U T A H   G E O L O G I C A L   S U R V E Y

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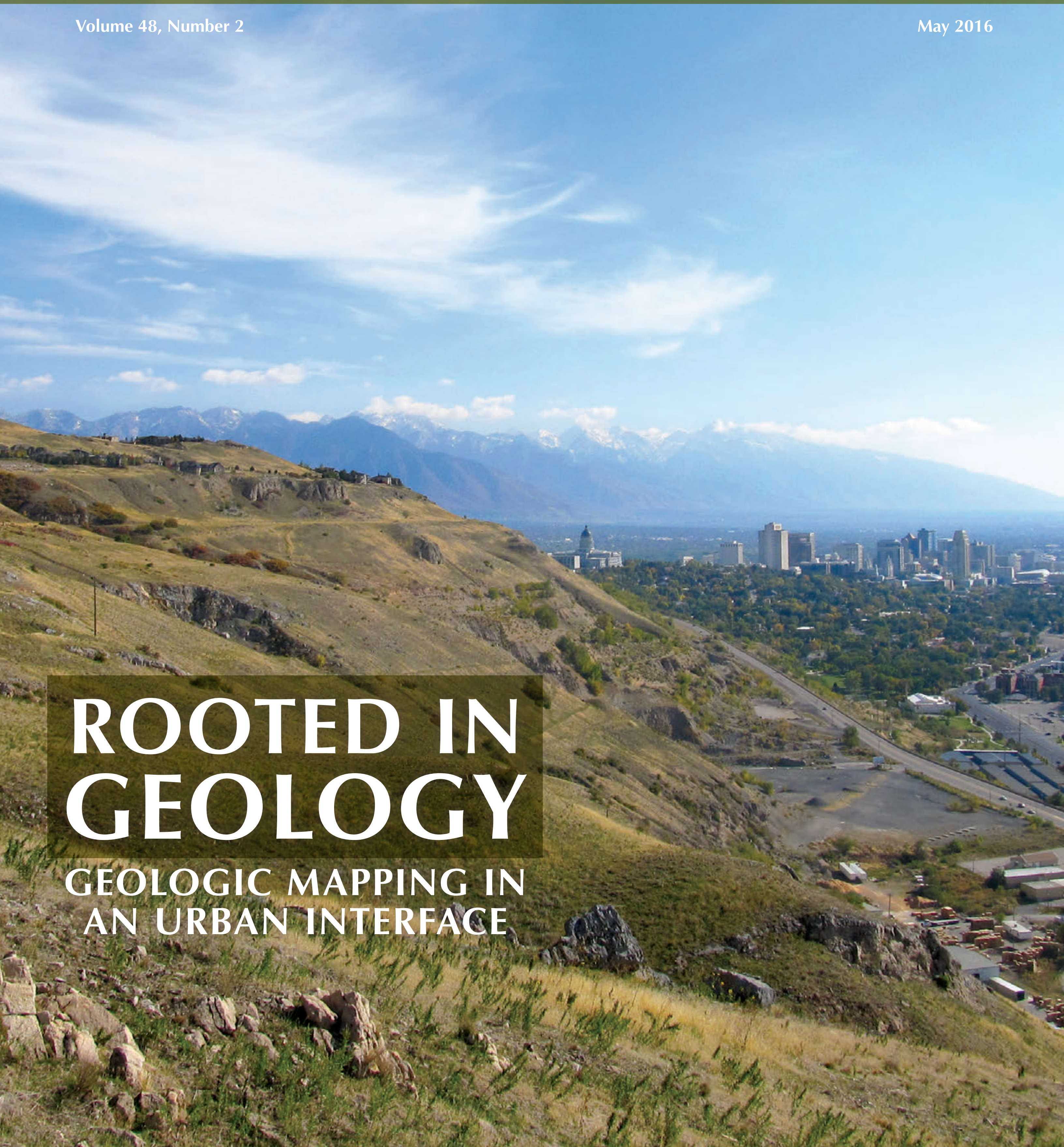

ROOTED IN GEOLOGY

GEOLOGIC MAPPING IN AN URBAN INTERFACE

Contents

Design | *Nikki Simon*

Cover | *Mississippian and Tertiary bedrock (left) is mantled by Lake Bonneville gravels above Salt Lake City. The Warm Springs fault scarp, where not removed by aggregate mining, trends along the right side of the photograph towards downtown. Photo by Adam McKean.*

THE DIRECTOR'S PERSPECTIVE

by Richard G. Allis

The year 2015 has been a tough one for the Utah Geological Survey (UGS). Annual mineral lease revenue decreased by more than $2 million as the price of oil declined from about $100 to close to $30 per barrel since late 2014 (West Texas Intermediate), and natural gas declined from $4 to less than $2 per mcf over the same period. The UGS tried to shed matching costs throughout the year through elimination of discretionary expenditure, layoffs, and unfilled retirements, and now has a staff of 65 full time equivalents compared to 80 in 2014. Unfortunately, the cost savings have not been enough to balance the revenue decline, which most energy experts think will last for years. After discussions with the Department of Natural Resources Executive Office and the Governor’s Office of Management and Budget, the UGS presentation to the Natural Resources legislative sub-appropriations committee in February outlined the value of the UGS to the state. We then revealed that without help further, large-scale staff reductions would be required to avoid a deficit of over $400k at the end of this fiscal year (FY) and over $900k for FY17.

Our committee was sympathetic to the sacrifices already made and recommended one-time funding of $500k for this FY and ongoing general funds of $1 million starting in FY17. These recommendations worked their way through the Executive Appropriations Committee and remained in the budget passed by the legislature as it closed the 2016 session. In recent years, the UGS has received between $2.6 and $2.8 million dollars as ongoing general funds, so the increase of $1.0 million represents a very important injection of funds at a crucial time. This increase in funds will stabilize our staffing at present levels and, once additional retirements occur in future years, will provide a basis for filling critical gaps in expertise. We are grateful to all who helped in the appropriations process—the new funding is recognition that the UGS plays an important role in assisting wise land-use decisions in a rapidly growing state.

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Recent Urban Geologic Mapping of NORTHWESTERN SALT LAKE VALLEY

BY ADAM McKEAN

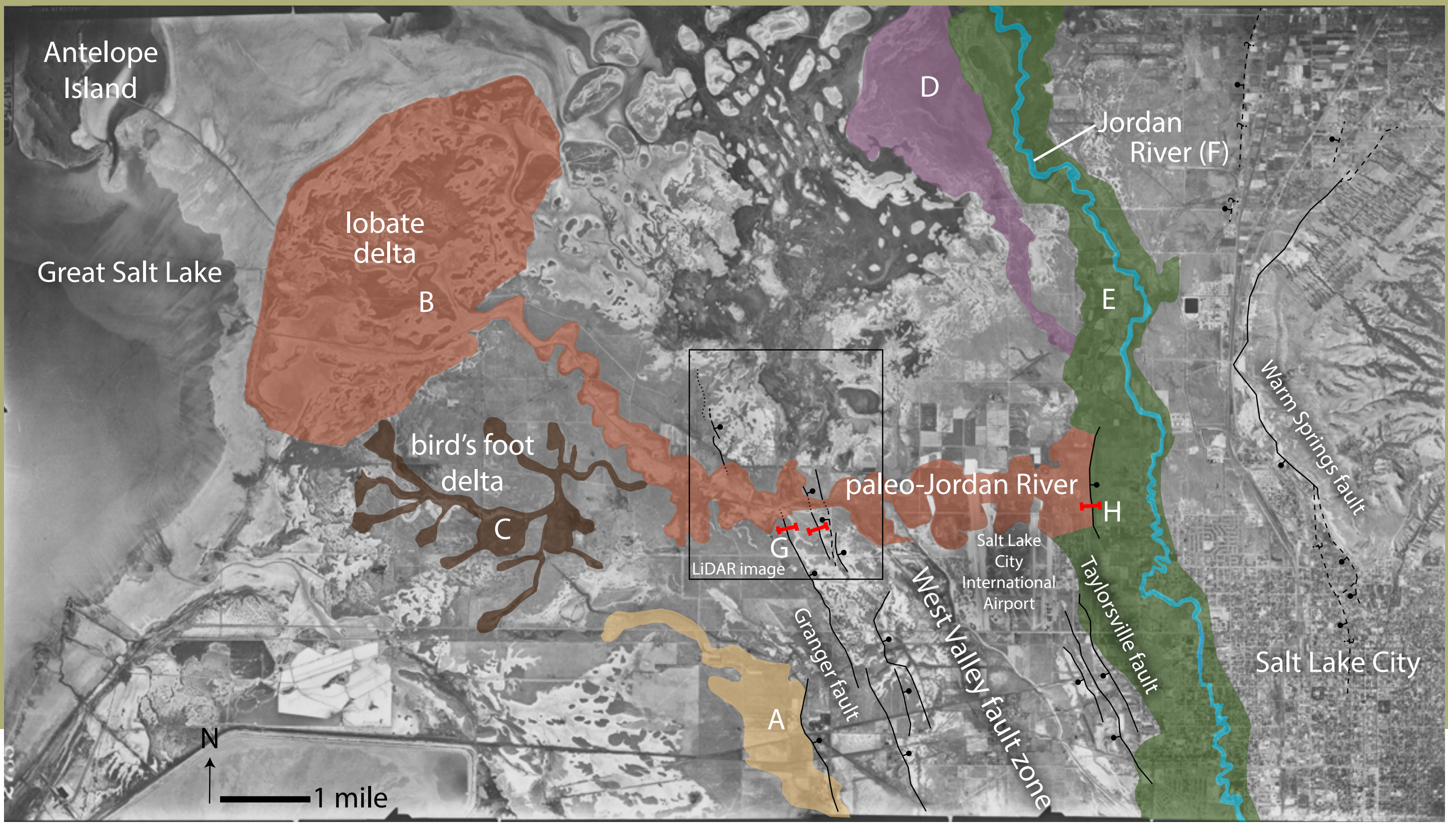
Urban geologic mapping may sound like a mapper's nightmare

considering the rapid expansion of limited-access property and disturbed land and development that cover up the geology. One may ask, "Why map geology in and near a city?" The simple answer is that urban areas need surficial geologic maps to aid the land development and management process by identifying potential geologic hazard issues. These mapping projects also provide valuable information needed for further geologic, geologic hazard, groundwater, geotechnical, and engineering investigations. In my recent geologic mapping of northwestern Salt Lake Valley, including the Baileys Lake (see UGS Open-File Report 624) and Salt Lake City North 7.5-minute quadrangles, I mapped a number of geologic hazards including problem soils, flooding potential, faults, landslides, and rockfalls.

Surficial Deposits

While mapping between Salt Lake City and Great Salt Lake, I documented several interesting river, delta, and lake deposits associated with late Pleistocene Lake Bonneville (30,000 to 13,000 years ago), the Gilbert-episode lake (~11,600 years ago), and Holocene Great Salt Lake (since ~11,000 years ago). Following the regression of Lake Bonneville, rivers and deltas migrated across the valley floor and deposited sediment in the Gilbert-episode lake at the southern margin of the mapped area (A in mosaic image). Then after withdrawal of the Gilbert lake, the paleo-Jordan River incised into the lake deposits of the previous larger and deeper lakes (B in mosaic image). At the mouth of the west flowing paleo-Jordan River, a lobate delta developed along the Holocene Great Salt Lake margin. During the late Holocene highstand (4800 to 2100 years ago), Great Salt Lake flooded the valley to an elevation of about 4217 to 4221 feet. A small bird's foot-style delta likely developed at this time to the south of the main river channel in shallow water covering the river floodplain and older lake deposits (C in mosaic image). Sometime after the late Holocene highstand, both deltas and the paleo-Jordan River channel were abandoned, and the river shifted to the north and now flows into Great Salt Lake through Farmington Bay (D, E, and F in mosaic image). This channel and delta shift may have been influenced by displacement on the Holocene-active Granger, Taylorsville, and Warm Springs faults.

The sand and silt from these river, delta, and lake deposits combined with shallow groundwater around the lake make them potentially liquefiable during future earthquake ground shaking. Other mapped surficial deposits contain clay, silt, and organic matter and pose a potential for problem soil and foundation settlement hazards. The mapping of these deposits is important for identifying and mitigating geologic hazards.



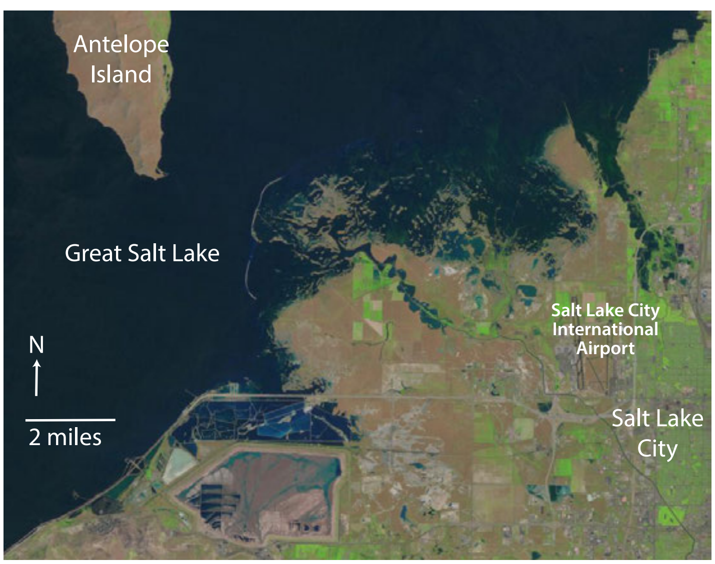
Mosaic of 1953 Army Map Service black and white aerial photographs of Great Salt Lake, Salt Lake City, and the southern tip of Antelope Island. Highlighted areas show a simplified representation of post-Lake Bonneville river channels and deltaic deposits. A) Gilbert-episode river channel and delta deposited as the lake receded, B) post-Gilbert, west-flowing paleo-Jordan River and associated lobate delta, C) bird's foot delta that was likely deposited during the late Holocene highstand of Great Salt Lake, D) delta deposited during northward flow of the Jordan River, E) approximate location of Jordan River meander floodplain, F) modern modified channel of the Jordan River, G) location of 2010 paleoseismic trench on the Granger fault, H) location of 1997 and 2015 paleoseismic trenches on the Taylorsville fault.

Great Salt Lake level changes, that in part contributed to the multiple migrating river channels and deltas, continue in response to climate cycles, water usage, and evaporation rate. The historical average lake elevation is about 4200 feet. In the late 1860s to early 1870s and again in 1986–87, Great Salt Lake rose to 4212 feet (1284 m). Mapping of this historically high level shows the potential for repeat damaging flooding adjacent to the lake and shallow groundwater rise in low-lying areas.

West Valley Fault Zone

The Granger fault of the West Valley fault zone is truncated by the incised paleo-Jordan River channel. A 2010 UGS paleoseismic investigation of the West Valley fault zone across two strands of the Granger fault documented four large (surface-faulting) earthquakes since the highstand of Lake Bonneville (~18,000 years ago) and the most recent earthquake occurred about 5500 years ago (see UGS Special Study 149, G in mosaic image). The paleo-Jordan River has since eroded and removed evidence of the earthquake fault scarp within its river bed.

Near the east end of the incised paleo-Jordan River channel, two organic-rich samples were collected from a consultant's 1997 paleoseismic trench on the Taylorsville fault of the West Valley fault zone near Interstate 215 (H in mosaic image) that yielded an average age of 2200 years for the timing of a surface-faulting earthquake (see *Survey Notes* v. 30, no. 3, 1998). My working hypothesis is that the 2200-year earthquake may have disrupted flow of the west flowing paleo-Jordan River, dropping the eastern margin of the river down to the east and potentially causing the Jordan River to shift and flow north instead of west (E in mosaic image). The abandonment of the paleo-Jordan River channel may have also been influenced by earthquakes on the Warm Springs fault by tectonically lowering its base level. Understanding the response of the Jordan River to earthquakes in the past will help us plan for future earthquakes, possible river migration, and other impacts from tectonic subsidence. A UGS paleoseismic investigation from the same area is in progress and will hopefully provide additional insight into the history of the Jordan River, Great Salt Lake, and their response to previous earthquakes (see this *Survey Notes* p. 4).



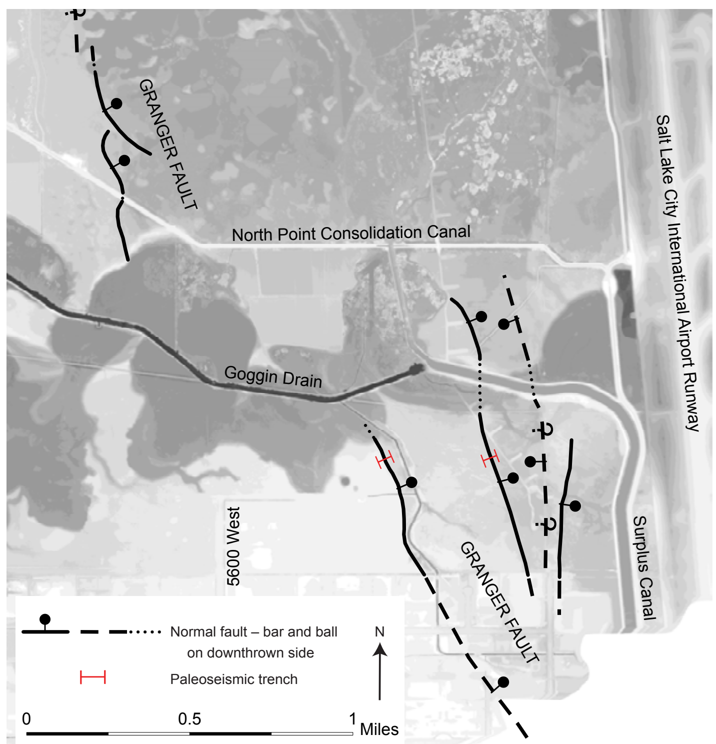
Cropped USGS/NASA Landsat 5 "natural color" image of the flooding that occurred during the 1987 highstand of Great Salt Lake, image date June 2, 1987.

Warm Springs Fault

Of particular importance to this project is the location of the Warm Springs fault through downtown Salt Lake City. Much of the evidence of the fault has been destroyed by development and aggregate mining activity along Beck Street. As a result, little is known about the Warm Springs fault and its location has long been debated. For this mapping, data on the location of the fault came from a number of sources: a cooperative project between the UGS and Salt Lake County to archive their collection of geotechnical and related investigation reports; available information from the consultant community; research at the University of Utah; and interpretation of multiple aerial imagery and topographic datasets, including new 0.5 meter LiDAR data. This data and an evidence-based approach to mapping of the Warm Springs fault led to increased understanding and confidence in the fault's location. Knowing the fault location with greater certainty can help reduce surface fault rupture damage to buildings, critical infrastructure, and reduce lives lost through proper planning. The fault is currently the subject of a detailed geophysical investigation by researchers at Boise State University. Upon the completion of their investigation and the incorporation of their findings, the Salt Lake City North quadrangle geologic map will be finalized for publication.

Landslides

During mapping in the City of North Salt Lake and Salt Lake City, I observed multiple landslides (Springhill, Parkway



LiDAR image of the Granger fault strands in black with paleoseismic trenches locations in red, draped over 2011, 1m LiDAR raster shade (LiDAR available from OpenTopography), see mosaic image for location. The Goggin Drain is within and follows the depression created by the paleo-Jordan River.

Drive, and City Creek landslides) that occurred in a weak tuffaceous bedrock unit (see *Survey Notes* v. 47, no. 1, 2015). This unit has significant future landslide potential as development continues. During a UGS-hosted field review of the area, we discussed the unit's landslide hazard potential with local government agencies, geotechnical consultants, and interested geologists in attendance. In addition to the landslides, I mapped known rockfalls in City Creek Canyon, which will help identify potential for additional rockfalls in the future.

Application for Local and State Agencies

These maps provide new and revised geologic mapping of existing urban areas in northern Salt Lake Valley and areas planned for significant development. The maps identify, delineate, and describe major geologic issues affecting development, including high Great Salt Lake water levels, the location of the Wasatch and West Valley fault zones, geologic units with liquefaction potential, problem soils, rockfalls, and landslides. The maps provide descriptions of surficial soil and rock units that can be used to identify problem geologic units. They also identify and delineate faults and landslides that may cross urban areas, where major industry, infrastructure, and residential areas exist. The geologic maps will be used in subsequent creation of geologic-hazard maps that show the location and relative severity of various geologic hazards. Geologic map publications, invited talks and meetings, and field reviews are all methods the UGS uses to share valuable information learned from these investigations with local and state agencies, researchers, consultants, and other interested parties. We hope that objective geologic information provided by the UGS will lead to hazard awareness and a reduction of geologic-hazard-related costs to society through informed and proactive development and risk minimization.

More Information:
Geologic Hazards Program
geology.utah.gov/?p=6583

Geologic Hazard Resources
geology.utah.gov/?p=6794

UGS field review at the Parkway Drive landslide in the City of North Salt Lake. The white and red tuffaceous deposits prone to landsliding are seen in the toe of the landslide (photo courtesy of Grant Willis, UGS).

ABOUT THE AUTHOR

Adam McKean joined the Utah Geological Survey (UGS) in 2010, and since 2011 has worked as a geologic mapper for the Geologic Hazards Program. His work focuses on mapping the surficial geology of the greater Wasatch Front urban area. During his time with the UGS, Adam has mapped the geology of seven 7.5-minute quadrangles. As a part of his mapping, Adam works closely with the geologic hazards mappers to identify the geologic hazards in each quadrangle for future UGS geologic hazards map sets. He is currently mapping the geology of the Sugar House quadrangle in eastern Salt Lake Valley. Besides geologic mapping, Adam is also involved in Lake Bonneville and Great Salt Lake research, LiDAR mapping of the Wasatch fault zone, landslide emergency response and monitoring, paleoseismic trenching, geologic map and geologic data archiving, and loves to work on the bedrock geologic problems of each of his projects.

PALEOSEISMIC INVESTIGATION OF THE TAYLORSVILLE FAULT, WEST VALLEY FAULT ZONE, UTAH

BY ADAM I. HISCOCK

The West Valley fault zone is the lesser known of the two major faults that run through the Salt Lake Valley (the other is the Salt Lake City segment of the Wasatch fault zone). The Salt Lake City segment has been well studied, but much less is known about the West Valley fault zone. The West Valley fault zone consists of two, subparallel main traces, known as the Granger fault (western trace) and Taylorsville fault (eastern trace). In 2011, the Utah Geological Survey (UGS) completed an investigation that analyzed the relation between the Granger fault and Salt Lake City segment to try and determine a link between major earthquakes on the Salt Lake City segment and the West Valley fault zone (see *Survey Notes*, v. 44, no. 2, 2012). The purpose of our current investigation is to expand our knowledge of the earthquake history for the lesser studied Taylorsville fault.

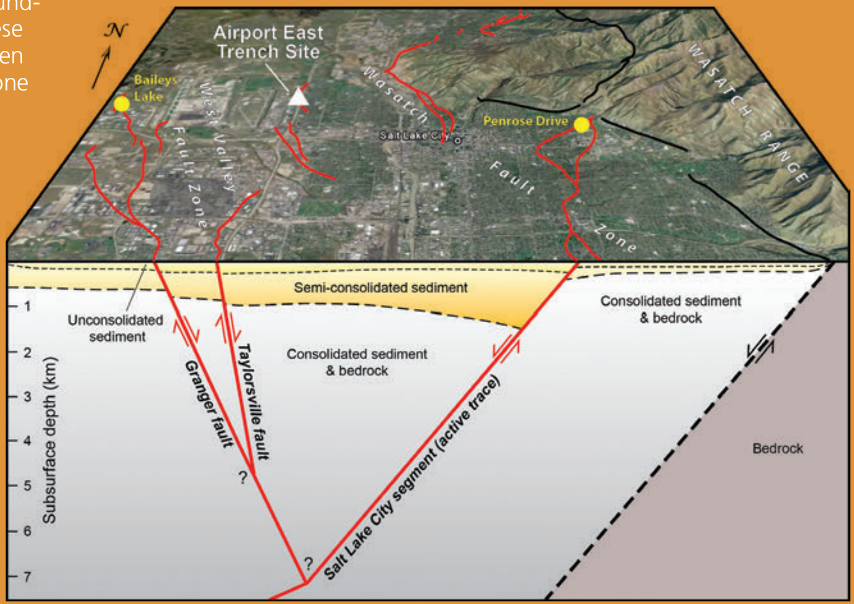
In August 2015, the UGS, aided by the U.S. Geological Survey (USGS), conducted a paleoseismic (fault trenching) investigation of prehistoric surface-faulting earthquakes on the Taylorsville fault. Two parallel trenches were excavated at the Airport East site across a 1 to 3 foot high scarp, east of the Salt Lake City International Airport at approximately 1140 North Flyer Way. The trenches exposed fine-grained sand and silt deposits. Groundwater at the site was very shallow, which was problematic for trench wall stability and prevented us from trenching deeper to expose older deposits that might record a more complete earthquake record.

Our preliminary findings include evidence for three post-Bonneville earthquakes at the Airport East site and distinguish seven separate units in the trench wall. These units consist of sand and silt deposits, probably deposited on the paleo-Jordan River floodplain and Great Salt Lake margin marshes over thousands of years. Several liquefaction-induced sand dikes and broad warping of older units indicate evidence of possibly two separate earthquake ground-shaking events. However, we found no evidence to link these features to the Taylorsville fault; the features could have been created from ground-shaking from an earthquake on any one of the many regional fault systems.

We collected samples for both radiocarbon (^{14}C) and optically stimulated luminescence (OSL) dating methods. Several units in the trench were very organic rich and one contained a burn horizon. The abundance of organic material allowed us to collect samples with numerous discrete charcoal fragments, which makes dating the material easier. The samples are currently being processed, and we are awaiting results. We will use the data to develop a model for the timing of prehistoric earthquakes at the Airport East site, as well as refine data from past trench investigations. These data will help us better understand the complex relationship between earthquakes on the West Valley fault zone and the Salt Lake City segment, increase our knowledge of the entire Wasatch fault zone, and will eventually be incorporated into the USGS National Seismic Hazard Maps that are part of the International Building and Residential Codes adopted in Utah. Research projects such as this allow us to better plan for and accurately characterize earthquake hazard in the Salt Lake Valley.

Funding for this project was provided through the USGS National Earthquake Hazards Reduction Program (NEHRP). Additional information on the link between the West Valley fault zone and Salt Lake City segment of the Wasatch Fault zone can be found in UGS Special Study 149, *Paleoseismology of Utah, Volume 24—Evaluating surface faulting chronologies of graben-bounding faults in Salt Lake Valley, Utah—New paleoseismic data from the Salt Lake City segment of the Wasatch fault zone and the West Valley fault zone*, by Christopher B. DuRoss and Michael D. Hylland, available at geology.utah.gov/?p=5283.

Trenches at the Airport East trench site exposed geologic evidence for three surface-faulting earthquakes on the Taylorsville fault. The fault plane is visible between the two red arrows in the center of the photo. Photo taken on September 2, 2015.



Block diagram of the West Valley fault zone and the Salt Lake City segment of the Wasatch Fault zone showing the Airport East trench site (white triangle) and previous UGS trench sites (yellow circles). These faults are antithetic to each other; that is, they dip towards each other and connect to form a "V" (a graben) at depth beneath the valley as shown in the figure.

UGS Updates Existing and Develops New Guidelines FOR INVESTIGATING GEOLOGIC HAZARDS

BY **WILLIAM R. LUND AND STEVE D. BOWMAN**

A variety of geologic hazards in Utah adversely affect life safety, health, property, and the state's economy. Although limited information exists on the direct and indirect costs of geologic hazards in Utah, the 1983 Thistle landslide alone resulted in direct costs of $200 million (1983 dollars), and the Utah Department of Transportation estimates that repairs to Utah State Highway 14 from a major landslide in 2011 cost between $13 and $15 million. The 2014 Parkway Drive landslide in North Salt Lake severely damaged a house and tennis and swim club, and threatened other houses and nearby regional natural gas pipelines; final remediation costs are expected to approach $2 million. Great Salt Lake flooding in 1983–1984 caused over $240 million in damage. Since 1847, approximately 5797 fatalities, and a significantly higher number of injuries, from geologic hazards have been documented in Utah. Radon gas exposure (a known cause of lung cancer) has been Utah's most deadly geologic hazard with over 5372 fatalities (data only available from 1973–2012), followed by landslide hazards with 337 documented fatalities, and then flooding hazards with 101 documented fatalities.

Fortunately, not all geologic hazards are life threatening; however, when not recognized and accommodated in project planning and design, all geologic hazards may result in significant additional construction or maintenance costs. To protect Utah's citizens from geologic hazards, the Utah Geological Survey (UGS) has long recommended that a comprehensive engineering-geology investigation be performed for all development to provide information on site geologic conditions, the type and severity of any geologic hazards present, and to recommend solutions to mitigate the effects of the hazards, both at the time of construction and over the life of the development.

To facilitate conducting the recommended engineering-geology investigations, the UGS has published guidelines for investigating geologic hazards and preparing engineering-geology reports that provide minimum techniques, standards, and report content to ensure adequate geologic site investigations to protect public health, safety, and welfare. Additionally, the UGS has urged the adoption of geologic-hazard ordinances at the municipal and county level, and provided school-specific guidelines to the Utah State Office of Education for engineering-geology evaluations of new public school buildings.

Recognizing that some of these guidelines are now nearly 30 years old, and that the state-of-engineering-geology practice is continually evolving, the UGS decided in 2015 to update its guidelines. Additionally, two other geologic hazards, rockfall (see photo) and land subsidence and earth fissures related to groundwater mining, have become sufficiently damaging over the past decade that the UGS has developed new guidelines for investigating and reporting on those hazards as well.

All of the updated guidelines, along with the two new guidelines, are now combined into a single publication for ease of use and to facilitate updates and additions to the guidelines in the future. The publication provides guidelines for conducting engineering-geology investigations and preparing engineering-geology reports (Chapter 2), surface-fault-rupture investigations (Chapter 3), landslide investigations (Chapter 4), debris-flow investigations (Chapter 5), land-subsidence and earth-fissure investigations (Chapter 6), rockfall investigations (Chapter 7), implementing geologic-hazard ordinances (Chapter 8), and preparing and reviewing engineering-geology reports for school sites (Chapter 9). The updated guidelines are currently in review and are expected to be published mid 2016. As the UGS develops additional geologic-hazard-investigation guidelines in the future (snow avalanche-hazard guidelines are expected in late 2016), this publication will be updated as necessary.

Users should refer to the UGS web page for the most current information and guidelines: geology.utah.gov/?p=6796.

2013 St. George rockfall that damaged a residence and severely injured the occupant of the home. Photo credit William Lund, January 2013.

2014 Parkway Drive landslide, North Salt Lake. The landslide damaged the Eagle Ridge Tennis and Swim Club (white tent structure), severely damaged one house (directly above the tent structure), and removed part of the backyard of a second home. Photo credit Gregg Beukelman, August 14, 2014.

Summary of known geologic-hazard fatalities in Utah.

GEOLOGIC HAZARD		FATALITIES			
Landslide Hazards					
Landslides[1]		4	1.2%	337	5.7%
Rockfall		15	4.5%		
Debris Flows[2]		15	4.5%		
Snow Avalanches		303	89.8%		
Earthquake Hazards					
Ground Shaking		2	100%	2	>0.1%
Flooding Hazards					
Flooding and Flash Floods		81	80.1%	101	1.7%
Debris Flows[2]		15	14.9%		
Dam and Water Conveyance Structure Failure[1]		5	5.0%		
Problem Soils					
Radon Gas[3]	1973–2001	1460	--	5372	92.6%
	2002–2011	3816			
	2012	96			
Total:		**5797**			

[1] Three fatalities are classified as from a landslide and a dam and water conveyance structure failure.
[2] Debris flows are both a landslide and flooding hazard.
[3] Limited data is available and contains various assumptions; exact number of fatalities is unknown.

"core center news"

Cores from Central Utah's Covenant Field: Oil-Bearing Ancient Sand Dunes

BY THOMAS C. CHIDSEY, JR.

Great Sand Dunes in Utah's Past

Around 200 million years ago, Utah was covered by a great "sea" of sand much like the modern Sahara. Huge sand dunes reached hundreds of feet in height. The winds were generally out of the north and northwest. Locally where the water table was high, small ponds or oases formed and were surrounded by vegetation that attracted various kinds of dinosaurs and other reptiles. Following a 10-million-year period of erosion (or non-deposition), a shallow marine sea transgressed into central Utah from the southwest about 175 million years ago. The eastern shore was marked by tidal flats and coastal sand dunes similar to those found today along the coast of Namibia in southwestern Africa. These coastal dunes were not quite as large as the earlier desert dunes and the wind was dominantly out of the northeast.

To Rocks and Oil

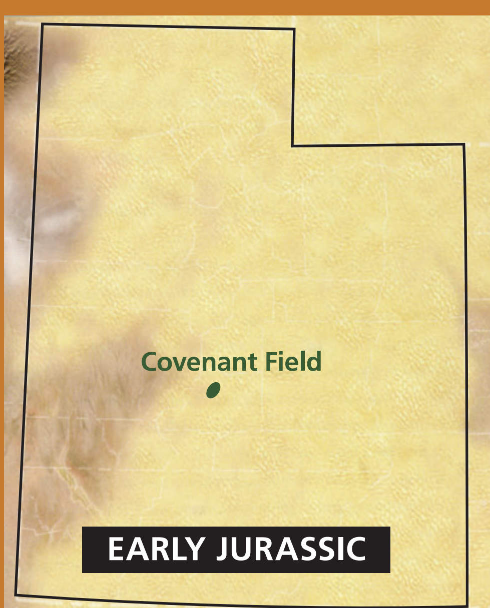
Over millions of years and burial to thousands of feet, the sand grains of both wind-blown (eolian) deposits of ancient dunes were compacted and cemented together to create sandstone—the Early Jurassic Navajo Sandstone and White Throne Member of the Middle Jurassic Temple Cap Formation. The boundary between these two sets of rocks is called an unconformity indicating a significant time gap (like a book missing a chapter). Today these rocks are widely exposed in southern Utah and best observed in Zion National Park where they form the spectacular cliffs of the canyons. However, where they remained deeply buried in other parts of Utah, the microscopic pore space between the sand grains became a reservoir for oil when certain conditions were met: (1) thick sandstone layers where sealed above by impermeable rocks like shale, (2) compressional forces folded the sandstone and sealed rocks to create a hydrocarbon trap, and (3) nearby organic-rich rocks were present and sufficiently "cooked" to have generated and expelled hydrocarbons into the pore spaces of the folded sandstone.

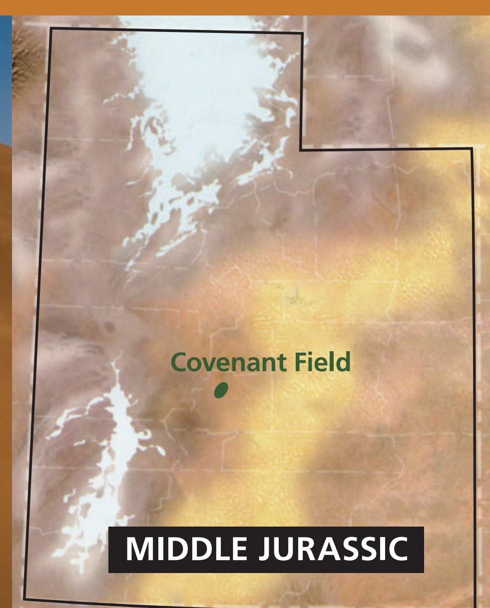
"The stuff that dreams are made of!"

A petroleum geologist's job is to locate a spot where all those right conditions occurred and determine how deep to drill to strike it rich. To help, there are two ways to study the Navajo and Temple Cap reservoir rocks up-close and personal: (1) go to locations where they are exposed around the state, and (2) examine cores taken through them from producing oil wells. Such cores are publicly available at a Utah Geological Survey (UGS) facility—the Utah Core Research Center (UCRC), located in Salt Lake City, Utah. In late 2004, Michigan-based Wolverine Gas & Oil Corporation discovered Covenant oil field about 8 miles east of Richfield, Sevier County, in a region referred to as the central Utah thrust belt; the new field was productive in the eolian sandstone beds of both the Navajo and Temple Cap Formations. Since then the field has produced nearly 22 million barrels of oil; averaging 3900 barrels of oil per day. Cores, test data, and other material from the field were generously donated to the UCRC by Wolverine.

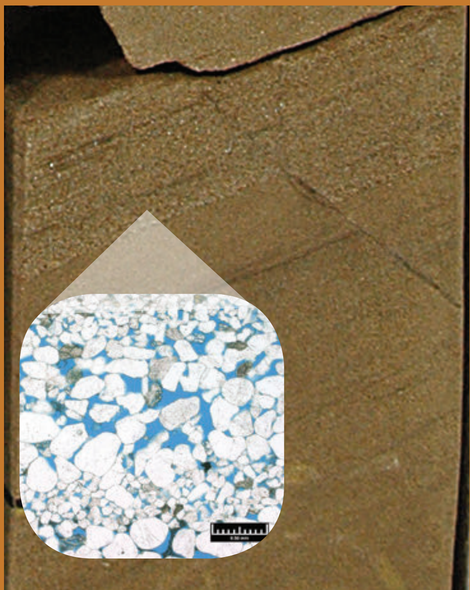
What Do Covenant Oil Field Cores Tell Us?

The cores from Covenant field provide an incredible wealth of information about the Navajo and Temple Cap depositional environments and oil reservoirs. Once slabbed (cut in half), the cores often reveal all the major parts of the ancient dunes encountered by the well—the windward dune flank and crest, and the leeward slipface (sometimes even displaying small avalanche deposits) and dune toe representing the base. The cores often show dune wind ripples and cross-bedding, and the reservoir quality (the amount of porosity and permeability [or how well-connected the pores are to each other]) varies with these features. The cores also show interdunal





Early and Middle Jurassic paleogeography in Utah. Note location of Covenant oil field. Maps modified from Blakey and Ranney, 2008. Modern sand dune in Coral Pink Sand Dunes State Park, Kane County; photo by Michael Vanden Berg.



Slabbed core (taken at a depth of 6773 feet) of Jurassic Navajo Sandstone from Wolverine's Federal No. 17-3 well in Covenant field, showing an oil-producing, cross-bedded and fractured sandstone that was deposited in an ancient dune. Inset: microscopic image displaying subrounded quartz sand with pore space (15%) shown in blue.

environments such as playas and oases, or coastal tidal flats in the case of the Sinawava Member of the Temple Cap, represented by mudstone or limestone, which can be barriers to the flow of oil. Some intervals are highly fractured which enhances oil productivity whereas others are oil saturated giving off a distinct petroleum odor—"the smell of money!" Unconformities (depositional gaps) can be recognized in cores by the presence of scoured surfaces, gravel zones, subtle changes in mineralogy, or age-defining microfossils.

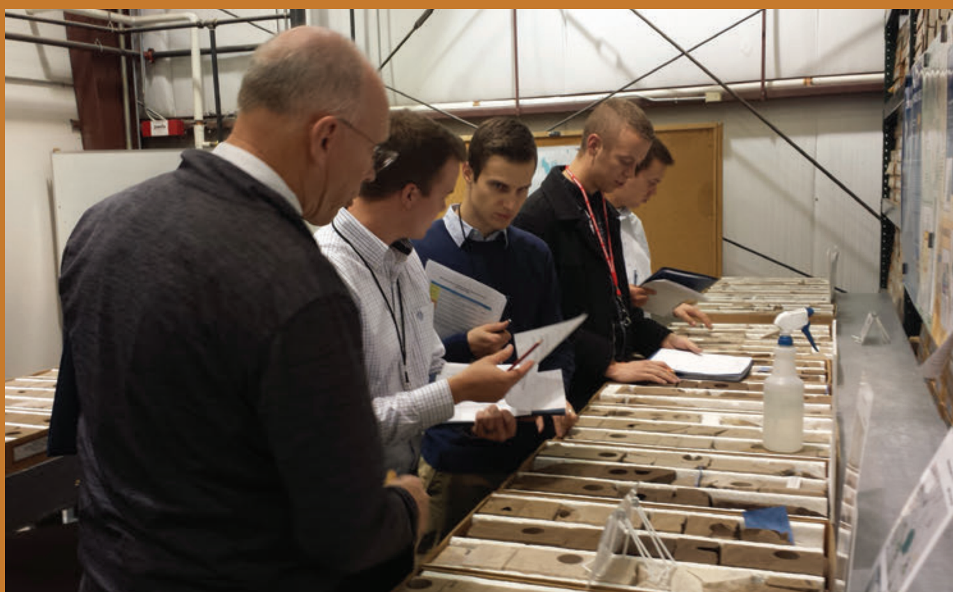
Well Logs to Cores

After a well is drilled, the operator sends down a sophisticated package of instruments in a long, skinny torpedo-like container. These instruments measure a variety of reservoir rock properties such as porosity, the conductivity of the fluids within the pores, and the natural radiation of the rocks. The resulting digital data is plotted as a series of depth-related curves, called a wireline or geophysical log, that can be used to determine if the well is a potential hydrocarbon producer and which intervals may produce. These logs are also used to correlate intervals and formations from one well to another within an oil field or regionally. When cores are available, like those at the UCRC, the data on wireline logs can be matched directly to the actual rocks from the well. Thus one can determine how Navajo Sandstone dune or oasis environments observed in the core, for example, are represented on the log curves. These logs then become templates to identify Navajo and Temple Cap Formation depositional environments and other core-derived information for wells that have no cores—an extremely valuable tool.

Covenant Field Core Research and Workshops

The Covenant cores have been used by Wolverine, professors and students from local universities, and the UGS for research to better understand the field and explore for potential new oil resources in the central Utah thrust belt. Numerous papers based on this research have been published in scientific journals or presented at petroleum geology meetings. The UGS offers workshops (and field trips) using these cores for industry training and university petroleum geology classes. Geology groups can examine the Navajo Sandstone cores at the UCRC and then visit the same rocks spectacularly exposed in places like the San Rafael Swell of east-central Utah or Zion National Park. During UGS workshops, petroleum geologists and students study the various rock types, environments of deposition, unconformities, and reservoir properties of the cored sections. Students are asked to make recommendations to the "company president and vice president" (i.e., the UGS instructors) as to whether the well could produce oil and from which intervals. These workshops help them prepare for the real world projects they may encounter as future petroleum geologists.

To see the Covenant oil field core set or schedule a workshop at the UCRC, contact Peter Nielsen, Curator (801-537-3359, peternielsen@utah.gov).



Students from Brigham Young University-Idaho examine the Navajo core set as part of their petroleum geology course. Photo by Peter Nielsen, UGS.

Outcrop of the Jurassic Navajo Sandstone and Temple Cap Formation near the east entrance to Zion National Park, southwestern Utah. Photo by Doug Sprinkel, UGS.

WHAT IS Geovandalism

GLAD YOU ASKED

BY JIM DAVIS

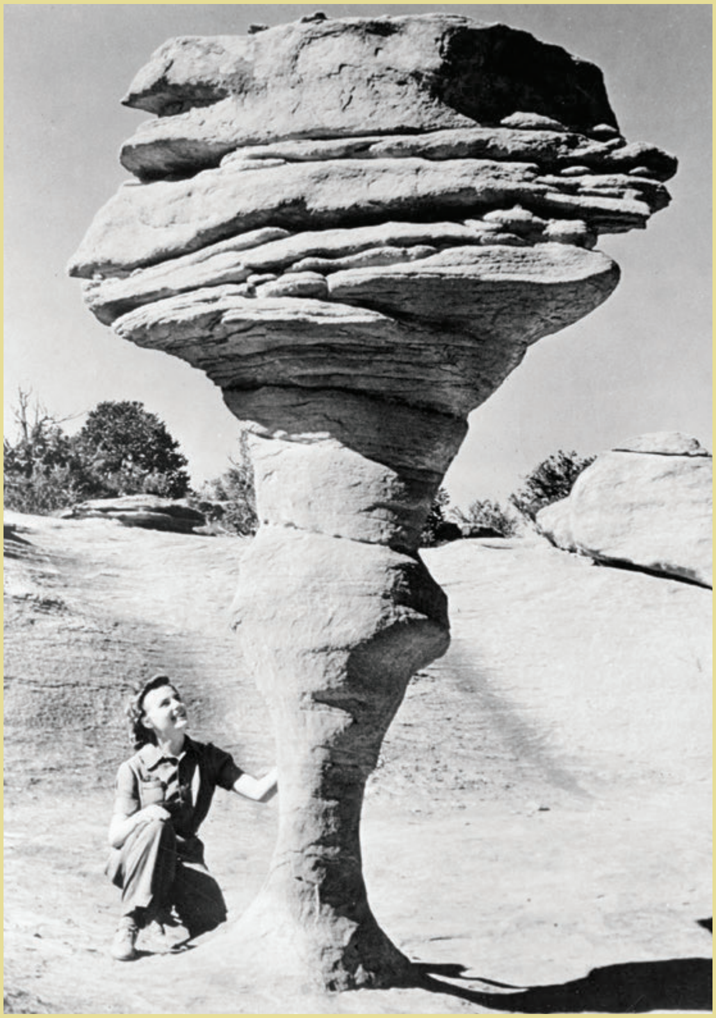
Geovandalism—the act of deliberately damaging natural features of the Earth's surface— is a global dilemma that has intensified in modern times by way of expanding human populations, greater mobility, instant information access, social media, and Internet-driven worldwide marketing of products.

Geovandalism is a recent term and notion that reflects an emerging collective desire to safeguard rare or superlative Earth objects that have cultural, historic, aesthetic, scientific, or spiritual significance.

Specifically, geovandalism is the alteration or ruin of valuable Earth features including landforms, rocks and minerals, fossils, or other geological features due to wanton or malicious conduct, including unauthorized extraction, specimen collection, and sampling for scientific study. Utah has witnessed many instances of geovandalism, in part due to our state's numerous treasured geological elements. In the first decade and a half of this century there have been varied and notable cases:

- **The mysterious, yet apparently intentional, fall and shattering of the intricate "Teapot" at Fantasy Canyon in Uintah County.**
- **Sampling of bedrock by electric saw and rock core drilling by a geologist in the highly popular biking area of Bartlett Wash near Moab for scientific analysis, a case of "professional geovandalism."**
- **The theft and mutilation of dinosaur prints and trackways around the Colorado Plateau and at Red Fleet State Park.**
- **A recent multi-state graffiti spree on rock outcrops in iconic western national parks, including several parks in Utah.**
- **A section of Arches National Park indefinitely closed due to tourists etching names in the sandstone, and a photographer permanently marring the sandstone at the base of Delicate Arch by burning chemical logs to enhance lighting.**
- **Desecration of Native American petroglyphs, pictographs, and rock shelters across the state including Nine Mile Canyon in Carbon and Duchesne Counties, the Lake Mountains in Utah County, and Chicken Creek Canyon in Juab County—this one by out-of-state geology students.**
- **Spray painting of rocks in the Wasatch Range and along the Bonneville Shoreline Trail.**
- **Likely the most infamous, the toppling of a hoodoo (goblin) at Goblin Valley State Park.**

A few of these incidents became international news and elevated the word "geovandalism" into the modern English vernacular. In the previous century, before the concept of geovandalism fully



Appearing in the June 1941 issue of Desert Magazine for a national award-winning article, University of Utah graduate geology student Olivia McHugh kneels beneath the Goblet of Venus, San Juan County. Photo courtesy of Utah State Historical Society.

arose, Utah lost some magnificent geological resources that have largely been forgotten. The Goblet of Venus, a gravity-defying rock pedestal near Natural Bridges National Monument, was called "one of the best known landmarks in the state" by Desert Magazine just a year before its fall. In June 1948, the Goblet was destroyed, and despite assistance from federal prosecutors and the Federal Bureau of Investigation, the culprits were never found. The most prevalent story is that a group of youths drove out one night and toppled the five-ton rock using a chain hooked to a jeep. However, a San Juan County newspaper noted a heavy pole, perhaps used to bring down the Goblet, was recovered at the scene of the crime by a park ranger. Another story claims uranium miners passing by would shoot at the narrow stem until the slender 16-inch diameter base eventually failed. A 1974 Salt Lake Tribune article stated that a tree branch rather than a pole was found at the site, and that two teenagers from Ogden fessed up that they had tried to climb atop the pedestal, knocking it down in the process. Regardless of the method, the destruction of the Goblet troubled Utahns. Substituting for the heartfelt loss a month later, "Atomic Rock" (it was the nuclear age after all) was hailed as the Goblet's less-elegant replacement in the Salt Lake Telegram article "Atomic Rock Replaces Spilled Goblet."

Although defining what constitutes a "cherished" Earth item is certainly not without subjectivity, Earth scientists and non-scientists alike commonly agree on what landscapes should be preserved for future generations. Various metrics have been devised to evaluate areas for certain levels of protection. Global UNESCO Geoparks protect extraordinary areas of natural resources and aim to increase economic benefit such as fostering tourism. Although the U.S. has no global geoparks, our national parks, monuments, and state parks showcase and protect geology and attract millions of visitors each year. Since 1962 National Natural Landmarks (NNL) in the U.S. have been designated to encourage preservation and appreciation of exceptional examples of American natural history. The four in Utah are Cleveland-Lloyd Dinosaur Quarry in Emery County, Little Rockies in Garfield County, Neffs Canyon Cave in Salt Lake County, and Joshua Tree Natural Area in Washington County. NNLs include both public and private holdings and participation in the program is voluntary. Closer to home, the concept of geoantiquities (see *Survey Notes*, v. 33, no. 1, 2001) targets scientifically, educationally, and historically meaningful landforms, such as outstanding Ice Age Lake Bonneville features, that have importance of preservation evaluated by using cultural antiquity conservancy as a framework.

Sometimes geovandalism has spurred the protection and management of remaining geological assets. Timpanogos Cave, for example, was declared a national monument soon after another American Fork Canyon cave, Hansen Cave or "Cave of Buried Rivers," was cleared out of its speleothems, the delicate cave formations ripped out and hauled off. Geovandalism can also spur outrage from the public, resulting in calls for increased protection and penalties as the destruction of the Goblet did in 1948, and the toppled goblin in 2013. One of the difficulties in prosecuting for geovandalism is assessing the value of geologic formations, because monetary loss is typically how we measure the severity of a property crime. Rock may not have any immediate commercial value, but is often irreplaceable or irreparable. Tourists come to Utah in good part to experience our spectacular natural scenery. Tourism is a vital element of the state's economy, supporting one in ten jobs with direct visitor spending of nearly $8 billion annually. Recently, a Utah legislator proposed a bill—Protection of State Park Resources— that would increase punishment for defilement of state parks' natural geologic wonders when he found limited legal action to "deal with people who actually destroy geologic formations" and "nothing to put the fear of God in them." Although the bill did not pass, it indicates laws expressly addressing geovandalism could be in the cards.

BLM Law Enforcement Ranger Tyler Fouss investigates the theft of a dinosaur footprint at Hells Revenge Trackway in Sand Flats Recreation Area, Grand County, in 2014. Eventually, it was discovered that the footprint was thrown into the Colorado River and lost. Photo courtesy of Moab Field Office, U.S. Bureau of Land Management.

The world-renowned biking area of Bartlett Wash, northwest of Moab, was heavily impacted when a geoscientist extracted a sample (to the upper left of yellow book) from the Slick Rock Member of the Entrada Sandstone in 2012. Photo Courtesy of Moab Field Office, U.S. Bureau of Land Management.

Off State Route 313 in Grand County, in 2014 vandals attempted to extract a dinosaur footprint from the Wingate Sandstone and likely destroyed it in the process. Photo courtesy of Moab Field Office, U.S. Bureau of Land Management.

GeoSights

Point of the Mountain — Salt Lake and Utah Counties

BY **MARK MILLIGAN**

Standing at Point of the Mountain today, one might see paragliders, hang gliders, or radio-controlled gliders flying above the valley floor. Standing here 18,000 years ago, one might have heard and seen waves crashing on the shore of Lake Bonneville, glaciers calving into the lake from Little Cottonwood Canyon, and perhaps mammoths, musk oxen, or a saber-toothed cat. Lake Bonneville was a huge freshwater lake that existed approximately 13,000 to 30,000 years ago. The shorelines left by Lake Bonneville can be seen around Salt Lake and neighboring valleys like rings around a bathtub. Shoreline features include beaches, deltas, wave-cut benches, spits, and bars. The Point of the Mountain spit and adjacent Steep Mountain beach are two of the most spectacular shoreline features in the Bonneville basin.

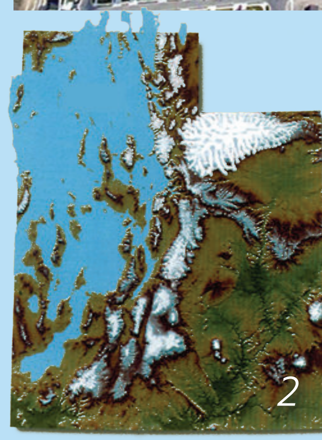
Geologic Information: The geologic equation for spectacular shorelines at this inland locale includes three parts: a former large lake, a mountain front oriented to receive the onslaught of waves generated by storms approaching from the northwest, and bedrock that is easily pulverized into sand and gravel.

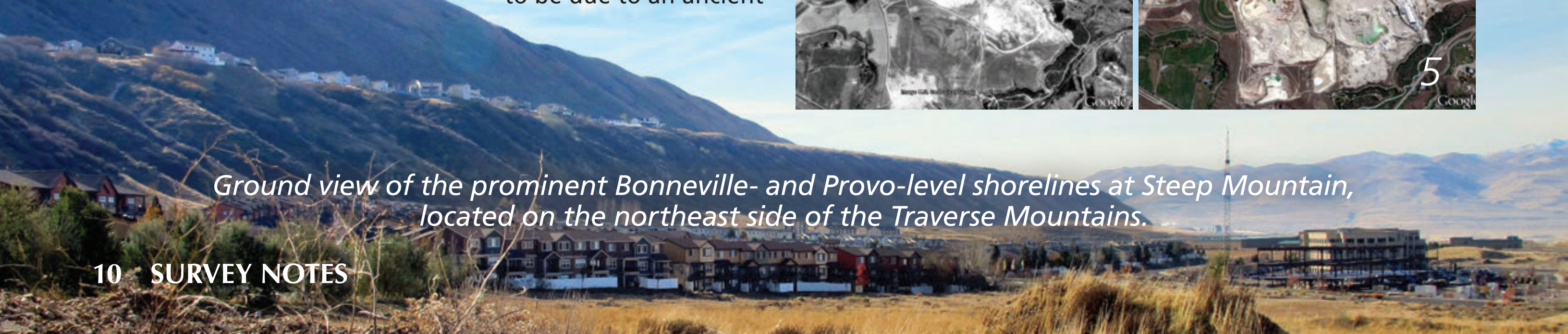
THE LAKE

A shift to wetter and colder conditions in the last Ice Age triggered Lake Bonneville's expansion from the location of the present Great Salt Lake into surrounding valleys. About 18,000 years ago, Lake Bonneville reached its maximum depth of over 1,000 feet and covered about 20,000 square miles. At that time one could have sailed from Point of the Mountain to Idaho, Nevada, or within 30 miles of Cedar City, Utah. While at its highest level (referred to as the Bonneville shoreline) the lake eroded through a sediment dam at Red Rock Pass in southeastern Idaho and catastrophically dropped over 300 feet to the Provo shoreline. Thereafter, a climatic shift to warmer and drier conditions (similar to present) caused Lake Bonneville to shrink, leaving Great Salt Lake as a salty remnant.

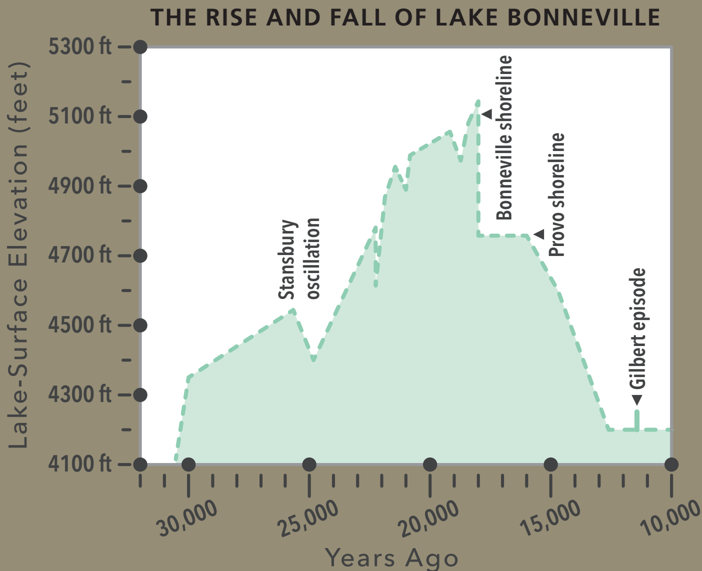
THE MOUNTAIN

The Traverse Mountains are an east-west trending range in an area dominated by north-south trending ranges. They extend between the Wasatch Range to the east and the Oquirrh Mountains to the west, and have a gap cut by the Jordan River. Additionally the Traverse Mountains lie at the boundary between two independent segments of the Wasatch fault, the Salt Lake City segment to the north and the Provo segment to the south. The location and orientation of the Traverse Mountains is thought to be due to an ancient

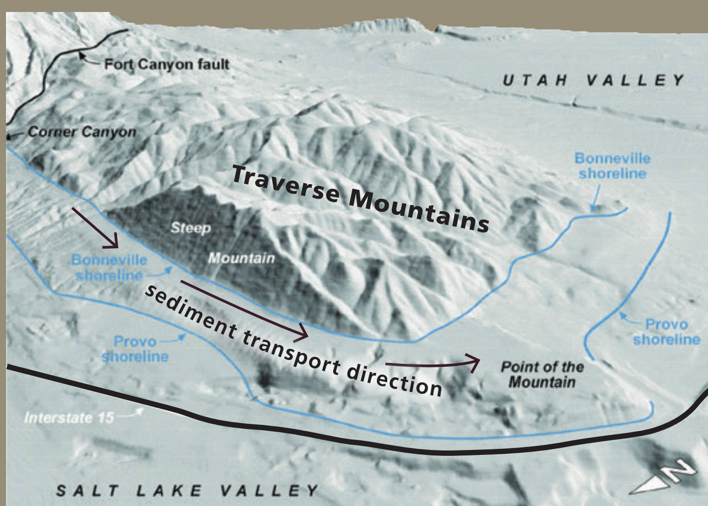




Ground view of the prominent Bonneville- and Provo-level shorelines at Steep Mountain, located on the northeast side of the Traverse Mountains.



This hydrograph shows the changes in lake level over time. Note that timing is from radiocarbon ages that have been calibrated to calendar years. Modified from Reheis and others, 2014, "Pluvial Lakes in the Great Basin of the Western United States—a View from the Outcrop," Quaternary Science Reviews.



Shaded-relief image of the east Traverse Mountains.

crustal structure that predates the crustal extension that created the modern landscape. The east-west orientation of these mountains subjected their north flank to intense waves generated across a long and unimpeded stretch of Lake Bonneville that once extended to the north.

THE ROCK

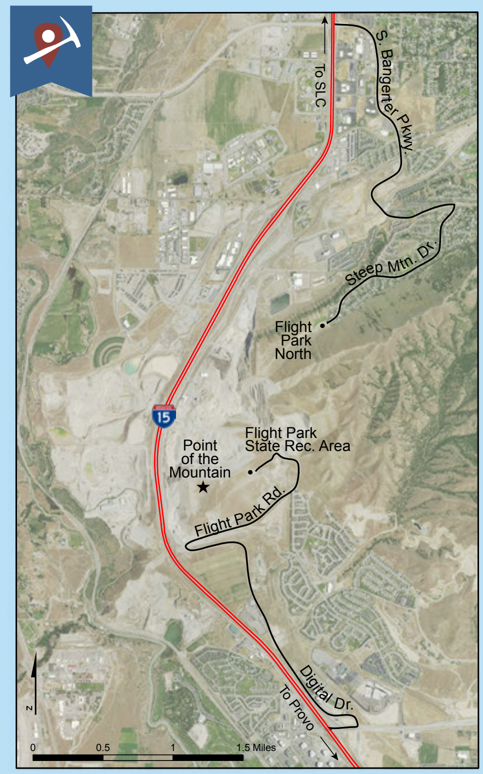
The north-facing Steep Mountain part of the Traverse Mountains is composed of highly fractured and weakened quartz sandstone (quartzite) of the roughly 300-million-year-old Oquirrh Group. This quartzite was readily pulverized by waves, creating an enormous supply of sand and gravel. Some of this sand and gravel remains on the Steep Mountain beach, but strong longshore currents traveling west and south through the Jordan River Narrows transported most of the material, redepositing it in the Point of the Mountain spit.

A spit is defined as a ridge or embankment of sediment attached to the shoreline at one end and terminating in open water at the other. The Point of the Mountain spit is a complex feature with various Lake Bonneville-age embankments that are underlain by sediments deposited by lakes that pre-dated Lake Bonneville and even older bedrock.

Photos on opposite page:

1. *Aerial view of the prominent Bonneville- and Provo-level shorelines at Steep Mountain, located on the northeast side of the Traverse Mountains. The straight face of Steep Mountain is believed to be due to a fault, the scarp of which is concealed by Lake Bonneville sediments. Photo by Mark Bennett, used with permission.*
2. *Lake Bonneville at its maximum extent.*
3. *View of the south side of the Point of the Mountain spit. The sediments forming the spit were transported from Steep Mountain.*
4. *Photo of gravel pit shows view to the north from Flight Park State Recreation Area in Utah County.*
5. *Mining has removed much of the Lake Bonneville deposits and some of the bedrock at Point of the Mountain. The total amount of sand, gravel, and rock removed is unknown, but according to Utah Division of Oil, Gas, and Mining documents, roughly 25 million tons was mined just from 2009 to 2014. Photos 1993 (left) and 2015 (right) Google Earth imagery. Google Earth imagery © 2015 Google Inc., left image U.S. Geological Survey, right image Landsat.*

HOW TO GET THERE



Point of the Mountain can be readily seen from I-15 where it marks the boundary of Utah County to the south and Salt Lake County to the north. For a closer view, the top of the spit can be reached from either county. However, the top of the spit is dissected by a large gravel quarry and can no longer be traversed.

To access the north side from Salt Lake County: Take I-15 south to exit 289 for UT-154/Bangerter Highway. Go left (east) at the fork and continue on Bangerter Highway (which becomes South Bangerter Parkway and then Traverse Ridge Road) for approximately 2.4 miles, then turn right onto Steep Mountain Drive. Continue for 1.4 miles to Flight Park North.

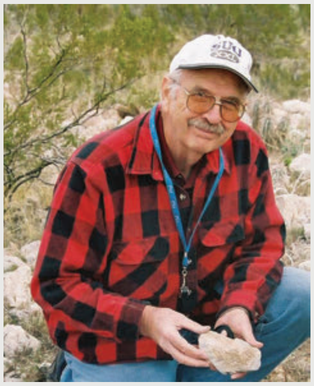
To access the south side from Utah County: Take I-15 north to exit 284 for UT-92 towards Highland/Alpine. Turn right (east) at the end of the off-ramp. After approximately 100 yards turn left onto Digital Drive (Frontage Road) and travel north for 2.1 miles to Flight Park Road. Turn right and continue 1.5 miles up to the Flight Park State Recreation Area.

Please stay well away from the sand and gravel pits. Pit high walls are indeed very high and may be unstable.

SURVEY NEWS

The Geologic Hazards Program welcomes **Emily Kleber** as a geologist. She comes from southern California, received a Bachelor of Science in Geology from UC Davis, and a Master of Science in Geology from Arizona State. Emily specializes in active tectonics and LiDAR data.

DAVE TABET retired at the end of March after 24 years of service with the UGS, including 16 years as manager of the Energy and Minerals Program. Dave came to the UGS with past knowledge and experience from both industry and government that focused mainly on coal. While at the UGS, Dave conducted studies, mapped, and published research on Utah's coal and coalbed methane resources, outcrop reservoir analogs (the Ferron Sandstone of east-central Utah), and best practices to manage produced water from oil and gas fields in the Uinta Basin. He also worked cooperatively with the Division of Oil, Gas, and Mining to help them create a digital petroleum well logs database, and began work with the U.S. Geological Survey and the Bureau of Land Management to digitize non-petroleum well data. As a program manager, Dave always watched out for his staff and put them first. Besides a Bachelor and Master of Science in Geology, Dave has a Master of Business Administration degree, which helped him manage the section budget and predict UGS revenue from mineral lease royalties. Outside the UGS, he served as treasurer and president of the Utah Geological Association (UGA), was co-editor of two UGA guidebooks, and treasurer of the Energy Minerals Division of the America Association of Petroleum Geologists. Dave's knowledge, expertise, and amiable personality will be greatly missed, and we wish him well in retirement!



IN MEMORIAM

Carl Frederick Lohrengel II, former professor of geology at Southern Utah University, passed away on December 17, 2015, in Cedar City, Utah. Fred had a passion for education, learning, and service. He obtained a Bachelor of Science in Geology from the University of Kansas City, a Master of Science in Geology from the University of Missouri, and a Ph.D. in Paleontology/Stratigraphy from Brigham Young University. He conducted post-doctoral research at the University of Georgia Marine Institute on Sapelo Island, Georgia, and worked in the Arctic surveying for oil companies. Fred taught geology and mathematics at Snow College for 17 years and geology at Southern Utah University (SUU) for 29 years. Fred published widely on geologic topics, was the SUU Geology Field Camp Director for many years, a member of the SUU Faculty Senate, past president of the Rocky Mountain Section of the Paleontological Society, a member of numerous community and charitable boards, and a strong supporter of the UGS office in Cedar City, particularly in the early days when both he and UGS were on the SUU campus. Fred is survived by his wife, Linda, and children Carl (III), Bethany Lynn, and Kara Marie.

2015 UGS Employee of the Year | **TYLER KNUDSEN**

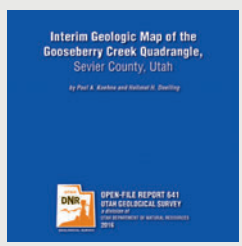
Congratulations to Tyler Knudsen who was named the UGS Employee of the Year. Tyler's geologic hazard and mapping knowledge is formidable, his computer skills are impressive, and he keeps up-to-date on the latest technologies. He produces many high quality studies, one of which recently received national accolades. He responds quickly to geologic hazard events and interacts well with the media. His knowledge of southwestern Utah geology is impeccable, which he enthusiastically shares with the public through blogs and local newspapers. He is wholly reliable, easy to be around, and a joy to work with. These special talents make him an essential member of the UGS Cedar City office. We are proud to recognize Tyler for his outstanding contributions to the UGS.

UGS WINS NATIONAL AWARD

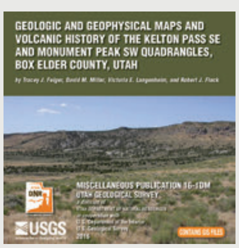
The Western States Seismic Policy Council, in partnership with the Northeast States Emergency Consortium, the Central U.S. Earthquake Consortium, and the Cascadia Region Earthquake Workgroup, recently awarded the **2016 National Award in Excellence for Educational Outreach to Business and Government** to the Utah Geological Survey for the *Basin and Range Province Seismic Hazards Summit III* (BRPSHSIII). The summit brought together over 250 scientists, engineers, emergency planners, and policy makers to discuss and evaluate the latest seismic-hazard research in the Basin and Range Province and identify ways to further reduce the risk from earthquakes in the region. More information and the *Proceedings Volume* are available at geology.utah.gov/?p=6504.

NEW PUBLICATIONS

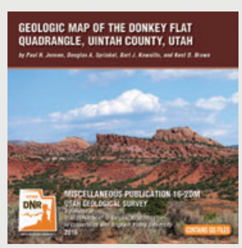
Landslide inventory map of the Sixmile Canyon and North Hollow area, Sanpete County, Utah, by Gregg S. Beukelman, Ben A. Erickson, and Richard E. Giraud, CD (1 pl. [contains GIS data]), ISBN 978-1-55791-921-2, **Map 273DM..............................$24.95**



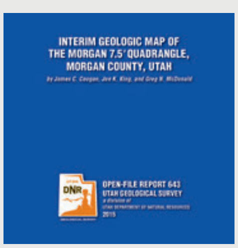
Interim geologic map of the Gooseberry Creek quadrangle, Sevier County, Utah, by Paul A. Kuehne and Hellmut H. Doelling, CD (11 p., 1 pl.), scale 1:24,000, **Open-File Report 641......................$14.95**



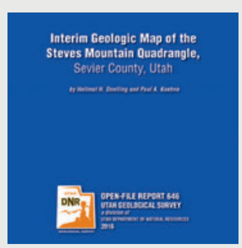
Geologic and geophysical maps and volcanic history of the Kelton Pass SE and Monument Peak SW quadrangles, Box Elder County, Utah, by Tracey J. Felger, David M. Miller, Victoria E. Langenheim, and Robert J. Fleck, CD (34 p., 2 pl.), ISBN 978-1-55791-919-9, **Miscellaneous Publication 16-1DM...$24.95**



Geologic map of the Donkey Flat quadrangle, Uintah County, Utah, by Paul H. Jensen, Douglas A. Sprinkel, Bart J. Kowallis, and Kent D. Brown, DVD (8 p., 2 pl. [contains GIS data]), scale 1:24,000, ISBN 978-1-55791-920-5, **Miscellaneous Publication 16-2DM...$24.95**



Interim geologic map of the Morgan 7.5' quadrangle, Morgan County, Utah, by James C. Coogan, Jon K. King, and Greg N. McDonald, CD (25 p., 2 pl.), scale 1:24,000, **Open-File Report 643.......................$14.95**



Interim geologic map of the Steves Mountain quadrangle, Sevier County, Utah, by Hellmut H. Doelling and Paul A. Kuehne, CD (12 p., 1 pl.), scale 1:24,000, **Open-File Report 646......................$14.95**

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Paleoseismology of Utah, Volume 27—Geologic mapping and paleoseismic investigations of the Washington fault zone, Washington County, Utah, and Mohave County, Arizona, edited by William R. Lund, CD (175 p.), **Miscellaneous Publication 15-6....$14.95**

Earthquake probabilities for the Wasatch Front region in Utah, Idaho, and Wyoming, by Working Group on Utah Earthquake Probabilities, CD (164 p.), **Miscellaneous Publication 16-3....$14.95**

Proceedings volume, Basin and Range Province Seismic Hazards Summit III, edited by William R. Lund, CD (7 technical sessions [47 presentations], 14 posters).

Presentations from the third Basin and Range Province Seismic Hazards Summit held in Salt Lake City, Utah, January 2015, **Miscellaneous Publication 15-5....$19.95**

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