra Petroleum responded by shipping their crude oil out-of-state in coil-heated and insulated tank cars. Historically, Uinta Basin waxy crude has been captive to the refineries around Salt Lake City, and was sold at a discounted price of about $13 to $17 per bbl less than oil from other areas in the U.S. Recently, the price differential has been high enough that even with the extra rail transportation costs, Utah oil could be shipped to other higher priced U.S. market areas at a profit.

One such nearby market is California. While recent overall U.S. and Utah oil production was increasing, oil production in California was generally declining to flat. In addition, oil production from Alaska, a major supplier to California refineries, has been in steady decline since 1990. Significant domestic rail imports of crude oil to California began in mid-2010, first mainly from North Dakota, but since then rail-based oil shipments have come from other places such as Canada, New Mexico, Oklahoma, and Texas. Rail shipments of Utah crude to California began in July 2013 at about 11,000 bbls, and have grown to over 100,000 bbls in September 2014. In May 2014, Arc Terminals in Portland, Oregon, reported that it had begun accepting rail shipments of oil from Utah under a contract with Chevron, but the volume was not disclosed. Oregon has no refineries so the oil was likely transferred onto ships or barges for delivery to another West Coast refinery.

Various alternatives to trucking crude oil out of the Uinta Basin are being considered. In February 2014, Tesoro Corporation, which owns one of the Salt Lake City oil refineries, announced a proposal



to build a heated, insulated pipeline from the basin to Salt Lake City. In June 2014, a feasibility report prepared for Duchesne and Uintah Counties was released for a new 100-mile rail line into the Uinta Basin to connect businesses and industries there directly with interstate rail lines. Both of these proposed projects are having Environmental Impact Statements prepared to determine their environmental feasibility and are at least several years away from inception. In the meantime, crude oil has begun to be trucked to rail terminals outside the Uinta Basin for shipment via rail to markets outside of Utah.

To ship Utah crude oil by rail, six new Utah-based oil transloading terminals have been constructed: (1) Musket Corporation near Helper in June 2010; (2) Newfield Exploration in Ogden in March 2013; (3) and (4) Savage Services in both Salt Lake City and Wellington in August 2013; (5) Crescent Point Energy in Salt Lake City in December 2013; and (6) Price River Terminal in Wellington in December 2013. These new terminals supplement an existing oil terminal built by Chevron Corporation in Salt Lake City in the 1980s. These transloading facilities accept truck shipments and transfer the oil into rail tank cars for transport to out-of-state markets. As of early 2014, these seven oil transloading terminals had a combined capacity of over 50,000 bbls per day, or roughly equivalent to the current Uinta Basin "waxy" crude oil refining capacity near Salt Lake City (total refinery capacity is about 173,000 bbls per day). The actual amount of crude oil shipped out of Utah by rail is difficult to determine, but for 2014 will probably be close to 0.9 million bbls, or about 2.3 percent of Utah's 2014 crude oil production. New U.S. Department of Transportation collision strength and safety standards for oil railcars, released in July 2014, may dampen rail oil traffic temporarily until sufficient new or retrofitted car capacity is available. Once the temporary, sturdier railcar shortage is overcome, the various oil transloading terminals will provide ample new markets for Uinta Basin waxy crude oil via rail, perhaps eventually capturing up to half of Utah's annual oil production.

Utah Crude Oil Transloading Terminals

COMPANY	CITY LOCATION	DATE OPENED	ESTIMATED CAPACITY
Chevron Corporation	Salt Lake City	1980s	?
Crescent Point Energy	Salt Lake City	December 1, 2013	10,000 barrels/day
Musket Corporation	Helper	June 14, 2010	2000 barrels/day
Newfield Exploration	Ogden	March 1, 2010	11,000 barrels/day
Price River Terminal	Wellington	December 1, 2013	15,000 barrels/day
Savage Services	Wellington	August 22, 2013	7500 barrels/day
Savage Services	Salt Lake City	August 22, 2013	7500 barrels/day
TOTAL			**53,000 barrels/day**

What is the Boxcar Seawall?

Glad You Asked

by Jim Davis

Great Salt Lake is split into a north arm and south arm by a railroad causeway. The two arms have differing color, chemistry, biology, and lake surface elevation (see article by J.W. Gwynn in *Survey Notes*, 2002, v. 34, no. 1, p. 1). The history of this disunion begins with a railroad shortcut, followed by periodic construction projects necessitated by the dynamic character of Great Salt Lake. A feature associated with the railroad causeway, known as the boxcar seawall, is an intriguing piece of this story.

An outstanding feat of American railroad engineering is the 102-mile-long Southern Pacific Railroad Lucin Cutoff stretching from Ogden to Lucin, Utah. It bypassed the circuitous 1869 Promontory Summit route, where the Golden Spike was hammered, by going straight across Great Salt Lake. The Lucin Cutoff took just over two years to construct and was fully operational by 1904. The segment crossing the open waters of Great Salt Lake was the most challenging, including more than 8 miles across Bear River Bay and more than 20 miles from the Saline railroad siding to the Lakeside settlement.

A prompt solution was required, so it was decided that the best initial step to maintaining the causeway was a "boxcar seawall" to act as a breakwater.

The original Lucin Cutoff included three rock embankments constructed in the lake: the Bagley Fill across Bear River Bay, the Rambo Fill on the westernmost side at Lakeside, and the Saline Fill at the southern end of the Promontory Mountains, all totaling nearly 15 miles. The 12 miles between the Rambo and Saline Fills was spanned with the longest wooden trestle bridge in the world, now dismantled and reclaimed. Fifty years after construction, the deteriorating trestle required extensive upkeep and an expensive overhaul loomed. Because rail traffic could not be disrupted, the idea of restoration was abandoned in favor of sidestepping the trestle with a solid-fill causeway to be placed 1,500 feet north of and parallel to the trestle, connecting the Rambo and Saline Fills. The causeway took three years to build and was completed in 1959. The amount of material handled was nearly a third of that excavated for the Panama Canal.

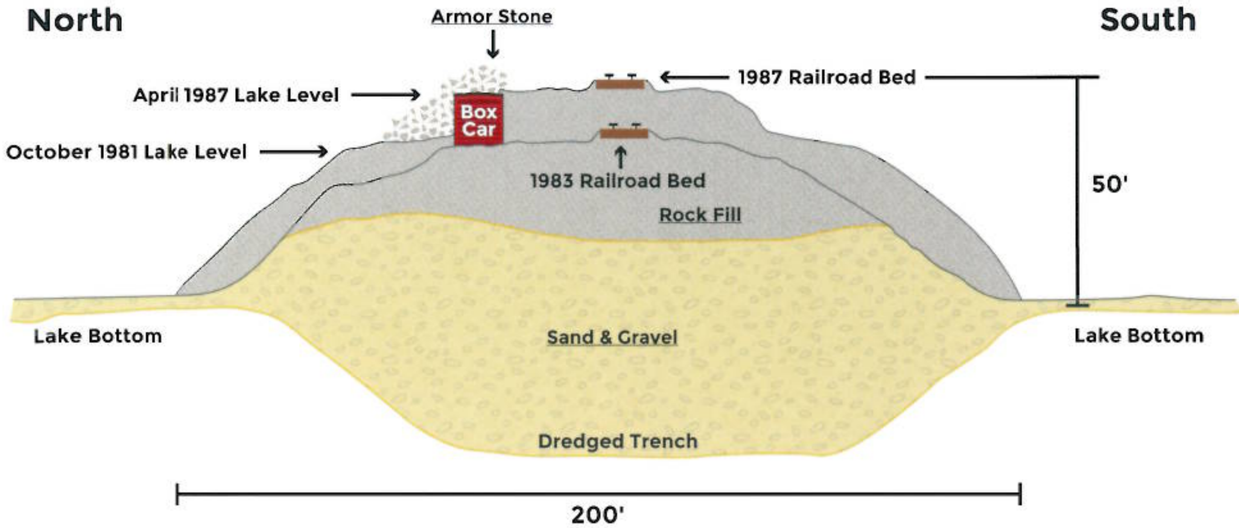
Boxcar seawall from the "seaward" side, September 1983, with berm on far left.

A year after completion, the causeway had sunk about a foot into the soft sediments of the lakebed, and nine years later had sunk 3 more feet. It continued sinking a few inches each year thereafter. The diminishing freeboard, or distance between the lake level and the top of the causeway, was not an immediate concern because the lake level remained low, at least for the first two decades after construction. Then, from October 1981 to April 1987, the lake rose more than 13 feet, to nearly 4,212 feet above sea level, a high not seen in more than a century. Storms over Great Salt Lake can generate waves greater than 8 feet in height, and due to the high salinity of the water, the waves are denser and have higher energy than ocean waves. Storms can also produce a storm surge on the lake, pushing the water against the shore or causeway and, in effect, raise the lake level 1 or 2 feet. By 1983, waves began to overtop the causeway, scouring and eroding the protective riprap.

A prompt solution was required, so it was decided that the

(below) A section of the boxcar seawall from the "landward" side of the causeway, September 1983. The top of the boxcars tower above the rails. Over the next five years the seawall was buried.

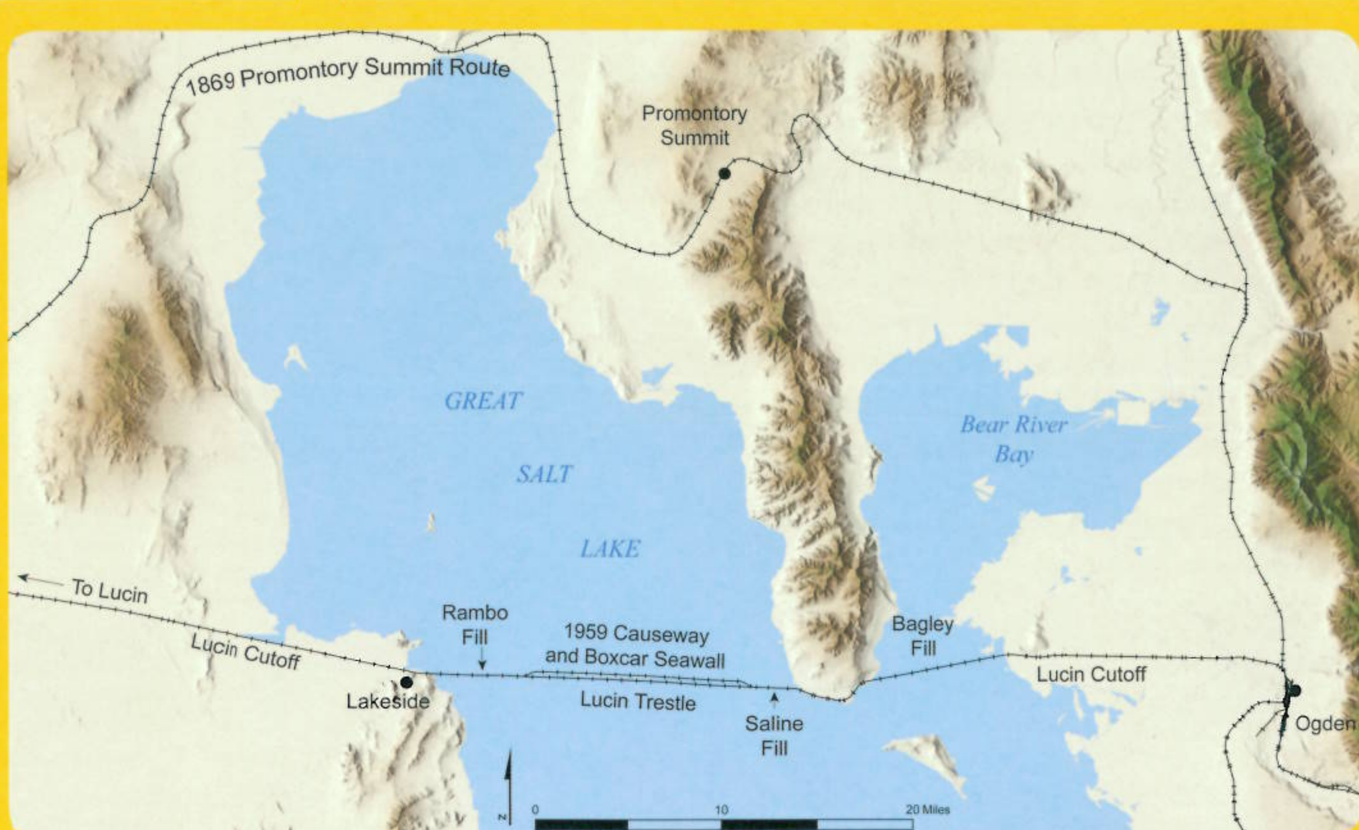
Photos obtained from the Paul A. Sturm Great Salt Lake collection, Utah Geological Survey.



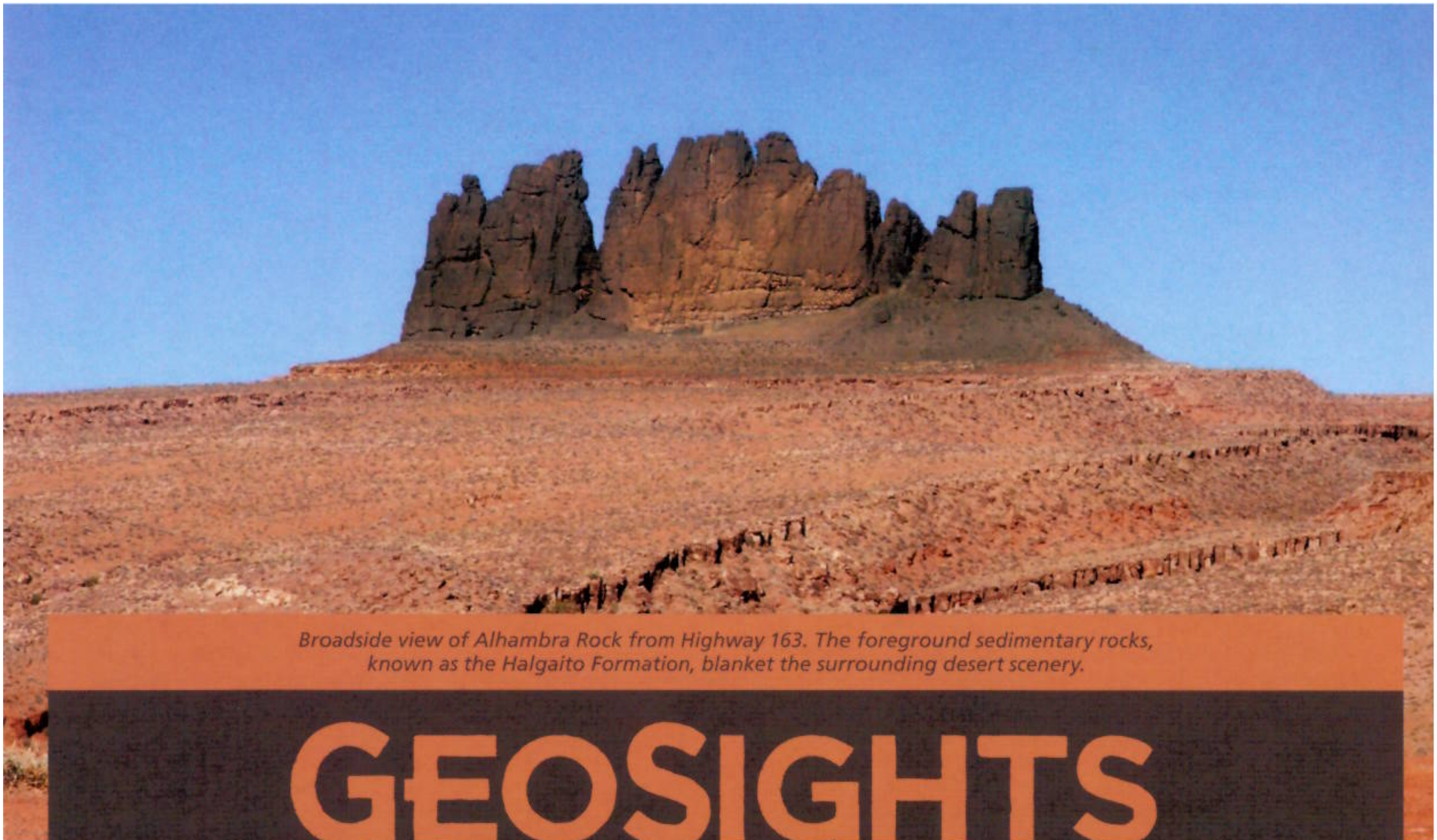
A generalized cross section of the 1959 Great Salt Lake causeway and the 1983–87 enlargement. Modified from Southern Pacific Lines, American Railway Engineering Association, Committee 1, August 24, 1992.

best initial step to maintaining the causeway was a "boxcar seawall" to act as a breakwater. The seawall was intended to defend the north side of the causeway, which bears the most intense impact from storm waves. In August and September of 1983, the Southern Pacific Company placed 1,430 surplus boxcars, hopper cars, and gondolas (low-sided, open-topped cars) along the edge of the embankment, creating a barrier between the causeway and lake. The wheel and axle assemblies were removed from the cars, and the ends of the roofs were cut out leaving only a center strip in the middle third. The cars were placed end-to-end in a shallow ditch between the causeway and a small berm and then filled with quarried rock.

Raising the elevation of the entire causeway began the same year the seawall was built and continued until 1987, requiring millions of tons of stone. Crushed limestone was used to raise the causeway more than flush with the top of the boxcars, as much as 10 feet in places. The remainder of the seawall was concealed with boulders weighing one ton or more, dubbed "armor stone," to shield the causeway from erosion. The boxcar seawall provided crucial protection during the time needed to raise the causeway, sheltering it for years and easing disruptions to train traffic, even as the lake continued its rapid rise. The seawall signifies yet another large-scale engineering success in the challenging and enduring history of the path across Great Salt Lake.



The Great Salt Lake segment of the 1902–1904 Lucin Cutoff.



Broadside view of Alhambra Rock from Highway 163. The foreground sedimentary rocks, known as the Halgaito Formation, blanket the surrounding desert scenery.

GEOSIGHTS

Alhambra Rock, San Juan County, Utah

BY **MARSHALL ROBINSON**

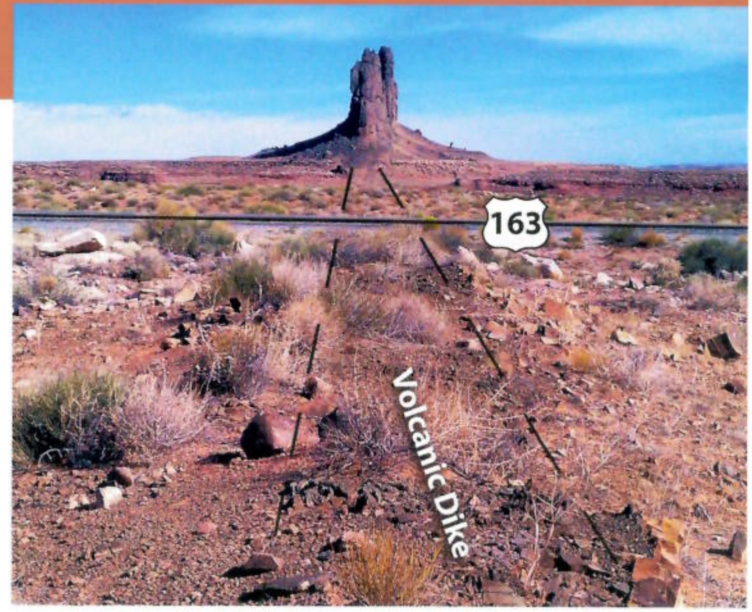
Beautiful sandstone buttes, mesas, and spires dominate the landscape of the Four Corners region, a fact proven repeatedly as these sedimentary splendors grace the covers of countless calendars, and provide perfect movie backdrops. The focus of this article, however, is on the lesser known yet equally remarkable volcanic remnants known as necks, plugs, and dikes in this same region, specifically Alhambra Rock.

Dozens of these volcanic landforms freckle an approximately 9,000-square-mile area in the Four Corners region called the Navajo volcanic field. Two of the most recognized names of these volcanic landforms are 1,581-foot-tall Shiprock and 1,437-foot-tall Agathla Peak, which are in New Mexico and Arizona, respectively. Though it lacks the towering height of Shiprock and Agathla Peak, Alhambra Rock's stark contrast to its surroundings makes it a worthy "GeoSight." Located in southeastern Utah, about 2 miles southwest of Mexican Hat, Alhambra Rock received its name from early Spanish travelers who thought that its profile resembled the medieval Moorish castle bearing the same name in Granada, Spain.

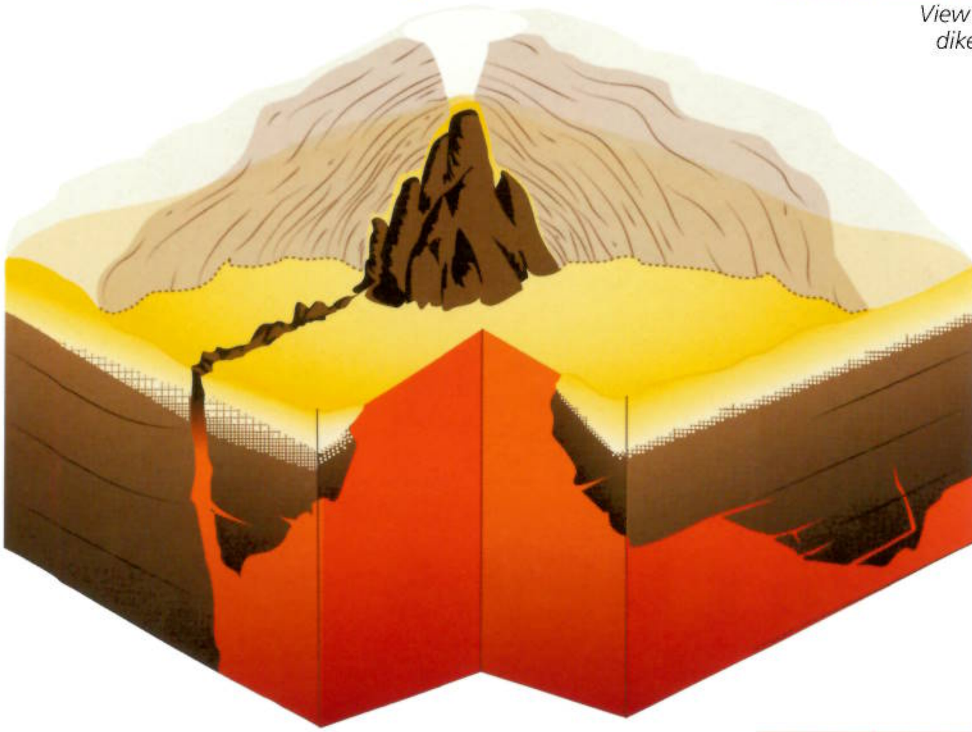
In plan view, the volcanic features in the region are typically circular in shape with multiple linear dikes radiating outward from a central point. Alhambra Rock is strange in that it protrudes upward from a *singular*, very low relief, 3-mile-long dike. This dike is easily seen when looking at it on an aerial image; however, it is easily missed when driving by due to its extremely low profile (the dike's igneous rocks eroded at nearly the same rate as the surrounding sedimentary rocks, leaving the dike very little vertical relief). If you ever find yourself driving south along U.S. Highway 163 near Mexican Hat, make sure to look to your right (west) after crossing the San Juan River and you will see Alhambra Rock jutting over 250 feet into the sky. Just do not expect to find its accompanying dike unless you take time beforehand to pinpoint where it intersects with the road.

GEOLOGIC INFORMATION:

Within the Navajo volcanic field, small cracks in the Earth's crust served as conduits along which rock fragments, gas, and magma were injected, approximately 25 to 30 million years ago, during the Tertiary Period. These explosive events left behind magma- and crushed rock-filled fissures in the crust in which the magma later cooled and hardened beneath the surface. *Diatreme* is the scientific term for these rock-filled fractures, but you would not hurt anyone's feelings if you called them a volcanic plug, throat, or neck instead. The north-south trending dike emanating from Alhambra Rock is essentially a large sheet of cooled magma that has cut through the surrounding rock layers. Alhambra Rock, as we see it today, is the result of millions of years of erosion that washed away the surrounding softer, more erodible rock, leaving behind the weather-resistant remains of the ancient volcanism. Alhambra Rock itself is a menagerie of different greenish-gray igneous rocks, but also engulfs fragments of sandstone, granite, and limestone.



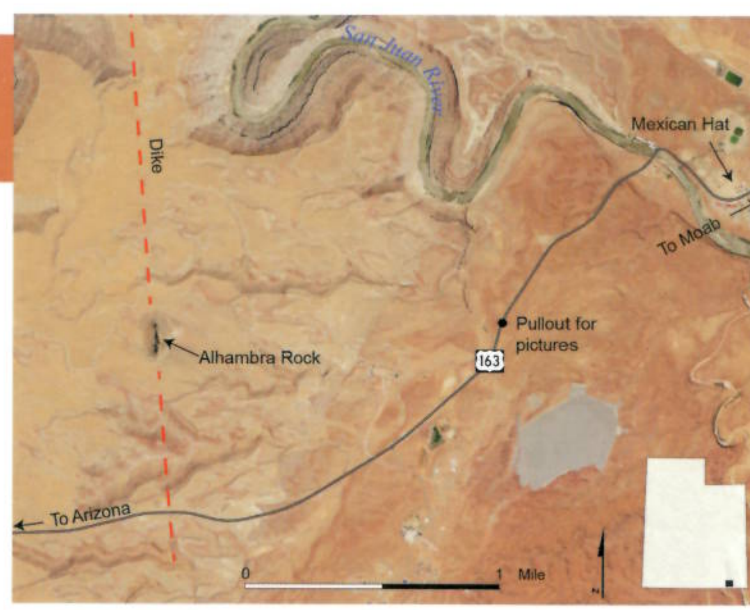
View of Alhambra Rock along the volcanic dike looking north from Highway 163.



This three-dimensional diagram shows a generalized view of Alhambra Rock's past and present landscape. The transparent, light-brown, mountainous shape represents the land surface during the episode of Tertiary volcanism. Millions of years of erosion stripped away these rock layers, leaving behind the bold-colored land surface shown.

How to GET THERE:

Alhambra Rock is located approximately 275 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 20.5 miles to where the bridge crosses the San Juan River. From here, continue another mile to a pullout along the west side of the highway where clear weather will allow a broadside view of Alhambra Rock to the west. To check out the dike, continue south for an additional 1.6 miles to where it intersects the highway. Alhambra Rock is visible from other nearby vantage points as well, including Goosenecks State Park, due to its relief and contrasting color.

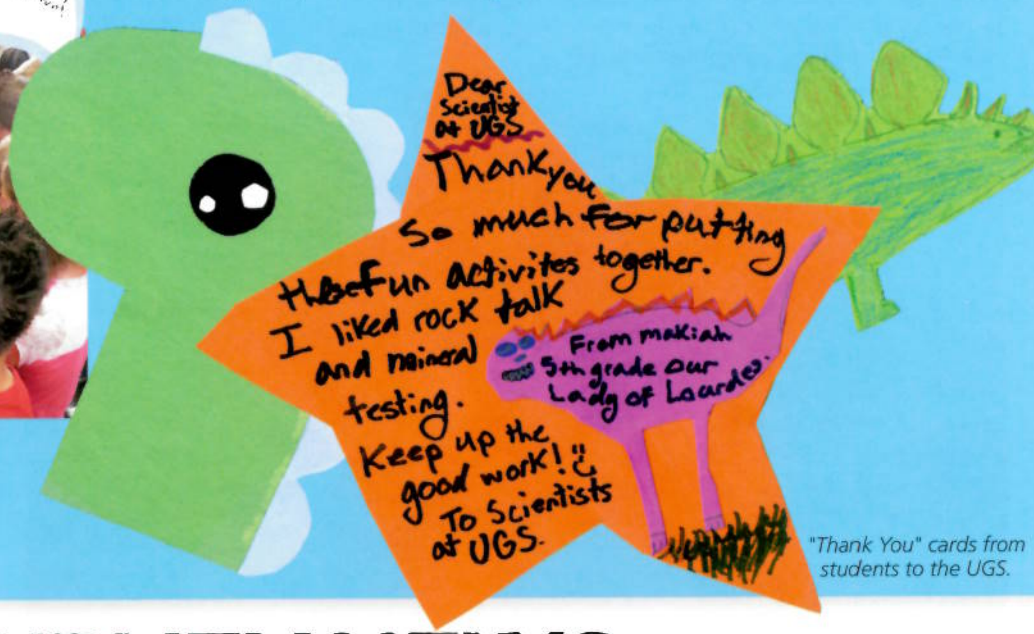


TEACHER'S CORNER I EARTH SCIENCE WEEK 2014

In October, the Utah Geological Survey held its 13th annual Earth Science Week (ESW). In all, 825 students, 11 schools, and some 70 teachers and parents came to celebrate and learn about the Earth. In addition, 34 outside volunteers from universities and numerous agencies in the public and private sector contributed to make the week a total success. We are grateful for all the support and extend a big thank you to our volunteers.

Since its creation in 1998 by the American Geosciences Institute, ESW has encouraged people everywhere to explore the natural world, promote Earth science understanding, application, and relevance in our daily lives, and encourage stewardship of the planet.

One of our favorite parts of ESW is receiving letters from students illustrating their experiences at the five geoscience stations: Rock Talk, Mineral Room, Stream Table, Paleontology Lab, and Gold Panning. We have included some here from ESW 2014.



"Thank You" cards from students to the UGS.

SURVEY NEWS

Pat Stokes recently retired after 17 years as the Natural Resources Map & Bookstore manager. Under her management, the bookstore expanded its geologic and recreational offerings, generating a broad and loyal customer base. Pat is looking forward to having more time for watercolor painting and traveling. We wish her well in her retirement!

Sandy Eldredge retired in September after 30 years with the UGS, including 18 years as manager of the Geologic Information and Outreach Program. Her work contributed to Earth science education in Utah by updating the curriculum in public schools, providing teaching kits, and conducting workshops for science teachers. Sandy's knowledge and cheerful disposition will be greatly missed.

Robert Ressetar bid farewell to the UGS and entered retirement after 10 years of service. Robert was a technical reviewer for the UGS and a senior geologist with the Energy and Minerals Program. Robert's geologic knowledge, law background, and wry sense of humor made him a valuable asset to the UGS. We wish him many happy years of retirement!

MORE SURVEY NEWS

Brian Butler has been promoted to manager of the Natural Resources Map & Bookstore. Congratulations Brian!

Congratulations to **Mike Hylland** who accepted the position of program manager for the Geologic Information and Outreach Program. Mike has worked for the UGS since 1994, mostly in the Geologic Hazards Program.

Chris DuRoss left the Geologic Hazards Program to accept a position as a research geologist with the U.S. Geological Survey in Golden, Colorado. Chris was instrumental in keeping earthquake research at the UGS on the cutting edge. We welcome **Gordon Douglass** as the new GIS analyst in the Geologic Hazards Program, replacing **Corey Unger** who accepted a position with the Utah Department of Transportation.

Welcome to **Brittany Dame**, who accepted a geologist position with the Groundwater and Paleontology Program. **Jennifer Jones** resigned from her position as Wetlands Coordinator to move with her family to Bozeman, Montana.

John Good joined the Editorial Section as a graphic designer, replacing **Elizabeth Firmage** who left to start a new adventure in Okinawa, Japan. Elizabeth has been a great asset to the UGS, and we will miss her creative talent. John comes to us from Utah State Parks and Recreation where he has worked for the past 12 years.

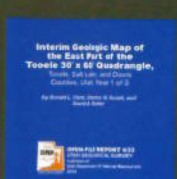
2014 Lehi Hintze Award Winner | PAUL ANDERSON

The Utah Geological Association (UGA) and the Utah Geological Survey (UGS) presented the 2014 Lehi Hintze Award to Paul B. Anderson, consulting geologist based in Salt Lake City. For nearly 40 years, Paul has been a quiet giant in his contributions to Utah geology. Students to experienced professionals within and outside Utah have benefited as he has enthusiastically shared his knowledge of Utah geology through project work, volunteering, and publications. Paul has worked in the private sector including the petroleum, coal, and environmental industries in Utah, and has performed contract work for the UGS, School and Institutional Trust Lands Administration, U.S. Geological Survey, and Utah Division of Oil, Gas, and Mining. Paul was a key member of several major UGS studies, including the Ferron Sandstone reservoir analog project in east-central Utah. His work has been the basis for a greater understanding of the Ferron and river-dominated deltaic oil and gas reservoirs worldwide. Paul has been an active volunteer in Utah's geological community, serving as presidents of the American Association of Petroleum Geologists Rocky Mountain Section and UGA, as well as holding many other offices. He has served as a member of the State Mapping Advisory Committee to help prioritize the UGS's ongoing geologic mapping program, and chaired the Bonneville Salt Flats Technical Review Committee for the Bureau of Land Management. Paul has authored over 20 publications on Utah geology, and was a co-editor of the popular UGA guidebooks *Geology of Utah's Parks and Monuments* and *Road, Trail, and Lake Guides to Utah's Parks and Monuments.*

Named for the first recipient, the late Dr. Lehi F. Hintze of Brigham Young University, the Lehi Hintze Award was established in 2003 by the UGA and UGS to recognize outstanding contributions to the understanding of Utah geology.

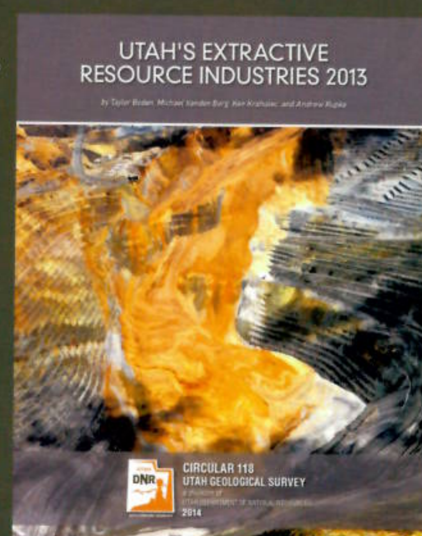
NEW PUBLICATIONS

Paleoseismology of Utah, Volume 25—History of late Holocene earthquakes at the Willow Creek site and on the Nephi segment, Wasatch fault zone, Utah, by Anthony J. Crone, Stephen F. Personius, Christopher B. DuRoss, Michael N. Machette, and Shannon A. Mahan, CD (43 p.), ISBN 978-1-55791-894-9, **SS-151..........$14.95**



Interim geologic map of the east part of the Tooele 30' x 60' quadrangle, Tooele, Salt Lake, and Davis Counties, Utah, year 1 of 3, by Donald L. Clark, Charles G. Oviatt, and David A. Dinter, CD (39 p., 1 pl.), scale 1:62,500, **OFR-633.........$14.95**

Interim geologic map of the east part of the Duchesne 30' x 60' quadrangle, Duchesne and Wasatch Counties, Utah (Year 2), by Douglas A. Sprinkel, CD (19 p., 1 pl.), scale 1:62,500, **OFR-634.........$14.95**



Geologic map of the Panguitch Lake quadrangle, Garfield and Iron Counties, Utah, by Robert F. Biek, John J. Anderson, Edward G. Sable, and Peter D. Rowley, CD (36 p., 2 plates), scale 1:24,000, ISBN 978-1-55791-897-0, **M-268DM....$24.95**

Geologic map of the Haycock Mountain quadrangle, Garfield County, Utah, by Robert F. Biek, John J. Anderson, Edward G. Sable, and Peter D. Rowley, CD (36 p., 2 plates), scale 1:24,000, ISBN 978-1-55791-898-7, **M-269DM......$24.95**

‹**Utah's extractive resource industries 2013**, by Taylor Boden, Michael Vanden Berg, Ken Krahulec, and Andrew Rupke, 29 p., ISBN 978-1-55791-901-4, **C-118......$9.95**

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LANDSLIDE HAZARDS IN UTAH

By Gregg Beukelman

UTAH DNR GEOLOGICAL SURVEY

Landslides: Serious and Common Geologic Hazards

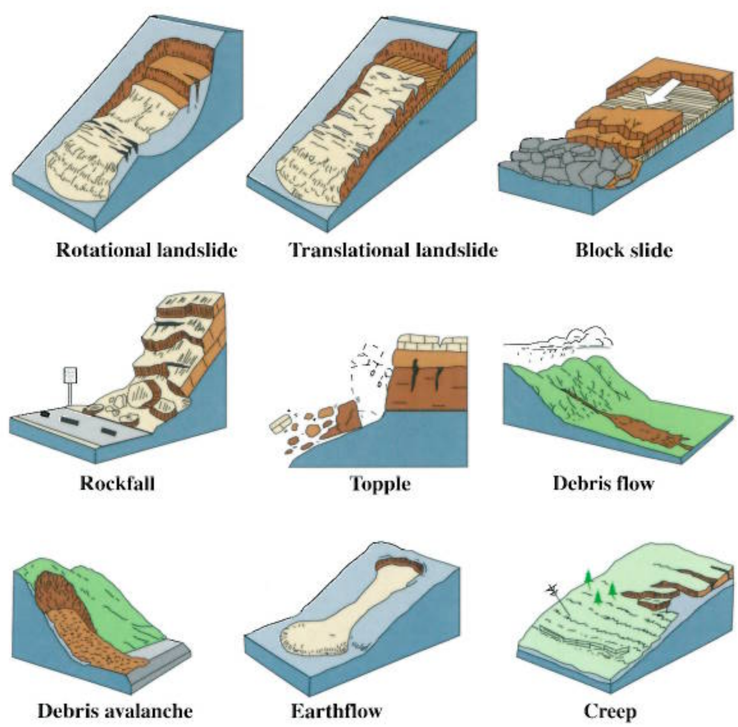
According to the U.S. Geological Survey, landslides are a serious geologic hazard common to almost every state in our country. Nationwide, estimated losses from damaging landslides exceed $2 billion annually. Annual losses from landslide damage in Utah vary, but are often in the millions of dollars; documented losses in 2001 exceeded $3 million and estimated losses in 2005 exceeded $10 million.

Diagram of an idealized landslide showing commonly used nomenclature for its parts.

Types of Landslides

The term "landslide" refers to a downslope movement of rock, soil, and/or organic debris under the influence of gravity. Specific types of landslides are classified by the material involved and type of movement. Material in a landslide can be rock, soil, organic debris or a combination of these materials, and movement types include fall, topple, slide, and flow. Typical landslides in Utah include slides, rock falls, debris flows, and earth flows.

In Utah, many landslides move slowly, but some move quickly with devastating results. Debris flows, which are a type of landslide having very high water content, can travel at speeds greater than 30 to 50 miles per hour.



Major types of landslides and their physical characteristics (from U.S. Geological Survey Fact Sheet 2004-3072 [http://pubs.usgs.gov/fs/2004/3072/fs-2004-3072.html]).

Causes of Landslides

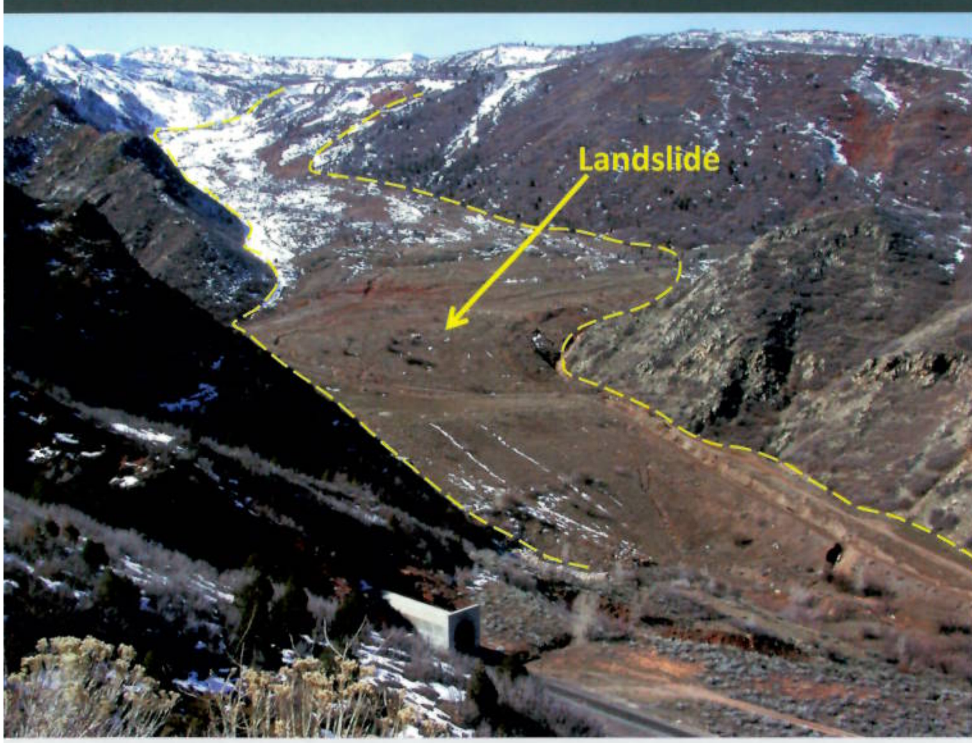
Landslides can be naturally occurring or human-caused. Landslides often result from a rise in groundwater levels caused by increased precipitation, rapid snowmelt, or by human causes such as landscape irrigation or leakage from water-conveyance structures (reservoirs, ponds, pipelines). Modification of a slope that results in oversteepening of the slope, either by removal of material from the lower part of the slope or addition of material near its crest, can also trigger landslides. Development-related slope modification can include loading by construction of buildings or fills, or removal of material during grading for building pads or roadways.

Landslide Distribution

The distribution of landslides in Utah is dependent on geology, topography, and climate. Landslides are most numerous in a zone stretching from the northern Wasatch Front and back valleys southwestward to the St. George area. This zone contains weak rock types, steep slopes, and the highest annual precipitation in the state.

An intense rainfall-triggered debris flow that began in an area burned by a wildfire flowed through part of Santaquin in Utah County in 2002. The debris flow quickly inundated this Santaquin subdivision, leaving behind the dark, muddy deposits seen in this photo. (Photo credit: Dale Deiter, U.S. Forest Service)

Thistle Landslide—World-Class Landslide in Utah



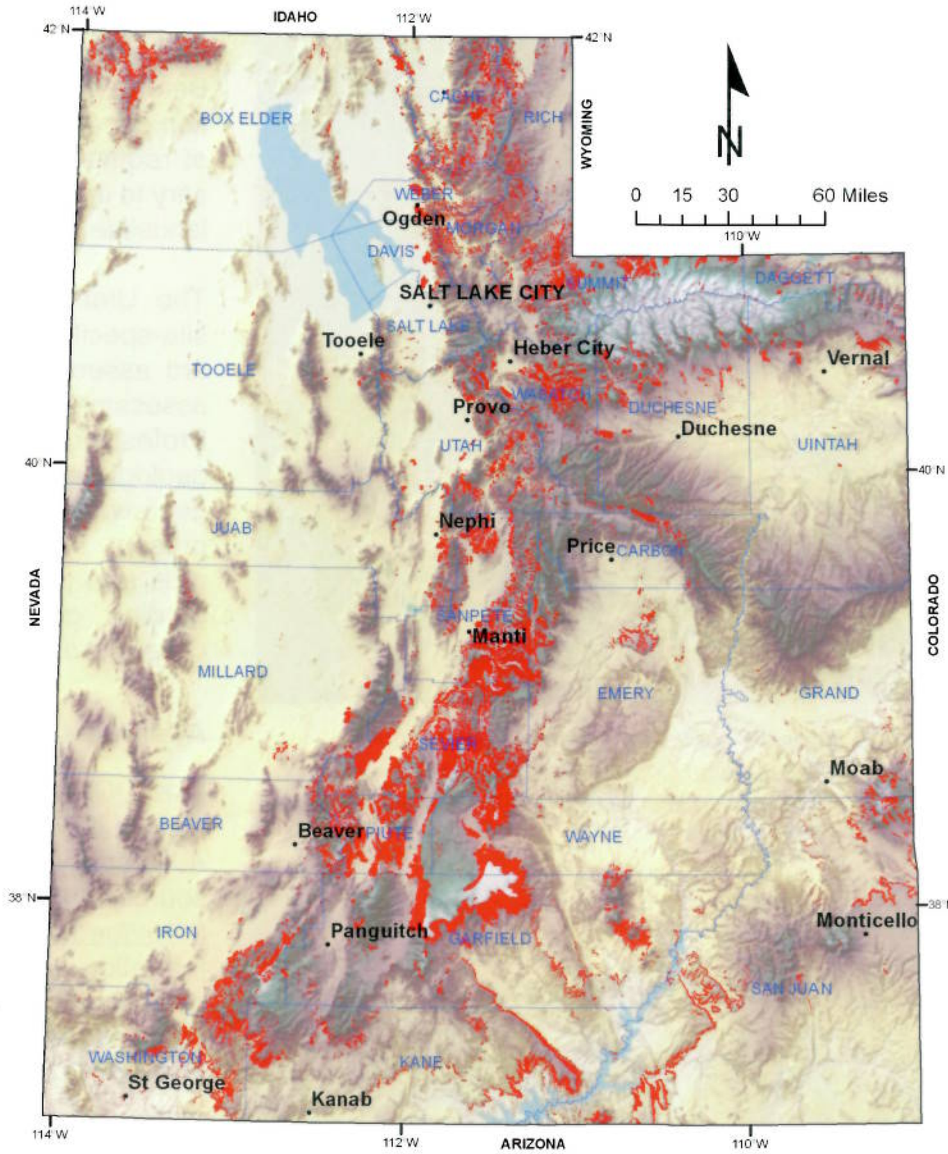
View of the Thistle landslide, Utah County. The railroad tunnel at bottom center of photograph was built as part of mitigation measures after landsliding in 1983 buried the original railroad grade. (Photo taken in 2005.)

In 1983, near the town of Thistle in Utah County, a landslide occurred when unseasonably warm weather caused rapid snowmelt, saturating a slope, and triggering a landslide that resulted in the greatest economic loss from any landslide in the history of the United States. The landslide destroyed U.S. Highway 89 and the adjacent Denver and Rio Grande Western railroad tracks. It also dammed the Spanish Fork River, causing inundation of the small town of Thistle. After the resulting lake was drained and sediment was shown to have partially buried the town, Thistle was abandoned. The Thistle landslide resulted in Utah's first U.S. Presidential Disaster. The economic loss associated with the Thistle landslide was several hundred million dollars (in 1984 dollars), which included the costs of rerouting the highway and railroad and draining the lake.

Landslide Warning Signs

Early recognition of landslide movement can be critical in attempts to avoid and/or minimize damage to property and structures. The following signs may indicate landslide movement:

- New cracks or unusual bulges in the ground, street pavements, or sidewalks.
- Soil moving away from foundations and other rigid objects.
- Decks and patios tilting and/or moving relative to the main house.
- Tilting or cracking of walls, concrete floors, and foundations.
- Sticking doors and windows, and visible open spaces and/or cracks, indicating jambs and frames out of plumb.
- Leaning telephone poles, trees, retaining walls, or fences.
- Sunken or down-dropped sidewalks and pavements.
- Springs, seeps, or saturated ground in areas that have not typically been wet before.
- Rapid increase in stream flow, possibly accompanied by increased turbidity (cloudy water).
- Sudden decrease in stream flow, though rain is still falling or just recently stopped.



A 2010 generalized landslide map of Utah with more than 22,000 mapped landslides shown in red (Utah Geological Survey compilation).

Reducing Risk from Landslides

As the population base of Utah continues to expand into areas that are susceptible to landsliding, damage and economic costs of this natural geologic process increase. Recognition of landslide risk prior to development and implementation of appropriate land-use planning and landslide mitigation measures are the most effective means to reduce their hazards. Many hillslopes are prone to landsliding, particularly where development has taken place on existing landslides or where grading has modified a slope and reduced its stability. In Utah, nearly all recent landslides have occurred as reactivations of pre-existing landslides. Therefore, historical landslides, prehistoric landslides, and steep slopes prone to landsliding must be thoroughly investigated prior to development activities. When considering development on a hillslope or adjacent area property, owners should consult with local planning and building officials, nearby property owners, and geotechnical consultants

The 2005 landslide above a residential subdivision in Springdale, Washington County. The landslide developed in loose deposits that had accumulated at the base of the steep east wall of Zion Canyon.

The 2005 landslide below the Davis-Weber Canal in South Weber, Davis County, that demolished a barn and covered part of State Route 60 (landslide outlined in yellow). The landslide occurred in one of the steeper parts of the slope composed of prehistoric landslide deposits that had been historically active.

knowledgeable about previous landslides and local landslide susceptibility before building in these areas. Before and during development activities, recognition of potential landslide activity and implementation of required engineered mitigation measures necessary to improve the stabilization of slopes can reduce landslide risk.

The Utah Geological Survey (UGS) recommends site-specific geotechnical investigations and hazard assessments for all new development. These assessments must be performed by Utah licensed Professional Geologists (specializing in engineering geology) and Professional Engineers (specializing in geotechnical engineering). If landslide hazards are present, the professionals should disclose the hazards and provide appropriate recommendations for grading, groundwater control, project design, and construction that will reduce the hazards.

Additional Landslide Resources

The UGS (http://geology.utah.gov/ghp) provides a variety of information on geologic hazards in Utah. Additionally, the online page for Geologic-Hazard Resources for Consultants and Design Professionals (http://geology.utah.gov/ghp/consultants) includes information on recommended report guidelines, UGS geologic-hazard maps and reports, geologic maps, groundwater reports, historical aerial photography, and other sources of useful information.

To find out more about landslides in general or those near you contact:

The home office of the Utah Geological Survey at 1594 West North Temple, P.O. Box 146100, Salt Lake City, UT 84114-6100, phone 801-537-3400, http://geology.utah.gov. The Southern Regional Office of the UGS is at 88 East Fiddler Canyon Road, Ste. C, Cedar City, UT 84721, phone 435-865-9034. Also contact your city, county, or regional planning departments, or "geologists, geotechnical engineers" in the phone book.

UTAH DNR GEOLOGICAL SURVEY

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