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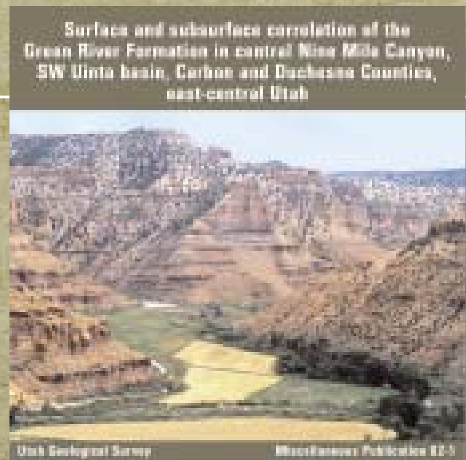

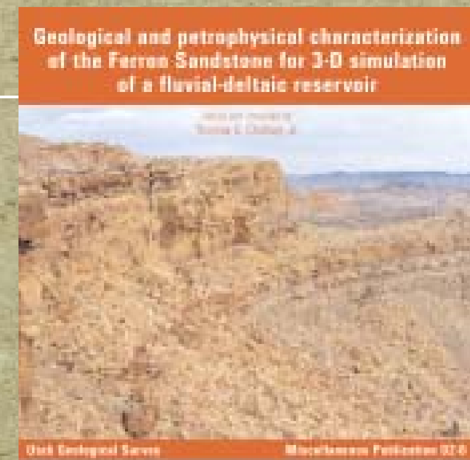

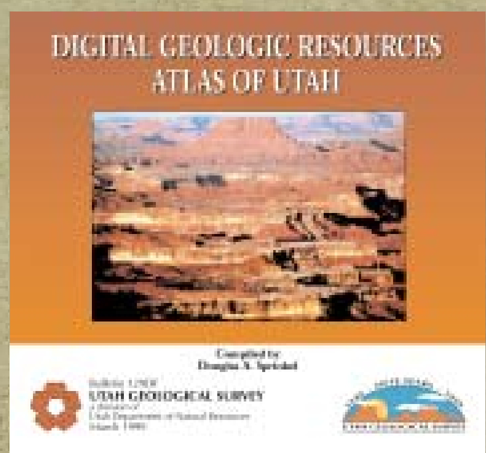

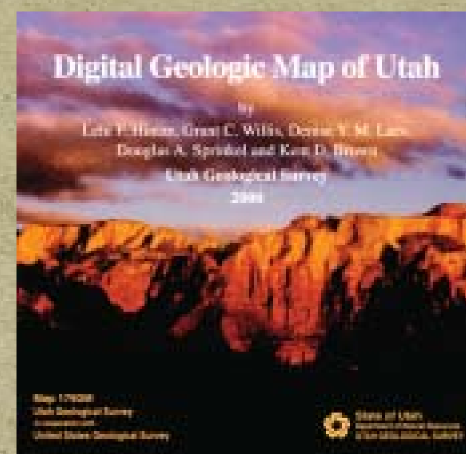

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UTAH GEOLOGICAL SURVEY

SURVEY NOTES

Volume 34, Number 3 September 2002

PINE VALLEY MOUNTAINS

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Design by Vicky Clarke

Cover: *West side of the Pine Valley Mountains laccolith. Remnants of massive landslides shed from the rising laccolith are exposed in the low hills to the left (photo by David B. Hacker).*

ISSN 1061-7930

The Director's Perspective

by Richard G. Allis

Utah, like most other states, is experiencing a tax revenue shortfall which is translating into funding cutbacks to state agencies. This financial year, the Utah Geological Survey's (UGS) General Appropriation has been cut by about 5%, which is on top of similar cuts last year. Our General Appropriation is close to half our total funding (about $4.5 million), with the remaining funding coming from Mineral Lease royalty payments and external grants and contracts. Unfortunately, due to an oversupply of natural gas in the western Rocky Mountain region, limited pipeline capacity, and depressed gas prices, Mineral Lease revenue to the UGS this year is likely to be near historic lows (12% of total revenue). This places added burden on other external funding sources if we are to avoid major impacts on staffing levels and program expenditure.

Collaborative relationships with federal and state agencies have always been important, but this year they have added importance because of the funding shortfalls. In addition to providing diversified funding sources, these relationships ensure that the UGS has the appropriate balance in expertise, and that it is working in areas of broadly perceived geologic need in Utah. This issue of Survey Notes contains two examples where a combination of federal and local funding is helping to advance awareness and use of geologic information in Utah. One important source of federal funding is for geologic mapping in priority areas of Utah. Funding increases over the last two years to the National Cooperative Geologic Mapping Program administered by the USGS have significantly accelerated our production of new geologic maps. Over the last 12 months, the UGS has published three new 1:100,000, 30′ x 60′ maps (Moab, Wah Wah Mtns North and Delta sheets), and is in process on three others (Tule Valley, San Rafael Desert, and Dutch John). In addition, the Great Salt Lake 30′ x 60′ quadrangle has been digitized, five 7.5′ maps have been published, and about 10 other 7.5′ quadrangles are being open filed. Hopefully this level of federal funding for our geologic mapping program can be sustained or even increased.

The second example of federal and state funding sources combining to enhance geologic projects is the preservation of the St George dinosaur track site. The unusual detail and abundance of tracks evident at this track site makes it unique, and it has rapidly become a main tourist attraction in the region. The track site urgently needed scientific documentation and tracks had to be stabilized and protected to avoid deterioration and theft. A combination of local volunteer help, and funding from the City of St George, the State of Utah, and the Federal Government will ensure that this track site becomes a geologic attraction of international renown. A climate-controlled shelter, museum, and Jurassic walkway through the 10-acre site should be built during the next 12 months. The federal contribution of $0.5 million matched dollars has passed the Senate committee and is expected to be signed into law during September.

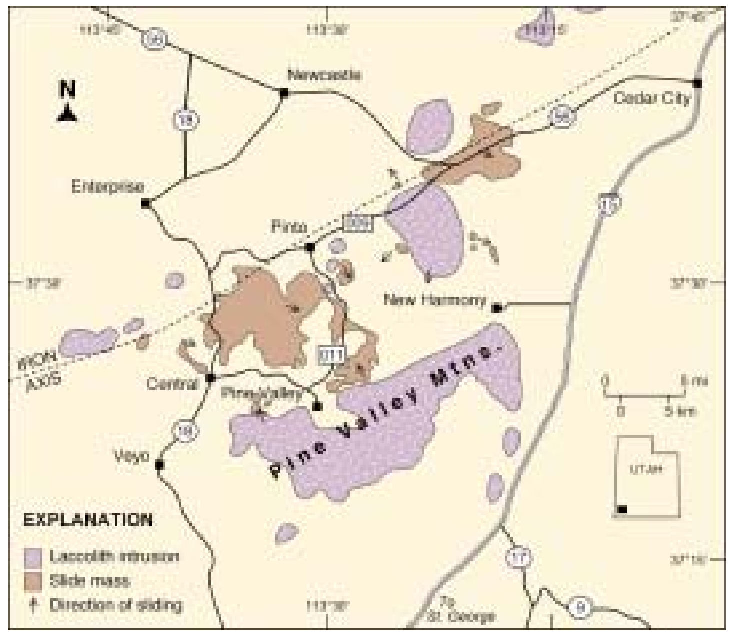
Survey Notes is published three times yearly by Utah Geological Survey, 1594 W. North Temple, Suite 3110, Salt Lake City, Utah 84116; (801) 537-3300. The UGS is an applied scientific agency that creates, evaluates, and distributes information about Utah's geologic environment, resources, and hazards to promote safe, beneficial, and wise use of land. The UGS is a division of the Department of Natural Resources. Single copies of *Survey Notes* are distributed free of charge to residents within the United States and Canada and reproduction is encouraged with recognition of source.

Massive Gravity Slides Show the Value of Detailed Mapping

by Grant Willis

Many Utah geologists have probably driven State Highway 18 in southwestern Utah between Newcastle and Veyo, looked to the east at the pinyon- and juniper-covered terrain with few outcrops, and wondered about the geology concealed in those hills. The old small-scale geologic maps of the area indicate that the rocks are mostly mid-Tertiary volcanic rocks, but reveal frustratingly little about their emplacement or history.

Recent detailed mapping and laboratory investigations, mostly by David Hacker of Kent State University, and colleagues Peter Rowley (U.S. Geological Survey, retired; now with Geologic Mapping, Incorporated), Richard Blank (U.S. Geological Survey), and Daniel Holm (Kent State University) unraveled the geology of those hills, revealing a fascinating story of rapid intrusion of laccoliths, with associated arching of overlying rocks, massive gravity sliding, and synchronous volcanic eruptions. In a recent field trip guidebook, Hacker and co-authors explained the story and indicated where the best geologic examples can be seen (U.S. Geological Survey Open-File Report 02-172). Their detailed geologic maps are nearly complete and will soon be submitted to the Utah Geological Survey for publication.



Laccolith intrusions and slide mass outcrops, major roads, and towns. The slide masses were much larger than the outcrops shown here, but were later mostly covered by post-slide volcanic rocks or eroded away. Arrows indicate primary direction of slide movement -- in all cases, directly away from the intruding laccolith (modified from Hacker and others, 2002).

Laccolith Intrusions

Laccoliths are certainly among the most unique and interesting geologic features, and Utah has some of the premier examples in the world. Best known are the Henry and La Sal Mountains laccoliths because of their spectacular exposures, but the Pine Valley Mountains and several nearby intrusions, called the "iron axis" due to the associated large iron deposits, are also world-class laccoliths. The Pine Valley Mountains laccolith may be one of the largest in the world.

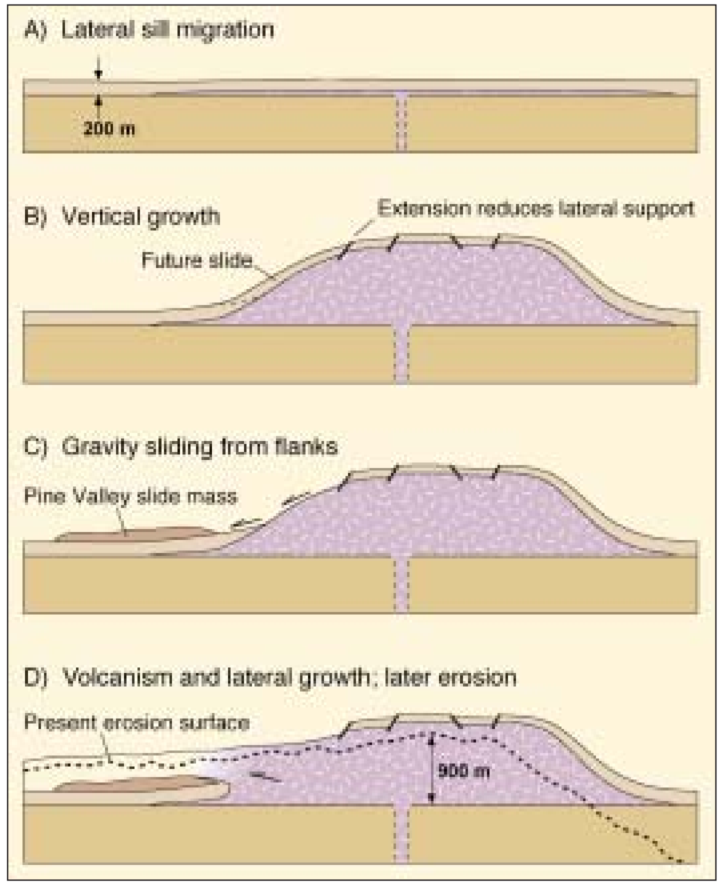
Laccoliths form as thick paste-like magma (the Pine Valley/iron axis group are mostly quartz monzonite and granodiorite) forces its way toward the Earth's surface. However, instead of erupting at the surface to form a volcano, as it nears the ground surface the magma reaches a level of zero buoyancy. Instead of continuing to rise, it then penetrates laterally outward between weak layers of rock, forming a pancake-shaped sill.

The overlying rock forms a confining layer much like the leather pieces that form a soccer ball. The sill, which cools enough to have internal strength, but is still plastic enough to not fracture and break, acts like the bladder of the soccer ball. Together the confining layer and the "bladder" prevent the magma from breaking through to the surface. Continued magma injection then "inflates" the sill, doming up the overlying rock to form a bulbous mound. Laccoliths in the iron axis group penetrated weak clay-rich beds in the Jurassic Carmel, Cretaceous Iron Springs, and Eocene Claron Formations, doming the overlying layered sedimentary and volcanic rocks.

Chain Reaction
The new mapping revealed a chain-reaction series of events that followed the intrusions. First, the doming magma fractured and oversteepened the overlying layered rocks. The elevated weakened layers then broke loose and slid down the flanks of the domes as massive gravity slides. The sudden removal of the slide masses produced an immediate large reduction in confining pressure. This then caused still-intruding magma to burst through the seal and erupt, first ejecting vapor-rich (high-volatile) tuffs, then vapor-poor lava flows, which draped across the new gravity slide masses.

Timing
One of the most interesting parts of the mapping and research was determining the speed and timing of emplacement of the intrusions and slide masses. The rocks themselves are relatively easy to date using the radioisotopic $^{40}Ar/^{39}Ar$ method. Hacker and colleagues showed that all of the laccoliths in the iron axis area intruded within only about a 1.5-million-year period between 22 and 20.5 million years ago. More difficult was to determine the sequence and length of time of closely spaced events. This required careful mapping of outcrops to determine relationships between intrusive and extrusive rocks using physical correlation (hiking out the outcrops) and crosscutting relationships, combined with radiometric ages, petrology, and geochemistry. Eventually, Hacker and his colleagues were able to establish the link between the intrusions, slides, and post-slide eruptions. Without the detailed fieldwork and mapping, this story would have remained hidden in the pinyon- and juniper-covered hills.

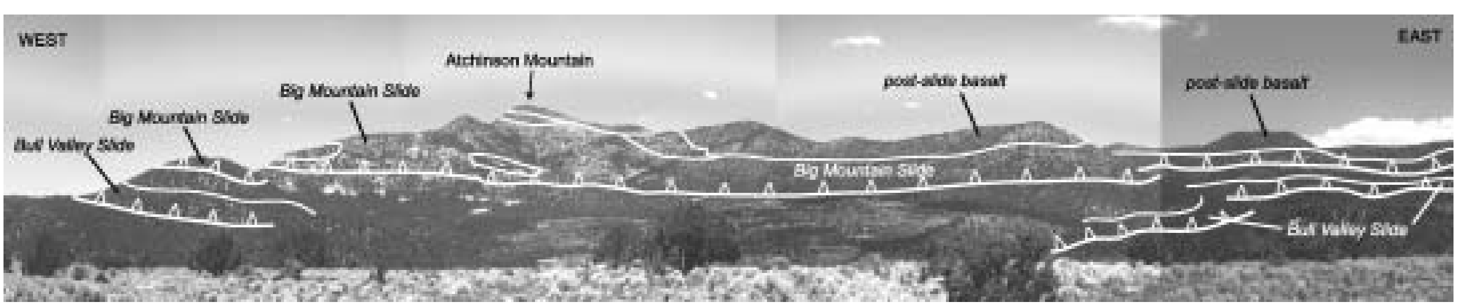
Ages and relationships of the outcrops throughout the area strongly indicate that each laccolith intruded and domed within just a few years, or less. The gravity slides probably occurred even faster. Most likely, they were catastrophic events that, once started, happened within minutes, similar to the massive landslide on Mount St. Helens in May 1980 that triggered the disastrous eruption that took 60 lives. It would have been an incredible sight to watch huge slabs of rock several hundred feet thick rush down a mountain slope and run out across the landscape several miles!



Four steps of intrusion of a laccolith, with resulting gravity slide, and post-slide volcanism and continued intrusion (modified from Hacker and others, 2002).

We do not know if other laccoliths in Utah generated similar gravity slides and eruptions, though it is likely that they did. Most are located on the Colorado Plateau where several thousand feet of erosion has removed the rocks that would be needed to recreate their story.

Where Can I See Them?
The remnants of several medium-sized laccoliths, massive gravity slides, and post-slide eruptions form most of the hills between Newcastle and Veyo. Hacker and colleauges reported that the largest slide complex is more than 60 square miles, 1,800 feet thick, and extends more than 12



Photomosaic looking north toward the Atchinson Mountain area, showing Bull Valley and Big Mountain slides. The Bull Valley slide was shed from the west, and was later overrun by the Big Mountain slide from the east (modified from annotated photograph by D.B. Hacker).

miles from the parent intrusion. As might be expected, the landslide masses were strongly fractured and brecciated, though the stratified rocks maintained their internal structure fairly well. As a result of the intense deformation, the masses erode easily and form relatively subdued tree-covered hills. Much of the story is best visualized with the aid of geologic maps, small versions of which are in the U.S. Geological Survey field trip guidebook (larger versions will soon be submitted to the UGS for open-file release).

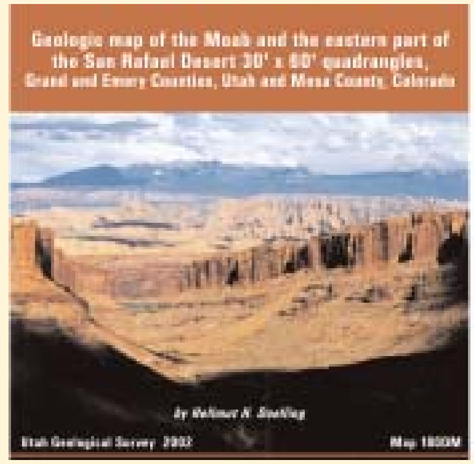
The best slide mass exposures are in State Highway 18 road cuts 2 to 4 miles north of Central that expose the Big Mountain slide complex. Post-slide extrusive volcanic rocks are moderately welded and form many small outcrops but few large cliffs. The best exposures are along the Pinto road (Dixie National Forest Road 009) near Pinto Peak and in the hills surrounding Grass Valley (Dixie National Forest Road 011). The laccolith intrusions themselves are generally the most resistant rocks in the area, and form most of the higher hills. The Stoddard Mountain intrusion is the easiest to access; it is exposed in a road cut about 2.5 miles south of the intersection of the Pinto road and State Highway 56 about 17 miles west of Cedar City. And of course, the spectacular Pine Valley Mountains are the core of the largest laccolith of all.

For a detailed discussion of the laccoliths and gravity slides of southwestern Utah, see Hacker, D.B., Holm, D.K., Rowley, P.D., and Blank, H.R., 2002, Associated Miocene laccoliths, gravity slides, and volcanic rocks, Pine Valley Mountains and Iron Axis, southwestern Utah, *in* Lund, W.R., editor, Field guide to geologic excursions in southwestern Utah and adjacent areas of Arizona and Nevada: U.S. Geological Survey Open-File Report 02-172, p. 235-283 (http://geopubs.wr.usgs.gov/open-file/of02-172).

Thank you to David Hacker for his assistance with this article.

New Geologic Maps of the Moab Area

Want a geologic map of your favorite recreation area? If your favorite area happens to be near Moab, we have you covered!



The Utah Geological Survey recently published a new geologic map of the Moab 30′x60′ quadrangle at 1:100,000 scale. The map area extends from the Green River on the west to the Colorado border on the east, and from north of Interstate 70 to the San Juan County line.

Don't want to purchase the paper map? The map is also available in digital form on compact disc. The CD is designed in an easy-to-use auto-run format with click-on menus. The map is in a .pdf file format that can be viewed with any .pdf reader (Acrobat Reader ™ freeware is included on the disk). An ARC/Explorer™ project file and ARC/Explorer™ freeware are also included for those who want a Geographic Information System (GIS) map with limited interactive capability. And of course, complete GIS files are included for those with GIS software.

Want more detail? The UGS also recently published the Moab and Fisher Towers 7.5′ quadrangle geologic maps. These 1:24,000-scale geologic maps contain much more detail than any other published geologic maps of the area. Together with previously published maps of the Big Bend, Merrimac Butte, Gold Bar Canyon, and Agate quadrangles, the UGS has now published full-color geologic maps of almost half of the 7.5′ quadrangles in the popular Moab/Arches National Park recreation area.

Any big changes? Besides the added detail and the digital version, probably the biggest change you will see is the revision of the nomenclature and hierarchy of the Middle Jurassic formations. For those familiar with the members of the Entrada Sandstone, the change may take a bit of getting used to. The Dewey Bridge Member of the Entrada Sandstone is now returned to the Carmel Formation, of which it was a member many years ago. New mapping has shown that the Dewey Bridge is an eastern tongue of the Carmel Formation rather than the Entrada Sandstone.

The upper member of the old Entrada, the Moab Tongue, is now informally assigned to the Curtis Formation pending formalization of this change. New mapping has now shown that the Moab Tongue is separated from the rest of the Entrada by an unconformity, and is an eastern eolian extension of the Curtis Formation of the San Rafael Swell area.

That leaves the Entrada with just one member in most of Grand County, the Slick Rock Member, the prominent arch-forming red and tan sandstone cliff in Arches National Park. In the westernmost part of the Moab 30′x60′ quadrangle, the Entrada also has a lower, informal, earthy member.

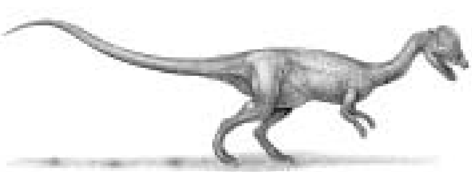
To order, contact the Natural Resources Map & Bookstore at 801-537-3320 or 1-888-UTAHMAP, or visit our website at http://mapstore.utah.gov.

The St. George Dinosaur Tracksite

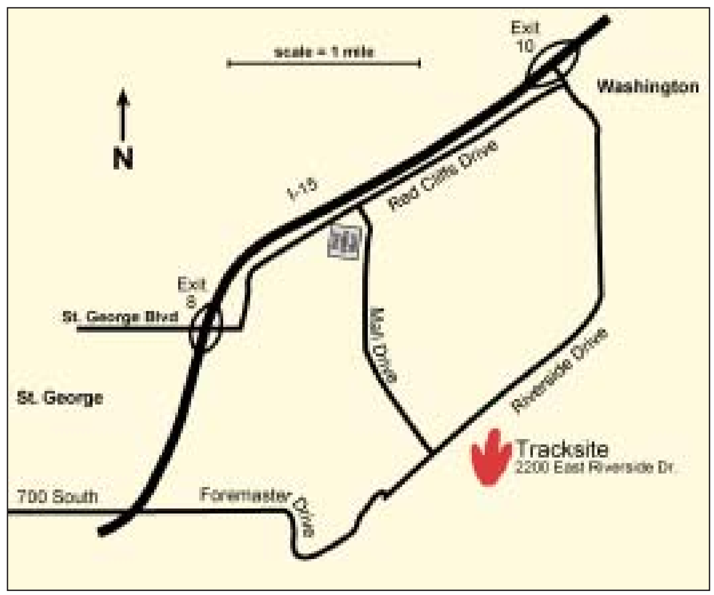
by James I. Kirkland (UGS), Martin Lockley (University of Colorado at Denver), and Andrew R. Milner (City of St. George)

In February 2000, Sheldon Johnson discovered numerous dinosaur tracks preserved at the bottom of a 3-foot-thick sandstone layer overlying a mudstone layer on his farm within the St. George city limits. As reported in *Survey Notes*, v. 32, no. 3, because of Johnson's public-mindedness, scientists from the Utah Geological Survey, University of Utah, and University of Colorado have been able to collect significant data from this important locality in the Whitmore Point Member of the Moenave Formation. Ongoing research has resulted in the identification of a number of different track makers, fossil plants, invertebrates, fossil fish, and beautifully preserved sedimentary structures that record a shallow, saline lake and its margin during Early Jurassic time (about 200 million years ago) in southwestern Utah.

The majority of tracks preserved at the base of the track-bearing sandstone are natural casts of the ichnogenus, or track name, *Eubrontes* and are from 13 to 18 inches long. These three-toed tracks are thought to represent a dinosaur similar to the crested, meat-eater *Dilophosaurus* known from the overlying Kayenta Formation. Some of the features are remarkably well preserved and include exquisite examples of the foot pads, claw marks, dew claws, and in one example, detailed skin impressions.

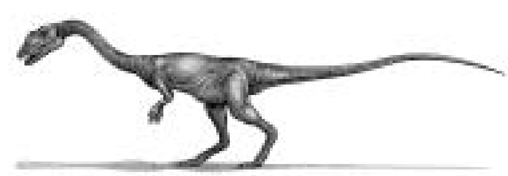


Dilophosaurus

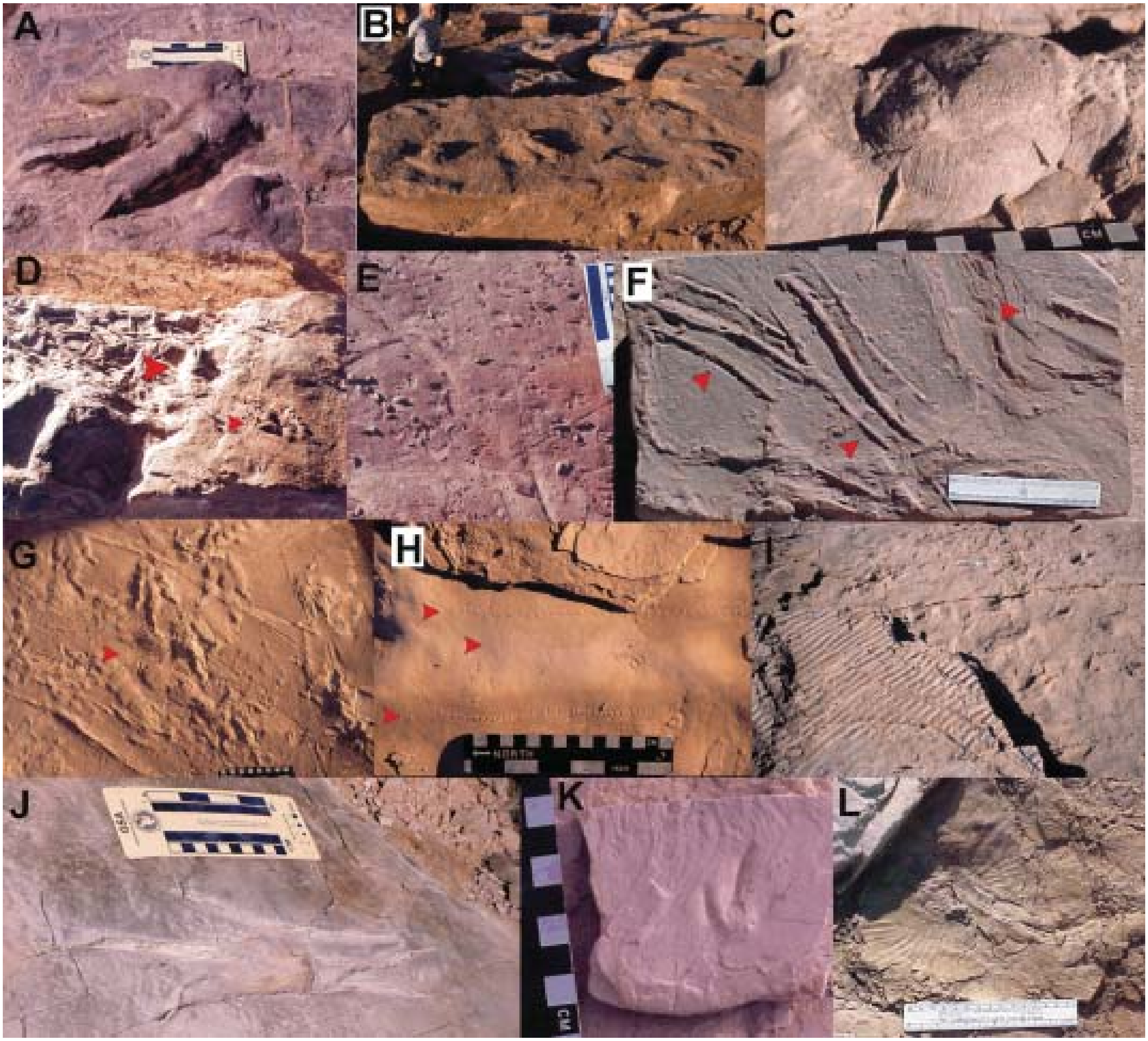


Less common are smaller tracks, 4 to 8 inches long, assigned to the ichnogenus *Grallator*. These are thought to represent the slender, meat-eating dinosaur *Megapnosaurus* (prior to 2002 known as *Syntarsus)* present in both the Moenave Formation and the overlying Kayenta Formation. Invertebrate traces, mudcracks, and diamond-shaped salt casts (trona) are also preserved. Cross-cutting relationships on northeast-directed scour surfaces at the base of the sandstone indicate more than one episode of track-making is preserved at the base of the sandstone. A surface about 4 inches above the base of the sandstone preserves evidence of an algal mat and abundant casts and molds of *Grallator.*

Reworking of the upper sandstone surface resulted in the deposition of alternating layers of thin sandstone and shale partings that preserve symmetrical and asymmetrical rippled surfaces and many tracks dominated by *Grallator*. A tiny one-inch dinosaur track and tracks (*Batrachopus*) of an early crocodilian (possibly representing *Protosuchys*) have also been recognized. Tracks of possible swimming and running dinosaurs are also preserved. Tracks of *Eubrontes* are less common on this surface, but include a trackway with a tail drag. Typically



Megapnosaurus

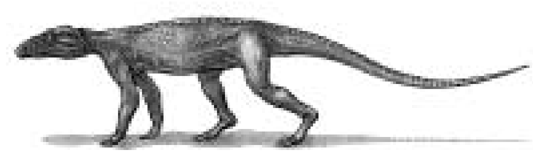


Fossil traces from the Johnson farm dinosaur tracksite. A) Eubrontes track cast on underside of main sandstone; note the long trace of the underside of claw on middle toe indicating the animal slipped in the mud. B) Eubrontes trackway cast on underside of main sandstone. C) Detail of Eubrontes track cast on underside of main sandstone showing skin impression. D) Underside of main sandstone showing mud cracks, fillings, and scour that removed part of Eubrontes track cast (large arrow). Note Grallator (small arrow) on scour surface indicating multiple episodes of track formation and preservation. E) Salt casts and mud-crack fillings on underside of main sandstone. F) Casts of Grallator swim tracks (arrows) on underside of main sandstone. G) Abundant Grallator track casts on parting surface 4 inches above base of main sandstone, arrow points to Eubrontes. H) Snail tracks on same parting surface as shown in G. I) Symmetrical ripple marks overlying layer with abundant Grallator tracks at top of main sandstone. J) Track of running or swimming Grallator at top of main sandstone. K) Tiny dinosaur track at top of main sandstone. L) Unusual lily-like plant fossil at top of main sandstone.

tail drags are rarely preserved, as we now understand dinosaurs held their tails off the ground as they walked. As many as six track-bearing surfaces are recognized in this complex sandstone bed.

A very interesting fossil plant similar in form to a water lily was found in the sediment filling a *Eubrontes* track. This fossil predates flowering plants by 100 million years and probably represents an undescribed plant mimicking the life habit of modern water

Continued on page 12...



Protosuchus

Energy News

Utah's Petroleum Industry Posts a Banner Year in 2001

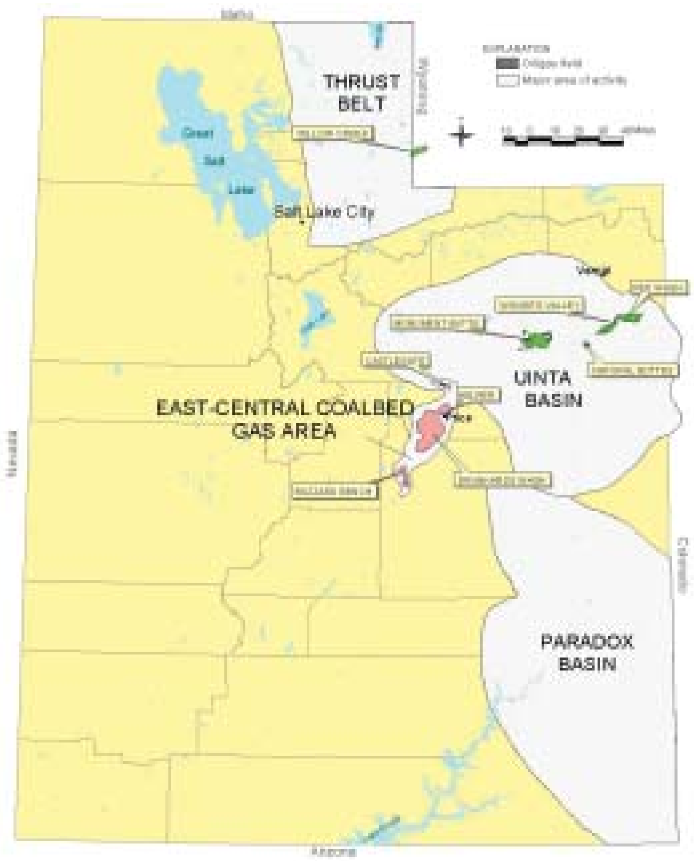
by Roger Bon

Utah's petroleum industry logged one of its busiest years in 2001. The Utah Division of Oil, Gas and Mining approved an all-time high of 880 Applications to Drill (APDs), a 31 percent increase over 2000's 673 permits. Most of these APDs were for wells in the Uinta Basin (709) and the east-central coalbed gas area (134). Two areas receiving less attention were the Paradox Basin (17 APDs) and the Thrust Belt area (17 APDs). Overall, APDs were approved for drilling in 14 of Utah's 29 counties. For the period 1980 through 2001, the number of approved APDs ranged from a high of 880 in 2001 to a low of 97 in 1989. The average number of APDs approved over the past five years is 615.

Looking at the number of sites where drilling actually began (spudded) shows that 2001 was the busiest year on record with a total of 617 wells. Drilling at those sites resulted in 580 wells completed or abandoned, a 30 percent increase over the 440 wells drilled in 2000. The number of wells completed in 2001 included 399 new wells within existing fields, 163 wells extending the boundaries of fields, and 18 wildcat wells. A closer look at the 580 wells completed shows that 444 were completed as gas wells, 111 were completed as oil wells, and 25 sites were plugged and abandoned. Two reasons for the high ratio of gas to oil wells were 1) the rapid rise in the spot gas prices, and 2) the recent rapid development of coalbed-gas resources in east-central Utah. However, in every year since 1997, completions of gas wells have exceeded oil wells.

The Uinta Basin was the most active petroleum province in the state with 453 well completions including 327 gas wells and 126 oil wells. The four most active fields there were Natural Buttes - 160 completions (all gas), Wonsits Valley - 88 completions (79 gas, 9 oil), Monument Butte - 42 completions (all oil), and Red Wash - 13 completions (all oil). Twenty-three gas wells and 18 oil wells were completed in undesignated areas near existing fields, and 12 wells were completed as wildcats (all gas).

The province with the second highest level of drilling activity was the coalbed-gas area that includes the Castlegate, Helper, Drunkards Wash, and Buzzard Bench fields.



2001 major areas of petroleum-industry activity in Utah.

Exploration for coalbed gas in 2001 resulted in 146 new wells, bringing the total number of producing gas wells to 490. The majority of well completions were in the Drunkards Wash field (110), followed by the Helper field (15), Castlegate field (7), Buzzard Bench field (4), and 10 other wells in undesignated areas nearby.

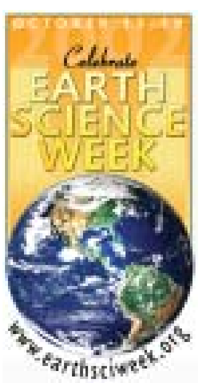
Drilling began on seven new wells in the Thrust Belt province, and one prolific gas well was completed in the southern part of Wyoming's Yellow Creek field, which trends southwest of Evanston, Wyoming and is partly located in Utah. This particular well was actually a re-drill of a well originally completed in 1997, and while the site's surface facilities are located in Utah, the lower, producing interval of the well is located in Wyoming.

Wildcat exploration drilling in Utah was at an all-time low in 2001. Eighteen wildcat wells (all gas) were attempted in 2001, most of which were successful. The wildcat wells were located in the Uinta Basin (12), near the coalbed-gas area (4), and in the Thrust Belt area (2). Of the 18 wildcat wells, 6 were completed as shut-in gas wells, 4 in the coalbed-gas area and 2 in the Uinta Basin; 7 were completed as producing gas wells, 6 in the Uinta Basin and 1 in the Thrust Belt area; and 5 wells were plugged and abandoned, 4 in the Uinta Basin and 1 in the Thrust Belt area.

The impetus for the high level of petroleum-industry activity in 2001 was the rapid rise in oil and gas prices, which began in mid-1999 and then fell in early 2001. More statistical and individual well data are available on the Division of Oil, Gas and Mining's web site at http://dogm.nr.state.ut.us/oilgas.

Teacher's Corner

EARTH SCIENCE WEEK



Utah Geological Survey
Utah Core Research Center
240 North Redwood Road
Salt Lake City

October 16 – 18, 2002
(Wednesday – Friday)
8:00 a.m. – 5:00 p.m.

Hands-on activities
for school/educational groups

Earth Science Week was initiated in 1998 by the American Geological Institute to increase public understanding and appreciation of the Earth sciences. The Earth sciences are crucial to our quality of life; the understanding of these sciences can help people make wise decisions for land management and use, address environmental and ecological issues, and prepare for and mitigate natural hazards. Therefore, states across the nation, including Utah, celebrate this important week. At the Utah Geological Survey, activities and demonstrations for schools and other educational groups will be offered October 16-18.

This year's theme is "Water is All Around You." To this end, the Utah Division of Water Rights will have a large stream table for hands-on learning about erosion-deposition processes. Other activities include rock and mineral tests and observing how fossils are excavated for study.

To reserve a time, please call Carolyn Olsen at 537-3359. The time slots fill up quickly, so some groups may have to schedule for next year – a year in advance!

MORE! ROCKS IN YOUR HEAD WORKSHOP

with

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May 17, 2003
Salt Lake City

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Less than $30.00

During the American Association of Petroleum Geologists annual convention in Salt Lake City, a workshop for teachers will be offered on Saturday, May 17, 2003. ***More! Rocks in Your Head*** is a nationally acclaimed workshop specially designed for Utah's teachers and including classroom-ready materials and rock and mineral kits. Teachers who want credit (1 Hour Inservice) can combine this workshop with one of two field trips on May 10: Geology along the Wasatch Front or Antelope Island and Great Salt Lake, Utah: A natural history view of Utah's un-dead sea and its biggest island.

Transportation (for the field trips), snacks, lunch, and handouts are all included for a nominal fee of about $10.00 for each Saturday.

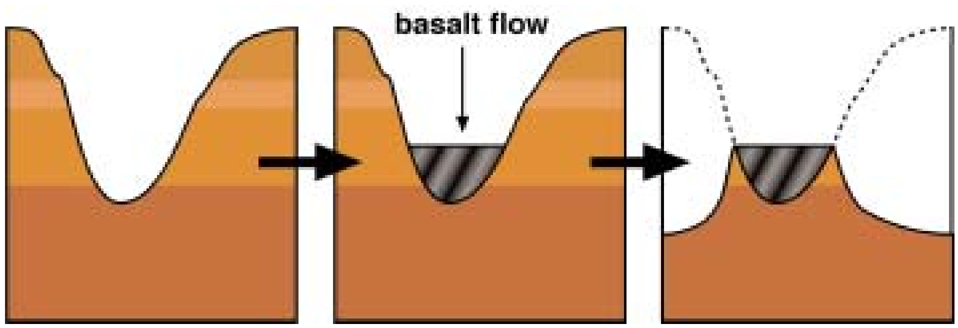
For further information, please contact Sandy Eldredge at 537-3325, sandyeldredge@utah.gov or visit the Utah State Office of Education's website http://www.usoe.k12.ut.us/curr/science/.

GeoSights

Inverted Topography in the St. George Area of Washington County

by Mark Milligan

Geologic Information: The St. George area of southern Utah exhibits many classic geologic features of the Colorado Plateau, including flat-lying layers of red sedimentary rock carved into buttes, mesas, and narrow canyons. However, unlike the rest of the Colorado Plateau, some of the small (less than 1,000 feet high) isolated bluffs in the St. George area are capped by black lava rock, called basalt. Examples include the bluff above Bluff Street (West Black Ridge, the location of the St. George Municipal Airport) and the bluff behind the outlet mall directly east of I-15 at Exit 8 (Black Ridge). The basalt on top of these bluffs originated as lava that intermittently flowed from small local volcanoes approximately 2.3 million to 20,000 years ago. Like other liquids, the basalt would flow downhill and into low areas such as stream beds, valleys, and canyons. This presents a puzzle: how does lava flowing downhill end up on hilltops? Unless it defied gravity, the lava should have flowed to low areas, not on bluff tops. And it did; the basalt that caps today's bluffs was originally deposited in canyons and channels. However, basalt is more resistant to erosion than the surrounding red sandstone and shale. Over time, erosion lowers the surrounding red rock faster than the basalt, leaving the basalt flows



Former canyon in layered sedimentary rocks. *Basalt flows down bottom of canyon.* *Erosion removes former canyon walls, leaving resistant basalt flow topographically higher.*

State Route 9, west of Hurricane, looking south at a road cut exposing a basalt-capped bluff. The red sandstone and shale on the left and right of the photo contained a channel that filled with lava approximately 350,000 years ago. This lava flowed from Volcano Mountain, southwest of Hurricane. Since the basalt is harder and more resistant to erosion than the sandstone and shale, it now stands out in relief as a bluff. What was low is now high - inverted topography. If you look closely you can find some channel-bottom gravel and pieces of sandstone that were trapped in the lava as it flowed.

high and dry – inverted topography.

How to get there: The bluffs in St. George above Bluff Street and behind the outlet mall are great examples of inverted topography. However, one of the best places to see that the lava originally flowed down streambeds or channels is in a road cut near Hurricane. From I-15 take the Hurricane exit (16) and travel east on State Route 9 for approximately 4 miles. The channel is exposed on the south side of the road before you reach Hurricane.

Approximately 1.2 million years ago, lava flowed down a small valley or canyon, that today is the basalt-capped bluff of the St. George Municipal Airport. View looking south. Photo courtesy of the Civil Air Patrol.

New Utah Minerals

by Carl Ege

Juanitaite, $(Cu,Ca,Fe)_{10}Bi(AsO_4)_4(OH)_{10} \cdot 2H_2O$

Juanitaite is a hydrated copper-calcium-iron-bismuth-arsenate hydroxide found on the 30- and 150-foot levels of the Gold Hill mine in Tooele County. The mineral is found as square plates or as crystallized aggregates. Individual crystals are up to 150µm long and 1µm wide. Juanitaite is olive-green to grass-green and has a pale greenish yellow streak. X-ray studies show a tetragonal symmetry. The mineral has a hardness of 1 and a density of 3.61 g/cm^3.

On the 30-foot level, juanitaite is associated with conichalcite, chrysocolla, azurite, gold, quartz, and mixite. On the 150-foot level, the mineral occurs with connelite, tyrolite, and azurite. Juanitaite is named for Juanita Curtis who discovered the mineral.

The Gold Hill mine where juanitaite was found on the 30- and 150-foot levels.

Dickthomssenite, $Mg(V_2O_6) \cdot 7H_2O$

Dickthomssenite is a hydrated magnesium vanadate found at the Firefly-Pigmay mine in San Juan County. The mineral is found as needle-like to platy prismatic crystals. Individual crystals are up to 1.5 mm long and 0.5 mm wide. Dickthomssenite is light golden brown, has a white streak, and a vitreous luster. X-ray studies show a monoclinic symmetry. Dickthomssenite has a hardness of 2.5 and a density between 1.96 and 2.09 g/cm^3.

Dickthomssenite occurs as thin coatings on sandstone, approximately 960 feet from the main portal of the mine. The mineral is associated with pascolite, sherwoodite, and native selenium. Dickthomssenite is named for Richard W. Thomssen, a consulting geologist from Nevada.

For more information

Hughes, J.M., Cureton, F.E., Marty, J., Gault, R. A., Gunter, M.E., Campana, C.F., Rakovan, J., Sommer, A., and Brueseke M.E., 2001, Dickthomssenite, $Mg(V_2O_6) \cdot 7H_2O$, a new mineral species from the Firefly-Pigmay mine, Utah - descriptive mineralogy and arrangement of atoms: The Canadian Mineralogist, v. 39, p. 1691-1700.

Kampf, A.R., Wise, W.S., and Rossman, G.R., 2000, Juanitaite, a new mineral from Gold Hill, Utah: Mineralogical Record, v. 31, p. 301-305.

"Glad You Asked"

by Carl Ege

What gemstone is found in Utah that is rarer than diamond and more valuable than gold?

The gemstone has several different names: red beryl, red emerald, or bixbite. Originally, the mineral was named bixbite, but now red beryl is the most accepted designation. Red beryl is estimated to be worth 1,000 times more than gold and is so rare that one red beryl crystal is found for every 150,000 diamonds.

In 1904, Maynard Bixby discovered red beryl in the Thomas Range located in Juab County, Utah. Bixby thought it might be a new variety of beryl, but the raspberry-red color did not correlate with any beryl known to exist at that time (green, blue, pink, yellow, and clear/white). W.F. Hillebrand, a geochemist from the National College in Washington, D.C., identified the mineral as a new type of beryl in 1905. In 1912, Dr. A. Eppler named it bixbite in honor of its discoverer. Laboratory analysis showed that manganese and small amounts of iron, chromium, and calcium create the raspberry-red color of red beryl. Like other beryl, red beryl has a hardness of 7.5 to 8.0 and its chemical composition is $Be_3Al_2Si_6O_{18}$.

Red beryl formation began with the eruption of a topaz rhyolite lava from volcanic vents. As the lava began to cool, shrinkage cracks formed, creating pathways for high-temperature gases rich in beryllium to escape. Oxidized surface water also began seeping into these cracks and mixed with the rising beryllium gases. The gases reacted with the surface water, silica, alkali feldspar, and iron-manganese oxides from the lava to form red beryl crystals. Red beryl probably grew at temperatures between 300 to 650 degrees Celsius. Red beryl is presently found at only three locations in the world: the Thomas Range and the Wah Wah Mountains in west-central Utah, and the Black Range in New Mexico.

In the Thomas Range, red beryl occurs primarily as short, flat, hexagonal crystals or more rarely as elongated, barrel-shaped crystals. The crystals are generally up to 2 –10 mm long and 4 – 6 mm thick. Many of these crystals are too small to be faceted. They are found in cavities and fractures within the Topaz Mountain rhyolite that erupted approximately 6 to 7 million years ago from volcanic vents in the area. Small crystals can be found in an area called "the Cove," where they may be attached to other minerals such as topaz, bixbyite, garnet, pseudobrookite, or hematite. Larger crystals that have been faceted into gemstones have been found in the northwest part of the Thomas Range near Wildhorse Springs.

The only known deposit of large, gem-quality red beryl in the world is from the Ruby-Violet claims in the Wah Wah Mountains of Beaver County, Utah. These are private claims and no collecting is allowed without permission from the present claim owners. The crystals occur primarily as elongated hexagonal crystals that are up to 15 mm in length, and the largest crystal discovered to date is 14 mm wide and 34 mm long. Red beryl is generally found along large, near-vertical, northwest-trending fractures and clay-filled seams within the rhyolite member of the Blawn Formation. The rhyolite erupted approximately 18 to 20 million years ago from volcanic vents in the area. The property has periodically been worked and continues to produce nice mineral specimens and stones suitable for faceting. Red beryl crystals from this location that have been faceted sell for an average of $2,000 per carat. For comparison, gold is currently worth $300 to $320 per ounce (one ounce is equal to 155 carats).

For more information regarding red beryl, contact the Natural Resources Map & Bookstore – (801) 537-3320, or toll free at 1 (888) UTAHMAP. The bookstore has several rock and mineral publications available for purchase that describe areas where to collect red beryl.

Specimen of red beryl from the Ruby-Violet claims in the Wah Wah Mountains. U.S. quarter for scale.

New Publications

Geologic map of the Wah Wah Mountains North 30 x 60 quadrangle and part of the Garrison 30 x 60 quadrangle, southwest Millard County and part of Beaver County, Utah, Lehi F. Hintze and Fitzhugh D. Davis, 2 pl. scale 1:100,000, 6/02, M-182 . . . . . $8.90

Geologic map of the Delta 30 x 60 quadrangle and parts of the Lynndyl 30 x 60 quadrangle, northeast Millard County and parts of Juab, Sanpete, and Sevier Counties, Utah, by Lehi F. Hintze and Fitzhugh D. Davis, 2 pl. scale 1:100,000, 6/02, M-184 . . . . . $8.90

Geologic map of the Moab and eastern part of the San Rafael Desert 30' x 60' quadrangles, Grand and Emery Counties, Utah, and Mesa County, Colorado, by Hellmut H. Doelling, scale 1:100,000, CD-ROM, 6/02, M-180DM $24.95

Mutituberculate mammals from the Wahweap (Campanian, Aquilan) and Kaiparowits (Campanian, Judithian) Formations within and near Grand Staircase-Escalante National Monument, southern Utah, by Jeffrey G. Eaton, 66 p., 7/02, MP-02-4 . . . . . $12.00

Post-Bonneville paleoearthquake chronology of the Salt Lake City segment, Wasatch fault zone, from the 1999 "megatrench" site, by James P. McCalpin, 5/02, 37 p., MP-02-7 . . . . . $15.95

Ground-water sensitivity and vulnerability to pesticides, Cache Valley, Cache County, Utah, by Ivan D. Sanderson and Mike Lowe, 28 p., 2 pl. scale 1:100,000, 6/02, MP-02-8 . . . . . $12.45

Post-Provo paleoearthquake chronology of the Brigham City segment, Wasatch fault zone, Utah, by James P. McCalpin and Steven L. Forman, 46 p., 5/02, MP-02-9 . . . . . $11.95

Earthquake scenario and probabilistic ground shaking maps for the Salt Lake City, Utah, metropolitan area, by Ivan Wong, Walter Silva, Susan Olig, Patricia Thomas, Douglas Wright, Francis Ashland, Nick Gregor, James Pechmann, Mark Dober, Gary Christenson, and Robyn Gerth, 50 p. + CD-ROM, MP-02-5 . . . . . $25.00

Interim geologic map of the Kolob Arch quadrangle, Washington and Iron Counties, Utah by Robert F. Biek, 31 p., 1 pl., 1:24,000, OFR-386 . . . . . $5.00

Interim geologic map of the Kolob Reservoir quadrangle, Washington and Iron Counties, Utah by Robert F. Biek, 22 p., 1 pl., 1:24,000, OFR-387 . . . . . $4.20

Interim geologic map of the Cogswell Point quadrangle, Washington, Kane, and Iron Counties, Utah by Robert F. Biek and Michael D. Hylland, 4/02, 23 p., 1 pl., 1:24,00, OFR-388 . . . . . $4.20

Ferron Sandstone permeability database, Ivie Creek area, Emery County, Utah, by Craig B. Forster and Stephen H. Snelgrove, 7/02, CD-ROM, OFR-389 . . . . . $19.95

Ferron Sandstone stratigraphic cross sections, Ivie Creek area, Emery County, Utah, by Paul B. Anderson, Thomas C. Chidsey Jr., Kevin McClure, Ann Mattson, and Stephen H. Snelgrove, 7/02, CD-ROM, OFR-390 . . . . . $19.95

Ferron Sandstone (Upper Cretaceous) core photographs, Ivie Creek and Muddy Creek areas, Emery County, Utah, by Carolyn M. Olsen and Cheryl Gustin, 4/02, CD-OFR-391 . . . . . $19.95

Documentation and installation guide for HOMCODE: a code for scaling up permeabilities using homogenization, by Joe Koebbe, 7/02, 416 p., OFR-392 . . . . . $25.00

Interim geologic map of the Springdale East quadrangle, Washington County, Utah by H.H. Doelling, G.C. Willis, B.J. Solomon, E.G. Sable, W.L. Hamilton, and L.P. Naylor II, 7/02, 20 p., 1 pl., 1:24,00, OFR-393 . . . . . $5.00

Interim geologic map of the Springdale West quadrangle, Washington County, Utah by G.C. Willis, H.H. Doelling, B.J. Solomon, and E.G. Sable, 7/02, 19 p., 1 pl., 1:24,00, OFR-394 . . . . . $5.00

Interim geologic map of The Guardian Angels quadrangle, Washington County, Utah by G.C. Willis and M.D. Hylland, 7/02, 27 p., 1 pl., 1:24,00, OFR-395 . . . . . $5.20

Interim geologic map of the Temple of Sinawava quadrangle, Washington County, Utah by H.H. Doelling, 7/02, 15 p., 1 pl., 1:24,00, OFR-396 . . . . . $5.00

Geothermal resources of Utah, a digital atlas of Utah's geothermal resources, compiled by Robert E. Blackett and Sharon I. Wakefield, 7/02, CD-ROM, OFR-397 . . . . . $24.95

Great Salt Lake: an overview of change, edited by J. Wallace Gwynn, 584 p. + 16-p. color insert, 6/02, DNR Special Publication $24.95

Large mine permits in Utah 2002, by Roger L. Bon and Sharon I. Wakefield. 3 p., 1 pl., apros. scale 1" = 14 mi., 9/02, OFR-398 . . . . . $4.50

Progress report - Geologic map of the Dutch John 30'x60' quadrangle, Utah, Colorado, Wyoming - year 3 of 3, compiled by Douglas A. Sprinkel, 3 pl., 1:62,500, 9/02, OFR-399 . . . . . $15.00

Progress report - Geologic map of the Provo 30'x60' quadrangle, Utah - year 2 of 3, compiled by J.C. Coogan and K.N. Constenius, 8/02, 15 p., 1 pl., 1:62,500, OFR-400 . . . . . $6.10

Deterministic maximum peak acceleration maps for Utah, by M.W. Halling, J.R. Keaton, L.R. Anderson, and W. Kohler, 8/02, 57 p., 1 CD-ROM, MP-02-11 . . . . . $20.95

Survey News

David Madsen has retired after nearly thirty years in state service. As the paleoecologist with the Utah Geological Survey (and previously as State Archeologist with State History), David explored topics as varied as paleo-Indian cultures to world-wide climatic changes. A profusion of publications resulted from his work, as well as several contracts and papers still in the works which will keep him occupied, and possibly out of trouble, for several years. Best of luck, and keep digging!

Dave Schmitt and **Jeff Hunt**, longtime paleogeologists, have also left the Environmental group to pursue other interests.

The mapping section has lost the services of two of our temporary workers, **Angela Wadman** and **Adam Davison**. Both are going on to further their education in earth science.

UGS Hosts National Mapping Workshop

On May 19 to 22, the Utah Geological Survey hosted the National Digital Mapping Techniques Workshop at the Eccles Auditorium in the Huntsman Cancer Institute in Salt Lake City. More than 100 registrants from about 30 state geological surveys, the U.S. Geological Survey, the Geological Survey of Canada, and a variety of private and industrial groups attended the workshop.

The workshop focused on the challenges of field mapping, data collection and conversion, map compilation, preparing maps for release in published and digital formats, and map distribution in the new digital world. It was a resounding success. Several new cutting-edge hardware and software tools and map production techniques were demonstrated that should improve UGS digital (GIS) production and map publication. By hosting it in Salt Lake City, several UGS staff benefited from the workshop, rather than just the one staff member who normally attends when the workshop is held out-of-state.

...continued from page 5

lilies. Additional fossil plants are found about 20 feet below in exposures of the Dinosaur Canyon Member of the Moenave Formation. These fossils include recognizable conifer (primitive pine relatives) branches with the needles still attached. Some of the plant material is stained green by malachite.

Above the main track-preserving horizon, lake-deposited sediments of the Whitmore Point Member exposed during construction north of the road bordering the Johnson property preserve numerous fossil fish (large semionotids), stromatolites (algal mounds), ostracodes (tiny bivalved crustaceans), and conchostracans (clam shrimps). Together with several horizons preserving mudcracks, these fossils indicate that the lake remained relatively shallow in the St. George area. The sandstone preserving the dinosaur tracks at the Johnson site represents the shoreline area of the lake with salt crystals forming in the sediment on the shore during times of drought.

The St. George Dinosaur Tracksite is the largest attraction in the city with visitation consistently exceeding all other St. George attractions combined and provides an outstanding educational opportunity. Volunteers from the local community and the Utah Friends of Paleontology have assisted the Johnson family and St. George in conducting tours for hundreds of thousands of visitors to the site and have helped document this important new discovery. Donation of the Johnson farm site to the City of St. George has been finalized and plans to preserve and display the tracks on site are moving forward with the help of federal and state funds. This past winter, construction across the road resulted in nearly doubling the known extent of the tracksite and the developer, Darcy Stewart, is investigating donating this site to the City of St. George as well. Utah can look forward to having an important interpretive site for paleontology in the southwestern part of the state in the not too distant future.

Currently the site is open every day, although hours vary. For information, call the St. George Leisure Services at 435-634-5860, or the Washington Travel and Convention Bureau at 435-634-5747.

Discovery of a New Pterosaur Tracksite at Flaming Gorge Reservoir

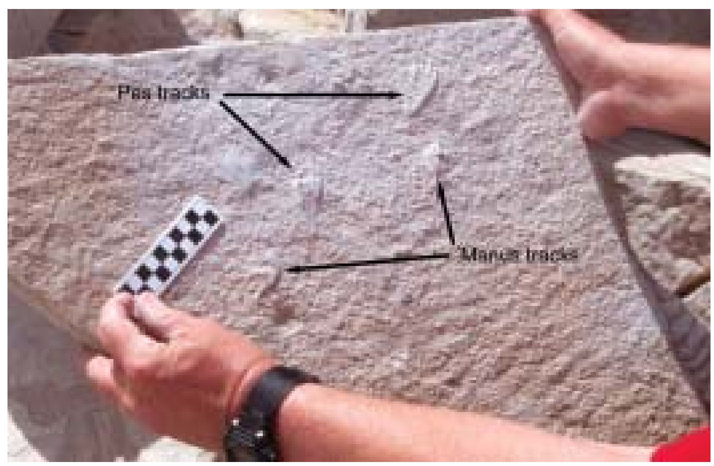
by Martha Hayden

In the spring of 2002 the Utah Geological Survey prepared a paleontological assessment of Flaming Gorge Reservoir for the U.S. Bureau of Reclamation, in order to protect fossil resources from the effects of fluctuating lake levels. With the assistance of Barbara Blackshear and others from the Bureau of Reclamation and the Ashley National Forest, the UGS conducted a two-day paleontological survey of formations that may contain important fossils. This survey resulted in the discovery of a very significant locality containing trackways from a sauropod dinosaur and pterosaurs, or flying reptiles.

Survey crew from the Utah Geological Survey, Bureau of Reclamation, Ashley National Forest and the Utah Field House of Natural History State Park examine a newly discovered tracksite at Flaming Gorge Reservoir.

Pterosaur tracks and trackways have been found on many of these rock slabs.

Overview of tracksite at the top of the Windy Hill Member of the Curtis Formation along the shoreline of Flaming Gorge Reservoir.



Close-up of well-preserved forelimb (manus) and hindlimb (pes) pterosaur tracks. Scale bar is in centimeters.

Sauropod trackway on mudcracked surface.