

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

SURVEY NOTES

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**The Curious Spring Creek
Road Landslide**

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Cover I Headscarp undercutting the garage of one of the evacuated homes in Riverdale City, October 23, 2018. Photo by Ben Erickson.

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DIRECTOR'S PERSPECTIVE

By Richard G. Allis



After writing about 50 "Director's Perspectives," this one is my last before retirement. It can be challenging to come up with something new each time. In

this issue I reflect on the biggest changes that have occurred in the work we've done since I began serving as UGS Director and State Geologist in 2000 and the biggest issues that confront the UGS looking forward. In 2000, changes in information technology were starting to substantially affect all aspects of geological information. These changes continue as we now develop applications online so that geological data can be viewed remotely and interactively, with information no longer stored in numerous file and map cabinets in our offices. We used to have a standard print run of 400 copies for UGS publications, and our Utah Core Research Center warehouse held large volumes of inventory. We went through a phase of publishing reports and maps on compact disc, and now offer the publications online or print them on-demand through our bookstore.

In the early 2000s our Energy and Minerals Program had twice as many staff as any other program, helped by multi-year federal contracts with the U.S. Department of Energy. This was a time when U.S. oil production was declining, and there were concerns about oil imports from unstable parts of the world. Now the U.S. is the world's largest oil producer due to new technologies for extracting oil from previously unproductive formations, and federal research programs for increasing domestic oil production have all but disappeared. The priority for finding and extracting more coal in Utah has also diminished as state exports have declined, and coal-fired power in Utah decreased from 96 percent of Utah's power consumption in 2000 to less than 60 percent today. As

our Energy and Minerals Program has shrunk to be similar in size to our other programs, our Groundwater Program has grown. Droughts and increasing demand for groundwater supplies, especially in remote basins far from the Wasatch Front, have increased the need for assessment of sustainable yield in these basins, a critical research area for our groundwater specialists.

In looking forward, we will continue to emphasize critical mineral-supply chains and reducing the vulnerability to disruptions. Utah is mineral-rich, and the UGS needs to continue its monitoring and promotion of exploration activity. However, the biggest geologic events could be natural hazard disasters. Statistically, a magnitude (M) 6 or greater earthquake occurs in Utah about every 30 years, and in the central Wasatch Front region, a M 7 or greater earthquake occurs every 200 to 300 years. We are overdue in both categories, with the last M 6.0 events in 1966 (near the Nevada border in southwest Utah) and 1975 (near the Idaho border), and a M 5.9 event near St. George in 1992. The UGS has an important role supporting the Utah Seismic Safety Commission in advocating for improved building safety and reducing the very large number of vulnerable unreinforced masonry buildings in Utah. The world is experiencing increased intensity of storms, and Utah will be part of this trend. The frequency and scale of landslides, debris flows, and rockfalls may also increase. It has been 35 years since the massive Thistle landslide, which occurred after prolonged, record-breaking precipitation in early 1983. Urban growth since then has allowed residential expansion into more vulnerable locations on or beneath steep hillsides. The dual drivers of economic growth and urban growth will ensure that the Utah Geological Survey is needed to provide objective guidance for prudent land use decisions in the coming decades. ■



Spring Creek Road landslide headscarp, showing evacuated homes at the top of the landslide. The darkened, wet areas are three springs at the base of the headscarp. Photo taken by Jon West, Davis County Sheriff's Office, June 26, 2018.

The Curious Spring Creek Road Landslide

By Ben Erickson

The Utah Geological Survey (UGS) Geologic Hazards Program investigates and researches landslides and other geologic hazards in Utah. Our applied research includes analyzing landslide behavior and developing models that can be used to determine future landslide activity to assist at-risk communities. Through research of previous landslides we know the general factors affecting landslide dynamics in Utah. These factors include the season, the type of rock or soil, seasonal snowpack and runoff, and land modification. These factors typically allow a geologist to anticipate landslide behavior, but in the case of the Spring Creek Road landslide in northern Utah, there was little indication of what was to come.

Located 1000 feet east of the Riverdale City offices, the Spring Creek Road landslide, a reactivation of a pre-existing landslide, started moving on November 19, 2017. The landslide reactivated on a steep, sandy bluff formed by the Weber River cutting down into the sediments of ancient Lake Bonneville. Several horse pastures are present at the base of the bluff, one of which was severely impacted by the landslide. The pasture owners were present and vividly recount the event: "fast and loud, snapping trees on its way down." The landslide quickly flowed and covered Spring Creek Road, narrowly missing buildings and machinery.

The pasture, which was a Christmas tree staging area at the time, was threatened by continued landsliding and sediment buildup. The landslide cut off access to a home on Spring Creek Road and stopped 120 feet short of a five-track Union Pacific rail yard. The quickly moving landslide and long runout was due, primarily, to abundant groundwater, which caused it to flow out over 250 feet from the base of the bluff, classifying the landslide as a rapid earthflow. The slide continued to flow in subsequent events for several months, but activity slowed through the summer of 2018.

When it first reactivated, the landslide was about 620 feet long and 160 feet wide. Homes at the top of the bluff were deemed unsafe as the slide slowly carved away at the backyards upslope. Riverdale City issued mandatory evacuation orders for three homes and a voluntary evacuation order for one. As the landslide headscarp continued to recede upslope, all four houses were permanently evacuated.

Following initial landslide movement, water flowing from springs near the base of the cliff face continued to erode the lower deposit to form a smooth alluvial fan. In addition, the steep headscarp was being undercut by spring water flow carrying sediment away and causing further landslide activity, driving the cliff face closer to the evacuated homes, and preventing the



Comparative images of landslide expansion after five months. Top photo taken November 29, 2017, and bottom photo taken April 3, 2018. The headscarp expanded farther upslope removing trees and additionally widened into an hourglass shape. Photos taken by Jon West, Davis County Sheriff's Office.

Drone image taken by Jon West, Davis County Sheriff's Office, June 26, 2018, Spring Creek Road Landslide, Riverdale, Utah.

slope from grading into a less steep, more stable surface. Flow from the springs also created a stream channel through the pasture and continues to periodically flood the area. The stream channel changes course as large headscarp blocks fall into the deposit. The unpredictable stream channel location has prevented the pasture owners from directing the water away from their structures, resulting in sediment deposition in and around their pasture and buildings that ranges from about 5 feet thick around the buildings to 10–15 feet thick near the base of the bluff. The Union Pacific Railroad added 4 feet of fill on their access road between their tracks and the landslide toe, preventing inundation of the tracks. At the end of summer 2018, the landslide deposit enlarged to about 690 feet long and 260 feet wide, and the headscarp widened 100 feet to the north and south and moved 70 feet toward the homes, undercutting a garage.

At first, the Spring Creek Road landslide did not appear to have any of the indicators typically observed in Utah landslides. The rapid landslide movement occurred in late November, a time when little surface water or precipitation is typically available to influence groundwater levels. The landslide impacted a well-established, 60-year-old residential development that had no recent modifications made to the bluff. The slide continued to enlarge at about the same rate for several months after initial movement. These factors seem to indicate an unusual landslide behavior; however, with further investigation, the behavior became better understood. The closer look started with the bluff.

The bluff is composed of layers of impermeable clay at the base overlain by sand and silt. The sediments were deposited in ancient Lake Bonneville approximately 12,000 to 24,000 years ago as part of a delta that formed at the mouth of Weber Canyon. The delta was over 200 feet thick at the Spring Creek Road landslide site. After Lake Bonneville receded, the Weber River eroded through the delta carving a bluff-bounded floodplain in which much of Riverdale City now resides.

The bluff is shown on geologic maps as a mass-movement deposit where several prehistoric and historical landslides are identified. Aerial imagery indicates activity of some of these landslides as recently as a few years ago. Imagery from June 17, 2017, shows an approximately 20-foot-wide by 70-foot-long area of bare soil on the vegetation-covered steep bluff. The bare soil probably indicates the initial landslide reactivation.



Pasture buildings and 6-foot-high fence inundated with sediment. Photo by Ben Erickson, June 7, 2018.

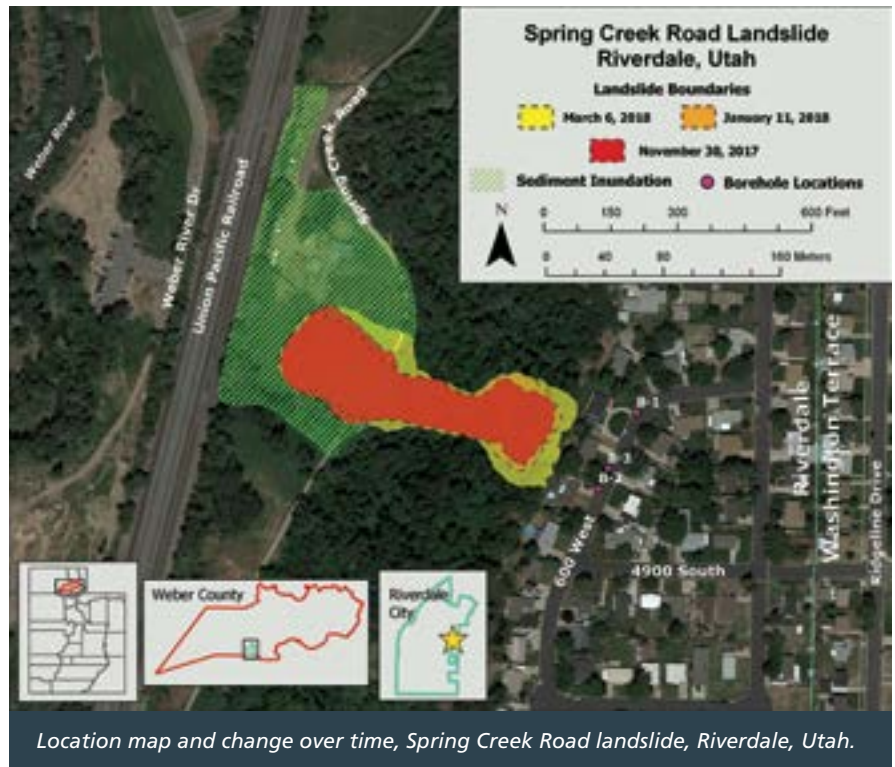
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The addition of water to the steep bluff is the key reactivation factor in this landslide's movement. Water is often the driving force or trigger of a landslide. In Utah, excess water is abundant in springs and creeks during snowpack runoff. This means that spring is an active season for landslides, predominantly during high-snowpack and rapid-runoff years. Summer monsoonal rain can also provide excess water, but storms are localized, short-lived, and generally do not provide enough time and water to saturate and mobilize large landslides like the Spring Creek Road landslide. This landslide reactivated with rapid movement in late fall. Groundwater influence, as opposed to seasonal precipitation, is the critical factor for the Spring Creek Road landslide.

Groundwater slowly travels from the Wasatch Range to Great Salt Lake. To determine local groundwater levels, Riverdale City drilled three observation wells east of the landslide in early spring of 2018. The UGS placed sensors in two of the wells to record water levels periodically throughout the day. In other places, groundwater-level spikes related to landscape watering have been linked to landslide activity. At Spring Creek Road, however, the observed groundwater levels slowly declined and there is no indication of a groundwater seasonal increase due to landscape irrigation. A delay in summer landscape watering spikes is possible and could be detected by continued monitoring.

Three of the homes affected by the Spring Creek Road landslide were built in 1960 and one in 1963, decades before formal geologic and geotechnical-engineering planning and construction ordinances were adopted in Utah. However, future planning for this area and similar geologic areas needs to take advantage of available resources to reduce the risk associated with this type of landslide and other geologic hazards. The 1988 slope-failure inventory map produced by Weber County and the 2004 geologic map of the Ogden 7.5-minute quadrangle published by the UGS show this landslide is within an area of previously mapped landslides along the bluff. These map resources can help established communities and developers evaluate risk and plan for disasters such as the 2017 landslide.

The UGS continues to study and monitor the Spring Creek Road landslide and provide information and advice to Riverdale City as requested. The active springs at the base of the landslide scarp continue to create a high risk for landslide activity and resulting damage to land and infrastructure. ■



Location map and change over time, Spring Creek Road landslide, Riverdale, Utah.

ABOUT THE AUTHOR

Ben Erickson is a Project Geologist in the Geologic Hazards Program who joined the Utah Geological Survey in 2011. He is a Utah native and has a B.S. in Earth Science from Utah Valley University and a M.S. degree in Geological Engineering from the University of Utah. Ben works to share knowledge of geologic hazards through mapping and working with communities. His role in emergency response ranges from logging digital data to explaining geological hazard conditions to local communities, civic leaders, and the media.

For more information see:

Spring Creek Road Landslide

<https://geology.utah.gov/hazards/landslides-rockfalls/spring-creek-road-landslide/>

Landslide Hazards in Utah

https://ugspub.nr.utah.gov/publications/public_information/pi-98.pdf

Ogden 7.5-minute Quadrangle Geologic Map

<https://ugspub.nr.utah.gov/publications/geologicmaps/7-5quadrangles/m-200.pdf>

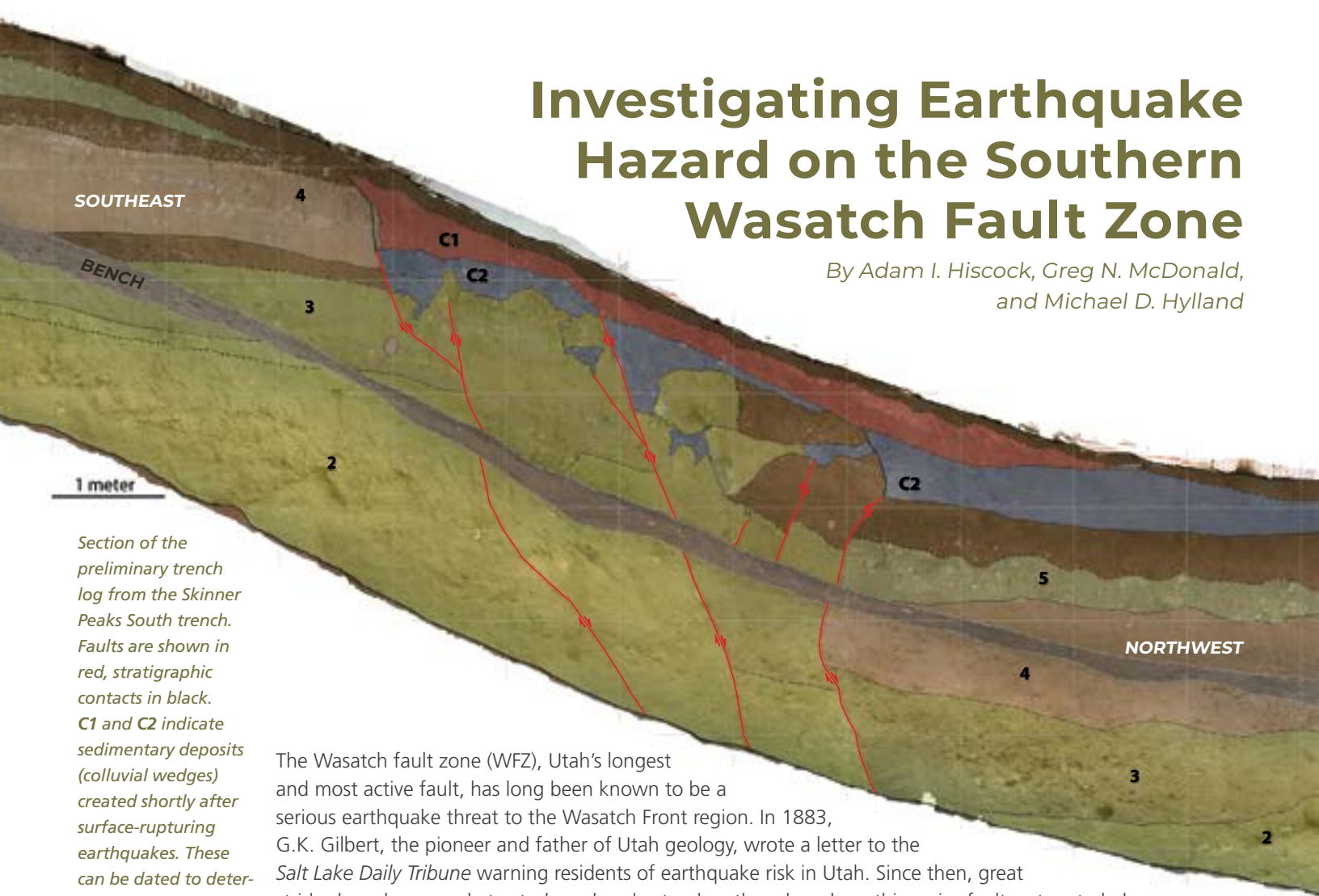
Weber County Slope Failure Inventory Map

<https://geodata.geology.utah.gov/pages/view.php?ref=15970>



Investigating Earthquake Hazard on the Southern Wasatch Fault Zone

By Adam I. Hiscock, Greg N. McDonald, and Michael D. Hylland



Section of the preliminary trench log from the Skinner Peaks South trench. Faults are shown in red, stratigraphic contacts in black. C1 and C2 indicate sedimentary deposits (colluvial wedges) created shortly after surface-rupturing earthquakes. These can be dated to determine timing of past earthquakes at this site. Scale shown, no vertical exaggeration.

The Wasatch fault zone (WFZ), Utah's longest and most active fault, has long been known to be a serious earthquake threat to the Wasatch Front region. In 1883, G.K. Gilbert, the pioneer and father of Utah geology, wrote a letter to the *Salt Lake Daily Tribune* warning residents of earthquake risk in Utah. Since then, great strides have been made to study and understand earthquakes along this major fault system to help reduce earthquake risk along the Wasatch Front. Most of this work has been conducted on the five central segments of the WFZ, leaving the northern and southern end segments relatively unstudied. An earthquake forecast, or probability model, for the WFZ was published in 2016 by the Working Group on Utah Earthquake Probabilities, but due to a lack of earthquake timing data, the end segments could not be characterized as rigorously as the central segments. This lack of data on the end segments hinders our ability to accurately model and forecast earthquakes on the entire WFZ.



View into the Skinner Peaks South trench on the Levan segment of the WFZ. The fault zone is visible between the red arrows.

Both the Levan and Fayette segments on the southern end of the WFZ show evidence for generating large, surface-faulting earthquakes in the Holocene time period (about the past 12,000 years). However, previous paleoseismic (the geologic study of past earthquakes) research on both segments is limited. In 2015, Utah Geological Survey (UGS) geologists remapped the segments in great detail using new high-resolution digital topographic data. This new mapping has allowed us to identify previously unknown and unmapped traces of faults along these segments, and helped us in selecting sites for paleoseismic fault trenching investigations.

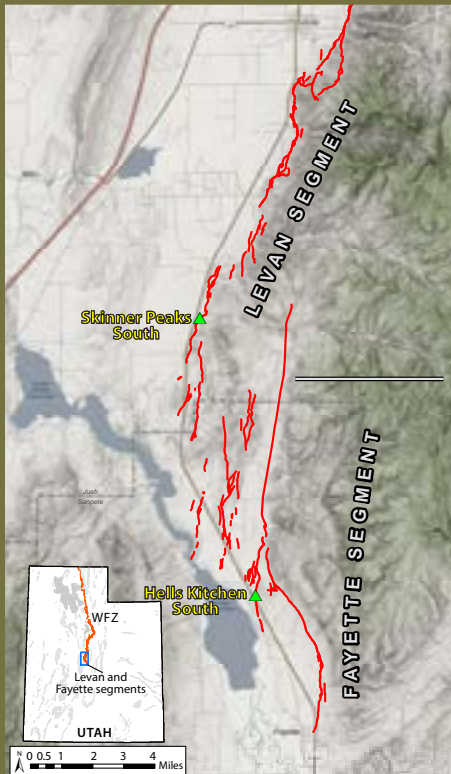
Investigations conducted in 1991 and again in 2008 on a natural exposure of the fault exposed by a stream cut on the Levan segment provided a timing estimate for the most recent large earthquake that occurred on that segment (approximately 1000 years ago). A fault trenching investigation on the south end of the Levan segment, also in 1991, produced data consistent with a large earthquake around 1000 years ago, but was unable to

Studying the end segments of the Wasatch fault zone is critical to helping us understand and forecast large earthquakes on the entire fault.

Skinner Peaks South trench site

U
D

Aerial view looking northeast of the Skinner Peaks South site. The trace of the Levan segment is shown in red (U = upthrown side of fault or footwall, D = downthrown side of fault or hanging wall).



The Levan and Fayette segments of the Wasatch fault zone (WFZ) are located in central Utah, in Juab and Sanpete Counties. Our trench sites lie along State Route 28; Skinner Peaks South is approximately 11 miles south of Levan and Hells Kitchen South is approximately 6 miles north of Fayette. Traces of the WFZ are shown in red, and the Levan-Fayette segment boundary is indicated by the gray line.

document the timing of any earlier earthquakes. Finally, data collected by creating topographic profiles across Levan- and Fayette-segment fault scarps has provided insights into earthquake rupture on both segments. Despite this past work, many unanswered questions remain about earthquake activity on these southernmost segments of the WFZ: How often do large earthquakes occur on these segments and how episodic or random are they? Do earthquakes rupture only the Levan segment or Fayette segment, or do they rupture and spill-over from one segment

to the other? What role does local geology play in faulting on these segments? How does the nature of faulting on these segments compare to faulting on the central segments of the WFZ (e.g., the Salt Lake City and Provo segments)?

To attempt to answer these questions and more the UGS, aided by the U.S. Geological Survey (USGS), conducted a fault trenching investigation of prehistoric surface-faulting earthquakes on the Levan and Fayette segments in October of 2017. We excavated one trench at the Skinner Peaks South site on the Levan segment and one trench at the Hells Kitchen South site on the Fayette segment. The excavations were open for about a month while we worked to collect data and map the exposures.

At the Skinner Peaks South site, we excavated a trench across a 10- to 13-foot-high scarp. We mapped five stratigraphic units in the trench, including highly weathered volcanic bedrock in the bottom of the trench and sandy alluvial-fan gravels containing several prominent buried soil horizons. At the Hells Kitchen South site, we excavated a trench across a 3- to 6-foot-high scarp. This trench exposed mostly coarse-grained alluvial-fan deposits and a loess (wind-blown fine sand) deposit at the bottom of the trench, and we mapped four stratigraphic units. We map the trench-wall exposures on high-resolution photomosaic images in the field, and then digitize our mapping back in the office later.

Our preliminary findings include evidence for two surface-rupturing earthquakes at the Skinner Peaks South site and one

surface-rupturing earthquake at the Hells Kitchen South site. We collected 20 samples for radiocarbon (^{14}C) dating and 15 samples for optically stimulated luminescence (OSL) dating. Combined with our stratigraphic mapping, the dating results will be used to develop earthquake timing models and recurrence intervals for the Levan and Fayette segments. Our final report will be published in the *Paleoseismology of Utah Series*, a UGS series of reports pertaining to the study of past earthquakes in Utah (<https://geology.utah.gov/hazards/technical-information/paleoseismology-of-utah-series/>). Eventually, our results will be incorporated into the USGS's National Seismic Hazard Maps, which are used by local engineers and architects to adequately plan and design for development and reduce earthquake risk along the Wasatch Front region and elsewhere.

Studying the end segments of the WFZ is critical to helping us understand and forecast large earthquakes on the entire fault. Through this investigation and others, the UGS is working to fill gaps in earthquake data along the WFZ. We have recently completed detailed fault mapping for the entire fault zone (see *Survey Notes* v. 49, no. 3, p. 1–3). We are also working to secure funding to conduct a similar investigation on the northern end segments, specifically the Clarkston Mountain and Malad City segments in northern Utah and southern Idaho. These investigations will help Utahns better understand the hazard from large earthquakes on the WFZ and help us strengthen our earthquake resiliency. ■

WHY A BUILDING FULL OF ROCKS IS SO IMPORTANT TO UTAH

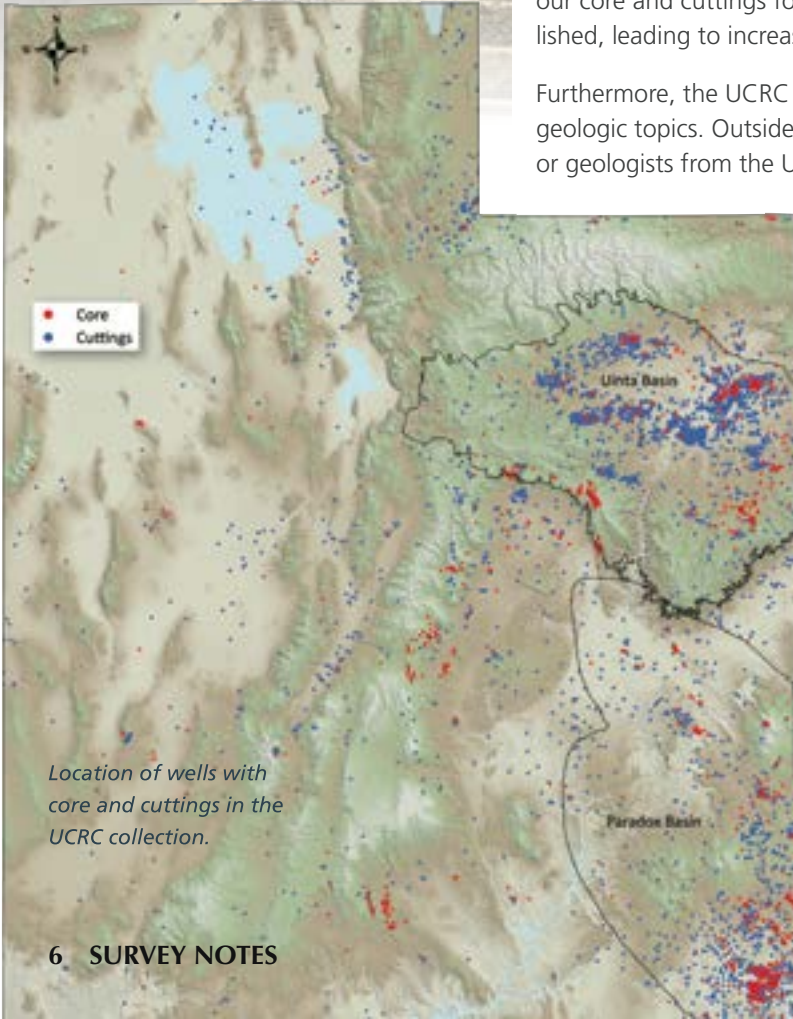
By Michael D. Vanden Berg

Established in 1951, the Utah Geological Survey's Utah Core Research Center (UCRC) contains the region's only publicly available and most complete collection of geologic core and cuttings from Utah. Think of it as a geologic library, storing inimitable archives of geologic knowledge for future generations. The current 15,000-square-foot facility was built in 1997 and presently holds core from over 1500 drill holes totaling about 400,000 feet of material (over 75 miles, roughly the distance from Salt Lake City to Logan!), and cuttings from nearly 5000 drill holes representing over 57 million feet of subsurface data (nearly 11,000 miles, almost half way around the Earth!). Most of this material came from oil and gas wells, but some came from metal and potash exploration wells, water/geo-thermal wells, coal exploration wells, and many others. This collection represents about \$5 billion worth of investment in Utah's natural resources and in many cases is irreplaceable.

The UCRC collection is an invaluable resource for companies looking to develop mineral and energy resources in Utah, most of which are in rural areas of the state. In 2018 alone, the UCRC hosted over 400 visitors from all over the world. Industry professionals often visit the UCRC to examine core and collect sample material for analytical testing. These examinations help them better understand their lease area, reduce exploration costs, and hopefully spur increased development. It is not uncommon for the UCRC to be the first place that a new-to-Utah petroleum company will visit before investing in Utah leases or drilling new wells. The collection is also widely used by the academic community. Professors and students from all over the world come to Utah to examine our core and cuttings for various research projects, the results of which are often published, leading to increased interest and understanding of Utah's geology.

Furthermore, the UCRC hosts educational workshops (20+ per year) on a wide variety of geologic topics. Outside groups will use our facility and core material to run workshops, or geologists from the UGS will organize custom educational courses for oil companies and university geology students. In the past few years, the UGS has organized workshops for geologists from several international companies including BP, ExxonMobil, Shell, ConocoPhillips, Anadarko, Total (France), Petrobras (Brazil), Equinor (Norway), and Repsol (Spain), as well as more local companies including QEP Resources, Wexpro, Newfield, Finley, Ultra, Berry, Crescent Point, Bayless, Bill Barrett, Axia, Resolute, Rose Petroleum, Fidelity, and many others.

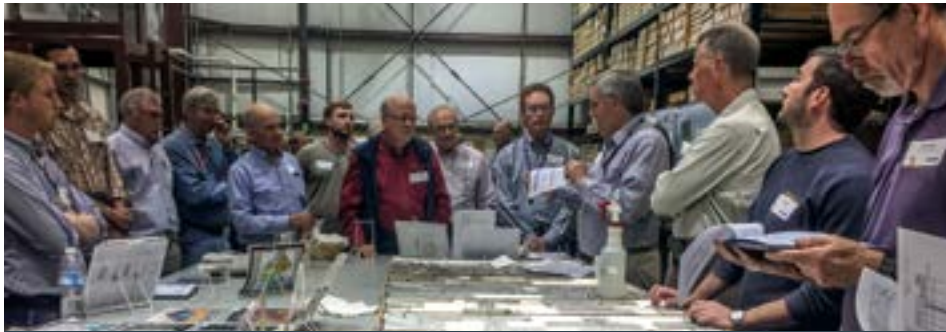
Since the downturn in oil and gas prices in late 2014, several companies have donated large quantities of core/cuttings material to the UCRC as a cost-saving measure. The most significant donation was from Resolute Energy, the former operator of Greater Aneth, Utah's largest producing oil field located in San Juan County (see *Survey Notes*, v. 49, no. 2, p. 6-7). This donation consisted of core from over 120 wells, stacked on about 140 pallets requiring six semi-truck loads to deliver the material from Texas. In addition, we have recently received new cores from the Green River Formation in the Uinta Basin, the Moenkopi Formation near the San Rafael Swell, and cores from the Navajo, Entrada, and Dakota Sandstones.



Location of wells with core and cuttings in the UCRC collection.



Proposed UCRC expansion.



In 2018 alone, the UCRC hosted more than 400 visitors from all over the world.

Proposed Expansion

With all the recent donations, the UCRC warehouse is at capacity. The UGS has proposed building an additional 9000 square feet of storage space to accommodate additional donations of core and cuttings. Without access to a secure/modern core center, operators looking to offload their core might opt to dispose of it instead of donating this valuable material. It is of vital importance that the State of Utah offers an option to collect and store this important material and make it available for companies, researchers, and students to use and examine.

In addition, the UCRC is in dire need of an updated and expanded core viewing area. The UCRC currently uses space in the warehouse portion of the facility. This space is not ideal for core examination or for teaching workshops because the area is too small, limiting the amount of core that can be displayed at one time and making examination difficult and inefficient; the area is not climate controlled, becoming too cold in winter and too hot in summer; and the area is within the active warehouse, making safety of guests a concern. With an improved core viewing area, we can provide a more user-friendly environment for core examination, increasing productivity and efficiency. We will also be able to host larger and more professional educational workshops, attracting more visitors to the state.

As the UGS tries to raise the funds necessary to expand and improve the UCRC, we want to emphasize that the facility is not just a warehouse full of rocks, but holds billions of dollars worth of investment in Utah's natural resources. UGS geologists are dedicated to curating this important collection and fostering its beneficial use for Utah industry and geologic knowledge. If you are interested in seeing this collection, using it for research, or teaching a core-based geologic workshop, please feel free to contact us at any time. Visit <https://geology.utah.gov/?p=5230> for more information.

Importance of the UCRC: Two Case Studies

Metal Exploration

In 1972, AMAX Exploration drilled four deep core holes near the historical Cactus copper-gold-molybdenum mine in the San Francisco district, Beaver County, Utah. Although these holes intersected alteration and some mineralization, they were not sufficiently encouraging at the time for AMAX to retain their property position and do further work. Rather than continue storing the core, they chose to donate it to the UGS.

In 2016, Alderan Resources acquired a large property in the San Francisco district, including the old Cactus mine. In the course of their due diligence, they discovered that the UGS had the AMAX core. Company geologists visited the UCRC to examine these cores and took samples for new assays. They recognized that the drill core was compatible with their geologic model of the Cactus mine being part of a much larger porphyry copper system, similar to the Bingham Canyon mine. As a result of the promising analyses performed on the core housed at the UCRC, in 2017 Alderan raised about \$20 million in an initial public offering, set up an office in Salt Lake City, hired some local senior staff, leased a field office in Milford, hired local support staff, and began an aggressive core drilling program. Their initial holes in 2017-18, totaling over 14,000 feet, targeted the Cactus mine area and intersected some interesting shallow mineralization. Alderan then raised another \$3 million to test additional targets in the district.

Oil and Gas Exploration and Production

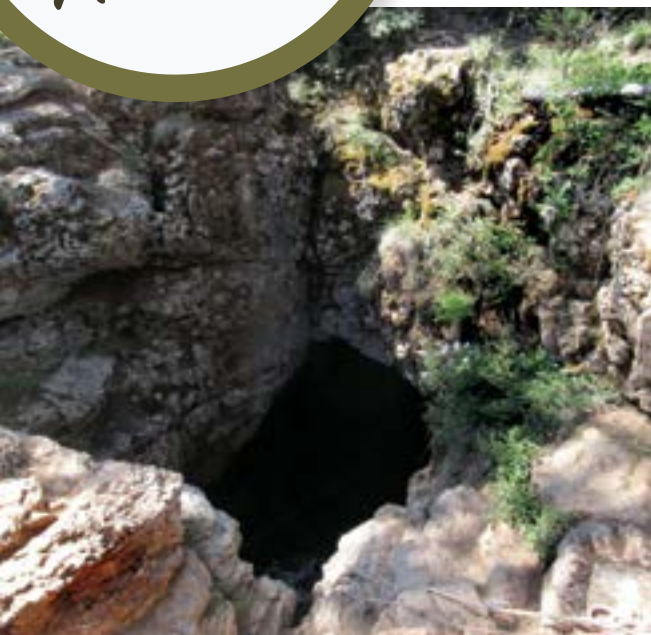
When new oil and gas leases are offered or if a company is looking to acquire acreage, potential buyers need to understand the geology and resources available on these lands. Often, prospective buyers send their geologists to the UCRC to examine core and cuttings material from the lands in question to gain a better understanding of the potential investment. For example, in spring 2018, QEP Resources decided to sell their long-held acreage in the Uinta Basin. Soon after the announcement, Middle Fork Energy visited the UCRC to examine our extensive collection of cores from this area. Subsequently, in July 2018, Middle Fork announced that it had purchased QEP's acreage for \$155 million. Several times a year, companies with no current assets in Utah will visit the UCRC to examine core material; most of these companies are doing initial data gathering to determine if they want to invest in Utah resources. UGS geologists are always on hand and available to help educate company representatives on Utah's natural resource potential. ■

Glad You Asked!

WHAT ARE ICE CAVES?

By Jim Davis

Ice caves are caves in bedrock that host year-round ice. They differ from caves formed within ice, which are designated *glacial caves*. Ice caves are exceptional because they are not only scarce, but they are located far outside zones of permafrost—at low elevations (near sea level) and low latitudes (between around 30° and 70°), where they maintain a much lower average annual temperature than that of the air above. How cold temperatures persist in these spaces is a matter of cave geometry; the physical properties of air, water, and rock; the weather; and time. In Utah, ice caves are well developed in limestone caves and sinks in the Bear River Range, Uinta Mountains, and other areas such as talus slopes and lava flows.



American explorer Edwin Swift Balch (1856–1927) attributed much of the cause of ice caves to *The Winter's Cold Theory*, the idea that the cold of the winter perpetuates through the summer. Balch took the presence of ice at the entrance of caves as evidence for the theory, noting that cold winter air is a requirement for ice cave formation and that ice had never been found beyond 200 meters (650 feet) from the entrance of a cave or deeper than 150 meters (490 feet). Therefore, the presence of year-round ice was due to capture and retention of cold from the previous winter rather than any natural processes operating in the cave.

Ice caves are differentiated into two types by air flow and cave structure: *static* ice caves and *dynamic* ice caves. Static ice caves flood with cold air in winter and have little air circulation in the summer, with the chilly, dense air settling in and remaining stable. Entrances in these caves are higher than the downward-sloping body of the cave and are referred to as “cold sock,” “cold pocket,” or “cold trap” caves. Conversely, dynamic ice caves have low entrances, an upward-sloping body, and conduits to the surface at the top of the cave. Dynamic ice caves are cooled by the “chimney effect,” where cold air is sucked up the entrance in winter as warm air exits the above conduits. Air flow is reversed in summer as cold air drains downslope out the entrance and warm air is drawn in through the higher conduits. The result is a continuous annual draft of cold air at the lower section of the cave. Dynamic air circulation also produces freezing talus slopes, which can be thousands of feet below areas of permanent ice.



Ice formation requires a source of water. Fractures and fissures in the bedrock allow water to seep in and freeze, or precipitation or runoff enter directly into the cave or sink. Masses of ice and snow in the cave from previous winters thwart rising temperatures in summer, as available heat energy is sunk into melting or sublimating the ice (latent heat) and warming water (specific heat) rather than warming the cave air. Once a cave builds up a sizable mass of ice and a large volume of the surrounding bedrock becomes cold, thermal inertia propels frigid temperatures through the heat of summer.

TOP: Duck Creek Ice Cave, Kane County, a classic “cold trap” ice cave that has a closed depression and descending body and a water source of direct snowfall into the cave. Elevation 8820 feet. Photo provided by Linda Hoernke.

BOTTOM: Layers of ice exhibit an angular unconformity (see arrows) in a Utah ice cave, October 2004. Photo provided by David Herron, U.S. Forest Service.

Duck Creek Ice Cave, formed in a sinkhole on the Markagunt Plateau, is an example of a cold trap ice cave. Duck Creek is small and, although always cool, does not quite meet the strict definition of an ice cave, often melting out in late summer. Similarly, the namesake of Ice Cave Peak in the Uinta Mountains, previously containing multiyear ice, has reportedly melted out. A classic disappearing stream, Big Brush Creek Cave, estimated at nearly 5 miles in length, is not just a cold air sink but a water sink consuming Big Brush Creek into its lengthy passageways. The *Vernal Express* wrote in 1893 “. . . it is called the Ice Cave because all summer long the entrance, to a depth of several hundred yards, is half filled with glittering ice . . .” During years of torrential spring runoff, the heat from floodwaters melts all the ice in the cave. An immense bluish ice column just inside the entrance has endured through multiple years in historical times, reported in August 1899 in the *Salt Lake Herald* as being “eight feet in diameter and reaches from the ceiling to the floor” and “would perhaps remain forever were it not for the rush of an occasional flood, which sweeps it away and into the depths below.”



Left: UGS geologist Sandy Eldredge (ret.) climbs out of an “aa” lava pit in the Ice Springs lava flow; elevation 4675 feet. **Right:** Below the surface of the Ice Springs lava flow ice coats the blocks of basalt. Green algae thrive beneath the ice, and the rocks are caked in white calcium carbonate on the otherwise dark-colored lava rock. Photos were taken on June 25, 2013, when air temperatures were in the lower 90s.

Ice has been reported beneath talus slopes in the Wasatch Range and Wasatch Plateau, and in the blocky lava flows of the Black Rock Desert. An extraordinary example is in the Ice Springs lava flow “cave” in Millard County where the annual mean air temperature is around 52°F, but the surface temperature of the dark basalt can exceed 140°F in summer. In his 1890 monograph, Grove Karl Gilbert labeled this the “Natural Ice House” and observed ice there in late September. Gilbert hypothesized the ice was a result of (1) accumulation of cold water from melting snow, (2) protection from the sun by “a heavy cover conducting heat poorly,” (3) shelter from wind, and (4) evaporation. Much of the causes of the Ice Springs ice cave can be attributed to the “Balch effect,” where flattish areas with coarse, blocky materials can have ground temperatures that are more than 10°F cooler than the surrounding mineral soils. Winter air descends into the spaces between the blocks, displacing lighter, warm air. In the summer the cold air remains in the spaces between the rocks. The Ice Springs cave has been without ice at times, however, as reported by the *Millard County Chronicle* on September 10, 1942, as dry and bare as “Mother Hubbard’s Cupboard,” with the *Chronicle* later reporting 36-inch-long icicles on April 22, 1948.

Akin to ice in blocky fields, humans have reproduced the conditions to make ice in places where the thermometer never dips below freezing. Allahabad, India, has no frost days, but ice was created in winter under the favorable weather of a clear night (for radiative cooling) and a dry, light northwest wind (to utilize the latent heat of evaporation). With these conditions met, small, porous earthen jars were placed on a thick bed of loose, dry rice straw for insulation in a 2-foot-deep hollow dug in the soil. The jars were filled with water, placed 6 inches below ground, and covered with mats. In the morning, thin films of ice were collected from the jars and stored in an ice house. An ice crop could be harvested when overnight temperatures dipped below 52°F. The Indian ice industry thrived in the early 19th century until supplanted by the cheaper, higher-quality New England ice, or “crystal blocks of Yankee coldness,” cut from the coastal ponds of Massachusetts and shipped to tropical ports around the world.

Humans have also unintentionally recreated ice caves as tunnels, mines, shafts, and wells. The *Salt Lake Mining Review* wrote in 1916 of an ice tunnel near the divide between Little Cottonwood and American Fork canyons known as the “North Pole.” In winter and in summer, the old mine tunnel had a “solid wall of ice.” ■

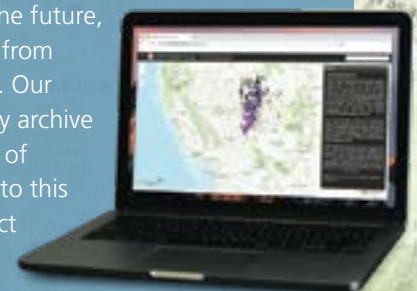
NEW GEOCHRONOLOGY DATABASE — A WEALTH OF DATING INFORMATION FOR UTAH SOIL & ROCK

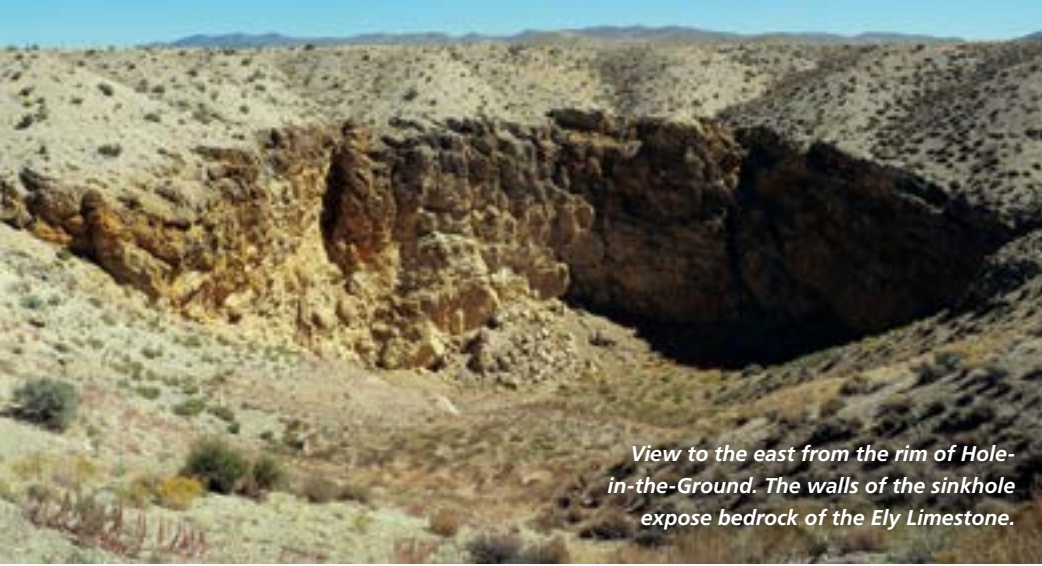
By Steve D. Bowman

The Utah Geological Survey (UGS) recently released the first version of the *Utah Geochronology Database*. The database contains numerical ages and related dating information for over 1700 soil and rock samples acquired in Utah. Numerical ages were obtained using argon ($^{40}\text{Ar}/^{39}\text{Ar}$), cosmogenic (^{10}Be and ^{36}Cl), fission track, luminescence (thermoluminescence [TL], infrared-stimulated [IRSL], and optically stimulated [OSL]), radiocarbon (^{14}C), rubidium-strontium (Rb-Sr), or uranium-thorium-lead (U-Pb and Th-Pb) dating methods. The samples were analyzed for a variety of geologic-related projects by the UGS, U.S. Geological Survey (incorporates data from the legacy *National Geochronological Database*), and others.

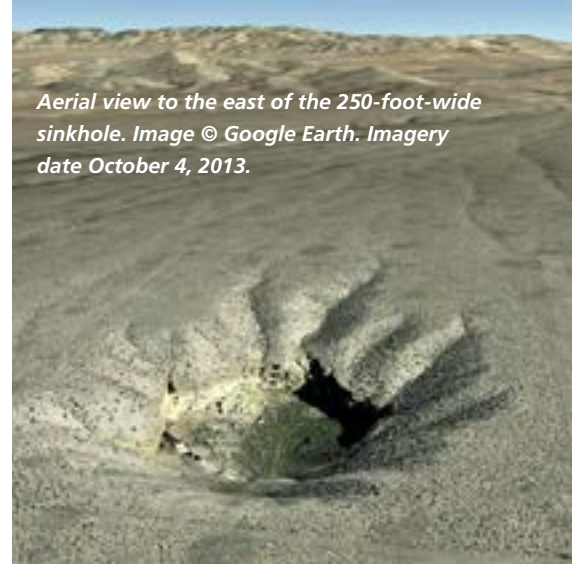
These data have been used to determine the timing of past earthquakes, age of basalt flows, and the age of geologic units for mapping. Since geochronologic methods have significantly evolved and improved over time, older data are often not as reliable or usable as more recently dated materials. However, this new database ensures that all these high-cost and valuable geochronologic data are archived and made available to all. Users can access the database through a web mapping application (<https://geology.utah.gov/apps/geochron/>) or an ArcGIS geodatabase (<https://gis.utah.gov/data/geoscience/geochronology/>).

As the database is expanded in the future, we anticipate adding age results from other geochronological methods. Our goal is to collect and permanently archive these invaluable data. Donations of Utah-based geochronology data to this database are appreciated. Contact the UGS for more details.





View to the east from the rim of Hole-in-the-Ground. The walls of the sinkhole expose bedrock of the Ely Limestone.



Aerial view to the east of the 250-foot-wide sinkhole. Image © Google Earth. Imagery date October 4, 2013.

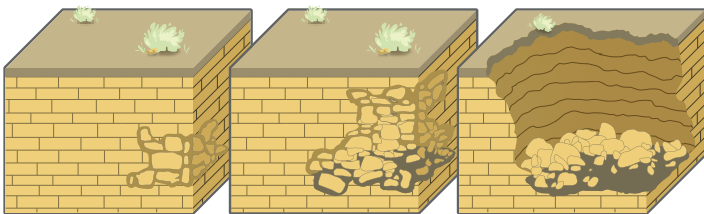
GEOSIGHTS

HOLE-IN-THE-GROUND, SNAKE VALLEY, MILLARD COUNTY, UTAH

By Mark Milligan

Hole-in-the-Ground is just that, a sinkhole created by the roof collapse of a buried limestone cavern. It is massive. A hole that measures over 250 feet wide and up to 110 feet deep on an otherwise flat valley floor is an impressive sight to see.

North-south-trending mountain ranges separated by broad and flat valleys characterize the Basin and Range physiographic province, which extends from the Wasatch Range across western Utah and westward to the Sierra Nevada in California. The valleys typically contain thousands of feet of sediment shed from their bounding ranges. However, this sediment does not always have a consistent thickness across a valley. Some locations have seemingly isolated rock outcrops of low-lying hills away from a range front. Nonetheless, when standing on a valley floor you tend to assume solid rock lies a great distance below your feet. Hole-in-the-Ground creates a portal into the subsurface that shows these assumptions and generalizations can be wrong. The walls of this sinkhole expose approximately 320-million-year-old (Mississippian- to Pennsylvanian-age) bedrock of the Ely Limestone a mere 30 to 40 feet below the surface. A buried fault is thought to have elevated the shallow bedrock.



Sinkholes form by dissolution of underlying limestone bedrock, a process in which acidic groundwater dissolves part of the limestone and carries it away in solution.

This creates a cavity which can continue to grow until the roof is unable to support its own weight and that of the overlying sediment. The collapse may occur as a single catastrophic event or a progressive series of smaller failures.

Whereas sinkholes in places like Florida and Kentucky pose a threat and sometimes swallow houses or the National Corvette Museum (a sad story, look it up), Hole-in-the-Ground is over 5 miles from Eskdale, the nearest settlement, and thus poses no risk to

any structures. Even cattle are protected by an enclosing wire fence. Furthermore, the timing of this sinkhole is unknown. Collapse may have started as long ago as a million years.

Hole-in-the-Ground lies within Snake Valley, which was flooded by ancient Lake Bonneville approximately 18,000 years ago during the most recent Ice Age. The rim of the sinkhole lies roughly 550 feet east of and 20 feet above the ancient lake's highest shoreline, named the Bonneville Shoreline. Thus, the bottom of the hole, being over 75 feet below ancient lake level, would have likely been a swimming hole filled with shallow groundwater related to the lake. Additionally, Lake Bonneville deposited impressive V-shaped sand spits, the closest of which lies less than half a mile to the southwest of the sinkhole. ■

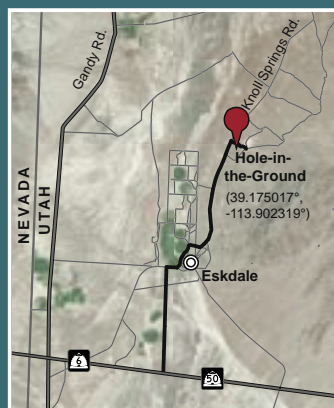


Approximately 5 vertical feet of exposed wind-blown dust (called loess) deposits near the bottom of the sinkhole and subsequently eroded when the bottom dropped further, suggesting multiple episodes of collapse.



HOW TO GET THERE:

The sinkhole is located on land administered by the U.S. Bureau of Land Management about 6 miles northeast of the small unincorporated community of Eskdale in western Millard County. This area is remote, so please plan accordingly. Eskdale has no services; the closest gas is available in Baker, Nevada, about 15 miles to the southwest.



0 100 200 MI

0 2 4 MI

From the Wasatch Front, head south on I-15 towards Nephi. Take exit 225 and turn right onto Utah State Route 132 (100 North). After 34 miles, turn left onto U.S. Route 6. After 16 miles, turn right onto U.S. Route 6/50. After 84.6 miles, turn right onto the paved two-way road towards Eskdale. There are no road signs beyond this point. Continue by using GPS navigation or the indicated mileage, beginning where you leave U.S. Route 6/50:

- 3.7 miles Turn RIGHT at the T-intersection.
- 0.4 miles Turn LEFT.
- 0.9 miles Turn RIGHT. (Pavement ends in Eskdale.)
- 0.6 miles Road curves to the left.
- 0.2 miles Continue straight/north at junction.
- 4.5 miles Turn RIGHT onto the unimproved two-track dirt road, which is passible in moderate to high-clearance vehicles. Proceed with caution or walk in.
- 0.7 miles End at sinkhole. The hole is surrounded by a wire fence, presumably to keep cattle out. The southwest corner of the fence has a stile for access.

Coordinates: 39.175017°, -113.902319°.

The sinkhole is located on the Hole-in-the-Ground 7.5-minute quadrangle map.

For information about other Utah sinkholes, see "GeoSights: Sinkholes in Big Round Valley, Washington County" in *Survey Notes*, v. 32, no. 3, p. 13–14. Also, "Where is the Coolest Place in Utah" in *Survey Notes*, v. 45, no. 3, p. 10–11.

TEACHER'S CORNER

EARTH SCIENCE WEEK 2018

This past October, 669 students from eight elementary schools participated in the Utah Geological Survey's 17th annual Earth Science Week (ESW) celebration. Students visited the Utah Core Research Center to learn about geology and paleontology through fun, hands-on activities like "gold" panning for colorful minerals, exploring the processes of erosion and deposition in a stream trailer, and getting up-close and personal with real dinosaur bones. To our many volunteers from professional associations, public- and private-sector institutions, other divisions within the Utah Department of Natural Resources, and individual geology enthusiasts who helped make ESW 2018 possible—thank you!

Since its creation in 1998 by the American Geosciences Institute (AGI), 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. For more information on ESW, see the AGI web page at www.earthsciweek.org; for information on next year's ESW activities at the Utah Geological Survey, see our web page at geology.utah.gov/teachers/earth-science-week.



UTAH GEOLOGICAL ASSOCIATION TEACHER OF THE YEAR AWARD:

Annelise Kelly of Willowcreek Middle School in Lehi, is this year's recipient of the Utah Geological Association's Utah Earth Science Teacher of the Year Award. Annelise teaches 8th Grade Integrated Science and 9th Grade Biology focusing on renewable and non-renewable energy resources and consumption, how natural resources are related to different rock types and geologic settings, and how earth processes control geologic and climatic settings.



Annelise was awarded \$1200 plus \$300 reimbursement for procuring resources related to earth science education. Additionally, her name will be entered in the regional contest sponsored by the Rocky Mountain Section of the American Association of Petroleum Geologists. Congratulations Annelise!

SURVEY NEWS



2018 EMPLOYEE OF THE YEAR

Congratulations to **Michael Vanden Berg** who was named the 2018 UGS Employee of the Year. Mike has been with the UGS for about 14 years; he is currently a Senior Scientist and manages the Energy and Minerals Program. Mike has established an excellent rapport with the petroleum industry through leading field trips, conducting core workshops, and helping to acquire new cores. He is considered a leading expert by both industry and academia on lacustrine systems based on his research on Great Salt Lake and the Green River Formation in the Uinta Basin. Mike was the general chair of the very successful 2018 American Association of Petroleum Geologists annual meeting in Salt Lake City that greatly benefited Utah economically and showcased the UGS. Mike's personality endears himself to his peers within and outside the UGS, he mentors younger staff and students without hesitation, and he is a great example of what the upcoming generation of UGS employees should try to emulate. Mike is an outstanding employee and deserving recipient of this special award and recognition.



Richard G. Allis

State Geologist and Director Rick Allis retired in January after 18 years of service with the UGS. Prior to joining the UGS, Rick was in senior management at the Institute of Geological and Nuclear Sciences in New Zealand, originally known as the New Zealand Geological Survey, and then was a research professor with the Energy and Geoscience Institute at the University of Utah for almost three years. While at the UGS, his steady leadership and strategic vision helped the agency meet a number of challenges over the past two decades. Rick's emphasis on making all UGS publications available for free on the UGS website, as well as providing geologic information interactively through web applications, led to the creation of the Web Services Section. Anticipating the continuing need for understanding the interactions between geology and water resources, Rick encouraged and supported expansion of groundwater

characterization studies and creation of the UGS Wetlands Section. A strong proponent of renewable energy, Rick played a key role in helping Utah be selected as the national Frontier Observatory for Research in Geothermal Energy (FORGE) field laboratory. After Mineral Lease revenues to the UGS plummeted following the crash in oil and gas prices that began in late 2014, Rick's convincing arguments to the Utah Legislature's Natural Resources Appropriations Subcommittee concerning the value of the UGS to Utah's citizens resulted in the 2016 Legislature approving a \$1 million ongoing increase in General Funds to the UGS, substantially stabilizing the agency's budget.

As the UGS's longest-serving director, Rick has left an indelible mark on the Utah Geological Survey, and the agency and the citizens of Utah are the better off for it. Thank you, Rick, and we wish you well in your retirement!



Ken Krahulec retired in January after 14 years of service with the UGS. As a Senior Geologist in the Energy and Minerals Program, his expertise was in the metallic mineral resources of Utah. Ken earned an M.S. degree in Geology from the South Dakota School of Mines & Technology and a B.S. in Geology from the University of Minnesota Duluth. Ken had over two decades of minerals industry experience across North America before

joining the UGS in early 2005. His primary responsibilities at the UGS included surveying, cataloging, and publishing information on Utah's metal occurrences, prospects, mines, and districts. Ken's knowledge and expertise will be greatly missed, and we wish him well in his retirement.

Pam Perri retired in January after six years of service. Pam joined the UGS in 2012 as an Office Specialist in the Geologic Hazards Program and later became the UGS Administrative Assistant where she typically went above and beyond what



was required to get the job done, and was quick to volunteer whenever help was needed. We will miss Pam's friendly demeanor and positive attitude and wish her luck in her retirement.

The Geologic Information and Outreach Program welcomes **Mackenzie Cope** as a new geologist and web manager. She comes to us from Southern Utah University where she recently graduated with a B.S. degree in Geology. **Jenny Erickson** joins the Editorial Section as a new graphic and web designer, replacing **Jen Miller** who was promoted to Publications Manager. Jenny has a Bachelor of Fine Arts degree in Communication Design from Milwaukee Institute of Art and Design (MIAD) and is already a great asset to the team. Best wishes to **Lindsey Smith** of the Groundwater Program who has accepted a private sector job in Texas.

2018 LEHI HINTZE AWARD – Marjorie Chan



The Utah Geological Association (UGA) and the Utah Geological Survey (UGS) presented the 2018 Lehi Hintze Award to Dr. Marjorie Chan for her outstanding contributions to Utah geology. Over her 34-year career at the University of Utah, Marjorie has developed a world-class research program studying rocks across Utah from the Precambrian to the Pleistocene and nearly every period in between. Her work has highlighted the unique geologic opportunities present in Utah, recently using Utah geology to inform Martian geologic discoveries. Her work puts Utah geology on the international stage and at the forefront of the search for life on other planets. Her Mars analog research comes as an extension of her work on the Permian, Triassic, and Jurassic units in Utah commonly seen by the public at many of Utah's national parks. Marjorie and her students have worked extensively in southern Utah, unearthing the story of these rocks from stages of deposition to diagenesis. Marjorie has made a profound contribution to the geology of Utah through her research, mentoring/education of students, her public and professional engagement, her encouragement and mentoring

of women and minorities in geoscience, and her work as an administrator at the University of Utah. Marjorie's contributions have widely raised the visibility of Utah geology across the globe.

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.

RECENT OUTSIDE PUBLICATIONS BY UGS AUTHORS

Characteristics and source rocks of Utah crude oils, by **T.C. Chidsey, Jr.**, in S.H. Emerman, B. Bowen, S. Schamel, and S. Simmons, editors, *Geofluids of Utah: Utah Geological Association Publication 47*, p. 149–177, 1 plate, 26 appendices.

New insights on the impact of tidal currents on a low-gradient, semi-enclosed, epicontinental basin—the Curtis Formation, east-central Utah, USA, by V. Zuchuat, A.R.N. Sleveland, **D.A. Sprinkel**, A. Rimkus, A. Braathen, I. Midtkandal: *Geology of the Intermountain West*, v. 5, p. 131–165.

The Utah Frontier Observatory for Geothermal Research (FORGE)—results of recent drilling and geoscientific surveys, by J. Moore, J. McLennan, **R. Allis**, K. Pankow, S. Simmons, R. Podgorney, P. Wannamaker, W. Rickard: *Geothermal Resources Council Transactions*, v. 42.

Seismic reflection profiling at the FORGE Utah EGS site, by J. Miller, **R. Allis**, **C. Hardwick**: *Geothermal Resources Council Transactions*, v. 42.

Geologic setting of the Utah FORGE site, based on new and revised geologic mapping, by **S.M. Kirby**, **T. Knudsen**, **E. Kleber**, **A. Hiscock**: *Geothermal Resources Council Transactions*, v. 42.

Geophysical surveys of the Milford, Utah, FORGE site—gravity and TEM, by **C. Hardwick**, **W. Hurlbut**, M. Gwynn, **R. Allis**, P. Wannamaker, J. Moore: *Geothermal Resources Council Transactions*, v. 42.

Rock properties of FORGE well 58-32, Milford, Utah, by M. Gwynn, **R. Allis**, **C. Hardwick**, C. Jones, **P. Nielsen**, **W. Hurlbut**: *Geothermal Resources Council Transactions*, v. 42.

Thermal characteristics of the FORGE site, Milford, Utah, by **R. Allis**, M. Gwynn, **C. Hardwick**, **W. Hurlbut**, J. Moore: *Geothermal Resources Council Transactions*, v. 42.

Stratigraphic geothermal potential in deep sedimentary basins, northeastern Great Basin, Utah, by R. Blackett, M. Gwynn, **C. Hardwick**, and **R. Allis**, in S.H. Emerman, B. Bowen, S. Schamel, and S. Simmons, editors, *Geofluids of Utah: Utah Geological Association Publication 47*, p. 75–118.

Shallow thermal anomalies and the deep thermal regime in west-central Utah, by M. Gwynn, **R. Allis**, and **S.M. Kirby**, in S.H. Emerman, B. Bowen, S. Schamel, and S. Simmons, editors, *Geofluids of Utah: Utah Geological Association Publication 47*, p. 119–138.



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or for purchase at utahmapstore.com.



Utah Mining 2017 by Taylor Boden, Ken Krahulec, Michael Vanden Berg, and Andrew Rupke, 30 p., ISBN 978-1-55791-948-9, **C-125**



Interim geologic map of the Bonneville Salt Flats and east part of the Wendover 30' x 60' quadrangles, Tooele County, Utah, by Donald L. Clarke and Charles G. Oviatt, 17 p., 2 pl., scale 1:62,500, **OFR-692**



Interim geologic map of the Devils Slide quadrangle, Morgan and Summit Counties, Utah, by James C. Coogan, Jon K. King, and Greg N. McDonald, 37 p. + appendix, 1 pl., scale 1:24,000, **OFR-691**



Interim geologic map of the Escalante 30' x 60' quadrangle, Garfield and Kane Counties, Utah, by Hellmut H. Doelling and Grant C. Willis, 13 p., 2 pl., scale 1:100,000, **OFR-690DM** *Supersedes OFR-368*



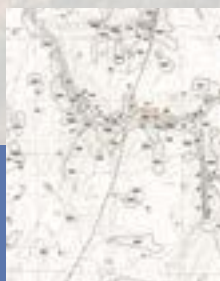
Interim geologic map of the Duchesne 30' x 60' quadrangle, Duchesne and Wasatch Counties, Utah, by Douglas A. Sprinkel, 37 p., 2 pl., scale 1:62,500, **OFR-689**



Interim geologic map of the Mount Pisgah quadrangle, Box Elder and Cache Counties, Utah, by Jon K. King, Barry J. Solomon, and Robert Q. Oaks, Jr., 29 p., 2 pl., scale 1:24,000, **OFR-688**



Interim geologic map of the Sugar House quadrangle, Salt Lake County, Utah, by Adam P. McKean, 29 p., 1 pl., GIS data, scale 1:24,000, **OFR-687DM**



Interim geologic map of the Monte Cristo Peak quadrangle, Cache, Rich, and Weber Counties, Utah, by James C. Coogan, 29 p., 1 pl., scale 1:24,000, **OFR-684**