UTAH GEOLOGICAL SURVEY

SURVEY NOTES

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Contents

Design | *Jennifer Miller*
Cover | One of the numerous beaver ponds and associated wetlands located on a tributary to Birch Creek in Rich County, Utah. Photo by Ryhan Sempler.

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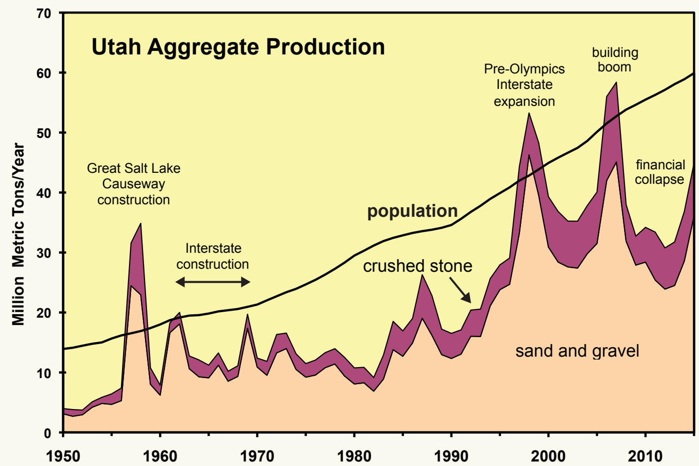
THE DIRECTOR'S PERSPECTIVE

by Richard G. Allis

There are many financial indicators of economic activity. One geological indicator that is a good metric for construction activity is the annual production of aggregate. Aggregate is largely made up of crushed stone (mostly limestone and sandstone) and sand and gravel. These commodities are used for concrete products, road base, fill, and a variety of other construction applications. Because aggregate is heavy and a low value commodity, it is relatively expensive to transport long distances so quarries are typically sited near major urban centers. As urban growth occurs, old quarries may become surrounded by residential areas, and dust and noise may become nuisance factors. The Utah Geological Survey is often asked where new deposits of stone or clean gravel and sand may occur. Our geologic maps are a good starting point for locating these deposits.

The U.S. Geological Survey (USGS) maintains databases on the production of geological commodities including aggregates. The trend for Utah up to the end of 2015 is shown on the figure below. Two of the big production peaks on the graph are unique to Utah—the Great Salt Lake causeway construction and the pre-Olympics Interstate expansion. However, the building boom that occurred between 2006 and 2008, and the subsequent financial collapse clearly reflected in the aggregate trend, were similar to what occurred across the U.S. Utah's economic recovery since 2012 can be seen in the steadily increasing production of aggregate in recent years.

The value of aggregate at the quarry gate averaged $8 per metric ton (about $7/U.S. ton) in 2015. The USGS estimated the total production value of Utah aggregate in 2015 to be $360 million, demonstrating its important role as a foundation to Utah's economy.



Thompson FIELD FORUMS
THE GEOLOGICAL SOCIETY OF AMERICA

Upcoming Field Forum

CATASTROPHIC MEGA-SCALE LANDSLIDE FAILURE OF LARGE VOLCANIC FIELDS

September 16-22, 2017, Cedar City and Bryce Canyon City, Utah

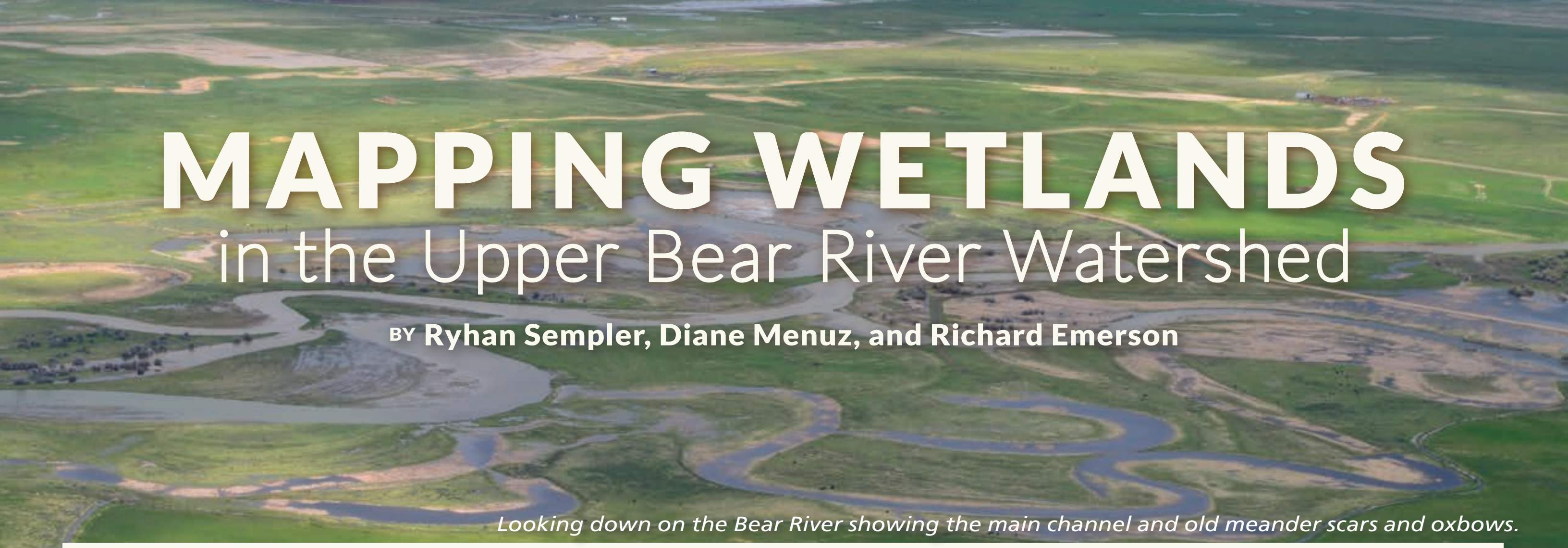
CONVENERS

Robert F. Biek—Utah Geological Survey, Salt Lake City, Utah, USA, bobbiek@utah.gov
David B. Hacker—Department of Geology, Kent State University, Kent, Ohio, USA, dhacker@kent.edu
Peter D. Rowley—Geologic Mapping Inc., New Harmony, Utah, USA, pdrowley@rushisp.com

A 6-day field forum designed to investigate the concept of exceptionally large catastrophic collapse of volcanic fields using the distinguishing characteristics and geologic implications of the gigantic Markagunt gravity slide and Marysvale volcanic field, southwest Utah.

Application deadline: January 31, 2017

For details, go to: www.geosociety.org/fieldforums/



MAPPING WETLANDS
in the Upper Bear River Watershed

BY **Ryhan Sempler, Diane Menuz, and Richard Emerson**

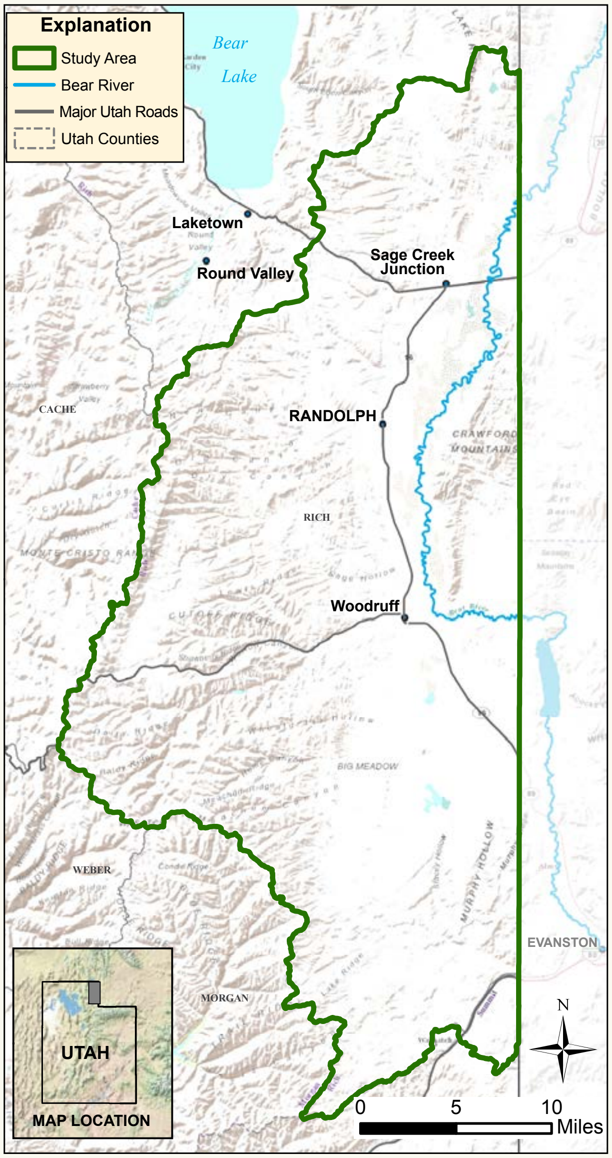
Looking down on the Bear River showing the main channel and old meander scars and oxbows.

Utah, the second driest state, has a steadily growing population and an increasingly scarce and vulnerable water resource. Wetlands are vital to protecting the quantity and quality of this resource as well as the quality of life for the state's residents. There are many types of wetlands, but they are universally defined by water on the soil surface or by soil saturation at or near the surface that causes oxygen deprivation for vegetation for at least part of the growing season. Wetlands are integral for flood prevention, replenishing groundwater, improving water quality, and providing wildlife habitat. Wetlands are also popular for waterfowl hunting, fishing, wildlife watching, boating, and other recreational opportunities that provide public enjoyment and a boost for the economy in the surrounding communities.

The Utah Geological Survey (UGS) has embarked on numerous projects to map and reclassify wetlands throughout the state to better understand their distribution, extent, and impact on the surrounding landscape. We recently mapped part of the upper Bear River watershed using the National Wetland Inventory (NWI) Program's mapping standards and the Cowardin classification system. The Cowardin system uses an alpha-numeric code to classify habitat attributes such as water levels, vegetation, and landscape modification to describe wetland habitat. The Bear River is North America's largest river that does not flow into an ocean, and it provides over 60 percent of the water flowing into Great Salt Lake. The upper Bear River watershed provides significant habitat for wildlife and livestock and supports the health and maintenance of the Great Salt Lake ecosystem. The upper Bear River project area extends from the entrance of the Bear River into Utah (near the outflow of Woodruff Narrows Reservoir in Wyoming) to its exit back into Wyoming (north of Utah County Route 30). Like most of Utah, wetlands in the watershed were originally mapped in the early 1980s using imagery and U.S. Geological Survey (USGS) topographic maps available at that time. Imaging quality has greatly increased since then, so remapping is important not only to track changes in land use, but because mapping can now be done at a finer scale.

Our wetland mapping was conducted primarily with geographic information system (GIS) software, using a variety of geospatial layers including aerial imagery, the National Hydrography Dataset, and geotagged historical photos. However, fieldwork was very important for providing baseline data for interpreting imagery. The updated mapping showed a 71 percent decrease in wetland acreage compared to the original mapping. The original 1980s mapping effort classified 7 percent of the watershed as wetlands, whereas our updated mapping has only 2 percent of the watershed classified as wetlands. The biggest change in acreage, a 74 percent loss, was from areas in the valley bottoms, followed by the lowland foothills having a 49 percent loss. The Wasatch Range foothills and montane areas had the lowest reduction in wetland acreage mapped, 30 percent and 1 percent, respectively.

What is the cause of such a large reduction in wetland acreage? There are probably several factors at play. First, we found that much of the acreage originally mapped as wetland in valley bottoms is actually non-wetland fields that are artificially flooded for agriculture. Second, mappers in the 1980s may have had a broader definition of wetland than that used today.



Upper Bear River watershed study area.

NWI mapping standards have been refined since the 1980s and some areas that are not wet enough to be considered true wetland may have been mapped in the 1980s. Third, there may be some true loss in wetland acreage due to changes in land use or regional drying trends. Note that the precise loss of wetlands over the past 30 years is impossible to determine due to changes in NWI mapping standards since the 1980s.

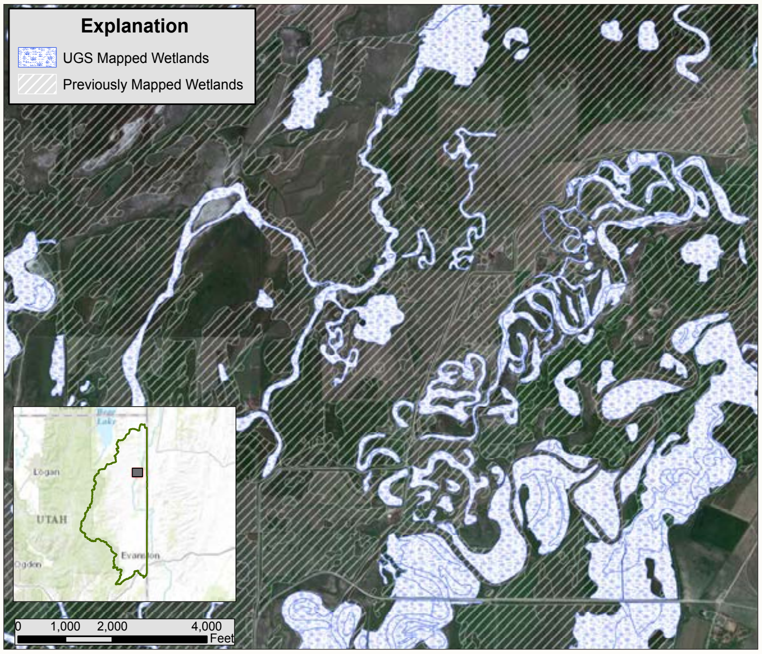
Though it seems intuitive to have negative feelings about this drastic reduction of wetland-designated acreage, we suggest that the new NWI map will benefit wetlands. Due to limited financial resources, it is imperative that resource managers know where true wetlands are located when planning conservation efforts. Our new mapping provides greater spatial accuracy and improved resolution and detail. Very little of Utah is classified as wetland and our data can better address which wetland types are rare in the upper Bear River watershed and where conservation, restoration, and protection should be prioritized.

Besides the overall reduction in wetland acreage, another significant change to the NWI map resulted in a more accurate tracking of beaver-inhabited streams. The original map only had 23 acres designated as being influenced by beavers, whereas we added an additional 101 acres. Beaver habitat is important to understand because beavers are a keystone species; their ponds slow the movement of water which allows suspended sediment to settle out of the water column, increasing overall water quality, and beavers alter the landscape in ways that increase biodiversity. The upper Bear River watershed wetland map can help restoration practitioners identify areas underutilized by beavers for possible reintroduction or restoration efforts.

(A) UGS-mapped beaver ponds. (B) Photo of a typical beaver pond.

A third change to the NWI map is greater inclusion of streams and rivers (which were not adequately mapped previously) in addition to wetlands. The original map only included two riverine areas, the Bear River and a small intermittent drainage on the northern edge of the study area, equaling roughly 90 linear miles. We added approximately an additional 300 linear miles of seasonally flowing or perennial riverine waterways, as well as roughly 1,600 miles of irrigation canals or ephemeral riverine waterways. Many of the stream segments were adopted from the National Hydrography Dataset following new NWI standards. The inclusion of these features produces a more complete and hydrologically connected water network. By accurately demonstrating when and where water is available on the landscape, biologists can better assess wildlife movement and riparian corridors, leading to a better understanding of biological carrying capacity (the number of animals in which the habitat can support).

Mapping the upper Bear River watershed is just one of many recent wetland mapping projects at the UGS. We are currently in the process of remapping the south, east, and north shores of Great Salt Lake, which contain roughly 75 percent of all of Utah's wetlands, and we will soon start a mapping project in the Uinta Basin. Project by project, we are moving towards an up-to-date and more standardized map of wetlands and other aquatic features in the state.



Above map shows the significant difference between the amount of land cover previously mapped as wetlands and our updated version.

about the authors

Ryhan Sempler is a Wetland Ecologist for the UGS where he has worked since 2013. When he is not out mapping wetlands throughout the state, he is typically working on shallow groundwater studies or on wetland assessment projects.

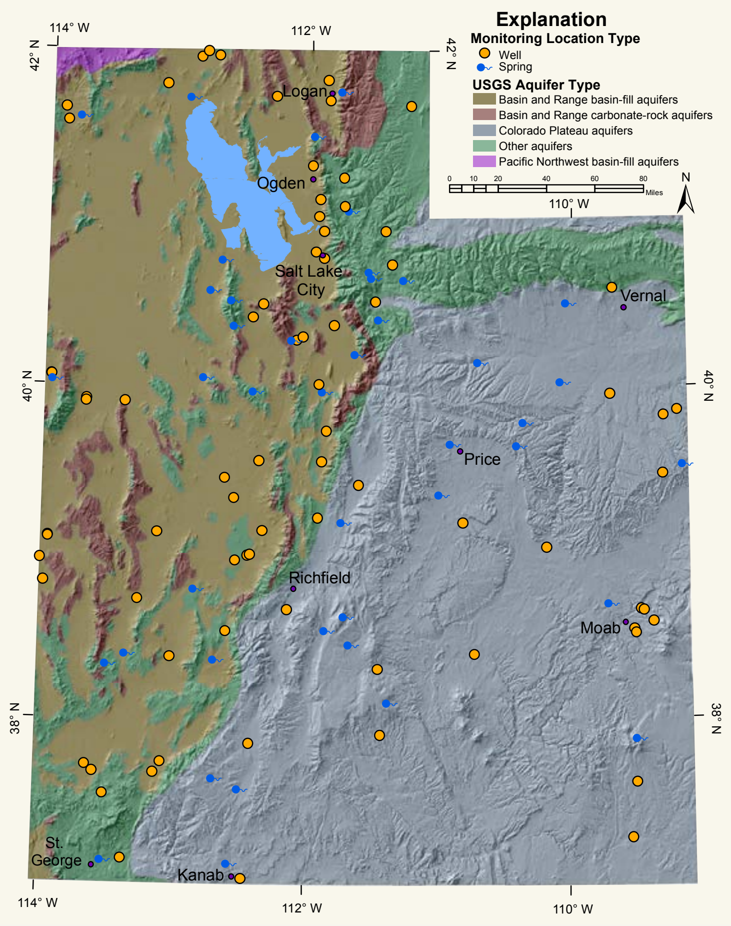
Diane Menuz has worked for the UGS since 2013 and is currently the Utah State Wetlands Coordinator. Her work focuses on developing the wetland program, managing wetland assessment projects, and determining how to meet wetland-related data needs for stakeholders in the state. Diane also has expertise in plant identification, species distribution modeling, and landscape analysis.

Rich Emerson joined the UGS in 2007 and is a Project Geologist in the Groundwater and Paleontology Program. Since 2009 he has been monitoring wetland hydrology and, more recently, mapping wetlands across the state of Utah.

UGS'S ROLE IN CONTRIBUTING WATER-QUALITY DATA
to the National Ground-Water Monitoring Network

BY Janae Wallace

The Groundwater Program at the Utah Geological Survey (UGS) is excited to be a major contributor of water-quality data to the nascent, but expanding, National Ground-Water Monitoring Network (NGWMN). The UGS has established a groundwater monitoring network in Utah to contribute to the recently established web-based data portal originated by the U.S. Geological Survey (USGS). The NGWMN Data Portal is a clearinghouse that displays water well data throughout the nation; in particular, it exists as a water-quality and water-level network designed to showcase wells having a historical collection of data for a subset of selected water wells established by each state.



Utah's groundwater monitoring network of water wells and springs sampled. The sites are also located on the USGS's National Ground-Water Monitoring Network Data Portal, a web-based clearinghouse designed to showcase different states' water-level and water-quality networks (http://cida.usgs.gov/ngwmn/index.jsp).

The UGS has been a fortunate recipient of funding from the federal government to establish a new network representing Utah. Previously, the UGS Groundwater Program regularly monitored sites at only a few areas of the state: Snake Valley, Castle Valley, and the Uinta Basin. Because the U.S. Environmental Protection Agency (EPA) has provided no-cost laboratory chemistry analysis for water samples and the USGS has funded submission of data to the portal, the UGS has been able to create a state-wide network and expand our monitoring efforts. We have also been a vanguard for other states by adding a new category to the data portal to include water-quality information for springs. Because springs are an important water resource to some of our state's public water suppliers, the USGS is currently adding a "spring" option to amend the data portal to include and recognize springs as significant water resources for other states.

The Utah monitoring network consists of approximately 100 wells and springs. We selected wells and springs in the principal aquifers of Utah (Basin and Range Basin-Fill Aquifers, Basin and Range Carbonate-Rock Aquifers, and Colorado Plateau Aquifers) and other aquifers that support withdrawals of regionally significant quantities of water. Our primary goal is to document water-quality changes over time by sampling annually, depending on funding. Additional goals include documenting water resources in a well-administered and maintained database and integrating all of our state-level water data with the national-level database. All of our data and stations will also be entered into the EPA's WQX (Water Quality Exchange) for data preservation, which also feeds into the NGWMN Data Portal.

Our site selection criteria follow guidelines of the framework document prepared by the Advisory Committee on Water Information's Subcommittee on Groundwater; the primary site selection criteria are accessibility and representativeness of aquifers of interest. Most of the sites in the UGS water-quality network are designated for "trend" monitoring, defined in the framework document as samples collected on a yearly basis. We attempt to sample each site during the season of greatest use and resample the sites during the same time of year every year. To ensure high accessibility, most of the wells in our network are privately owned and regularly pumped. A public water supply source is included only if it is the only representative, accessible well in the area or sampled infrequently for limited water-quality chemistry (for example, only nitrate and/or sulfate every few years), and only if the location is widely known and allowed to be disclosed (such as a campground). We chose wells that have well logs or sufficient aquifer information to ensure that they represent the aquifer of interest. We sample about 35 springs throughout the state, ranging from smaller springs in mountain blocks or mountain fronts to large regional springs. Selected springs are (1) accessible sampling points that represent major aquifer chemistry where no nearby well is available, (2) large springs that represent the integrated aquifer chemistry for an entire drainage basin, or (3) springs in mountain areas that represent the chemistry of water recharging the adjacent aquifers.

Data acquisition typically occurs during suitable sampling seasons, weather permitting, seven months of the year (April through October). Samples analyzed by the EPA follow stringent guidelines and analytical methods. For quality assurance, we collect one field blank or one duplicate sample during each monthly sampling trip. We provide each sample to the EPA laboratory within mandatory holding times. Analytical results are then compared to previously collected data for quality control and to identify possible anomalies. We also conduct a charge balance of water chemistry to verify the authenticity of data analyses. We regularly review the data in the database to ensure that sampling sites are correctly located and have the correct information associated with them.

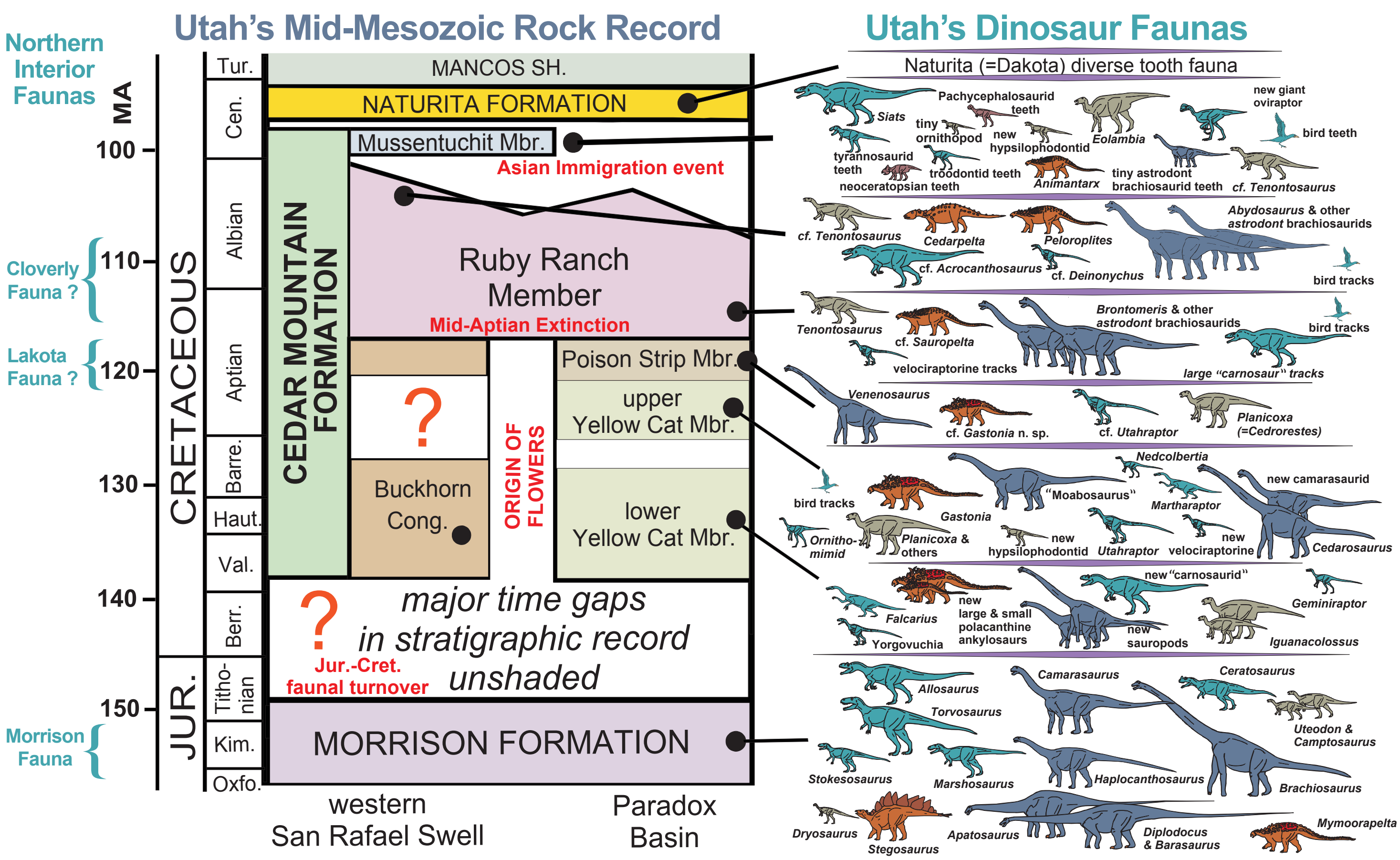
As we expand our water-quality monitoring network (as funding allows), we will continue to supply data and maintain our connection to the USGS NGWMN Data Portal, which makes all of our data publicly available. Over time, our new network will allow us to characterize the water quality of key aquifers in Utah and allow us to fill in gaps across the state. Our water-quality sites and data are available online through the data portal at http://cida.usgs.gov/ngwmn/index.jsp, where a user can click on the Utah map to display water-quality information we have collected over the past three years (2014 to present).

DOES UTAH PRESERVE NORTH AMERICA'S OLDEST CRETACEOUS DINOSAURS BECAUSE OF ANCIENT SALT DEPOSITS?

BY JAMES I. KIRKLAND

Utah has the most complete dinosaur record located in any one area in the world. Currently, the Utah Geological Survey (UGS) Paleontology Section recognizes the presence of 27 sequential, non-overlapping dinosaur faunas spanning 165 million years, from 230 to 65 million years ago. These faunas range from the very first North American dinosaur-bearing strata in the Upper Triassic Chinle Formation, through Utah's real "Jurassic Park" in the Upper Jurassic Morrison Formation, to the uppermost Cretaceous North Horn Formation which has a lone example of *Tyrannosaurus* and a record of the extinction of the dinosaurs. Although the dinosaur record of the Middle Jurassic San Rafael Group is limited to dinosaur tracks, the only real gap in Utah's extraordinary record is in the transition between the Jurassic and Cretaceous, an interval of up to 25 million years. This interval of non-deposition and erosion extends across the entire interior of North America.

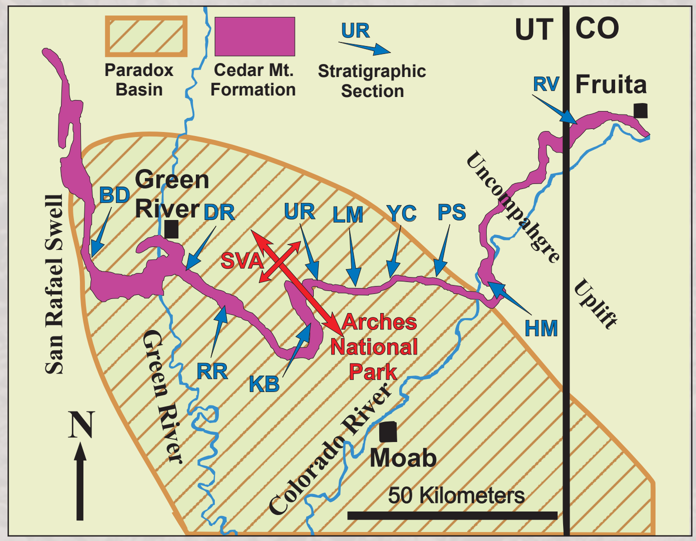
Distribution of Dinosaurs in the Mid-Mesozoic of Utah



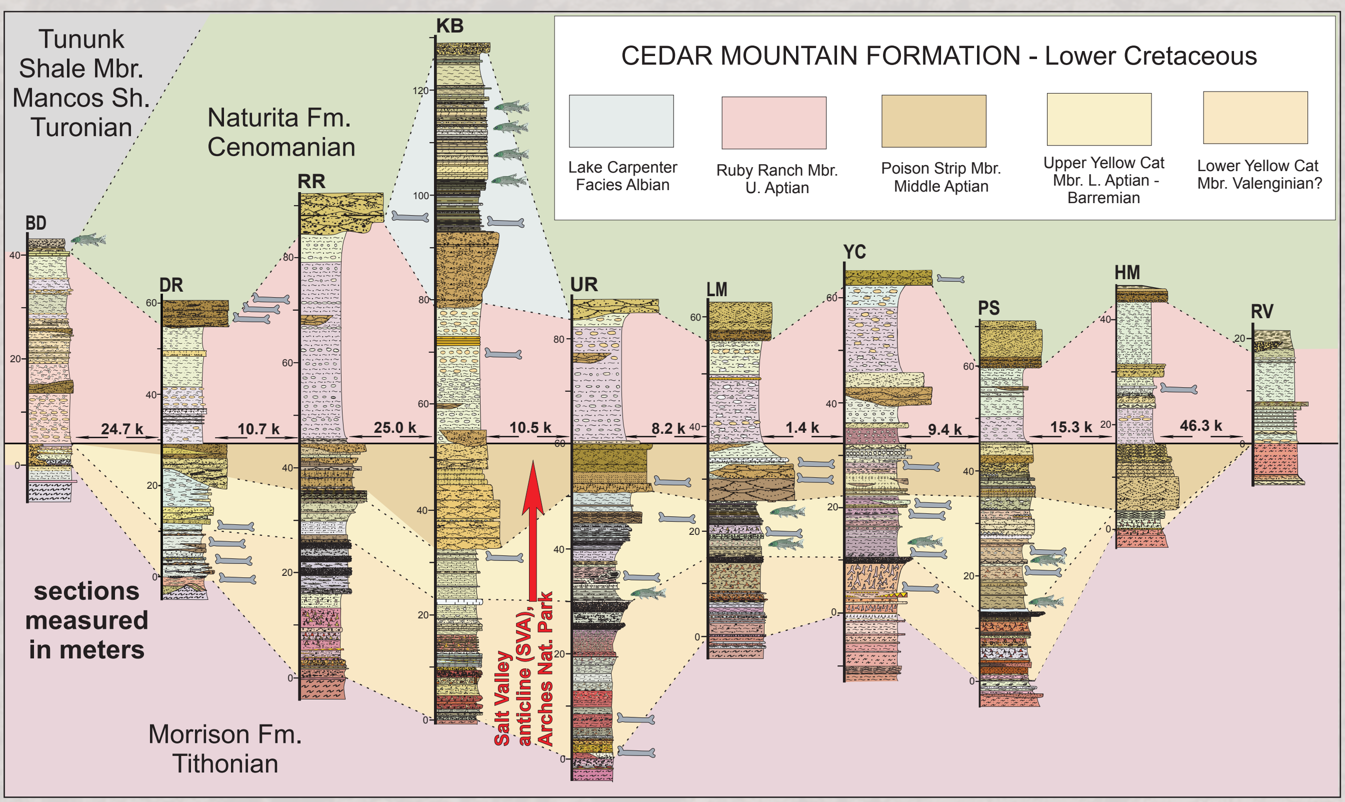
The UGS Paleontology Section has focused on filling this gap by studying the Lower Cretaceous Cedar Mountain Formation (CMF), which is exposed across east-central Utah (see *Survey Notes*, v. 37, no. 1). The CMF is complex and we have divided it into a basal lower and upper Yellow Cat Member, a middle Poison Strip Member, and an upper Ruby Ranch Member in the northern Paradox Basin. As we prepared a guidebook to the CMF as part of co-hosting the 2016 annual meeting of the Society of Vertebrate Paleontology, we combined data generated from our research with that of our extensive network of collaborators. The results from this compilation confirmed our long-held suspicion that Utah's oldest Cretaceous dinosaurs are restricted to northern Grand County in eastern Utah as a result of local salt tectonics. When we plotted the distribution of the CMF's stratigraphic units across the region, we demonstrated that, not only is the basal Yellow Cat Member restricted to the Paradox Basin, but it is thickest in the central part of the basin where salt tectonics had a major influence. Furthermore, the dinosaurs (*Gastonia lorriemcwhinneyae* and *Planacoxa venenica*) preserved in the overlying Poison Strip Member appear to be most closely related to dinosaurs in the oldest previously identified Cretaceous fauna in the Lakota Formation of the Black Hills region of South Dakota. Therefore, we have proposed that Utah preserves the two oldest Cretaceous dinosaur faunas in North America, and that both are restricted to the northern Paradox Basin in Grand County.

We also proposed that Utah's more complete record of the Jurassic-Cretaceous boundary is due to salt tectonics. During the uplift of the Ancestral Rockies in the late Paleozoic (about 300 million years ago), a deep basin formed on the west side of the Uncompahgre Uplift along the Utah-Colorado border. Shallow seas repeatedly spilled into this basin and evaporated, resulting in the deposition of thousands of feet of salt, which is much more plastic or ductile than other sedimentary rock types. After the salt was buried under thousands of feet of coarse debris shed westward from the Uncompahgre Uplift, it was squeezed and deformed into a series of ridges and depressions that folded and faulted the overlying rock. The height of salt movement occurred during the early Mesozoic and is well reflected by the Salt Valley anticline at Arches National Park and by the Moab fault. Our research has documented that salt tectonics was also an important control on deposition in this area during the Early Cretaceous, while erosion was occurring across much of the rest of North America. As salt migrated into anticlines causing additional uplift of the terrain, the adjoining areas subsided, leading to local deposition of Lower Cretaceous sediments in these resulting depressions.

The distribution of ancient wetlands in the area during the Early Cretaceous also appears to be controlled by salt tectonics. In the upper Yellow Cat Member, the presence of an aquatic fauna of diverse fish, freshwater turtles, crocodilians, and aquatic microfossils indicates that an extensive wetland or lake system was present east of the Salt Valley anticline. We believe that salt movement was asymmetric, and more salt entered the Salt Valley anticline from the east than from the west during the deposition of the Yellow Cat Member. This led to greater subsidence east of the Salt Valley anticline and Arches National Park resulting in the development of lakes and wetlands, while the rest of the region records a drying trend. This pattern is reversed in the overlying Ruby Ranch Member which is much thicker on the west side of Arches National Park, and its upper half preserves a lake system that is dominated by carbonate deposition. Preliminary radiometric dating suggests that these rocks are younger than other Ruby Ranch strata in the area. Pending ages from several volcanic ashes preserved in the lake strata will confidently date these rocks. The dramatic thickening of the Ruby Ranch Member suggests tens of meters of local subsidence along the west side of Arches National Park as salt migrated east into the Salt Valley anticline near the end of the Early Cretaceous. Perhaps the presence of extensive wetlands in the localized basins in eastern Utah during the Early Cretaceous helps explain the abundance of dinosaur localities in the Lower Cretaceous rocks of Grand County, Utah.



Location map.



Geological cross section of the Cedar Mountain Formation across the northern Paradox Basin. Note the distribution of aquatic fossils (fish) as an indicator of the distribution of wetlands relative to the Salt Valley anticline. Bones indicate terrestrial fossils. See location map for stratagraphic section location.

Energy News

NOT ALL MEGAWATTS ARE CREATED EQUAL

An Examination of Electric Generation Capacity Factor

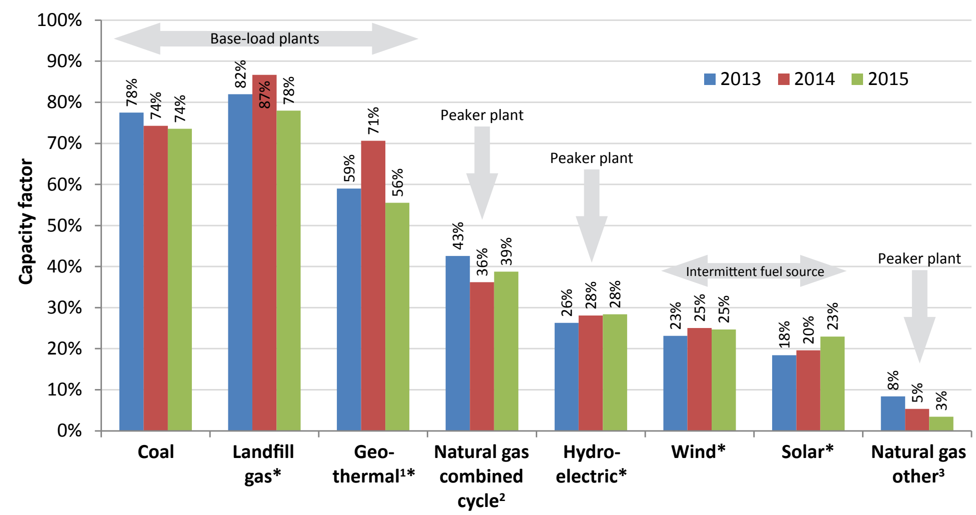
BY Michael D. Vanden Berg

The Utah Geological Survey recently published the fourth edition of *Utah's Energy Landscape*, a comprehensive, visually-based publication detailing Utah's diverse energy portfolio. The highlight of this new edition was the exponential growth in Utah's utility-scale solar electric generation capacity. In 2015, 166 megawatts (MW) of new utility-scale photovoltaic solar capacity was installed in southwestern Utah and 601 MW was under construction and expected to be complete by the end of 2016. By the time this article is published, 767 MW of solar capacity will be operational, surpassing the installed capacity of all other renewable energy sources (wind, hydroelectric, geothermal, and biomass) combined. The new solar capacity accounts for about 8.6 percent of Utah's total electric utility capacity of about 8,900 MW, the vast majority of which comes from fossil fuels (coal accounts for 54 percent and natural gas accounts for 35 percent). However, not all megawatts of generation capacity are created equal when comparing fossil fuels to renewable energy resources.

The capacity factor (CF) of an electric power plant is the ratio of its actual output over a period of time to its potential output if the plant could operate 100 percent of the time. The CF for a power plant is calculated by dividing the actual amount of electricity generated by the plant by how much electricity the plant could have generated during the same amount of time at 100 percent capacity. For example, if a coal plant with a nameplate capacity of 100 MW generated 1,200 megawatt-hours (MWh) in one day, it would be operating with a CF of 50 percent (1,200 MWh / [24 hours x 100 MW]). Using electricity data collected by the U.S. Energy Information Administration, we can calculate the CF for various electric plants and fuel types employed in Utah and observe how the CFs change throughout the year.

The chart to the right displays the average annual CF for different fuel types in Utah for a three-year period (2013–2015). The first observation that stands out is the difference between base-load electric plants and "peaker" plants. Base-load plants produce the lowest-cost electricity and are designed for maximum efficiency. Coal-fired power plants in Utah essentially run full time (CF of about 75 percent) and provide important base-load power to users in Utah and surrounding states. No power plants, even base-load plants, run at 100 percent capacity due to unexpected equipment failures or routine maintenance. Landfill gas and geothermal operations also have high CFs, 82 percent and 62 percent, respectively, and are run as base-load plants, but only account for 1.3 percent of Utah's total electric generation. Combined-cycle natural gas (CF of about 40 percent) and hydroelectric (CF of about 28 percent) power plants are often used as "peaker" plants. These operations can be rapidly brought online to provide power at times of high demand, like during hot summer days when air conditioners are running full steam. The CF for the above-mentioned power plants can all be manually changed depending on the amount of electricity needed at the time. In the case of hydroelectric plants and depending on the availability and quantity of stored water, operators can quickly increase the amount of water running through the plant's turbines. In contrast, the CF for wind and solar installations is entirely dependent on external factors, for example the sun only shines during the day and the wind only blows at certain times. Utah's two utility-scale wind farms (a third was added in 2016, but generation data are not yet available) operate at an average CF of 24 percent, and preliminary data from Utah's new solar installations indicate that these plants operate at an average CF of about 20 percent, far below that of a typical base-load power plant.

Average annual capacity factors for Utah power plants by fuel type



	Coal	Landfill gas*	Geothermal[1]*	Natural gas combined cycle[2]	Hydroelectric*	Wind*	Solar*	Natural gas other[3]
Percent of Utah's total capacity	54%	0.1%	0.9%	24%	2.9%	3.6%	1.9%	11%
Percent of Utah's total net generation	76%	0.1%	1.2%	17%	1.4%	1.5%	0.1%	2.0%

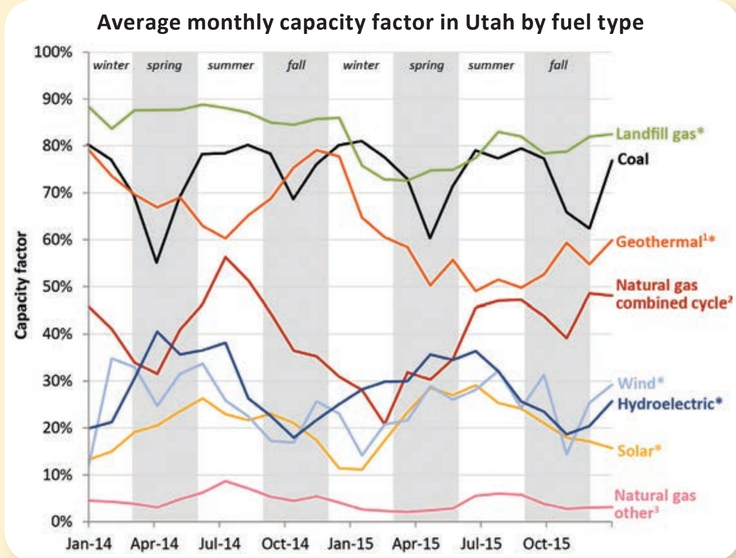
**Classified as a renewable energy source*

[1]Typically geothermal power plants average a CF of near 90 percent, while this is true for the largest and oldest geothermal plant in Utah, PacifiCorp's Blundell plant, the other two smaller geothermal plants, Cove Fort and Thermo, typically average a CF of only 57 percent, dropping the overall average for all geothermal plants in Utah.

[2]Combined cycle steam plant or combined cycle combustion turbine plant. These plants (e.g., Lakeside power plant in Utah County) are typically larger natural gas plants run by major electric utilities (e.g., PacifiCorp).

[3]Combustion gas turbine, steam turbine, or internal combustion engine plants. These plants are usually much smaller and are run by individual municipalities.

The graph to the right displays the average monthly CF for Utah power plants for 2014 and 2015. This graph nicely highlights the seasonal changes in CF depending on the fuel type. For example, base-load coal plants show large dips in generation during the spring and fall when electricity demand for heating and cooling is generally lower. Natural gas plants run at their highest capacity during the summer months to supply needed electricity for air conditioners and run lowest during the winter months. Hydroelectric plants can boost capacity in the spring as snow melts and runoff increases, and solar enjoys an expected increase during the longer summer days. In general, wind capacity is highest in the spring and lower in the late fall to early winter. Geothermal plants are most efficient during the winter months when they can take advantage of greater differences between the hydrothermal water and air temperatures, and are less efficient in the summer months. Geothermal and solar installations are perfect compliments, providing peak energy at opposite times of the year, a situation in which Utah can take full advantage.



In summary, caution needs to be used when speaking about the nameplate capacity of power plants and then comparing these numbers across different fuel types. In reality, 1 MW of coal capacity can generate about three times more electricity than 1 MW of solar capacity. It is still a remarkable achievement for Utah to have nearly 767 MW of new solar capacity, but with only a 20 percent CF, most of that added capacity can never be used. For this reason, it is essential to have a diversified fleet of electric power plants in the state to provide a stable and reliable supply of electricity to all Utah citizens.

For more information on Utah electricity or other energy-related information, refer to the *Utah Energy and Mineral Statistics* website at http://geology.utah.gov/resources/energy/utah-energy-and-mineral-statistics.

TEACHER'S CORNER

Utah Geological Association's 2016 Teacher of the Year

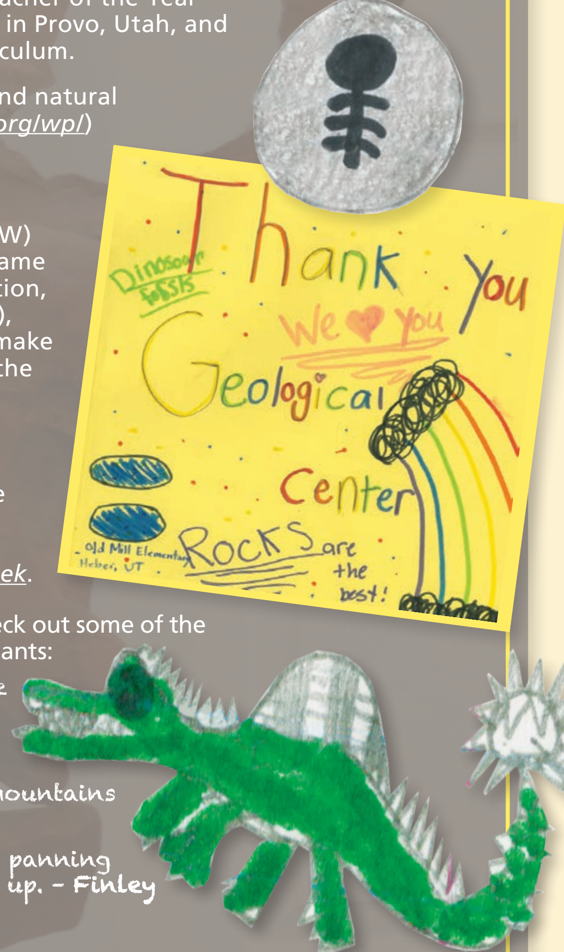
Congratulations to David Black, who received the Utah Geological Association's Teacher of the Year Award for 2016. David is an Earth Science teacher at Walden School of Liberal Arts in Provo, Utah, and was recognized for his development of the innovative "Elements Unearthed" curriculum.

The Teacher of the Year Award is open to all Utah K–12 teachers of earth science and natural resources. See the Utah Geological Association website (http://www.utahgeology.org/wp/) for more information.

Earth Science Week 2016

In October, the Utah Geological Survey held its 15th annual Earth Science Week (ESW) celebration at the Utah Core Research Center. Over 800 students from 11 schools came to learn about geology and paleontology through fun hands-on activities. In addition, 29 volunteers from professional associations, universities (instructors and students), public- and private-sector institutions, and individual geology enthusiasts helped make the week a total success. A great time was had by all! We are truly grateful for all the support and extend a big thank you to our volunteers.

Since its creation in 1998 by the American Geosciences Institute (AGI), ESW has encouraged people everywhere to explore the natural world; promote earth science understanding, application, and relevance in our daily lives; and encourage stewardship of the planet. For more information on ESW, see the AGI web page at www.earthsciweek.org; for information on next year's ESW activities at the Utah Geological Survey, see our web page at geology.utah.gov/teachers/earth-science-week.



If you are not sure whether ESW would be a worthwhile field trip for your students, check out some of the endorsements we received in thank you letters from this year's 4th and 5th grade participants:

- I most of all LOVED touching the real life dinosour bone. P.S. Everyone loved it so much they have been non stop talking about it. – **Josie**
- That feild trip was one of the coolest things I have ever seen. – **Emry**
- I had a lot of fun doing the gold panning and getting to wreck the mountains in the sand. – **Cooper**
- My favorite parts were when we did the sand erosion and how we went panning for minerals. I've actually always wanted to be a geologist when I grow up. – **Finley**
- Thank you for one of the best days of my life. – **Gabe**

GLAD YOU ASKED

YOU HAVE A BOOKSTORE?

IN THE DIGITAL AGE?

BY MARK MILLIGAN

Yes, the Utah Geological Survey (UGS) has a bookstore, the Natural Resources Map & Bookstore in Salt Lake City.

Why does the UGS have a bookstore? State law mandates the UGS to "…prepare, publish, distribute, and sell maps, reports, and bulletins, embodying the work accomplished by the survey…" The Survey was founded in 1949 and originally sold publications from a sales desk in its office, then located on the University of Utah campus. The original "desk top" sales model lasted until 1992, shortly after the Survey moved its headquarters to Foothill Drive. The new offices included a "sales floor" for selling the roughly 1,300 maps, books, pamphlets, brochures, and various other publications the Survey had produced by that time. Shortly after the Survey opened this sales floor, the U.S. Geological Survey (USGS) closed its Salt Lake City sales office and donated its entire inventory of topographic maps and geologic publications to the UGS. The volume of material received was enormous. Just the 7.5-minute quadrangle topographic maps included over 1,500 unique titles and a total inventory numbering in the tens of thousands. Thus the sales floor expanded, additional staff were hired, and the "modern" UGS bookstore was born. In 1996 the Survey, along with the map and bookstore, moved to its current location in the Department of Natural Resources building on North Temple.

The bookstore…can print on demand any of the more than 55,000 topographic maps for the entire United States.

But aren't UGS publications available online? Most of them are. The Survey's publication count now exceeds 2,300. Our publications have gone from print only, to primarily compact disc, to most recently digital files released through our website (see sidebar). Nearly all of our older publications are also available as scanned digital files on our website. Similarly, USGS topographic maps are available digitally from multiple sources online. However, this wealth of online information has not caused our brick and mortar bookstore to perish. Sales decreased with the Great Recession, beginning in 2008, but have slowly increased since 2012. The Natural Resources Map & Bookstore's survival in the digital age appears to be an example of an industry trend. Local, independent bookstores across the country have reported growth for several years, and a February 2016 article in *Publishers Weekly* reports that bookstore sales (including chain stores) rose 2.5 percent in 2015, though this was the first gain since 2007.

Utah Geological Survey publication sales, circa 1964.

UGS Publications on Compact Disc a Thing of the Past

July 2016 brought the end of an era at the Utah Geological Survey, with the discontinuation of UGS publications on compact disc (CD). For about the past 15 years, the CD has been the primary format for UGS publications. During that time, we have also provided our publications free of charge through the UGS website. Now, with the decline in popularity of the CD as a data storage medium, we are focusing our efforts on online publishing.

With few exceptions, all new UGS publications are being released as digital files through our website. The publications can be accessed and downloaded from our new, searchable UGS Publications Database (http://geology.utah.gov/map-pub/publications/). At a customer's request, the UGS can provide the digital publication files on a USB flash drive; this service is available for a nominal fee through the Natural Resources Map & Bookstore. Also, customers can continue to purchase print-on-demand copies of UGS publications through the bookstore.

What is available at the bookstore? The bookstore carries a variety of books, maps, and publications by the UGS and other government entities, as well as private publishers. Specifically, the bookstore:

- Carries or can print on demand any of the UGS's 2,300-plus geologic books, maps, and other publications.
- Sells government publications from other divisions of the Utah Department of Natural Resources, as well as the USGS, Bureau of Land Management, U.S. Forest Service, and other federal agencies.
- Stocks more than 1,500 USGS topographic maps and can print on demand any of the more than 55,000 topographic maps for the entire United States.
- Specializes in books and maps for and about outdoor recreation including hunting, fishing, hiking, off-highway vehicles, rockhounding, and other activities.
- Includes a unique collection of Utah-centric books on history and folklore; birds, flowers, and other flora and fauna; outdoor survival and orienteering; treasure hunting (not limited to rocks and minerals); wild game and outdoor cooking; petroglyphs and associated rock art; and more.
- Prints or photocopies any of the 14,000 items cataloged in the UGS Library (subject to copyright restrictions).
- Sells Utah State Parks annual passes and Utah non-resident off-highway vehicle permits.
- Takes both online and phone-in orders and will ship worldwide.

Why do customers still come in? There are probably as many reasons as there are customers. But here is a short list of some advantages of paper and other reasons to shop at the Natural Resources Map & Bookstore:

- Go Big! Maps printed on a large sheet of paper can be much easier to use. Scrolling around the screen of a portable device or even a desktop computer is cumbersome and literally does not provide a big picture. Most home printers are limited to letter or legal-sized sheets of paper. The bookstore can print up to 36 inches in width and practically unlimited length.
- Research yields some conflicting results, but reading from paper arguably yields better comprehension than reading on a digital device. If nothing else, customers may find it easier to highlight and annotate printed material.
- Desktop computers cannot be used outdoors and not everyone has a portable device.
- Portable devices can be fragile and expensive. Using them in harsh environments while hunting, fishing, or doing fieldwork can damage or destroy them.
- Paper can be easier to read than a screen in the bright light conditions found outside.
- Paper pamphlets can work better than providing an on-screen link for takeaway information at public meetings. For example, customers presenting at neighborhood emergency preparedness fairs often use our informative pamphlets on rockfalls, landslides, earthquakes, and other hazards.
- Some items are not available online. Although nearly all of the bookstore's government publications are digital, many of the recreation and historical books are not.

In addition to stocking over 1,500 shelved topographic maps, the Natural Resources Map & Bookstore can print on demand any of the more than 55,000 topographic maps for the entire United States.

The Natural Resources Map & Bookstore is a place to research your next adventure.

The Natural Resources Map & Bookstore is located in the first floor of the Utah Department of Natural Resources building at 1594 West North Temple, Salt Lake City, Utah, 84116. You can also visit the bookstore online at www.mapstore.utah.gov.

- Browsing! There is still a place for the not yet lost art of perusing spines and thumbing through printed paper books. The store stocks an eclectic collection. Come in and you may find a gem such as *Wanted!: Wanted Posters of the Old West*, which includes posters for "'One Fingered' George, a big, dark complexioned man" who has "pit of back and legs hair, walks very erect," and "is wanted for murder," or "Robert Paul Campbell who has a dimple in chin, soft peculiar voice, and a good set of teeth; takes short steps and lifts feet quickly," and is "wanted for seduction under promise of marriage." Sound intriguing? Come in and see what you can find.

GEOSIGHTS

The Cockscomb and Kaibab Uplift of Southern Utah

BY **Lance Weaver**

Tourists and geologists alike come from all over the world to see and study the magnificent exposures of geologic units displayed in Utah's Colorado Plateau region. Of particular interest is the Grand Staircase, which is an immense sequence of sedimentary rock layers that stretches south from Bryce Canyon National Park and Grand Staircase–Escalante National Monument (GSENM) into Grand Canyon National Park. Some have compared these exposed rock layers to the pages of an open book which invite visitors to look back in time at the geologic history of the area. This is especially true on the edges of massive geologic folds such as the Kaibab uplift, which extends across much of the Grand Staircase area. Where the eastern edge of the Kaibab uplift crosses GSENM, normally flat-lying rock strata tilt abruptly to the east as part of a sharp fold known as the East Kaibab monocline. Erosion of the steeply tilted strata has formed a long, imposing ridge called The Cockscomb—named after the ridge's resemblance to the colorful "comb" on a rooster's head.

The Cockscomb has a long geologic history that can be simplified into three phases. The oldest layers exposed at the base of this unique geologic feature were deposited between about 270 and 185 million years ago in the Permian to Early Jurassic periods. During this time, Utah was situated on the west coast of North America with much of present-day California and Nevada existing as offshore islands. Warm, shallow seas accumulated thick layers of siltstone and limestone which form the cap rock for much of the Kaibab uplift, but represent the lowest exposed layers of The Cockscomb. As North America drifted westward, Utah was uplifted above sea level, transitioning into a terrestrial environment of west-flowing rivers and streams that deposited thick layers of colorful sediments now exposed in the Vermilion and Chocolate Cliffs of The Cockscomb and Grand Staircase (seen best from Stop #1 on the map).

The rocks of the Vermilion Cliffs , as seen on the west side of The Cockscomb from Stop #1, were deposited predominately in rivers, lakes, and streams between 270 and 185 million years ago. Paleogeographic reconstruction modified from UGS Public Information Series 54.

Beginning sometime after 200 million years ago, the rivers, lakes, and streams of the previous phase began to dry out as the climate in Utah transitioned to that of a desert. In this second phase of the region's evolution, sediments deposited by the older river systems were blown into sweeping dune fields up to thousands of feet thick. These dune fields were inundated by a shallow, narrow seaway that provided minerals to cement the sand deposits now known as the Navajo and Entrada Sandstones, which form the impressive White Cliffs of the Grand Staircase and The Cockscomb (best seen from Stop #2 on the map). Other deposits associated with these shallow seas include interbedded limestone, siltstone, and mudstone of the Late Jurassic period.

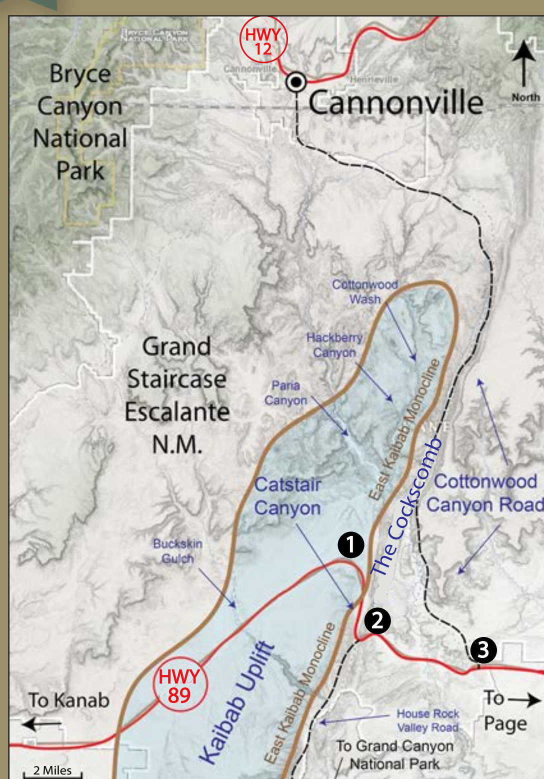
The tilted strata on the east side of The Cockscomb, as seen from Stop #2, were deposited between 200 and 155 million years ago, when much of Utah was a large desert. Paleogeographic reconstruction from UGS Public Information Series 54.

By the beginning of the third phase, in Early Cretaceous time about 145 to 79 million years ago, regional drainage became completely reversed from that of the first phase. Instead of rivers draining westward into the Pacific Ocean, they now drained eastward into a large sea that covered most of eastern Utah and Colorado. Sea level fluctuations in this Cretaceous seaway left thick, alternating layers of sand, mud, and silt. These more dull-colored deposits make up The Cockscomb's iconic layers such as the Dakota Sandstone, Tropic Shale, and Straight Cliffs Formation. These units form the Gray Cliffs and Straight Cliffs of the Grand Staircase and can be seen from Stop #3 on the map or along the east side of the Cottonwood Canyon Road. During the end of the Cretaceous period, the Kaibab uplift and East Kaibab monocline began to take shape due to compressive forces affecting western North America. As this massive fold rose and was eroded by tributaries of the Colorado River, the scenic features of the Grand Staircase such as The Cockscomb and Bryce Canyon, and the Grand Canyon began to form along its tilting periphery.

The dull-gray layers, seen from Stop #3 near the bottom of Cottonwood Wash, were deposited near the shores of a large inland sea which existed in eastern Utah between 145 and 79 million years ago. Paleogeographic reconstruction from UGS Public Information Series 54.

Geologists are not completely sure when the Colorado River drainage took its present shape, but most agree that sometime in the past 65 million years (and possibly as recently as 6 million years ago) rivers started to cut their way across the Kaibab uplift, eventually finding their current outlet into the Gulf of California. Small Colorado River tributaries which slice their way across the seemingly impenetrable cliffs of The Cockscomb include Cottonwood Wash, Hackberry Canyon, Paria Canyon, Catstair Canyon, and Buckskin Gulch. These drainages originate near Bryce Canyon National Park and flow southeast across the northern reaches of the Kaibab uplift, only to join the Colorado River and then turn and recross the southern part of the Kaibab uplift in the Grand Canyon! How these rivers were able to cut their way through the uplift is a subject geologists have been debating for many years. Do the rivers predate the East Kaibab monocline? Did the rivers erode through the uplift after it was fully formed? Either way, these drainages provide important clues to geologists as they attempt to reconstruct the sequence of events that formed the present topography. And The Cockscomb, as an eastern expression of the Kaibab uplift, will continue to attract visitors and geologists from around the world as they not only enjoy its beauty, but use the feature to study the geologic processes that shaped the Grand Staircase.

HOW TO GET THERE



The Cockscomb is most easily viewed from Highway 89, about 38 miles east of Kanab, Utah. Highway 89 cuts through The Cockscomb in Catstair Canyon about halfway between Kanab and Lake Powell. The three stops mentioned in this article are located on Highway 89 at about milepost 17 (Stop #1), milepost 25 (Stop #2), and milepost 30 (Stop #3). For the more adventurous traveler, the entire length of The Cockscomb can be driven using the Cottonwood Canyon Road. **The dirt road is only passable in dry conditions** and can be accessed near milepost 17 on Highway 89, approximately 8 miles east of Catstair Canyon. The Cottonwood Canyon Road is an improved dirt road extending approximately 45 miles from Highway 89 to Cannonville on Highway 12 near Bryce Canyon National Park. Travelers should inquire about road conditions with a GSENM Bureau of Land Management field office before attempting passage on the Cottonwood Canyon Road.

IN MEMORIAM

It is with great sadness that we report the passing of **Dr. M. Lee Allison**, former State Geologist and Director of the Utah Geological Survey (UGS), on August 16, 2016, as a result of a tragic accident at his home in Tucson, Arizona. He was 68.

Photo courtesy of the Arizona Geological Survey

Lee served as the UGS Director from 1989 to 1999, arriving with an impressive educational background (B.A., M.S., and Ph.D. degrees in geology from the University of California [Riverside], San Diego State University, and University of Massachusetts [Amherst], respectively) and extensive experience in petroleum and geothermal geology. During his tenure at the UGS, he took the Survey to new heights. He always instilled his effervescent enthusiasm and endless energy into his work and his staff. Lee placed an increased emphasis on the Oil and Gas Section, but not at the expense of other UGS programs, all of which were expanded during his administration. He pushed for increased funding for many new projects through grants and contracts, often contributing his own geologic knowledge and technical skills to the research. Lee was a national leader in geoinformatics, providing massive amounts of geothermal and other geologic information to industry, academia, and the public. He also greatly enhanced public and industry visibility of the UGS, underscoring its benefits to them and the State as a whole through increased UGS publications, technical and non-technical presentations at various geologic and public meetings, UGS exhibit booths at geologic conventions, and hosting numerous conferences and workshops. To that end, Lee served as the general chair for national conventions of both the Geological Society of America and the American Association of Petroleum Geologists, held in Salt Lake City in 1997 and 1998, respectively, showcasing Utah's great geology. Though sometimes controversial and despite political pressures, Lee always was on the side of science and wanted what was best for the citizens of Utah and the UGS. After departing the UGS, he became Director of the Kansas Geological Survey and then Director of the Arizona Geological Survey in 2005. Lee leaves behind his beloved wife Ann and an amazing legacy of geologic contributions in Utah and elsewhere. He will be missed by all.

2016 Lehi Hintze Award | GENEVIEVE ATWOOD

The Utah Geological Association (UGA) and the Utah Geological Survey (UGS) presented the 2016 Lehi Hintze Award to **Dr. Genevieve Atwood** for her outstanding contributions to Utah geology. Genevieve has devoted her professional life to earth science education by teaching the geography and geology of Utah to teachers, geologists, students, and the general public. She has actively worked to "reach and teach" as many people as possible about the importance of earth science in everyday life. Her distinguished professional career has included many influential positions, including State Geologist and Director of the Utah Geological Survey, member of the Utah House of Representatives, Chief Education Officer of Earth Science Education, adjunct professor of geography at the University of Utah, member and former program chair of the Utah Geological Association, president of the Association of Women Geoscientists, and fellow of the Geological Society of America.

Genevieve was the first woman in the United States to become a State Geologist. She was also the first and only geologist elected to the Utah legislature, where she was instrumental in establishing Utah's mined land reclamation program, Utah's Seismic Safety Advisory Council, Utah's dam safety program, and the State's acquisition of Antelope Island. As Director of the Utah Geological Survey, she lobbied the Utah legislature for funding to establish the Mapping and Geologic Hazards Programs at the UGS, helping to create the diverse agency it is today.

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

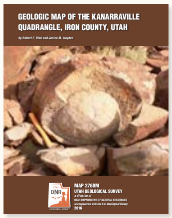
UGS EMPLOYEE NEWS

Former UGS employee **Fitzhugh Davis** (Fitz) passed away on November 5, 2016, at the age of 82. Fitz started at the UGS in 1974 and worked as an engineering geologist, economic geologist, environmental geologist, and mapping geologist. He was the author or co-author of 45 publications about Utah geology. Fitz retired in 1996.

Brittany Dame left the Groundwater and Paleontology Program in August and is now teaching Earth Science at Northwest Middle School in Salt Lake City. We wish her well in her new endeavor.

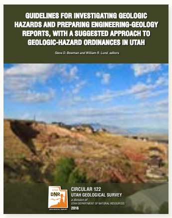
NEW PUBLICATIONS

UGS publications are available for download at geology.utah.gov or for purchase at mapstore.utah.gov.

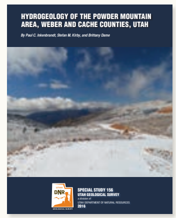


Geologic map of the Kanarraville quadrangle, Iron County, Utah, by Robert F. Biek and Janice M. Hayden, 21 p., 2 pl., GIS data, ISBN 978-1-55791-929-8, scale 1:24,000, **Map 276DM**

Liquefaction hazards in Utah, by Mark Milligan, 4 p., ISBN 978-1-66791-926-7, **Public Information Series 100** Free printed brochure available



Guidelines for investigating geologic hazards and preparing engineering-geology reports, with a suggested approach to geologic-hazard ordinances in Utah, edited by Steve D. Bowman and William R. Lund, 156 p. + appendices, ISBN 978-1-55791-929-8, **Circular 122**



Hydrogeology of the Powder Mountain area, Weber and Cache Counties, Utah, by Paul C. Inkenbrandt, Stefan M. Kirby, and Brittany Dame, 36 p. + appendices, ISBN 978-1-55791-928-1, **Special Study 156**

Aeromagnetic map of northwest Utah and adjacent parts of Nevada and Idaho, by Victoria E. Langenheim, 8 p., 1 pl., ISBN 978-1-55791-931-1, **Miscellaneous Publication 16-4**

Utah's extractive resource industries 2015, by Taylor Boden, Ken Krahulec, Michael Vanden Berg, and Andrew Rupke, 29 p., ISBN 978-1-55791-933-5, **Circular 123**

Assessment of wetland condition and wetland mapping accuracy in Upper Blacks Fork and Smiths Fork, Uinta Mountains, Utah, by Diane Menuz, Ryhan Sempler, and Jennifer Jones, 31 p. + appendices, ISBN 978-1-55791-925-0, **Report of Investigation 274**

Aquifer storage and recovery in Millville, Cache County, Utah, by Paul Inkenbrandt, 44 p. + appendices, **Report of Investigation 275**

Interim geologic map of the east half of the Salina 30' x 60' quadrangle, Emery, Sevier, and Wayne Counties, Utah, by Hellmut H. Doelling and Paul A. Kuehne, 2 pl., GIS data, scale 1:62,500, **Open-File Report 642DM**

Lithofacies, deposition, early diagenesis, and porosity of the Uteland Butte member, Green River Formation, eastern Uinta Basin, Utah and Colorado, by S. Katherine Logan, J. Frederick Sarg, and Michael D. Vanden Berg, 30 p., **Open-File Report 652**

Interim geologic map of the Bicknell quadrangle, Wayne County, Utah, by Robert F. Biek, 18 p., 2 pl., scale 1:24,000, **Open-File Report 654**

Radon hazard potential map of southern Davis County, Utah, by Jessica J. Castleton, Ben A. Erickson, and Emily J. Kleber, I plate, **Open-File Report 655**

Interim geologic map of parts of the Tooele 30' x 60' quadrangle, Tooele, Salt Lake, and Davis Counties, Utah–year 3, by Donald L. Clark, Charles G. Oviatt, and David A. Dinter, 39 p., 1 pl., scale 1:62,500, **Open-File Report 656**

OUTSIDE PUBLICATIONS BY UGS AUTHORS

Birdwell, J., **Vanden Berg, M.D.**, Johnson, R.C., Mercier, T.J., Boehlke, A.R., and Brownfield, M.E., 2016, **Geological, geochemical, and reservoir characterization of the Uteland Butte member of the Green River Formation, Uinta Basin, Utah**, *in* Dolan, M.P., Higley, D.K., and Lillis, P.G., editors, Hydrocarbon Source Rocks in Unconventional Plays, Rocky Mountain Region: Rocky Mountain Association of Geologists.

Vanden Berg, M.D., and Birgenheier, L.P., 2016, **Evaluation of the upper Green River Formation's oil shale resource in the Uinta Basin, Utah**, *in* Spinti, J., and Smith, P., editors, Utah Oil Shale–Science, Technology, and Policy Perspectives: CRC Press/Taylor & Francis Group, p. 59–85.

Mehmani, Y., Burnham, A.K., **Vanden Berg, M.D.**, and Tchelepi, H., 2016, **Quantification of kerogen content from optical photographs**: Fuel 177, p. 63–75.

DuRoss, C.B., Personius, S.F., Crone, A.J., Olig, S.S., **Hylland, M.D., Lund, W.R.**, and Schwartz, D.P., 2016, **Fault segmentation–new concepts from the Wasatch fault zone, Utah, USA**: Journal of Geophysical Research – Solid Earth, v. 121, 27 p., doi: 10.1002/2015JB012519.

Castleton, J.J., Moore, J.R., Aaron, J., Christ, M., and Ivy-Ochs, S., 2016, **Dynamics and legacy of 4.8 ka rock avalanche that dammed Zion Canyon, Utah, USA**: GSA Today, v. 26(6), p. 4–9, doi: 10.1130/GSATG269A.1.

Gwynn, M., Allis, R., Hardwick, C., Hill, J., and Moore, J., 2016, **A new look at the thermal regime around Roosevelt Hot Springs, Utah**: Geothermal Resources Council Transactions, v. 40, p. 551–558.

Kirkland, J.I., Simpson, E.L., **DeBlieux, D.D.**, Madsen, S.K., Bogner, E., and Tibert, N.E., 2016, **Depositional constraints on the Lower Cretaceous Stikes Quarry dinosaur site–upper Yellow Cat Member, Cedar Mountain Formation, Utah**: PALAIOS, v. 31, p. 421–439.

Kirkland, J.I., Suarez, M., Suarez, C., and Hunt-Foster, R., 2016, **The medial Cretaceous in east-central Utah–The Cedar Mountain Formation and its bounding strata**, *in* Kirkland, J.I., Hunt-Foster, R., McDonald, G., Hayden, M., and Sprinkel, D.A., editors, Geology of the Intermountain West–Field Trip Guide: Society of Vertebrate Paleontologists Annual Meeting, October 26–29, 2016, Salt Lake City, Utah, 117 p.

Joyce, W.G., Lyson, T.R., and **Kirkland, J.I.**, 2016, **An early bothremydid (Testudines, Pleurodira) from the Late Cretaceous (Cenomanian) of Utah, North America**: PEERJ, 22 p. doi: 10.7717/peerj.2502

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