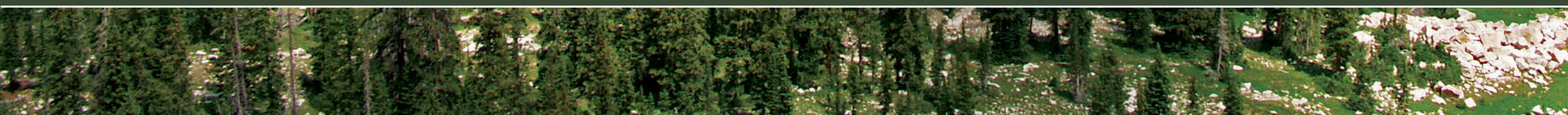
U T A H G E O L O G I C A L S U R V E Y

SURVEY NOTES

Volume 46, Number 3 September 2014

UINTA MOUNTAINS



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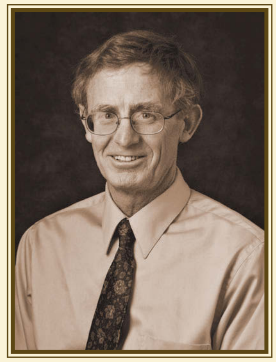
Design ▸ Elizabeth Firmage

Cover ▸ *Cutthroat Lake is a tarn, a lake filling a natural basin formed in a glacial cirque. The enclosing mountains are composed of Neoproterozoic Uinta Mountain Group quartz sandstone and micaceous shale. This view is toward the northwest, Summit County. Photo by Ken Krahulec.*

THE DIRECTOR'S PERSPECTIVE



by Richard G. Allis

This year marks the 65th anniversary of the modern Utah Geological Survey (UGS) (see the *Survey Notes* issue from September 1999 for a historical summary marking the 50-year anniversary—http://geology.utah.gov/surveynotes/archives/snt31-3.pdf). In addition, this current issue of *Survey Notes* marks exactly 50 years of publishing news about UGS activities. The first issue, which in those days was called *Quarterly Review*, was published in August 1964. Issues were published quarterly until 1993, and subsequently there have been three issues per year. All issues are available online (http://geology.utah.gov/surveynotes/svntsarchive.htm), and they make fascinating reading for those interested in the evolution of geological concerns within the state. Those early issues had articles on the hazards and potential economic losses from earthquakes, and the potential for mineral and water resources to contribute significantly to economic growth. Investigations on the varied mineral potential of the state included the salt deposits around Great Salt Lake, oilfield brines, tar sands, and coal beneath the Kaiparowits Plateau. In 1963, Utah was the third-largest producer of lead and zinc (after Idaho and Tennessee) with 19 active mines producing 80,000 tons per year of the two metals, valued at $80 million at that time. Today, Utah has no lead-zinc mines (the Clean Air Act of 1970 caused them to shut down), but production of copper, molybdenum, and gold from Bingham Canyon alone amounts to about $2 billion per year. The second issue of *Quarterly Review* showed that from the early 1950s to early 1960s Utah's share of mineral lease royalties on federal lands had increased from $1 million per year to $3–$5 million per year, and continued strong growth was predicted. Today, mineral lease revenue from federal lands is around $150 million per year. In 1964, 1:24,000-scale topographic maps covered only 59 percent of the state, with active mapping occurring on another 10 percent, and 31 percent of the state was still unmapped at that scale. The UGS proposed in 1965 to allocate $50,000 per year to the ongoing mapping effort of the U.S. Geological Survey so that an additional 10 quadrangles per year could be produced. The goal was to have topographic maps around Great Salt Lake published within about four years.

Advocacy for increased mineral resource development in Utah was surprisingly strong in those early issues of the *Quarterly Review*. The following statement appeared in a 1965 issue: "The citizenry of the Beehive State must cease to stand solidly like the steles of Stonehenge, guarding their water and agriculture, and let a well-behaved mineral industry assist in expanding the tax base." The population of Utah is now three times larger, the state economy (gross state product in current dollars) is over 40 times larger, and debate over the best use of our precious water is as contentious as ever. After 65 years, the UGS also remains strong, contributing objective information to decisions on wise land-use as Utah continues to grow.

UGS Awarded Geologic Mapping Grant

The UGS Mapping Program was recently awarded $182,557 by the U.S. Geological Survey National Cooperative Geologic Mapping Program as a 50:50 federal/state cost share to conduct geologic mapping of five areas around the state. The funds will be used to continue regional mapping in the Duchesne area of the Uinta Basin, the Tooele Valley and Stansbury Mountains area, and volcanic terrain south and west of Loa near Boulder Mountain. They will also support detailed mapping in southern Salt Lake Valley near the mouth of Little Cottonwood Canyon and southeast of Salina in Sevier Valley. The UGS applies for these funds each year, which support a large part of our geologic mapping and GIS database efforts around the state. Over the past 20 years, nearly every part of the state has benefitted from this improved geologic mapping. Nearly all the maps are available on the UGS website through the Interactive Map and map search indexes.

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The Uinta Mountains

A Tale of Two Geographies & More

by Douglas A. Sprinkel

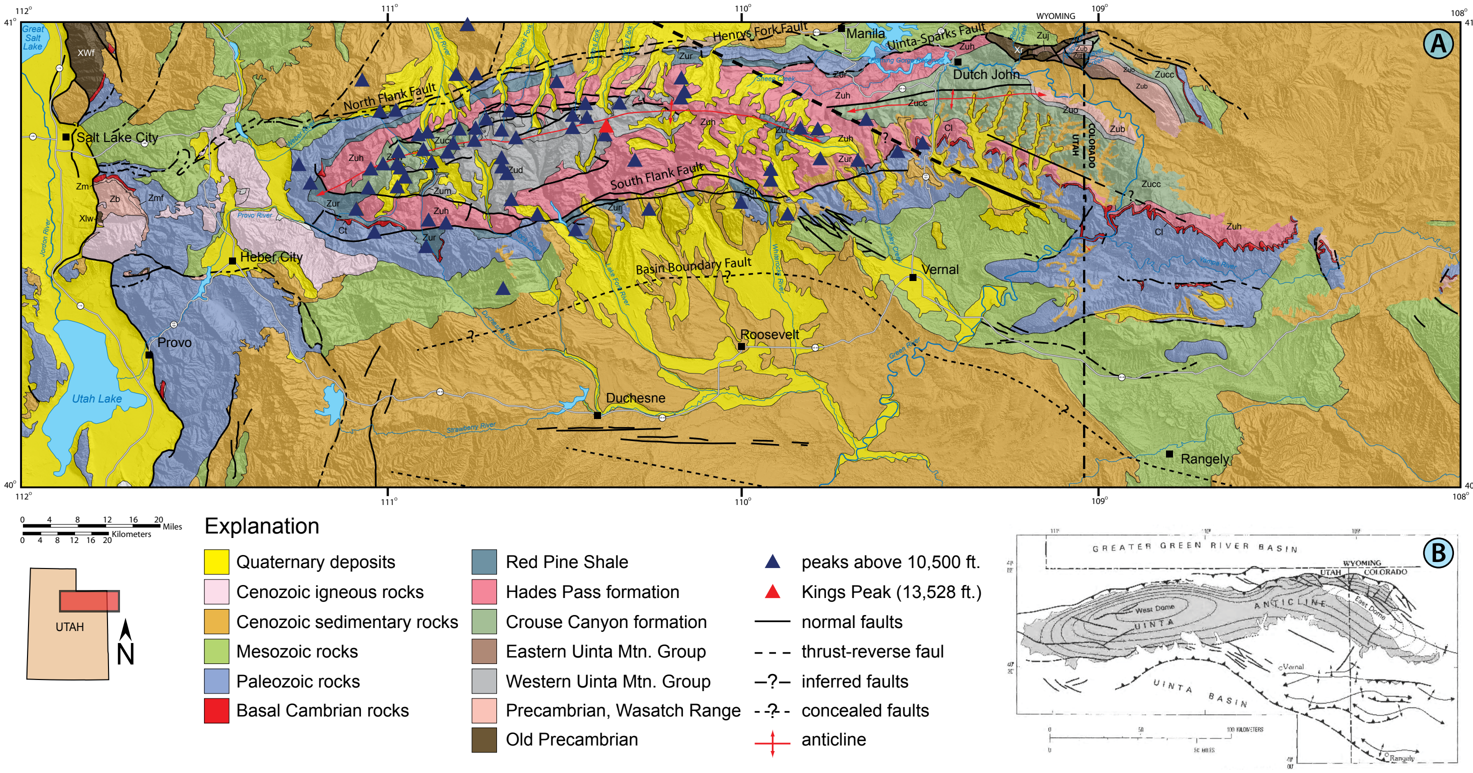
The Uinta Mountains are one of Utah's premier mountain ranges. Rising above the Uinta Basin in Utah on the south and the Green River Basin in Wyoming on the north, they stretch from near Kamas eastward into northwestern Colorado. They form the roof of Utah, having more peaks greater than 11,000 feet than any other mountain range in Utah, and our only peaks over 13,000 feet, including Kings Peak, our highest at 13,528 feet. However, the Uintas are a tale of two geographies, so much so that many people refer to the "western (or high) Uintas" and the "eastern Uintas." I have often wondered why the high peaks—and glaciation—are concentrated in the western part of the range and why the Uinta Mountains consist of two anticlines. I was also curious why the eastern part of the range is seemingly bent. Why the difference? The answer may lie in part in the long geologic history of this part of Utah, and in a newly recognized fault zone that seems to cut across the range.

Most scholars of the Uinta Mountains know that the story began more than 1.7 billion years ago, and most know that the mountains we see today formed during the Laramide mountain-building event between about 70 and 34 million years ago (mya). But, many Utah geologists may think that since 34 mya the range has just sat there, passively being carved away by streams and glaciers, not fully realizing it has been structurally modified by Tertiary extension during the past 23 million years. Recently, through new research and mapping, we have learned that there is much more to the story—we now recognize that structural changes began at the end of the Precambrian (Neoproterozoic), that the Uintas have large active faults that may present an earthquake hazard today, and that at times these faults localized mineralization. These answers are arising from 15 years of detailed geologic mapping in the Uinta Mountains and Uinta Basin by the Utah Geological Survey, with additional supportive mapping and stratigraphic studies by other researchers and their students, including Carol Dehler (Utah State University), Bart Kowallis (Brigham Young University), Paul Link (Idaho State University), Charles "Jack" Oviatt (Kansas State University), and Joel Pederson (Utah State University). Below, I outline a case for a previously unrecognized fault zone that bisects the Uinta Mountains and remains active today. But first we need to briefly review the older history of the range.

Regional tectonic events drive the uplifts that form most major mountain ranges, and the Uinta Mountains are no different. Their existence is largely due to the compressional forces of the Laramide orogeny (orogeny means a mountain-building event). The Laramide uplift folded rocks in the Uintas into a broad arch or anticline, which is actually formed of two separate anticlinal culminations. The Uintas rose along a set of faults—the north flank, Henrys Fork, and Uinta-Sparks faults on the north flank, and a smaller complimentary fault system on the south flank called the basin boundary fault. The north flank system generally parallels the Cheyenne belt, a weak zone in the earth's crust that marks the "suture" where the ancient (2.6 billion-year-old) Wyoming province was "stitched" to a younger plate called the Yavapai-Mazatzal province about 1.7 billion years ago. This weak zone has influenced structures in the Uintas ever since. During part of the late Neoproterozoic (about 770 to 740 mya) it formed the northern boundary of a faulted basin in which a huge amount of sand, gravel, and mud accumulated that today are rocks of the Uinta Mountain Group and form the core of the Uinta Mountains. The Uintas owe their east-west trend to this ancient boundary.

We also know that other tectonic events modified the Uinta Mountains structure. The Sevier orogeny was a thrust-type compressional mountain-building event from about 130 to 40 mya that in part overlapped the Laramide orogeny in time and space. The westernmost parts of the Uinta Mountains and Uinta Basin preserve the different structural geometries of the two orogenies. More recently, Tertiary extension modified the Uinta Mountains by lowering the eastern Uintas as early as about 23 mya, but most actively from about 15 mya to present day.

Above photo: Ridge top near the Paint mine about 2.5 miles west of Moon Lake, Duchesne County. Mississippian carbonates overlain by Tertiary rocks. Photo by Ken Krahulec.

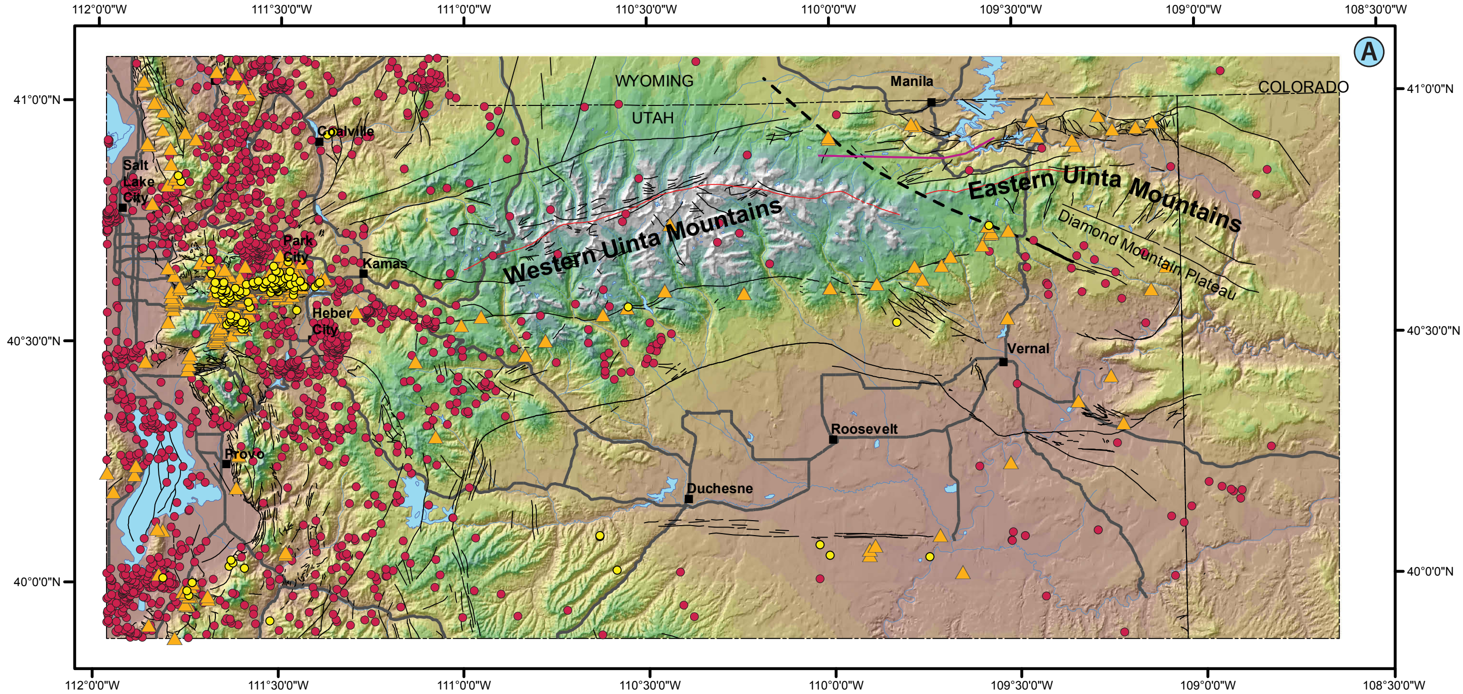


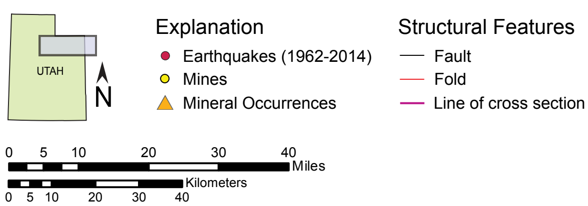
(A) The Uinta Mountains have more peaks greater than 11,000 feet than any other mountain range in Utah, including Utah's highest, Kings Peak at 13,528 feet. Peaks greater than 10,500 feet are concentrated in the western part of the range, whereas the few demure peaks in the eastern Uintas barely exceed 10,000 feet, and most are well under 10,000 feet. An inferred northwest-trending fault zone cuts the formations of the late Neoproterozoic Uinta Mountain Group but does not significantly cut the overlying Paleozoic and Mesozoic rocks, suggesting movement along the fault zone was late Neoproterozoic. (B) Wallace Hansen, in his 1986 report on the Neogene tectonics of the Uinta Mountains, showed the broad Uinta arch is actually two misaligned anticlines separated by a structural saddle. The anticlines may have formed in late Neoproterozoic time and been significantly enhanced during the Laramide orogeny.

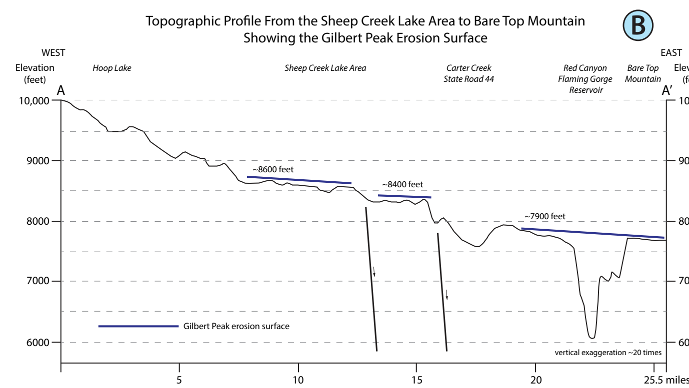
Our new mapping has helped clarify the older and younger parts of the story—I propose that a northwest-trending fault zone bisects the Uinta Mountains and is largely responsible for the west-east division of the range. This inferred fault zone is not obvious because it does not regionally offset Paleozoic and Mesozoic rocks, but the alignment of a series of oblique subsidiary folds and short northwest-trending fault segments help constrain its position. I first suspected that a range-bisecting fault zone may be present after examining digital elevation data looking for fault scarps in the Diamond Mountain Plateau area. I noticed a linear trend extending from known fault scarps on the plateau, northwest through a broad structural saddle in the center of the range, to the apparent termination of the north flank fault zone. Other structural features also seem to terminate along this lineation, including the south flank fault zone and a fault zone on the north side of the Uintas near Utah State Road 44. The inferred fault zone may also help explain the two anticlines and their different orientations and misalignment.

Although the fault zone does not significantly cut Paleozoic and Mesozoic rocks, Uinta Mountain Group (UMG) rocks are cut. In a 2007 geologic map of the Dutch John 30′ x 60′ quadrangle, the UMG in the eastern Uinta Mountains consisted of the basal Jesse Ewing Canyon Formation overlain by a thick unnamed and undivided interval, and capped by the Red Pine Shale. Since release of that map, Carol Dehler and her students divided the unnamed interval into three new informal formations (Diamond Breaks, Outlaw Trail, and Crouse Canyon) and we extended the overlying Hades Pass formation, an informal unit in the western Uintas, into the eastern Uintas. This new stratigraphy, combined with detailed new mapping shows that, interestingly, this inferred northwest-trending fault zone actually placed the older Crouse Canyon formation near the capping Red Pine Shale, making the intervening Hades Pass formation anomalously thin near Leidy Peak. Additionally, thickness variations of the Hades Pass formation are common all along the inferred fault zone. Timing of movement on the inferred northwest-trending fault zone must be near the end of Precambrian (late Neoproterozoic) time because the UMG formations are offset and tilted westward but the overlying Paleozoic rocks have little to no offset or pre-Laramide deformation. In addition, the Paleozoic formations overlie progressively older parts of the UMG in a generally eastward direction making a regional angular unconformity.

So, the evidence is strong that this fault was active in the late Precambrian—what about my claim that it has also been active since the late Tertiary? Lines of evidence include earthquake data, mineral occurrences, and offset Tertiary and Quaternary deposits and surfaces. Let's look at a few of these briefly. The southeast extent of the inferred fault zone is along a fault scarp on the Diamond Mountain Plateau. The fault scarp is likely in middle Pleistocene gravel that covers the Oligocene Bishop Conglomerate, which suggests the fault could be considered potentially active. A widely spaced cluster of small earthquake epicenters that plot along the fault scarp and in the inferred fault zone supports this hypothesis. If true, the inferred northwest-trending fault seems to be a reactivated major Precambrian fault and is one more example of a pattern found so often in the Uinta Mountains, old structures being reborn as new structures in different tectonic settings.





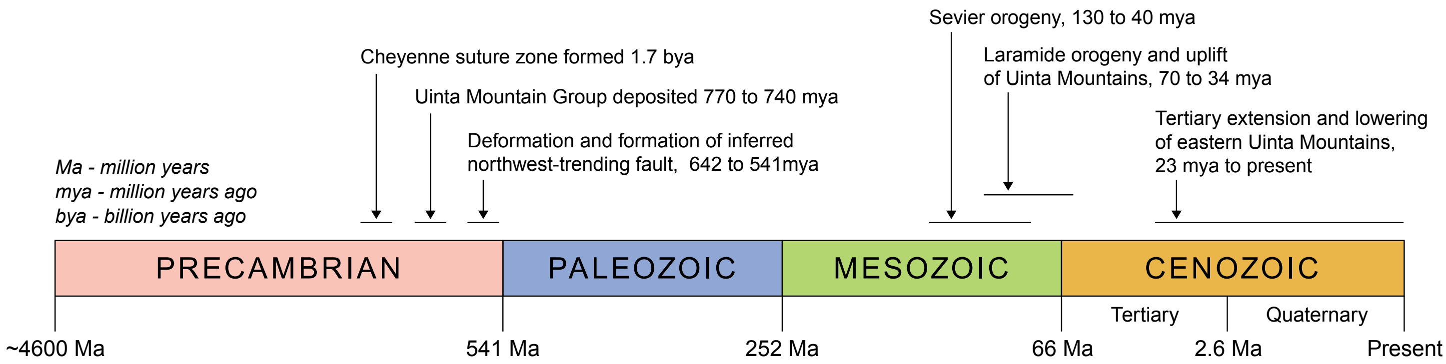


(A) The inferred northwest-trending fault seemingly truncates several structural features like the north flank and south flank faults, and separates the Uinta arch into two anticlinal culminations first described by Wallace Hansen. The southeast extent of the inferred fault zone is traced to a normal fault and associated fault scarps of possible Pleistocene age on the Diamond Mountain Plateau. A cluster of widely spaced earthquake epicenters is generally aligned along the inferred fault zone and fault scarp, suggesting the fault is active. Most of the mineral occurrences and mines in the Uintas are closely associated with faults, including the inferred fault zone. Note that the Dyer mine and nearby minerals occurrences are aligned along the zone in the eastern Uintas. (B) A topographic profile from east of Sheep Creek eastward to Bare Top Mountain (topographic maps show Bare Top Mountain as Bear Mountain) shows the offset of the 34- to 30-million-year-old Gilbert Peak erosion surface in two locations that coincide with the projected trace of the inferred fault zone. Although the Tertiary movement is down to the east, movement on the fault zone in the late Neoproterozoic was up on the east, an example of fault reactivation with a reverse sense of motion.

The Uinta Mountains are a remarkably unmineralized mountain range; however, a plot of mines and mineral occurrences shows that much of the mineralization that does exist is closely associated with faults including the proposed northwest-trending fault zone. The copper-producing Dyer mine and associated mineral occurrences seem to lie along the inferred fault zone.

A remarkable feature of the Uinta Mountains, the Gilbert Peak erosion surface, provides another line of evidence. The surface formed about 34 to 30 million years ago after the Laramide orogeny and prior to Tertiary extension. The Bishop Conglomerate blankets the Gilbert Peak erosion surface along the south flank of the Uintas, but the surface is mostly bare, with the exception of thin unconsolidated Quaternary deposits, on the north flank. Faults cut the Gilbert Peak erosion surface at many places, including across the projection of the inferred northwest-trending fault on the north flank, indicating that movement must have happened in the middle Tertiary or later. Displacement data indicate that many faults first moved as compressional Laramide-age faults, and were later reactivated as extensional Tertiary faults.

The inferred northwest-trending fault zone can explain many of the intriguing features we observe in the Uintas, including the abrupt eastward termination of the high Uinta peaks, the various structural features on the north and south flanks of the range, and the two distinct anticlinal culminations. It helps clarify the long history of the Uintas, including an early period of compressional deformation in the late Neoproterozoic (between about 642 and 541 mya) in which the UMG basin was inverted, folded into a subtle low-amplitude anticline, and faulted. Like the later Laramide orogeny, the late Neoproterozoic uplift occurred along faults that paralleled the Cheyenne suture. This event produced a subtle, generally east-west-trending fold that extended from Colorado to western Utah and eastern Nevada to form the Uinta-Cortez arch. This deformation also faulted the UMG along the inferred northwest-trending fault zone, creating the initial bisection and possibly the two anticlinal culminations. Precambrian west-southwest movement on the inferred fault zone placed older formations of the UMG on the east up against the younger formations of the UMG on the west, and may have set the stage to give the later eastern mountains their unusual bend. At the end of the Precambrian,



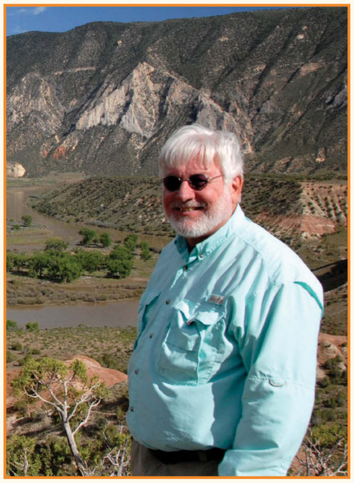
Timeline showing the main geologic events that contributed to the formation and modification of the Uinta Mountains.

the UMG was also eroded into an undulating paleotopography prior to the deposition of the Paleozoic formations. Much later, during the Laramide orogeny and uplift of the Uinta Mountains, the inferred fault zone may have had some movement, but most of this deformation was accommodated by enhancing the amplitude of the two anticlines and forming smaller folds oblique to the trend of the zone. The fault zone moved again during late Tertiary extension, but this time the eastern part of the range moved down relative to the western part. Lowering the eastern Uintas along the reactivated inferred fault zone and other faults offset the Gilbert Peak erosion surface, caused a reorganization of the drainage system, and terminated the string of high peaks of the Uintas. Timing of mineralization associated with the inferred fault zone and others faults in the Uinta Mountains is unclear but is likely Tertiary in age. Proximity of earthquake activity in the eastern Uinta Mountains with the inferred fault zone is intriguing.

Much more work is needed to define clearly the position and extent of the inferred northwest-trending fault zone and constrain its deformational history. It is an interesting structural feature of the Uinta Mountains, and if proven, can explain many of the topographic, geomorphic, and geologic oddities of the range.

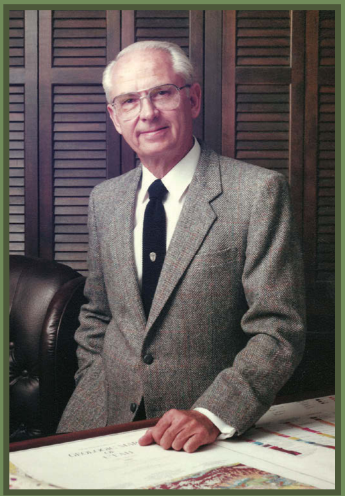
about the author

DOUG SPRINKEL *is a senior geologist in the Geologic Mapping Program at the Utah Geological Survey. His principal responsibility is to map the geology of 30' x 60' quadrangles that cover the Uinta Mountains and Uinta Basin. In addition to his mapping efforts in northeastern Utah, Doug has mapped quadrangles in the central Utah thrust belt. Other ongoing projects include a regional study of Early and Middle Jurassic strata and regional Mesozoic unconformities. Doug has co-edited four popular books on Utah geology and authored or co-authored 10 geologic maps and nearly 100 professional reports, articles, and abstracts.*



in memoriam
LEHI F. HINTZE

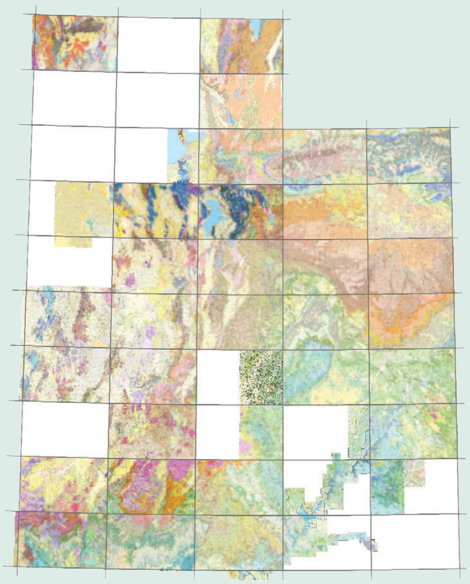
On July 1, 2014, with the passing of Dr. Lehi Ferdinand Hintze, Utah lost its most visible icon of Utah geology. We offer our condolences to family, friends, and colleagues. Lehi is best known as the co-author with W. Lee Stokes of the 1963 *Geologic Map of Utah*, author and compiler of the 1980 *Geologic Map of Utah* that stills stands as our "state geologic map," and the author of the popular *Geologic History of Utah*, the "bible" of Utah geology used by professionals, students, and countless nongeologists. Lehi spent most of his long career at BYU where he supervised 38 Master's theses, and taught over 600 field camp students. Like many great geologists, he never did retire—after leaving BYU, he worked half time for the Utah Geological Survey, producing four 30' x 60' quadrangle geologic maps and a masterful bulletin on the geology of Millard County. Lehi authored or co-authored over 150 publications, including over 80 geologic maps. He served the geologic community on many committees, including one with Genevieve Atwood and Hellmut Doelling that created a state geologic mapping program (at a time when geologic mapping was on the decline) and became the model for a national program. He received the (Utah) Governor's Medal for Science and Technology, the national Dibblee Award for geologic mapping, and the American Association of Petroleum Geologists Rocky Mountain Section's highest award—the R.J. Weimer Lifetime Contributions Award. Lehi was the namesake and first recipient of the Award for Outstanding Contributions to Utah Geology, given by the Utah Geological Association and the UGS. His contributions to Utah geology will live on forever.



STUDENTS HELP FILL THE GIS GAP

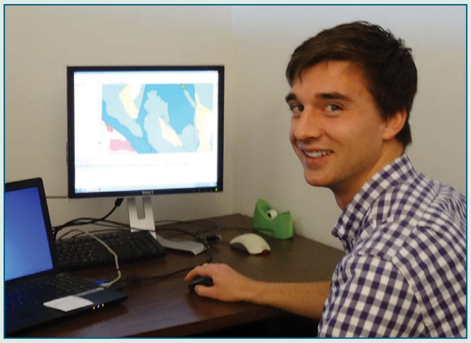
by Grant Willis and Zach Anderson

The rapid growth of Geographic Information Systems (GIS) as the preferred land management, exploration, and research tool for government, education, and industry has precipitated a huge need to produce GIS geologic map data in a very short time. Unfortunately, geologic mapping and GIS database construction are slow, labor-intensive processes, meaning that detailed GIS data of some areas is literally decades out. But, who wants to wait several decades?! To help bridge this gap, the UGS Mapping Program developed a new initiative to work with undergraduate students in geology departments at nearby universities to produce GIS data of older existing geologic maps. These projects fulfill a student's class or senior project assignment, and creating GIS data of a geologic map is one of the most challenging learning experiences a GIS student can have. In addition, the students get the satisfaction of knowing that their hard work does not follow the path of most student projects. If they do good work, six to twelve months later the students will see their map posted on the UGS website for all the world to view and use. Students tell us that knowing real geologists will actually use their data is one of their biggest incentives to do their best work.



Status of 30′ x 60′ quadrangle geologic mapping in Utah (not all are released yet).

The 30′ x 60′ quadrangle geologic map series is our primary statewide GIS goal. Currently, GIS data are released for 27 of 46 quadrangles, with 12 more well under way, leaving 7 that are not even started. Fortunately, GIS data of moderately accurate older maps can temporarily fill some gaps until new and more accurate mapping can be completed. We have identified about two dozen older maps that could be valuable contributions to our databases. Most of these older maps cover about 1/8 of a 30′ x 60′ quadrangle, making them nice-size GIS projects for a small group of students. During this past school year, students completed or nearly completed GIS products for four of these maps. The students enjoyed learning new GIS skills while working on projects directly related to their field. In general, the results have been very good and these maps will be posted to our website when we complete our reviews. It's a win-win for everyone.



BYU student Anthony Blackham examines his GIS data on USGS Map I-1796, Geologic Map of the Southern Mountain Home and Northern Indian Peak Ranges (central Needle Range), Beaver County, Utah, which fills a hole in the unmapped Wah Wah Mountains South 30′ x 60′ quadrangle.

2014 CRAWFORD AWARD

The prestigious 2014 Crawford Award was presented to UGS geologists (left to right) Tyler Knudsen, Paul Inkenbrandt, Bill Lund, Mike Lowe, and Steve Bowman in recognition of their combined work on the outstanding geologic publication *Investigation of Land Subsidence and Earth Fissures in Cedar Valley, Iron County, Utah* (UGS Special Study 150).

This 116-page book documents the first known instance of land subsidence and earth fissures related to groundwater mining affecting Utah's urban environment. The report shows that groundwater pumping in excess of recharge has lowered the potentiometric surface in Cedar Valley up to 114 feet, causing compaction of the valley aquifer. It recommends that the aquifer be managed as a renewable resource, and site-specific-hazard investigations be required for new development in areas known or suspected to be subsiding as long as groundwater mining continues. Guidelines for conducting detailed site-specific land-subsidence and earth-fissure-hazard investigations are included.

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

geo sights

Roosevelt Hot Springs Geothermal Area, Beaver County

by Mark Milligan

The Roosevelt Hot Springs area includes steaming and hissing geothermal vents, bubbling pools, and boiling mud pots. This landscape seen today is a recent and evolving phenomenon resulting from dropping groundwater levels caused by the operation of a geothermal power plant.

geologic information

A traditional geothermal field includes high heat flow and circulating groundwater. The Roosevelt Hot Springs geothermal area has both.

The Roosevelt Hot Springs geothermal area is believed to be heated by an underlying body of cooling magma, as suggested by rocks in the Mineral Mountains to the east. Most of this mountain range consists of an intrusive (sub-surface) mass of cooled magma called a batholith. This batholith and related volcanic rocks are geologically young, ranging in age from 25 million to perhaps 600,000 years. The body of cooling magma believed to underlie the geothermal area could have once been part of or closely associated with the magma body that fed the youngest volcanic rocks (rhyolite) in the Mineral Mountains. This magmatic heat explains why the area is Utah's hottest geothermal system, as most of Utah's hot springs derive their heat solely from deep groundwater circulation without an associated magma body.

Rain and snowfall in the Mineral Mountains provide water to recharge the deep groundwater within the Milford Valley. This deep, hot water then flows back to the surface through a zone of highly fractured and thus highly permeable bedrock found beneath the geothermal area. The highly fractured bedrock resulted from two intersecting faults, the Negro Mag fault and the Opal Mound fault.

blundell geothermal power plant

The thermal energy of the Roosevelt Hot Springs area is tapped by the 34 megawatt Blundell power plant owned by PacifiCorp Energy. Production well drilling for the project started in 1975, and the steam power plant began operation in 1984. Most wells are between 2,500 and 6,500 feet deep and are currently producing fluid that is 470°–480°F. This fluid is then separated into steam and brine at the surface. The heat-derived energy of each is used to run turbines that generate electricity. The used brine and water (condensed from steam) cool to roughly 104°F before being re-injected back into the underground reservoir.

Not all of the fluid pumped out is re-injected, some is lost to evaporation from cooling towers. Such water loss has contributed to dropping groundwater levels. Steam is replacing this lost groundwater such that a large subsurface steam zone now overlies the water table. Thankfully some of this steam is venting to the surface, for rapid steam buildup can result in *phreatic* (steam-driven) explosions. At the Roosevelt Hot Springs geothermal area this venting steam creates the steaming and hissing ground, boiling mud pots, bubbling pools, vegetation dead zones, and other assorted features. The vibrant colors found near steam vents are due to yellow sulfur crystals and various colors of bacteria and algae.

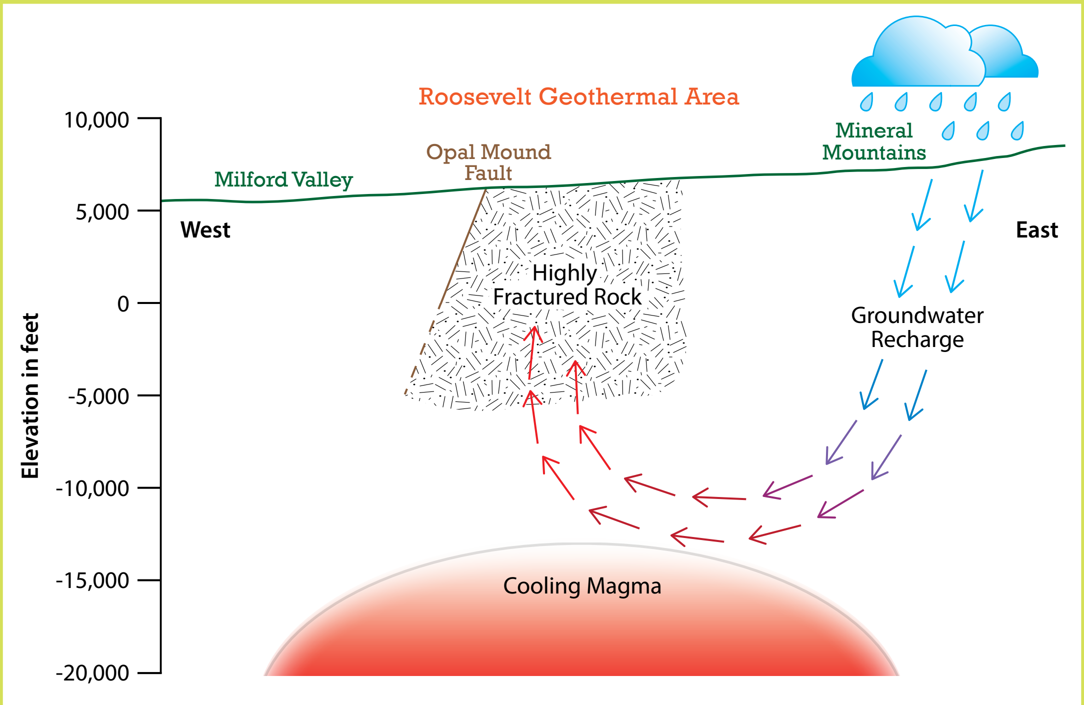
The Roosevelt Hot Springs area has a colorful history. In the late nineteenth and early twentieth centuries, men would travel from nearby Milford (the end of southern Utah railroad line) to enjoy a hot bath or a swim at a development called Roosevelt Hot Springs Resort (area 1 on map), or a hot bath or a massage at "Negro" Mag's "resort" (located somewhere near Negro Mag fault, see map on page 8). Much has changed since then. The original springs dried up by 1966 and now all that remains of the resort are the remnants of several buildings and a swimming pool, bottom photo. Top photo, circa 1929, shows this pool (see arrow) and a wood frame building that no longer exists. Top photo used by permission, Utah State Historical Society, all rights reserved.

Area locations are indicated on the map on the next page. From left to right:

Area 1 ▸ *Boiling mud pots and yellow sulfurous soil can be seen near the ruins of the Roosevelt Hot Springs Resort.*

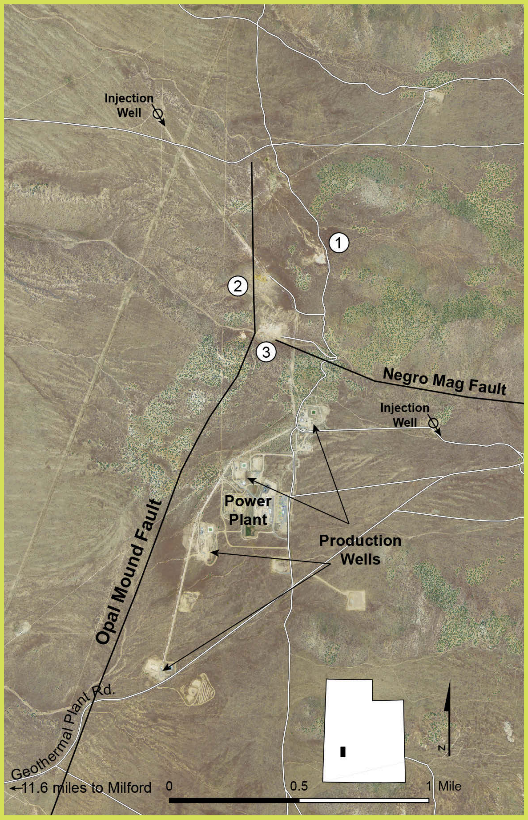
Area 2 ▸ *High temperatures and sulfurous gases have left the ground devoid of vegetation and covered with sulfur-stained soil in various shades of yellow and orange.*

Area 3 ▸ *Bubbling pools and hissing steam vents are often vibrantly colored by yellow sulfur crystals and various colors of bacteria and algae. This area, named Negro Mag Wash on topographic maps, is thought to be the former location of "Negro" Mag's brothel (as stated in* A History of Beaver County *by Martha Sonntag Bradley, 1999).*



Simplified conceptual model of the Roosevelt Hot Springs geothermal area showing heat source and groundwater recharge and flow path. (Negro Mag fault trends roughly parallel to cross-section.)

The Blundell Geothermal Plant produces electricity from hot water and steam underlying the Roosevelt Hot Springs geothermal area.

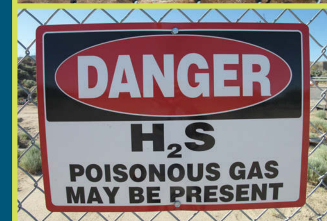


how to get there

Roosevelt Hot Springs geothermal area lies roughly 11 miles northeast of Milford in central Beaver County.

From northern Utah take I-15 to Nephi. From I-15 take exit 225 to State Route 132. Travel west on State Route 132 for 34 miles, then turn left onto U.S. Route 6 towards Delta (the highway sign indicates to Ely, Nevada). In Delta, U.S. Route 6 merges with U.S. Route 50 at a stop sign where the road turns right to become U.S. Route 6/50. Continue west from this stop sign for 5.6 miles, then turn left (south) onto State Route 257. Continue on Route 257 for 66.2 miles, then turn left (east) onto Geothermal Plant Road towards the “Blundell Geothermal Plant.” Roosevelt Hot Springs geothermal area is approximately 9 miles off Route 257. Areas labeled 1, 2, and 3 are pictured on previous page.

Roosevelt Hot Springs geothermal area contains many hazards including scalding water and steam, unstable ground, and poisonous gas. Please view all thermal areas from a safe distance, stay out of fenced areas, and heed warning and private property signs.



NEW PUBLICATIONS

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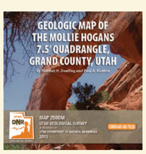

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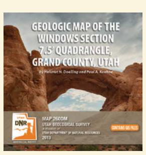

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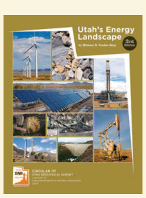

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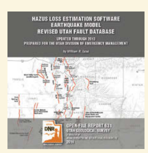

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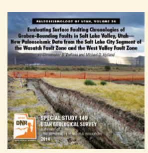

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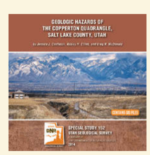

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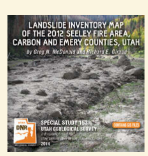


Landslide inventory map of the 2012 Seeley fire area, Carbon and Emery Counties, Utah, by Greg N. McDonald and Richard E. Giraud, CD (I pl. [contains GIS data]), scale 1:24,000, ISBN 978-1-55791-900-3, SS-153..$19.95

TEACHER'S CORNER

Students pan for gold at Earth Science Week.

EARTH SCIENCE WEEK
October 6–9, 2014

Hands-on Activities for School Groups

Come celebrate Earth Science Week this year with the Utah Geological Survey at the Utah Core Research Center. We will be offering hands-on activities (especially relevant to 4th- and 5th-grade classes) including panning for "gold," observing erosion and deposition on a stream table, identifying rocks and minerals, and learning how Utah's dinosaur discoveries are excavated and prepared. For more information and photos of last year's activities, please visit our website at http://geology.utah.gov/teacher/esweek.htm. To make reservations, contact Jim Davis or Sandy Eldredge at 801-537-3300. Groups are scheduled for 1½-hour sessions.

Matt Affolter accepting his award at the UGA's July meeting.

Utah Geological Association's
TEACHER OF THE YEAR AWARD

This year's Utah Geological Association's Teacher of the Year Award was presented to Matt Affolter on July 14, 2014. Matt, who is an Earth science teacher at Granite Park Jr. High School, received the honor for excellence in the teaching of natural resources in the Earth sciences. Matt's application was entered into the regional competition sponsored by the Rocky Mountain Section of American Association of Petroleum Geologists. Congratulations Matt!

core center news

Ferron Sandstone Cores

Excellent Teaching Tools to Spark the Imagination!

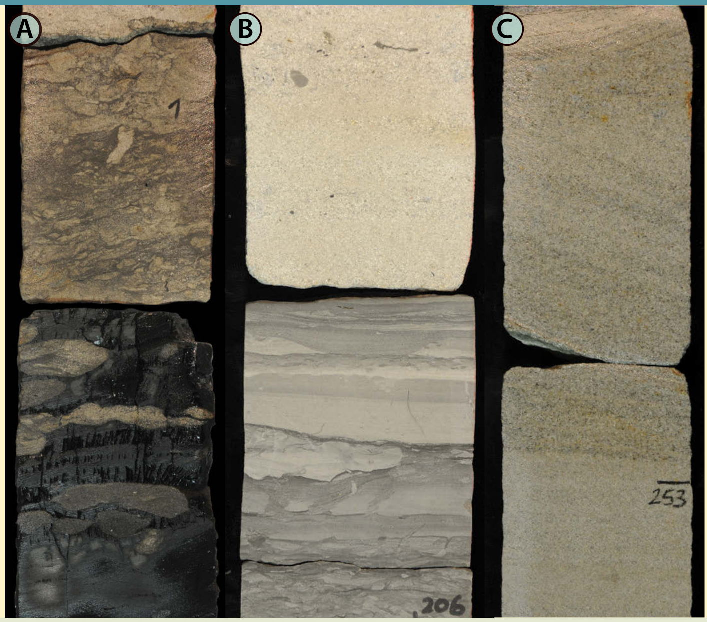
by Thomas C. Chidsey, Jr.

An Imaginary Journey into Utah's Geological Past

Take a drive about 70 miles south of Price through the arid Castle Valley in east-central Utah. Then imagine you are on a huge river delta with swamps and marshes of lush vegetation similar to the Mississippi Delta. Silt- and sand-laden streams and rivers meander through the area flowing east to a nearby sea that stretches east as far as Kansas. To the west lies a towering, north-south-trending mountain range (the Sevier orogenic belt)—the source for the sediments that the river system used to form the delta you are on. Dinosaurs are roaming around and reptiles fly in the sky. This is what east-central Utah looked like around 94 to 86 million years ago during the Late Cretaceous Epoch.

This ancient delta's streams and rivers deposited their loads of sand and silt as point bars, levees, and channel fills where the rivers met the sea or along beaches, barrier islands, and in tidal inlets. Mud accumulated in bays, lagoons, and farther offshore, whereas vegetation in swamps piled up to form peat bogs. Eventually, the sea retreated and environmental conditions changed. The delta was buried by over 8000 feet of sedimentary rocks. Then regional uplift began about 70 million years ago exposing these rocks to the forces of erosion.

A) Late Cretaceous paleogeography in Utah. After UGS Public Information Series 54 (1998). B) Modern Mississippi Delta. NASA's Terra satellite on March 5, 2001.



A) Coal (swamp) overlain by burrowed offshore marine sandstone. B) Oil or gas reservoir-quality point bar/channel sandstone overlying offshore marine siltstone and shale. C) Cross-bedded "clean" shallow marine, delta-front sandstone that would make an excellent oil and gas reservoir.

The Ferron Sandstone—Analog for River-Dominated Deltaic Oil and Gas Reservoirs Worldwide

Rapid erosion of the Colorado Plateau by the Colorado River and its tributaries over the last 5 million years and continued uplift have, once again, revealed the ancient river delta, which is now beautifully displayed along the west flank of the San Rafael Swell in the rocks known as the Ferron Sandstone—one of the most extensively studied cliffy exposures of rock in Utah. Why is the Ferron so important to geologists? It shows, spectacularly, vertical and lateral changes (the exposed rock belt

Core Center News is a new column that will appear in every other issue of future *Survey Notes*. Each column will highlight a variety of rock cores stored and publicly available (for a nominal fee) at a Utah Geological Survey (UGS) facility—the Utah Core Research Center (UCRC), in Salt Lake City, Utah. These cores, obtained through UGS projects and generous industry donations, are used for teaching geology students and training industry professionals, particularly those who search for oil and gas, and for research. Utah is unique in that the rocks in the UCRC collection of cores are also exposed in canyons, mountains, and plateaus throughout the state. Thus, geology groups and researchers often head to the field to get an up-close view of the same rocks they examined at the UCRC. To assist, the UGS offers core workshops (and field trips) using cores showing classic examples of Utah geology to enlighten bright young minds and train the working professionals. The Ferron Sandstone is one of the best and most popular training sets at the UCRC.

extends northeast-southwest for over 80 miles) in the deltaic deposits, which serve as a visual analog for similar rocks that produce nearly half the world's oil and gas hidden deep below the surface. Examples are found in the U.S. Gulf Coast, Alaska, North Sea, and Utah's own Uinta Basin fields.

The earliest Ferron Sandstone study goes back to 1874, to investigate coal resources in the area. Well over one hundred years and many studies later, the UGS conducted its own major investigation of the Ferron in the 1990s. The project involved two oil companies, three local universities (professors and students from the University of Utah, Brigham Young University, and Utah State University), and several consulting geologists. The goals of the project were to provide petroleum companies better tools and models to apply to their own oil and gas fields, as well as exploration efforts, using the Ferron rock exposures as examples. A major question, however, was what did the Ferron look like in the subsurface beyond the outcrop cliff face—a critical factor in predicting changes in the rocks in three dimensions. To answer that question, the UGS drilled four core holes and acquired, through donation, five more rock cores collected from shallow wells immediately west of the outcrop belt. These rock cores proved invaluable to the study, which resulted in over fifteen scientific publications.

Governor Gary Herbert visits the Utah Core Research Center on July 31, 2014. Photo courtesy of Justin Harding.

Students examine the Ferron core set as part of their geology course in stratigraphy and sedimentation.

UGS Ferron Core Workshops for Students and Industry Professionals

The UGS collection of Ferron Sandstone cores stored at the UCRC continues to be invaluable as training materials for students and industry professionals. After the cores were drilled, they were slabbed (cut in half) to remarkably reveal the various rock types and depositional environments seen in the Ferron outcrops—sandstone beds, representing river channels, sand bars, and beaches; siltstone and shale containing shells and burrows of marine and brackish water organisms that lived offshore or in bays; and coalbeds that formed from vegetation in swamps and peat bogs. The cores also show rock boundaries indicating times with major changes in sea level, critical information when developing oil and gas fields or exploring for new ones. The cores also provide information about oil and gas reservoir quality (pores in the rocks capable of storing hydrocarbons and permeability—the connection between those pores that permits fluids to flow within the rock to a wellbore). Such descriptive reservoir characteristics can be applied to oil and gas exploration and development of similar ancient delta deposits throughout the world.

The UGS annually hosts or conducts numerous workshops (and companion field trips) using the Ferron cores for educational and industry training. Local universities regularly bring their geology students to the UCRC for Ferron core classes. Attendees of UGS-sponsored and industry training groups have come from all over the U.S., as well as Great Britain, Norway, Ireland, France, Argentina, China, and Indonesia, and researchers continue to use the Ferron cores for new studies.

Someone once said, "Oil is not found in the ground, it is found in the minds of geologists!" Geologists, both students and professionals, use their minds to better understand the geologic past and imagine where to find oil and gas, employing tools such as the UGS core set and rock exposures of the Ferron Sandstone.

To see the Ferron Sandstone core set or schedule a workshop at the UCRC, contact Peter Nielsen, Curator.

Phone: 801-537-3359 • Email: peternielsen@utah.gov

GLAD YOU ASKED

what are keeper potholes & how are they formed?

by Lance Weaver

Keeper potholes are found in slot canyons.

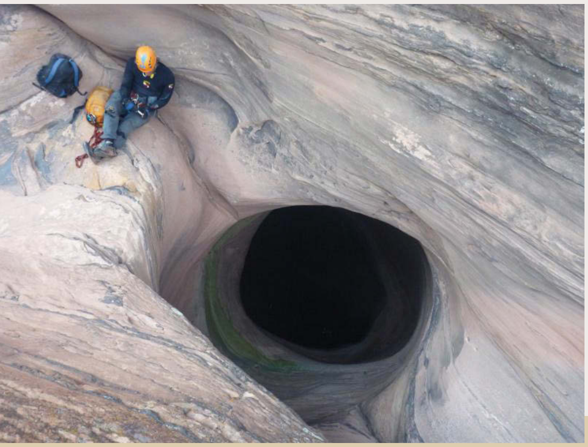
In the recent decades "slot" canyoneering has become a major sport, and very few areas of the world have nearly the number or diversity of slot canyons as southern Utah. People come from all over the world to descend slot canyons of varying difficulty in places such as Zion National Park, Grand Staircase–Escalante National Monument, Capitol Reef National Park, the San Rafael Swell, and Glen Canyon National Recreation Area.

Many clubs, organizations, and websites have been created to aid people in sharing route descriptions, pictures, videos, and techniques for descending the various canyons. A rating system similar to that of sport climbing has even been devised to rate the difficulty of the slot canyons based on factors such as:

- the technicality of the terrain and the need for rope work such as climbing or rappelling,
- complications due to flowing or still water such as cold, long pools of water, which require wet-suits for prolonged swimming,
- the time required because of distance or obstacles, and
- additional risks due to unique obstacles such as keeper potholes.

Potholes, which are smooth, bowl-like hollows eroded in bedrock, are common features in slot canyons and form as a result of a number of different geologic processes. A pothole becomes a "keeper pothole" when it is sufficiently deep and smooth so as to "keep" those who descend into it from being able to easily get back out. These are major obstacles when they block the entire width of the slot canyon, forcing canyoneers to descend into the pothole and devise a strategy to ascend back out the other side. Keeper potholes can be especially dangerous when they are only partially full of water—often forcing those foolhardy souls who rappel or jump into them to tread water as they attempt to set or drill climbing anchors into rock to get back out. Some keeper potholes exist at the bottom of a long rappel in very dark and winding slot canyons. In these instances canyoneers might not know a keeper pothole is below them until they rappel into it and find themselves seemingly trapped, swimming in a cold, deep pool of water.

"The Pit of Despair" in Poe Canyon, also known as "smiling cricket," is a difficult to traverse keeper pothole in the Waterpocket Fold south of Capitol Reef National Park.



"The Wart Pothole" is a deep keeper pothole often partially filled with water, also in Poe Canyon of the Waterpocket Fold.

Opposite: A canyoneer descending into a dark keeper pothole in Boundary Canyon, a tributary of Kolob Creek, Zion National Park.

Keeper potholes tend to form when a variety of conditions are met, including the character of the stream channel's bedload (sand, gravel, and boulders moving along the bottom of a stream), the shape of the stream channel in relation to the rock type, and the cementation characteristics of the rock unit.

- **Stream channel bedload:** Keeper potholes form predominately in streams where just the right amount of sand, gravel, and rocks can be swirled within the eddies of a stream channel. These rotational currents create a vortex which can spin a large amount of debris from the bedload like a giant drill-bit, eroding out depressions in the bedrock of the canyon floor. When the flow rate is high enough to mobilize the bedload of keeper potholes, the abrasive grinding sound has been known to be audible to those nearby. For the stream to deepen the pothole, it is essential that the flow's carrying capacity be capable of mobilizing nearly the entire bedload. If the size of rocks and debris in the bedload exceeds the flows carrying capacity, the channel's potholes will fill up, prohibiting active erosion. If the channel has little to no bedload the flow will lack the abrasive material needed to rapidly "drill" into the channel. Canyons with keeper potholes usually have a delicate balance between stream capacity and bedload volume which keeps debris constantly filling up and emptying out of the potholes from one season or flood to the next. This is one of the reasons that most of Utah's deepest keeper potholes form on the steeply tilted rock strata of San Rafael Swell or Waterpocket Fold in Capitol Reef National Park and the high hanging canyon areas of Zion National Park where there are no highly resistant rock units upstream to choke the stream channel with large, hard boulders.

- **Stream channel shape and rock type:** In Utah, keeper potholes are common in cliff-forming sandstone units such as the Navajo Sandstone, Wingate Sandstone, White Rim Sandstone, and Entrada Sandstone. Potholes often form away from water channels, but tend to be deeper, steeper-sided, and more prevalent when they form within winding water channels subject to flash flooding. The shape or morphology of the stream channel is important because a bending or winding stream channel is more likely to create the fluvial eddies that facilitate pothole formation. Drop-offs or waterfalls, caused by vertical changes in rock density, are notable contributing factors for the same reason. The general density and cohesive strength of the rock unit is also important. For deep keeper potholes to form, the rock unit must be soft enough to be eroded by the debris-laden flow, but hard enough to maintain near vertical faces without crumbling or collapsing.

- **Cementation characteristics:** Once a depression in the bedrock has been deepened enough to retain standing water, the slightly acidic stream or rainwater begins to dissolve the calcite cement that holds the grains of sandstone together. Other more complicated biological processes also work to dissolve the rock cementation (see "Glad You Asked," *Survey Notes,* 2007, v. 39, no. 3, p. 11). Both syndepositional (occurring at the time of sediment deposition) and diagenetic (occurring after deposition, but before exposure) processes can greatly affect cementation characteristics. When the sand in sandstone is first deposited, interspersed fine-grained silts and clays can inhibit the migration of calcium- and carbonate-laden groundwater that carries the cement to "glue" the grains of sand together. These fine-grained deposits can create pockets of poorly cemented or even uncemented sandstone, which erode much more easily than cemented sandstone. After deposition, hydrothermal fluids (naturally heated fluids that circulate through the ground) or soft-sediment deformation (sediments deformed during or shortly after being deposited) may also play a role in creating pockets of poorly cemented or uncemented sandstone in the rock units.

These cementation characteristics, as well as the shape of the stream channel, type of rock unit, and character of the channel bedload, all combine to create the potholes and keeper potholes of southern Utah's slot canyons.

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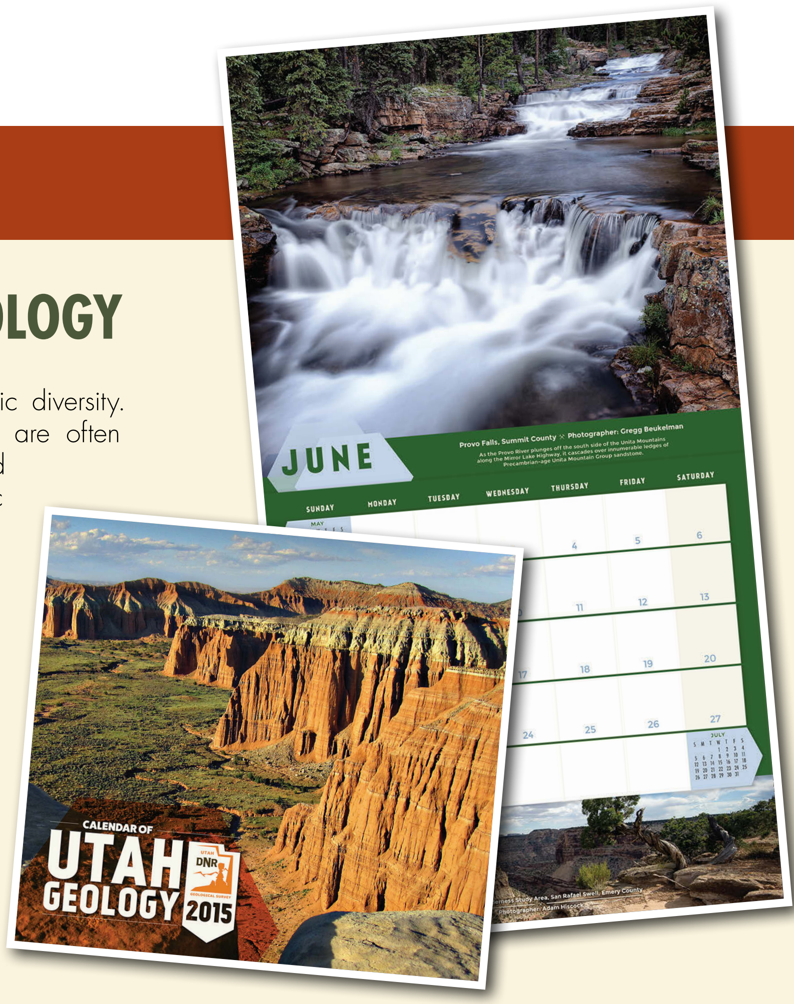
Featuring scenic photographs highlighting Utah's geologic diversity. The photographs were taken by UGS employees who are often on assignment in some of the state's most interesting and unique locations. Pictures are accompanied by geologic descriptions and location information. The calendar is available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



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