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 Nephi Segment of the Wasatch Fault Zone

CONTENTS

Design: Liz Paton
Cover: View north along Wasatch fault at base of southern Wasatch Range. Photo by Ronald Bruhn.
Inset: UGS geologists presenting evidence for a large, prehistoric earthquake on the Wasatch fault (see article on p. 1).

THE DIRECTOR'S PERSPECTIVE

The return to average or above-average precipitation conditions in Utah during 2005 and 2006 resulted in a dramatic increase in geologic-hazard emergencies that the UGS responded to during the subsequent spring (four per year for 2002–2004, compared to 13 per year for 2005–2006). Most of these were landslide-related, and some involved property damage that amounted to several millions of dollars each year (see article, page 6 of this issue). The publicity surrounding the damaging landslides raised questions in the media about the wisdom of some new residential developments on hillsides, and whether the geologic hazards were adequately considered during the approval process.

In May 2006, Governor Huntsman requested that a Geologic Hazards Working Group be established to "improve the subdivision-approval process to reduce losses from geologic hazards to an acceptable level." Gary Christenson, UGS Geologic Hazards Program manager, is chairing the Working Group, which includes members representing the Utah League of Cities and Towns, Utah Association of Counties, Governor's Office of Planning and Budget, Utah Division of Homeland Security, Utah City Engineers' Association, Utah Chapter of the American Planning Association, and various officials of cities recently affected by landslides. Several meetings have been held, and major topics being covered are:

1. how to ensure local governments adopt modern, effective geologic-hazard ordinances,
2. how to ensure implementation of these ordinances and how local governments can get access to technical (geologic and engineering) expertise to assist,
3. how to ensure final risk reduction recommendations are enforced, and
4. how disclosure should enter into the process.

Once draft recommendations are developed, public input will be sought, and the final draft should be completed in early 2007.

Last fall, the Association of State Boards of Geology (ASBOG) held their annual meeting in Park City, Utah, with the Utah Geology Board of the Division of Professional Licensing (DOPL) acting as host. On the field trip, one problem we highlighted was the ongoing property damage from landsliding in the Sherwood Hills subdivision in Provo City. This raises the related issue of whether our professional licensing boards have any role in helping to reduce losses from geologic hazards. To date, no disciplinary cases in engineering geology have been brought before DOPL, but Utah has had geological licensure for only four years. A portion of the license fees are set aside for educational purposes, but so far they have been largely untapped. There appears to be a need for workshops or courses on aspects of engineering geology for practicing geologists. A course on ethics in the practice of geology that was offered two years ago attracted few non-UGS attendees. One solution may be that geological licensure rules need to be amended to include a continuing education component. Other solutions will need to involve recognition by local jurisdictions, developers, and practicing geologists that some areas with known geologic hazards will preclude, or severely limit, development.

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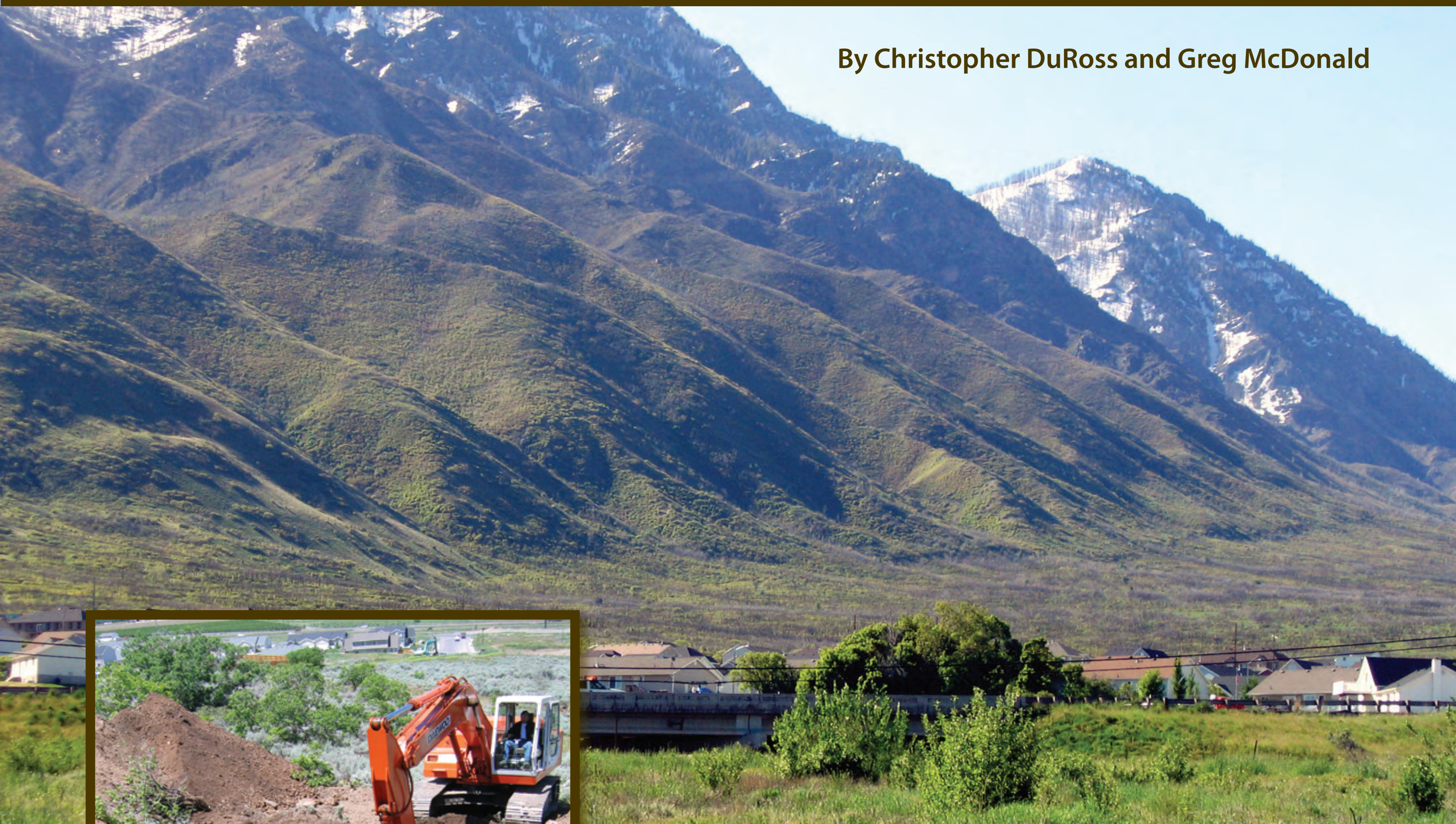
THE MOST RECENT LARGE EARTHQUAKE ON THE NEPHI SEGMENT OF THE WASATCH FAULT ZONE NEAR SANTAQUIN: RESULTS FROM 2005 FAULT TRENCHES



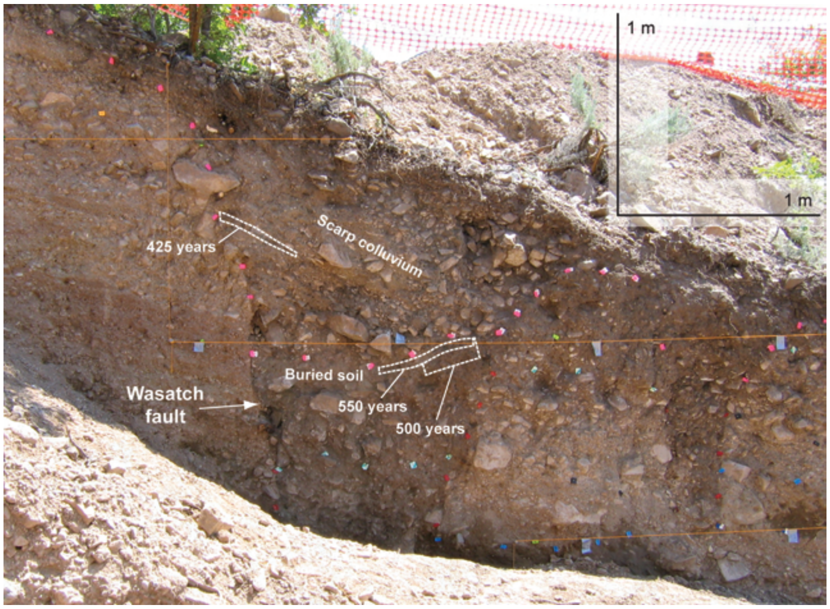
By Christopher DuRoss and Greg McDonald

Excavating a research trench across the Nephi segment of the WFZ at the Santaquin trench site. New trenches on the Nephi segment were excavated in the summer of 2005 as part of a cooperative research project between the UGS and USGS.

Top: The Nephi segment of the Wasatch fault zone near Santaquin. Fault scarps, which indicate recent surface-faulting earthquakes on the segment, are evident as thin, linear shadows extending along the base of Dry Mountain. View is to the southeast.

The Wasatch fault zone (WFZ) is Utah's longest and most active fault. The central (and most active) part of the fault, roughly from Brigham City to Nephi, includes five segments. The Nephi segment, the southernmost of the five, extends from Payson to Nephi. Until recently, the Nephi segment had the most poorly constrained record of prehistoric earthquakes of the central segments, despite having the youngest-looking fault scarps of all the WFZ segments and a location close to the Provo-Spanish Fork metropolitan area. Evidence for large-magnitude (M 7) earthquakes on the Nephi segment includes surface faulting along two distinct strands: a northern strand bounding Dry Mountain near Payson and Santaquin and a southern strand bounding the Wasatch Range east of Juab Valley near Mona and Nephi.

During the summer of 2005, the Utah Geological Survey (UGS) excavated trenches on the northern strand of the Nephi segment near Santaquin, in conjunction with trenches excavated on the southern strand east of Mona at Willow Creek by the U.S. Geological Survey (USGS). Studying the earthquake history at the Santaquin site is critical for determining (1) the timing, frequency, and magnitude of surface-faulting earthquakes on the previously untrenched northern strand, and (2) the extent of surface-faulting earthquakes on the Nephi segment, including whether all or part of the segment ruptures during a large earthquake. Ultimately, the geologic information being developed for the Nephi segment will contribute to our knowledge of the frequency,



Exposure at the Santaquin trench site showing the main trace of the Wasatch fault (white arrow) and a soil displaced down-to-the-right (west) along the fault and buried by scarp colluvium (above pink-and-white flags). Horizontal level lines (orange, three shown in photo) are 3 feet (1 m) apart. White-dashed boxes indicate material collected for radiocarbon analysis; age estimates indicate average age of sample in calendar years before the present.

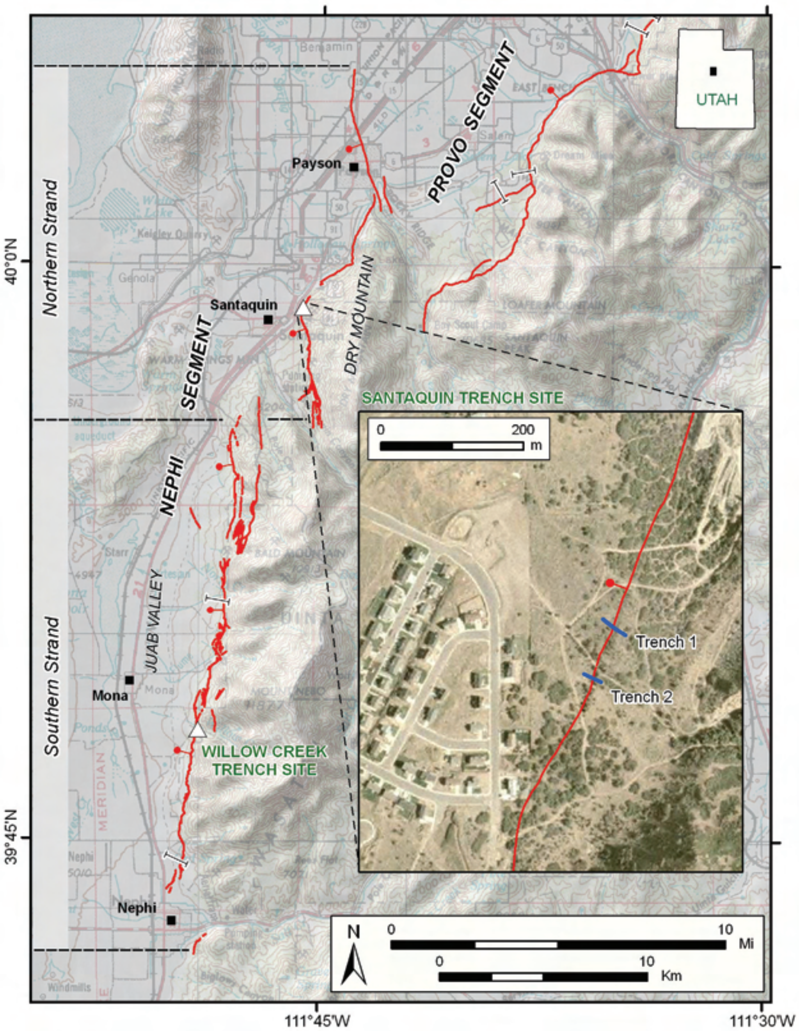
Low-sun-angle oblique aerial photograph of youthful fault scarps (marked by white arrows) near the south end of the Nephi segment of the WFZ. View is to the east. Photo courtesy of Ronald Bruhn (University of Utah).

magnitude, and distribution of large surface-faulting earthquakes on the Wasatch fault zone, and allow for the refinement of both fault-segmentation and seismic-hazard models for the Wasatch Front.

At the Santaquin site, surface faulting from a prehistoric Wasatch fault earthquake displaced late Holocene (less than 5000 years old) alluvial-fan deposits, forming a 10- to 13-foot-high (3-4 m) scarp. To investigate the prehistoric earthquake, we mapped the surficial geology, measured topographic profiles across the fault scarp, and excavated two 65- to 100-foot-long (20-30 m) trenches.

The fault trenches exposed subsurface evidence for one prehistoric surface-faulting earthquake in the alluvial-fan sediments. We identified wedge-shaped deposits of scarp-derived colluvium (sediment eroded from the scarp face and deposited shortly after the earthquake) and, based on the correlation of faulted alluvial-fan deposits in the trenches and scarp profiling, found that 9.8 feet (3.0 m) of vertical ground-surface displacement accompanied the earthquake. To determine the timing of the earthquake, we collected samples for radiocarbon dating from an organic-rich soil buried beneath the scarp colluvium and therefore older than the earthquake. Two samples from the soil indicate a maximum time since the earthquake of 500-550 years. Organic material from within the scarp colluvium yielded an average age of 425 years, which represents a minimum constraint on the timing of the earthquake. Samples collected from within older, pre-faulting alluvial-fan deposits indicate that the minimum time since the next older earthquake, for which evidence was not exposed in the trenches, is at least 1500 years and likely more than 6900 years.

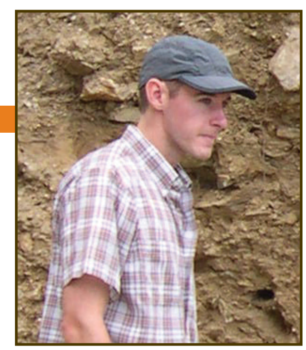
Slip rate and recurrence (repeat) time between large earthquakes are important fault parameters, which indicate how fast strain energy accumulates and is stored on the fault (slip rate) and how often that energy is released by fault movement in large earthquakes (recurrence time). At the Santaquin site, we estimated 30 feet (9m) of fault displacement across the nearby Bonneville highstand shoreline (which was abandoned about 16,800 years ago) and determined a long-term slip rate of 0.5 millimeters per year. By dividing our earthquake displacement (10 feet [3 m]) by the long-term slip rate we determined an average recurrence time between large surface-faulting earthquakes at the site of about 6000 years.



Our Santaquin trench study indicates that the most recent surface-faulting earthquake on the northern strand of the Nephi segment displaced the ground surface 10 feet (3 m) about 500 years ago. By comparing both the extent of surface faulting along the Nephi segment and the displacement observed in the Santaquin trenches with empirical relations between the magnitudes of historical earthquakes and the length and slip of the earthquake-producing faults, we estimate that the Santaquin-site earthquake had a magnitude of about 7.0. Strong ground shaking from the earthquake would have been felt strongly in both the Provo and Salt Lake metropolitan areas. To complete our ongoing investigation, we will compare the Santaquin-site data with data currently being developed by the USGS for the southern strand of the Nephi segment, and analyze whether the entire segment or just part of the segment ruptures during a large earthquake, and whether multi-segment or spill-over rupture may occur between the Nephi and adjacent segments. These issues are important from an emergency-response standpoint because longer surface-fault ruptures generally produce larger earthquakes, which generate more intense ground shaking and result in more extensive damage.

Surface-fault trace of the Nephi segment and southernmost part of the Provo segment of the WFZ (red), showing locations of the UGS Santaquin trench site (inset map), the USGS Willow Creek trench site, and pre-2005 trench sites (I shapes). Inset map shows trenches (blue lines) excavated at the Santaquin site.

ABOUT THE AUTHORS


Chris DuRoss

Chris DuRoss is a geologist with the UGS Geologic Hazards Program, primarily involved in investigating Quaternary fault hazards in Utah. He specializes in studying geologic evidence for the most recent (but prehistoric) large-magnitude, surface-faulting earthquakes in the Wasatch Front region. His recent work has included fault-trench investigations on the Provo and Nephi segments of the Wasatch fault zone, research into the potential for multi-segment ruptures on the Wasatch fault zone, and an update of the Utah Quaternary fault and fold database. Chris' upcoming research will focus on the prehistoric earthquake histories of the Weber segment of the Wasatch fault zone and the poorly understood West Valley fault zone in Salt Lake Valley. Prior to joining the UGS in 2004, Chris worked as a U.S. Geological Survey intern, studying geologic hazards in the Pacific Northwest, and completed a Master's degree in geology at the University of Utah.

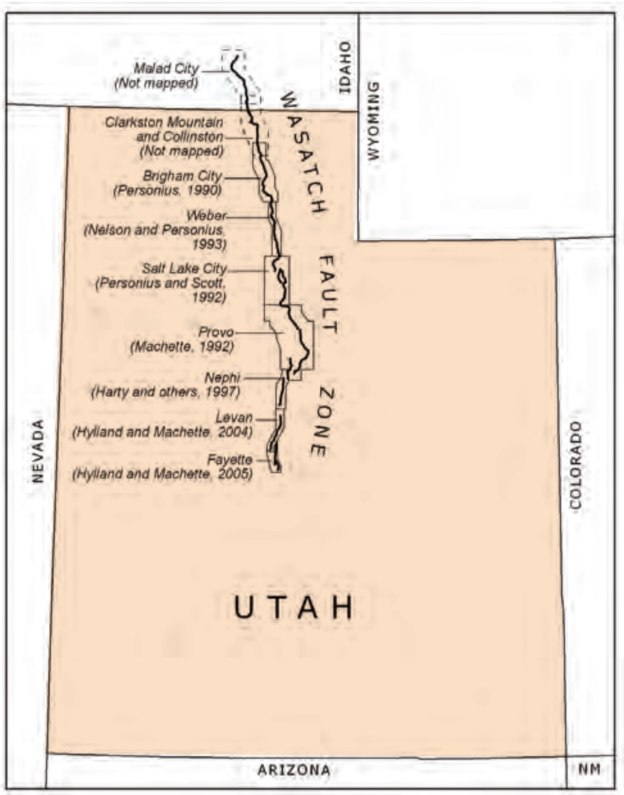

Greg McDonald

Greg Mc Donald is a geologist with the UGS Geologic Hazards Program and worked on both the Salt Lake City- and Provo-segment "megatrench" paleoseismic studies. Since joining the UGS in 1998, Greg's work has included several landslide and debris-flow investigations, surficial geologic mapping in Morgan and Ogden Valleys, analyzing geologic and shear-wave-velocity data for seismic-site-response characterization along the Wasatch Front urban corridor, and implementing survey-grade GPS-monitoring techniques to measure long-term movement of landslides. Prior to joining the UGS, Greg worked in Salt Lake City for an environmental/geotechnical consulting firm for over five years after graduating from the University of Utah in 1992.

How active are the end segments of the Wasatch fault zone? New information from geologic mapping and scarp studies

by Michael D. Hylland

Over 30 years of systematic research on the prehistoric surface-faulting earthquakes of Utah's Wasatch fault zone have made it arguably the most well-studied long, segmented normal fault in the world. Most of this research has focused on the central segments (Brigham City, Weber, Salt Lake City, Provo, and Nephi), which are the most active fault segments in Utah and also happen to be where the vast majority of Utah's citizens reside. At the more sparsely populated ends of the Wasatch fault zone, the less active Levan and Fayette segments (south end) and Collinston, Clarkston Mountain, and Malad City segments (north end) have received much less attention from researchers.



The Wasatch fault zone comprises 10 segments that rupture more-or-less independently, producing large (roughly magnitude 7) earthquakes. The southern seven segments have been geologically mapped at a scale of 1:50,000.

As part of a three-year (2003-05) cooperative agreement with the U.S. Geological Survey (USGS), the Utah Geological Survey (UGS) performed geologic studies on the end segments of the Wasatch fault zone in Utah to gain a better understanding of the earthquake hazards associated with these fault segments. The studies included detailed surficial-geologic mapping of the Levan and Fayette segments, detailed reconnaissance of key sites on the Collinston and Clarkston Mountain segments, and fault-scarp studies on all four segments. The Malad City segment, entirely in Idaho, remains relatively unstudied. The mapping of the Levan and Fayette segments follows a concerted effort by USGS geologists in the mid-1980s to map the Brigham City, Weber, Salt Lake City, and Provo segments, and later mapping of the Nephi segment by UGS and USGS geologists. Now, the entire length of the Wasatch fault zone having evidence for surface faulting in the Holocene Epoch—that is, earthquakes during the past 10,000 years large enough to create a fault scarp—has been geologically mapped at a scale of 1:50,000.

In a large normal-faulting earthquake (magnitude 6.5 or greater), the amount of vertical movement on the fault deep in the Earth's crust is sufficient to rupture and offset the ground surface, producing a steep break or scarp. Topographic profiles measured across fault scarps, combined with information on the age of the faulted deposits, can provide

UGS geologist Chris DuRoss measures a profile across a small scarp on the Levan segment. Distance and slope angle are measured using a telescoping stadia rod and Abney level, respectively.

Profile measurements on large scarps were facilitated by use of a laser range finder (above the shrub) and reflecting prism (held by DuRoss). View from near the top of a large scarp on the Fayette segment, looking northwest across northern Sevier Valley to the Valley Mountains (Canyon Mountains in far distance).

Near Levan, stream erosion at Deep Creek has exposed the Wasatch fault (dashed red line). Radiocarbon dating of a buried organic-rich soil layer, being described here by the author during field review of the Levan-Fayette mapping in May 2005, helped establish that the scarp-forming earthquake occurred about 1000 years ago. Photo courtesy of Don Clark.

Fault scarp at the mouth of Elgrove Canyon on the Clarkston Mountain segment. This scarp is less-than-ideal for profiling due to ground disturbance associated with use of the site as a trailhead and installation of the green stock-watering tank. Still, the scarp yielded information pertaining to two large prehistoric earthquakes. U.S. Forest Service sign is approximately 6 feet (2 m) high.

insights into several important questions regarding large prehistoric earthquakes on a particular fault: (1) The height and shape of a fault scarp can indicate if the scarp formed as the result of a single earthquake or multiple earthquakes. (2) The height of a scarp is proportional to the vertical slip on the fault, which in turn relates to earthquake size (magnitude). (3) Relationships between scarp height and the steepness of the weathered scarp face can be used to determine timing of the scarp-forming earthquake, at least in a relative sense. USGS geologist and veteran Wasatch fault researcher Michael Machette provided data from 40 scarp profiles that he measured on the Levan and Fayette segments during a reconnaissance study in 1984. Chris DuRoss (UGS) and I measured an additional 12 scarp profiles for a sizeable dataset of 52 profiles. Unfortunately, the dataset for the Collinston and Clarkston Mountain segments consists of only two profiles due to a lack of scarps, as discussed below.

The mapping and profile data, combined with information from a research trenching study completed in 1991, indicate that the Levan segment has had one or possibly two surface-faulting earthquakes in the Holocene. This is a lower frequency of large earthquakes compared to the more central segments of the Wasatch fault zone, each of which has evidence for three or more surface-faulting earthquakes in the Holocene. The Fayette segment has had one large earthquake that may have occurred as recently as the early Holocene. The profile data suggest complex patterns of surface faulting on these two segments, with some ruptures spilling over onto the adjacent segment during an earthquake (a phenomenon that has been observed during historical earthquakes on other segmented normal faults in the region).

The Collinston and Clarkston Mountain segments are the least active segments of the Wasatch fault zone in Utah. These segments lack fault scarps on geologically young deposits; any scarps that may have existed at one time are now buried beneath sediment deposited in prehistoric Lake Bonneville during its maximum extent—the Bonneville highstand—around 18,000 years ago, and there have been no surface-faulting earthquakes since that time. I was able to measure only two profiles across a scarp on pre-Bonneville deposits on the Clarkston Mountain segment. The profiles indicate the scarp formed from two earthquakes, the most recent having occurred shortly before the Bonneville highstand. When compared to the length of the segment, the amount of vertical ground-surface offset during each earthquake (6 feet [2 m]) suggests a longer rupture is needed to produce the observed offset. Therefore, during a large earthquake on the Clarkston Mountain segment, at least part of an adjacent segment probably ruptures simultaneously.

The segments at the ends of the Wasatch fault zone have been less active in recent geologic time and expose far fewer people to earthquake hazards as compared to the more central segments. Nonetheless, fault movement on these segments could produce earthquakes of about magnitude 6.9, potentially generating hazardous geologic effects over large areas. Our recent studies give us a better understanding of the earthquake hazards associated with these segments, which ultimately helps us reduce seismic risk in Utah.

"GLAD YOU ASKED"

GREAT SALT LAKE TRIVIA QUESTIONS

By Mark Milligan

In the last "Glad You Asked" article we highlighted some of the public inquiries we have been unable to answer. In this issue we present you with three trivia questions related to Great Salt Lake. Can you answer them?

1. What do Great Salt Lake, the Bahamas, the old Hansen Planetarium in downtown Salt Lake City, the Manti LDS Temple, and Hearst Castle in San Simeon, California, have in common?

2. What does the original Saltair resort on the south shore of Great Salt Lake have in common with the coasts of Indonesia, Thailand, and northwestern Malaysia?

3. What two things do Great Salt Lake, Apollo 16, and northern shovelers and common goldeneyes (ducks) have in common?

Answers can be found on page 11.

2006

In 2006, a locally wet spring on the heels of a statewide wet year in 2005 resulted in an active landslide season in northern Utah. Nearly all of the 2006 landslides were reactivations of pre-existing landslides, including slides that had previously moved sometime during the past decade. The following are some of the landslides UGS geologists investigated to assist local governments with their emergency response. Additional information on several of those landslides is available online at geology.utah.gov/utahgeo/hazards/landslide/index.htm.

● *Location of 2006 landslides discussed in this article.*

by Richard Giraud and Francis Ashland

1650 EAST LANDSLIDE, SOUTH WEBER

Around 9:30 p.m. on Sunday, April 9, a rapidly moving landslide in South Weber broke through the back wall of a house at 7687 South 1650 East, injuring a child inside. The landslide started on a steep slope near a pond in a gravel pit atop a bluff behind the house. Subsequent investigation found evidence of subsurface water flow from the pond to the slope. Water seepage and saturation of materials on the bluff top likely triggered the landslide, but the steep slope, the weight of fill placed on the top of the slope, and weak underlying geologic materials were contributing factors. Also, a major rain and snow storm on April 4 through 6 dropped approximately 2 inches of water, likely causing surface and subsurface water levels to rise. After the landslide, the pond was drained to reduce further landsliding. The 1650 East landslide and a nearby similar one that demolished a barn and blocked South Weber Drive (State Route 60) in 2005, demonstrate the destructive nature of rapidly moving landslides and the risk of building at the base of steep slopes.

SUNSET DRIVE AND BEECHWOOD DRIVE LANDSLIDES, LAYTON

Homeowners along Sunset Drive in Layton recognized in mid-April that the Sunset Drive landslide had reactivated. In 1998, landslide movement damaged seven lots and resulted in a house having to be condemned and demolished. The 2006 movement affected six lots, including two houses. The house at 1843 East Sunset Drive straddles the main scarp, and landslide movement has removed support from beneath part of the foundation. Layton City building inspectors found the house unsafe for occupancy due to structural damage, and it may be moved off the landslide to another location. UGS geologists measured a 4- to 8-foot increase in ground-water levels in and near the landslide between March 16 and April 17, which apparently triggered movement. The 2006 peak ground-water level is a threshold that can be used to predict future landslide movement.

The Beechwood Drive landslide is a quarter-mile south of the Sunset Drive landslide and reactivated at about the same time. The Beechwood Drive landslide is a reactivation of a pre-existing landslide with no documented historical movement. The landslide main scarp cuts across the back of five lots and has damaged landscaping in backyards. The landslide also affected the upper part of the proposed Beechwood subdivision phase 6 development. Both the Sunset and Beechwood Drive landslides show how prone some slopes in Layton are to landslide movement.

CREEKSIDE DRIVE LANDSLIDES, MOUNTAIN GREEN

In 2005, three landslides formed in the Creekside Drive area of Mountain Green in Morgan County, in a northeast-facing slope underlain by pre-existing landslide deposits. In 2006, the three landslides re-

The rapidly moving landslide that slammed into this house at 7687 South 1650 East, South Weber, broke through the back wall and injured a child inside.

This house at 1843 East Sunset Drive straddles the main scarp of the landslide. Landslide movement has removed support from beneath part of the foundation.

ANOTHER YEAR OF DAMAGING LANDSLIDES IN NORTHERN UTAH

activated, and two new landslides formed nearby. Continued movement of the largest of the five landslides forced the evacuation of a severely damaged house at the top of the slide, and damaged two others. Damage also occurred to Creekside Drive and utilities beneath the road, disrupting the power and water to the affected subdivision. Despite favorable subdivision-wide and lot-specific geotechnical studies, landsliding occurred within only a few years of development on the pre-existing landslide deposits. Stabilization of the landslides, particularly the largest one, will likely prove costly and technically challenging.

SHERWOOD HILLS LANDSLIDE, PROVO

The Sherwood Hills landslide in northern Provo is one of several in northern Utah that has undergone repeated movement over the past 25 years. Damage to houses and roads caused by renewed landslide movement was first documented in the early 1980s. The landslide has been systematically monitored since May 1999 when Provo City established survey points on the slide and began using high-precision Global Positioning System survey techniques to measure movement. The survey results suggest that the landslide remained active even during the drought years between 1999 and 2004. With the return of wetter-than-normal conditions in 2005, the rate and area of landslide movement increased. By 2006, three houses in the upper part of the landslide had been abandoned, including one built in 2000, and a road had been severely damaged. Some data suggest that landslide movement is continuous, slowing in the summer to an undetectable rate, and increasing in the late winter and early spring as groundwater levels rise during the snowmelt. The continuing losses due to movement illustrate the potential high costs, both public and private, associated with development on large pre-existing landslides.

Offset on main scarp by repeated landslide movement, City Creek Canyon, Salt Lake City. Concrete covers the main scarp that formed between 1999 and 2004. Fresh soil is exposed below due to continued offset in 2005 and 2006.

CITY CREEK CANYON LANDSLIDES, SALT LAKE CITY

A cluster of historical landslides is visible from the hairpin turn in Bonneville Boulevard in lower City Creek Canyon in Salt Lake City. Movement of the largest and most damaging of these landslides has been monitored since June 1998 by the UGS and the Salt Lake City surveyor. Since June 1998, the toe of the landslide has moved about 24 feet, and the main scarp has offset the ground surface about the same amount. Like most recurrently active landslides in northern Utah, movement typically occurs between March and June as ground-water levels rise following the snowmelt. Four houses at the top of the slide are threatened, and efforts to protect one house have cost in excess of $300,000. In 2006 the landslide reactivated again, moving about 2 feet, despite drier-than-normal conditions in Salt Lake City.


Beechwood Drive landslide main scarp, cutting across backyards.


Landslide movement left this concrete driveway slab suspended in the air in the Creekside Drive area, Mountain Green.


Damage to road in upper part of Sherwood Hills landslide, Provo.

TAKING ANOTHER LOOK AT UTAH'S TAR SAND RESOURCES

by J. Wallace Gwynn

Recent increases in the price of crude oil have sparked renewed interest in unconventional energy resources, including Utah's tar sands. Tar sands (also called oil-impregnated sandstones, oil sands, and bituminous sandstones) are, as the names imply, sandstones that are saturated or filled with black, heavy hydrocarbons or bitumen. The sandstone can be unconsolidated, that is, the sand grains are held together mainly by the bitumen, or it can be consolidated, whereby the sand grains are held together by silica or carbonate cement with the bitumen filling the remaining voids. The bitumen is viscous, relatively immobile in the rock, and cannot be extracted by conventional oil-production techniques. The bitumen often "bleeds" from outcrops that are warmed by the sun, however.

Origin, API gravity, chemical properties, and character of Utah tar sand bitumen.

	Uinta Basin	SE Utah
Origin	Lacustrine	Marine
API Gravity	5.5 to 17.3	-11.1 to 9.6
Sulfur Content (wt. %)	0.19 to 0.76	2.37 to 6.27
Nitrogen Content (wt. %)	0.17 to 1.8	0.3 to 0.9
Character	Naphthenic	Aromatic

North America has the greatest measured tar sand resources in the world. Canada holds the majority of these tar sands, followed by the United States. Utah's measured tar sand resource, though small in comparison to that of Canada, is the largest in the United States. Smaller resources exist in Texas, California, Alabama, Kentucky, and several other states. The speculative tar sand resource of Alaska is nearly equal to the total resource of Utah.

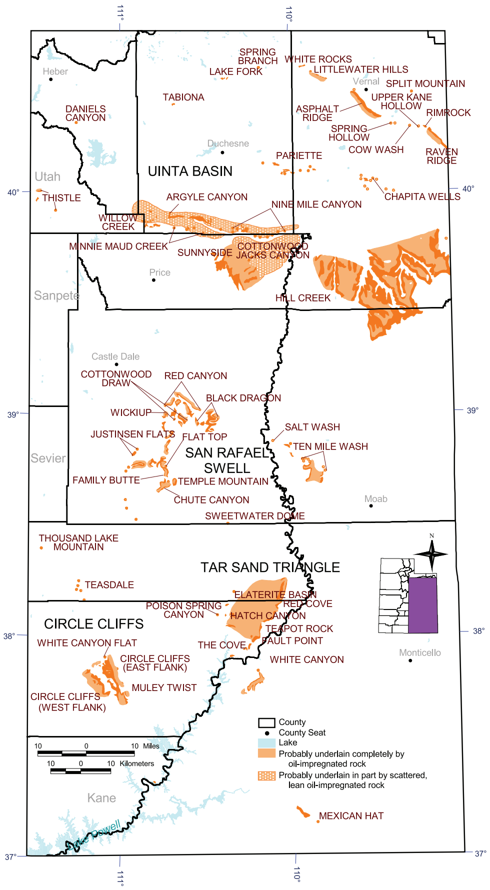
Bitumen "bleeding" from Navajo Sandstone in the Whiterocks deposit, Uinta Basin.

Utah's tar sand deposits contain 14 to 15 billion barrels of measured oil in place, with an additional estimated resource of 23 to 28 billion barrels. These deposits are within the eastern part of the state (Colorado Plateau physiographic province). Twenty-four individual deposits exist in the Uinta Basin, mainly around its periphery, and an additional 50 deposits are scattered throughout the southeastern part of the state. Utah's major tar sand deposits individually have areal extents ranging from 20 to over 250 square miles, as many as 13 pay zones, gross thickness ranging from 10 to more than 1000 feet, and overburden thickness ranging from zero to over 500 feet. The estimated/measured oil-in-place resources of individual deposits range from 100 million barrels to more than 22 billion barrels.

A few geologic units contain nearly all of Utah's tar sand resource. In the Uinta Basin, the Asphalt Ridge and Asphalt Ridge Northwest deposits are in the Eocene-Oligocene Duchesne River Formation, the P.R. Spring and Hill Creek deposits are in the Douglas Creek Member of the Eocene Green River Formation, and the Sunnyside deposit is in the Green River Formation. In the southeastern Utah deposits, the Tar Sand Triangle deposit is in the Permian White Rim Sandstone of the Cutler Group, and the Circle Cliffs deposit is in the Triassic Moenkopi Formation.

By the late 1800s and early 1900s, many of Utah's tar sand deposits had been discovered and described, and in some cases efforts were made to extract the tar or to use the tar sand as paving material. Increased interest in Utah's tar sands really began in the mid-1900s as evidenced by an increase in the number of publications on the subject. By 1975, interest was fueled by the first major increase in the cost of crude oil above $10 per barrel. Tar sands were now viewed as less of a novelty and more as a new and hopefully less expensive source of oil. During the next 20 years, interest in tar sands continued, as did tar sand research, which included detailed geologic mapping and core drilling, bitumen characterization, development of bitumen extraction techniques, and development of bitumen upgrading processes. Funding for tar sand research during this time came from the U.S. Department of Energy and major corporations, as well as private and other sources. Unfortunately, in spite of the great amount of research, testing, and initial developments, a lasting and successful tar sand industry in Utah was not realized.

After 1995, interest in tar sands waned, and tar sand research dropped dramatically even with the price of crude oil fluctuating within the $10- to $30-per-barrel range. Foreign and domestic crude oil supplies were abundant, so production of synthetic crude from tar sands was not profitable. In late 2001, however, the price of crude oil started a steep rise from around $18 per barrel to over $75 per barrel by 2006. During this period of rising crude oil prices, interest in tar sands, as well as oil shales, again came to the forefront, prompting tar sand and oil shale initiatives on the federal, state, corporate, academic, and private levels. With the high price of crude oil as an incentive, coupled with the vast amount of past research information that is available, new drilling, bitumen extraction, and upgrading techniques may provide the necessary ingredients for the successful and sustainable development of Utah's tar sand deposits in the near future. However, in spite of the current favorable economical and technological setting, factors such as site accessibility,



Tar sand deposits of eastern Utah.

adequate infrastructure, water availability, environmental concerns, land access and permitting, and the heterogeneity of reservoir sands must be resolved before tar sand development will become a reality in Utah.

UGS *Annotated Bibliography and Databases of Utah Tar Sands*, and other sources of information from the UGS

Over the past two years, the UGS has been assembling an annotated compilation of over 550 references and data sources for Utah tar sands. The *Annotated Bibliography and Databases of Utah Tar Sands*, by J. Wallace Gwynn and F. Hanson (University of Utah), provides references to information on the geology, chemistry, extraction techniques and trials, and upgrading of tar sand bitumen in Utah. Sources of information include journal articles, theses and dissertations, UGS files, and industry files. The compilation will be released as a UGS Open-File Report on compact disk and the UGS Web site, and is expected to be available in early 2007.

Additional information on Utah tar sands is available online in the following UGS publications:

Blackett, R.E., 1996, Tar-sand resources of the Uinta Basin, Utah (a catalog of deposits): Utah Geological Survey Open-File Report 335, 122 p. http://ugspub.nr.utah.gov/publications/open_file_reports/OFR-335.pdf

Campbell, J.A., and Ritzma, H.R., 1979, Geology and petroleum resources of the major oil-impregnated sandstone deposits of Utah: Utah Geological and Mineral Survey Special Studies 50, 24 p. http://ugspub.nr.utah.gov/publications/special_studies/SS-50.pdf

Utah Geological and Mineral Survey, 1983, Energy resources map of Utah: Utah Geological and Mineral Survey Map 68, scale 1:500,000. http://ugspub.nr.utah.gov/publications/energy_maps/M-68.pdf

UGS HOSTS BASIN AND RANGE PROVINCE EARTHQUAKE WORKING GROUP MEETING

By William R. Lund

In March 2006, the Utah Geological Survey (UGS) organized and hosted a three-day meeting of the Basin and Range Province Earthquake Working Group (BRPEWG) in Salt Lake City. The BRPEWG was convened under the auspices of the U.S. Geological Survey (USGS) National Seismic Hazard Mapping Project (NSHMP) and the Western States Seismic Policy Council to provide consensus recommendations to the USGS on five seismic-hazard issues in the Basin and Range Province (BRP) important to the 2007 update of the USGS National Seismic Hazard Maps. These maps form the basis for the seismic design requirements in the International Building Code, and as such are important in ensuring the safety of new buildings in Utah. The BRPEWG consisted of 27 geologists, seismologists, and geophysicists who are leading experts on BRP earthquake hazards.

The five seismic-hazard issues considered by the BRPEWG were first identified by scientists who attended the Basin and Range Province Seismic Hazard Summit II (BRPSHSII) held in Reno, Nevada, in 2004. The five issues were:

1. use and relative weighting of time-dependent, Poisson, and clustering models in characterizing fault behavior,
2. proper magnitude-frequency distributions (Gutenberg-Richter versus characteristic earthquake models) for BRP faults,
3. use of length versus displacement relations to estimate earthquake magnitude,
4. probabilities and magnitudes of multi-segment ruptures, and
5. resolving discrepancies between geodetic extension rates and geologic slip rates.

The BRPEWG consensus recommendations were published in UGS Open-File Report 477, *Basin and Range Province Earthquake Working Group Seismic-Hazard Recommendations to the U.S. Geological Survey National Seismic Hazard Mapping Program*, and were presented for USGS consideration at the NSHMP Intermountain West regional meeting held in Reno, Nevada, in May 2006. For those interested in the details of the BRPEWG process and recommendations, Open-File Report 477 is available from the Utah Department of Natural Resources Map & Bookstore, as is the BRPSHSII Proceedings Volume published by the UGS as Miscellaneous Publication 05-2.

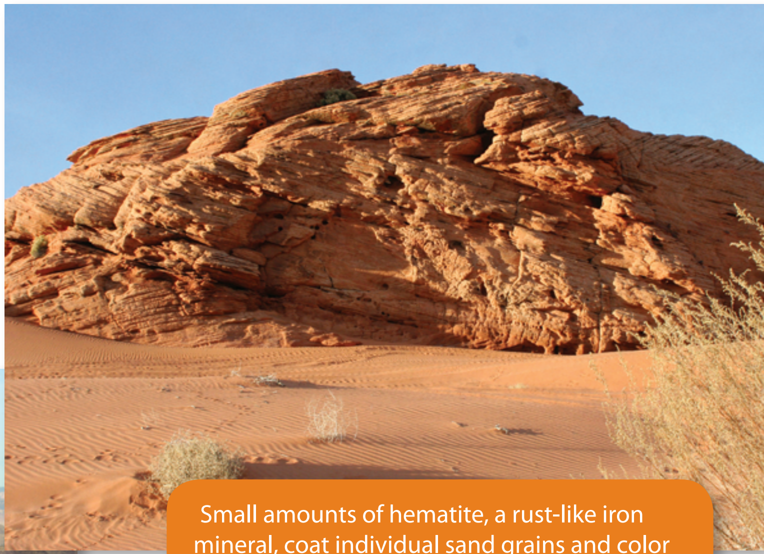
Sand Dunes on the Navajo Sandstone at Sand Mountain, Washington County, Utah

By Mark Milligan

During the Age of Dinosaurs, approximately 200 million years ago, the red rock (lower half of photo) was blowing sand. This "sand sea" was bigger than the dune fields of the modern Sahara, covering parts of what is now Utah, Arizona, Nevada, and Colorado. Over time, deep burial and mineral cements turned the sand to sandstone. Uplift and erosion later exposed the sandstone, and ongoing weathering and erosion of the rock supplies sand for the modern dunes (top of photo).

GEOLOGIC INFORMATION:

Virtually every geology student is introduced to the phrase "the present is the key to the past," a summarization of one of the underlying principles of geologic interpretation, the principle of uniformitarianism. A strikingly obvious place to see the geologic present juxtaposed with the geologic past is Sand Mountain, immediately south of Sand Hollow State Park in Washington County, where modern, active sand dunes blow across ancient, "petrified" dunes of Navajo Sandstone.



Small amounts of hematite, a rust-like iron mineral, coat individual sand grains and color the rock reddish orange. Note the exposed multidirectional cross-bedding due to changing wind directions.

The vistas from this GeoSight are as interesting as the geology underfoot. Looking to the northeast, one-million-year-old black basalt caps the bluff on the far side of the reservoir. The brown hill just beyond the bluff is a 350,000-year-old volcano. The cliffs of Zion National Park can be seen in the distance. And then there's the water: completed in March of 2002, Sand Hollow Reservoir is an off-canyon reservoir filled with water diverted from the Virgin River after it flows out of Zion National Park. Why a reservoir in a shallow sandy basin underlain by porous sandstone? The reservoir is designed to supply water to the Navajo Sandstone aquifer for storage and later retrieval from wells located off site.

HOW TO GET THERE

From I-15 in southwestern Utah, take exit 16 and travel east toward Hurricane. After approximately 4 miles turn right on Turf Sod Road (just past the wastewater treatment ponds). Turn left after approximately 1 mile and stay on the paved road past the Sand Hollow State Park main entrance. Stop at the sand dunes, but mind the "No Parking" signs.

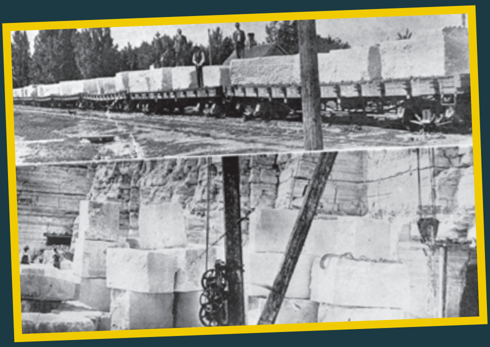
GEOSIGHTS

ANSWERS TO GREAT SALT LAKE TRIVIA QUESTIONS

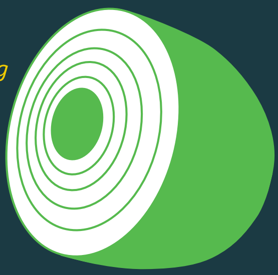
(continued from page 5)

1. What do Great Salt Lake, the Bahamas, the old Hansen Planetarium in downtown Salt Lake City, the Manti LDS Temple, and Hearst Castle in San Simeon, California, have in common?

OOIDS! Ooids are small, rounded, sand-sized grains composed of concentric layers of calcium carbonate precipitated around a nucleus, and they form in shallow, wave-agitated water. The resulting deposit is said to be oolitic. Great Salt Lake and the Bahamas have oolitic sand beaches, and the old Hansen Planetarium, the Manti LDS Temple, and Hearst Castle incorporate oolitic building stone. The buildings all utilize oolitic limestone of the Green River Formation. This unusual stone was deposited in a large lake during the Eocene Epoch, approximately 55 to 38 million years ago.



Oolitic limestone quarried and shipped from a quarry in the Green River Formation near Ephraim in Sanpete County (unknown date, possibly early 1900s). Used by permission, Utah State Historical Society, all rights reserved.



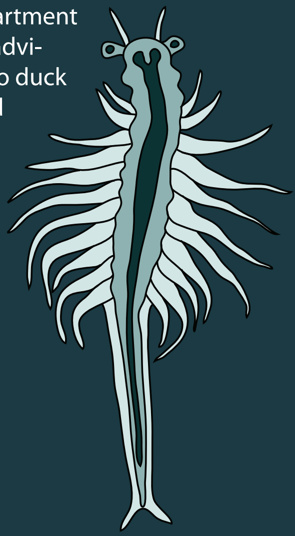
An ooid cross section depicting onion-like layers of calcium carbonate around a tiny shell, mineral fragment, or in the case of Great Salt Lake, brine shrimp fecal pelet.

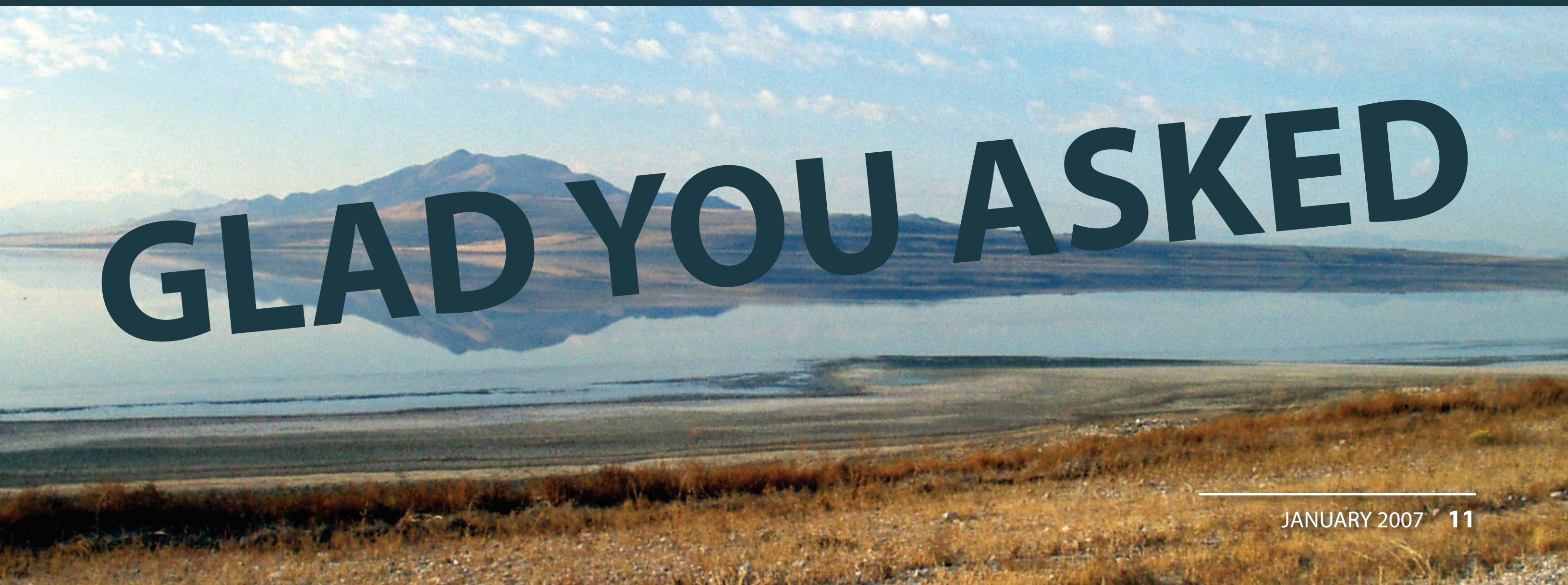
2. What does the original Saltair resort on the south shore of Great Salt Lake have in common with the coasts of Indonesia, Thailand, and northwestern Malaysia?

EARTHQUAKE GENERATED WAVES! The coasts of Indonesia, Thailand, and northwestern Malaysia were all hit by the devastating tsunamis generated by a magnitude 9.1 earthquake under the Indian Ocean in December 2004. Similarly, in 1909 an estimated magnitude 6 earthquake near the north arm of Great Salt Lake generated a wave that damaged the original Saltair resort and overtopped the old wooden railroad trestle that crossed the lake. This trestle was 12 feet above lake level, suggesting the wave was at least that high. The wave in Great Salt Lake (technically a "seiche") differed somewhat from the Indian Ocean tsunamis in that it resulted from ground shaking in a closed basin rather than fault rupture and offset of the seafloor.

3. What two things do Great Salt Lake, Apollo 16, and northern shovelers and common goldeneyes (ducks) have in common?

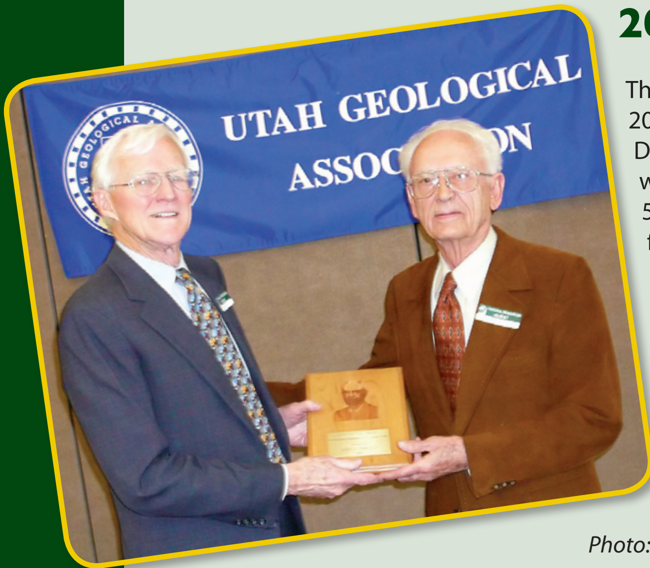
BRINE SHRIMP and MERCURY! On Sept. 29, 2005, high mercury levels prompted the Utah Department of Health to issue a waterfowl consumption advisory recommending people not eat these two duck species. The high mercury levels are believed to be due to the ducks' consumption of brine shrimp from Great Salt Lake. Brine shrimp eggs were used in an experiment on the effects of cosmic radiation, conducted by Apollo 16 astronauts on their way to the moon. Apollo 16's "primitive" electronics presumably contained mercury as well.





SURVEY NEWS

2006 LEHI HINTZE AWARD



The Utah Geological Association and UGS presented Dr. John C. Osmond the 2006 Lehi Hintze Award for outstanding contributions to the geology of Utah. Dr. Osmond has spent over 50 years working on the oil potential of Utah. He was a co-discoverer of Wonsits field in the Uinta Basin that has produced over 50 million barrels of oil. Dr. Osmond has authored or co-authored over 25 professional papers, mostly on the Uinta Basin and the Basin and Range Province. His career has included employment with Humble Oil, Gulf Oil, Pacific Gas and Electric, and Natural Gas Corporation of California, and he continues to contribute to Utah's geology as a consultant for the petroleum industry.

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

Photo: Dr. John C. Osmond (left) and Dr. Lehi F. Hintze

EMPLOYEE NEWS

Carl Ege announced his resignation in October after working with the Geologic Information and Outreach Program for the past 10 years. He has accepted a position with a local geologic consulting company.

NEW PUBLICATIONS

Preliminary geologic map of the Mount Waas quadrangle, Grand County, Utah, by Michael L. Ross, 18 p., 2 pl., 1:24,000, OFR-496 .... $10.25

Preliminary geologic map of the Warner Lake quadrangle, Grand County, Utah, by Michael L. Ross, 18 p., 2 pl., 1:24,000, OFR-497 .... $10.25

Shoreline superelevation: Evidence of coastal processes of Great Salt Lake, Utah, by Genevieve Atwood, 323 p., CD, ISBN 1-55791-761-2, MP-06-9 .... $14.95

Interim geologic map of the Spanish Fork quadrangle, Utah County, Utah, by Barry J. Solomon, Donald L. Clark, and Michael N. Machette, 29 p., 1 pl., 1:24,000, OFR-488 .... $7.25

History and mineral resource characterization of Sevier Lake, Millard County, Utah, by J. Wallace Gwynn, CD (144 p.), ISBN 1-55791-753-1, MP-06-6 .... $14.95

Geologic map of the Lehi quadrangle and part of the Timpanogos Cave quadrangle, Salt Lake and Utah Counties, Utah, by Robert F. Biek, CD (2 pl., 1:24,000, CD [contains GIS data]), ISBN 1-55791-7467-7, M-210DM $19.95

Interim geologic map of the Kanab quadrangle, Kane County, Utah and Mohave and Coconino Counties, Arizona, by Janice M. Hayden, 12 p., 1 pl., 1:24,000, OFR-487 .... $7.25

The available coal resource for eight 7.5-minute quadrangles in the Alton Coalfield, Kane County, Utah, by Roger L. Bon, Jeffrey C. Quick, Sharon I. Wakefield, Brigette P. Hucka, and David E. Tabet, CD (23 p.), ISBN 1-55791-757-4, SS-118 .... $19.95

Interim geologic map of the Soldiers Pass quadrangle, Utah County, Utah, by Robert F. Biek, Donald L. Clark, and Eric H. Christiansen, 23 p., 1 pl., 1:24,000, OFR-484 .... $7.25

Progress report geologic map of the east part of the Provo 30′ x 60′ quadrangle, Utah and Wasatch Counties, Utah, by Kurt N. Constenius, James C. Coogan, and Robert F. Biek, 31 p., 1 pl., 1:62,500, OFR-490 .... $7.25

Ground-water sensitivity and vulnerability to pesticides, Central Virgin River Basin, Washington and Iron Counties, Utah, by Mike Lowe, Janae Wallace, Justin Johnson, Anne Johnson, and Rich Riding, CD (24 p., 2 pl., 1: 145,000), ISBN 1-55791-756-6, MP-06-4 .... $19.95

Interim geologic map of the Goshen Valley North quadrangle, Utah County, Utah, by Donald L. Clark, Robert F. Biek, and Eric H. Christiansen, 13 p., 1 pl., 1:24,000, OFR-486 .... $6.00

Interim geologic map of the West Mountain quadrangle, Utah County, Utah, by Donald L. Clark, 21 p., 1 pl., 1:24,000, OFR-482 .... $6.00

Interim geologic map of the Horse Ridge quadrangle, leading margin of Willard thrust sheet, Morgan, Rich, and Weber Counties, Utah, by James C. Coogan, 19 p., 1 pl., 1:24,000, OFR-480 .... $7.25

Interim geologic map of the Dairy Ridge quadrangle, leading margin of Willard thrust sheet, Cache, Rich, and Weber Counties, Utah, by James C. Coogan, 19 p., 1 pl., 1:24,000, OFR-479 .... $7.25

Teacher's Corner

Integrating *Survey Notes* Articles in the Classroom

by Nancy Carruthers

Is it possible to predict when or where the next large earthquake in Utah will take place? To examine this question further read the two articles in this issue of Survey Notes that discuss research being conducted on the Wasatch fault. The Utah Geological Survey (UGS), in conjunction with the U.S. Geological Survey and other researchers, performs studies to determine the timing, frequency, and magnitude of large, prehistoric, surface-faulting earthquakes on the Wasatch fault and other active faults in Utah. The Wasatch fault, comprising 10 segments that rupture independently, is the longest active normal fault in the United States. Its five central segments extend through the Wasatch Front urban corridor between Brigham City and Nephi. During the past 10,000 years at least 25 surface-faulting earthquakes have taken place on the Wasatch fault. In Utah, earthquakes that rupture the ground surface are in the magnitude range of 6.5 to 7.5. The amount of time between large surface-faulting earthquakes on the Wasatch fault averages about 300-400 years.

In the two Wasatch fault articles, learn how geologists study large prehistoric earthquakes by measuring topographic profiles and excavating trenches across fault scarps. The information obtained in these types of studies has given researchers tremendous insights into the location, timing, and magnitude of past surface-faulting earthquakes in Utah, and on the Wasatch fault in particular. Knowledge of past earthquake behavior helps us understand the risks associated with future earthquakes, but scientists remain unable to specifically predict the timing and magnitude of future earthquakes at a given location. Residents of earthquake-prone areas such as Utah should become familiar with the earthquake risk where they live, take appropriate emergency-planning measures, and not be surprised when "the big one" happens.

For more information on earthquake hazards in Utah, visit geology.utah.gov.

8TH-GRADE INTEGRATED SCIENCE

Standard 2, Objective 4
a. Describe how energy from the Earth's interior causes changes to Earth's surface.

5TH-GRADE SCIENCE

Standard 2, Objective 2
c. Describe how volcanoes, earthquakes, and uplift change landforms.
d. Cite examples of how technology is used to predict volcanoes and earthquakes.

POSSIBLE DISCUSSION POINTS

- What causes earthquakes?
- How can large earthquakes change landforms?
- What are two methods discussed in these articles that provide data on large prehistoric earthquakes?
- What dating method was used to determine the timing of a large prehistoric earthquake at Santaquin?
- How does movement on a normal fault (like the Wasatch fault) differ from movement on a strike-slip fault (like the San Andreas fault in California)?

Earth Science Week 2006

In October, the UGS held its 7th annual Earth Science Week celebration. Assisted by the Utah Geological Association, Utah Friends of Paleontology, and other volunteers, 600 students—ranging from 2nd to 8th grade—attended. Seven different activities engaged the students and adults alike.

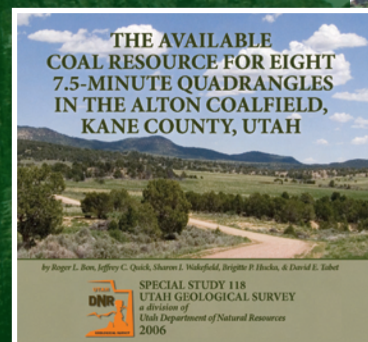
fossils

stream table

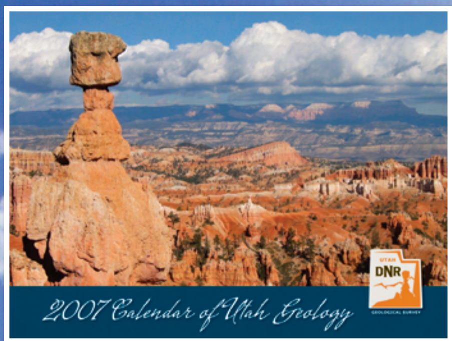
gold panning

The available coal resource for eight 7.5-minute quadrangles in the Alton coalfield, Kane County, Utah

The Utah Geological Survey (UGS) has re-evaluated the coal resource available for mining in the Alton (formerly Kanab) coalfield in Kane County, Utah, and found nearly double the coal compared to a previous investigation in 1972. The updated available resource is approximately 2.91 billion tons, which includes about 503 million tons (17%) of surface minable coal and 2.41 billion tons (83%) of underground minable coal. The available coal resource of the Alton field is found in two Dakota Formation coalbeds, the (lower) Bald Knoll and (upper) Smirl beds. Maps and associated tables showing the distribution and quantity of the available coal are provided for each coalbed. Sixty-four percent (1.88 billion tons) of the available coal is in the Smirl coalbed, and 36% (1.04 billion tons) is in the Bald Knoll coalbed. The coal in the study area is subbituminous A in rank. The average sulfur content is 1% or more for both beds, but the sulfur content is markedly lower in the Bald Knoll bed. The UGS estimates that about 1.25 billion tons of the 2.91 billion-ton available coal resource might be recovered from the Alton coalfield.



Special Study 118 .... $19.95



2007 Calendar of Utah Geology

The Utah Geological Survey has produced a scenic calendar highlighting interesting geological features from across the state. The calendar also lists important dates in geologic history. On sale now at the Natural Resources Map & Bookstore for just $1.

Price Reduced! $1.00

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