UTAH GEOLOGICAL SURVEY

SURVEY NOTES

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New core study unearths insights into Uinta Basin evolution and resources

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Design | Jenny Erickson

Cover | View to the west of Willow Creek core study area. Photo by Ryan Gall.

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DIRECTOR'S PERSPECTIVE

by Bill Keach

As the incoming director for the Utah Geological Survey (UGS), I would like to thank Rick Allis for his guidance and leadership over the past 18 years. In Rick's first "Director's Perspective" he made predictions of "likely hot-button issues" that the UGS would face. These issues included:

- Renewed exploration for oil and gas in the State.
- Renewed interest in more fossil-fuel-fired electricity in Utah, especially from coal.
- Increased demand for groundwater supplies to supplement reservoirs during the summer months.
- Preserving the quality of strategic groundwater supplies by preventing contamination from sources such as agricultural waste, sewage, industrial/mining waste.
- Competing demands for land access.
- Ongoing interest to develop on sites like floodplains, areas having landslide risk, and areas with seismic zoning issues.

Rick was right. Exploration and production of oil and gas have grown but have also had downturns; the Uinta Basin felt the impacts of both. Fossil-fueled electricity generation has shifted from coal to natural gas. In arid western Utah, groundwater continues to be a critical issue, impacting both urban growth and agricultural needs. Different groups vigorously advocate for access rights to public lands, both to allow and limit; the recent reductions to National Monuments underscore this issue. Lastly, forecasts predict Utah will add another 250,000 households by 2025 and developers are looking for places to build.

Looking forward, these issues will continue to be important and new ones may present themselves:

- Where to safely dispose of domestic and industrial waste.
- Renewable energy resources. Utah continues to develop geothermal, solar and wind resources.
- Exploration and development of unconventional resources. Oil shale and sand continue to be a provocative opportunity still searching for an economic threshold.
- Earthquake early warning systems. Can they work on the Wasatch Front?
- Incorporating technology into field mapping and hazard recognition and using data analytics and knowledge sharing in our work at the UGS.

The last item is dear to my heart. A large part of my career has been in the development and promotion of technology to solve complex geological/geophysical problems. Certainly, in my time I have seen a significant shift from qualitative to quantitative geology. Under Rick's direction the UGS made significant strides and it is important that we continue to embrace the shift.

On a personal note: I am married and have four children. After earning a B.S. degree in Geology from Brigham Young University and an M.S. degree in Geophysics from Cornell, I spent more than 5 years working for Sohio/BP in California followed by 17 years with Landmark Graphics (now Halliburton). While there I traveled the world developing 3D visualization technology and adoption. I took a sabbatical in 2006 and returned to Utah to spend time doing research and teaching at both the University of Utah and Brigham Young University. In 2017 I accepted a role with California's Division of Oil, Gas, and Geothermal Resources to evaluate reservoirs and bring technology into the division. I continue to hold an adjunct position with the U. of U. and BYU. One of my favorite roles in academia has been developing and leading field courses in Utah and introducing students and professionals from around the world to the many geologic wonders of this great State.

Today, I am excited to work with the wonderful folks that comprise the UGS, and by extension those agencies we work with. Studying the geologic past and present is a great way to spend the future.

New Core, New Insights into Ancient Lake Uinta Evolution and Uinta Basin Energy Resources

by Ryan Gall

Utah geologists are lucky to have outstanding outcrop exposures in every corner of the state. Our understanding of ancient Utah is built upon these outcrops and geologists from around the globe frequently travel here to study these irreplaceable sources of geologic information. However, outcrops lose some geologic information due to surface weathering that obscures sedimentary features and alters rock chemistry. Fine-grained rocks like claystone are especially prone to poor surface exposure as they break-down quickly and become rooting grounds for modern plants. In contrast, borehole core provides a rare glimpse of strata untouched by surface processes. Cores allow geologists to clearly see sedimentary features like ancient insect burrows and wave ripples in fine-grained rocks that help interpret ancient environments. In addition, cores provide an opportunity to collect geochemical data that can be used to reconstruct paleoenvironments and to characterize petroleum systems.

The Eocene-age Green River Formation in the Uinta Basin of northeastern Utah particularly benefits from core study. The Green River Formation was deposited about 55 to 43 million years ago in ancient Lake Uinta, which had similar characteristics to the modern Great Salt Lake (see *Survey Notes*, v. 46, no. 1, p. 1–3). With abundant fine-grained, organic-rich rocks deposited in the lake, the Green River Formation has gained global attention for its hydrocarbon resources and its paleoclimatic records from the Early Eocene Climatic Optimum (EECO), a period of elevated concentrations of atmospheric greenhouse gases (e.g., carbon dioxide) and extreme global temperatures. In the quest to understand the Eocene environment and better characterize our energy resources, the Utah Geological Survey (UGS) recently partnered with the U.S. Geological Survey (USGS) to drill a new 240-foot-long core from the Uinta Basin—Willow Creek No. 1.

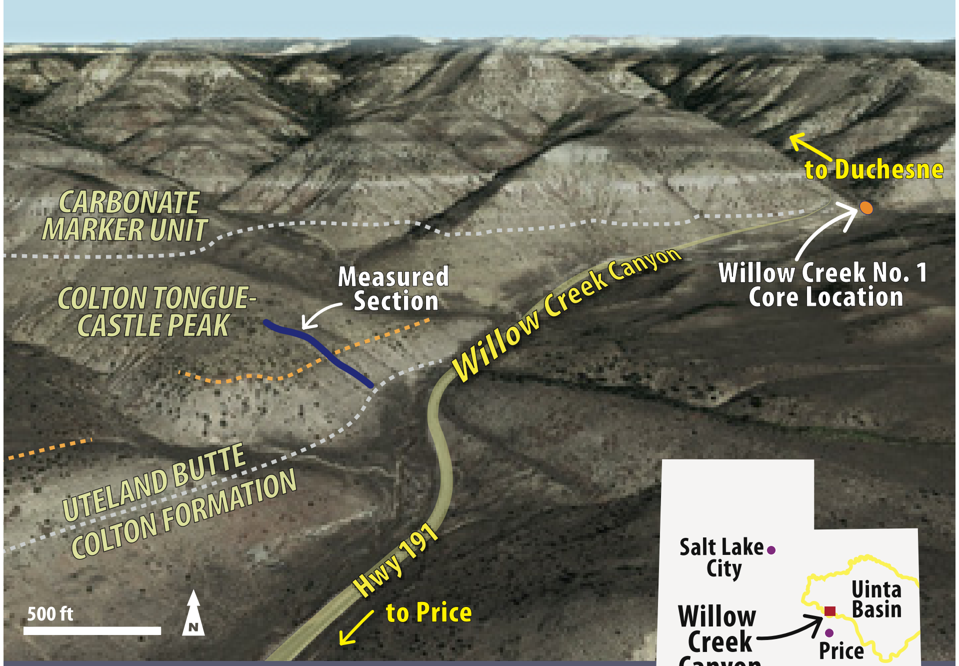
The Willow Creek No. 1 core targets the Uteland Butte member and overlying Colton Tongue–Castle Peak interval of the lowermost Green River Formation. The Uteland Butte is a rising horizontal-well target that has produced over 15 million barrels of oil and over 21 billion cubic feet of natural gas (2010 to present, just from horizontal wells) from a >100-foot-thick interval of interbedded porous dolostone and limestone in the western Uinta Basin (see *Survey Notes*, v. 50, no. 2, p. 1–3). The Uteland Butte rocks represent the first widespread transgression (expansion) of ancient Lake Uinta. The overlying deposits represent a period of Lake Uinta regression (contraction) dominated by expansive river channels and soil development around the perimeter of the basin (Colton Tongue) and deposition of siliciclastic sediment

Willow Creek No. 1 field site (view to the east) with wireline coring rig in Willow Creek Canyon.

(e.g., sand) in the relatively small Lake Uinta (Castle Peak). Since 2015, the Castle Peak interval has also been targeted with horizontal wells (28 at time of writing) and numerous vertical/directional wells.

The southwestern Uinta Basin provides a unique opportunity to study the Uteland Butte and Colton Tongue intervals in outcrop, but several details are missed due to heavy weathering and erosion. To obtain fresh rock material, a coring location was selected one mile from where the outcrop of the target interval dips into the subsurface. The site is in Willow Creek Canyon, 18 miles north of Price on a section of land owned by the Utah School and Institutional Trust Lands Administration (SITLA). This dual outcrop-core study will allow us to fully characterize the broad lateral variation of individual beds visible at the ground surface and use the core to collect geochemical data and make detailed observations. These important tasks will help us understand ancient lake-level fluctuations and aid in predicting future oil and gas development potential.

The core was drilled in mid-August 2018 by a crew from the USGS drilling program. It took only two days to prepare the site and drill 240 feet of core using a wireline coring rig with a special hollow drill bit and a 10-foot core barrel. Upon arrival at the surface, each 10-foot-long core interval was marked with the depth and "up direction" before being packaged for transport to the Utah Core Research Center (UCRC). Once at the UCRC, the core was cut in half—one side will remain in Utah while the other half will be housed at the USGS core facility in Lakewood, Colorado. UGS geologists are currently describing the core inch-by-inch, noting the lithology, sedimentary structures, fossils, and other characteristics. They will also create



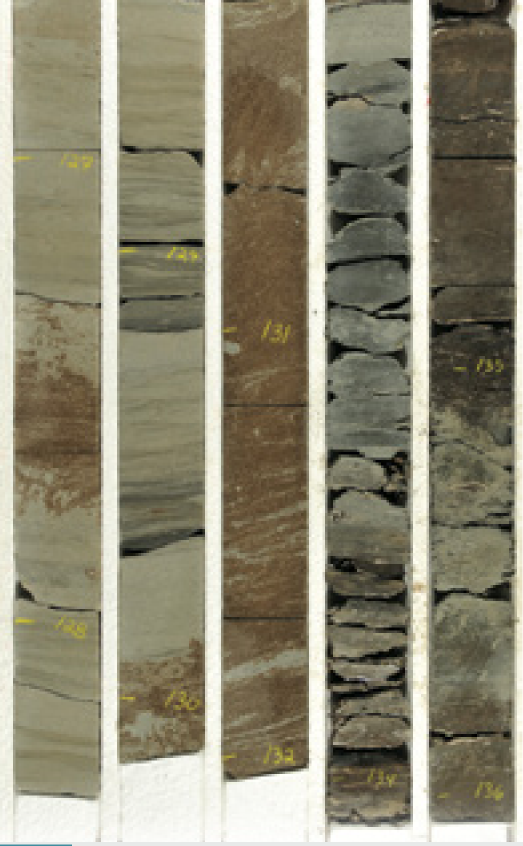
Oblique view of Willow Creek Canyon study area (view north) with overlain stratigraphy, measured section location, and coring location. Satellite images from Google Earth (Landsat/Copernicus 2018; accessed Jan 2019).

thin-section slides of selected zones for microscopic analysis and acquire elemental and mineralogical data. Colleagues at the USGS will collect additional mineralogical data and assess thermal properties of the organic matter.

In addition to studying the new core, UGS geologists measured and described a 360-foot-thick stratigraphic section of the Uteland Butte member and Colton Tongue–Castle Peak interval in Willow Creek Canyon in October 2018. The geologists collected an additional 90 samples from quality outcrop exposures to aid geochemical characterization. Outcrop gamma-ray measurements were also taken every two feet along the measured section. These measurements tell us how the natural radioactivity of the rock varies by layer and is used to tie the outcrop to the gamma-ray log measured in the borehole.

Early observations from core and outcrop show surprising variation in depositional environments over the relatively small study interval. A clear look at the fine-grained rocks, coupled with geochemical analyses, shows that numerable rapid transgressive-regressive lake cycles are the dominant feature of the Uteland Butte and Colton Tongue intervals. These rapid cycles indicate a dynamic hydrologic regime that was incredibly responsive to environmental change and also created the conditions necessary to form dolomite, which acts as a major reservoir for oil and gas deeper in the basin.

Once detailed datasets from the core and outcrop are compiled, UGS geologists can look at basin-scale variation of the lower Green River Formation. This work begins with correlating the wireline logs (gamma, resistivity, porosity, density) collected from Willow Creek No. 1 to the oil and gas well logs and cores (also stored at the UCRC) from the central basin. The correlation will help determine the lateral extent of important strata and how transgressive-regressive cycles are expressed differently near the ancient shore and in the deeper basin. With ongoing collaboration with the USGS, the UGS will also assess the variation of organic maturity to help better understand oil and gas development potential.



This timely core-outcrop study is helping geologists understand some of Utah's most important petroleum resources and the ancient processes that created them. Given the high-quality data acquired from core and a plethora of outcrop exposures, the UGS has great interest in conducting similar studies of additional Uinta Basin strata to gain a deeper understanding of the evolution of lake basins and their resources.

Core-box photo displaying depth-marked and slabbed sandstone with tar accumulation (left, 126.6–132.0 ft) and shallow lake deposits with freshwater bivalves (clams) (right, 132.0–136.0 ft) from the Colton Tongue–Castle Peak interval.

ABOUT THE AUTHOR

Ryan Gall joined the Energy and Minerals Program at the Utah Geological Survey in September 2018. With prior experience in sedimentary-hosted mineral exploration and oil and gas production across the western USA, Ryan now primarily focuses on understanding economically important resources in Utah through detailed study of ancient depositional environments.

Drones for Good: Utah Geologists Take to the Skies

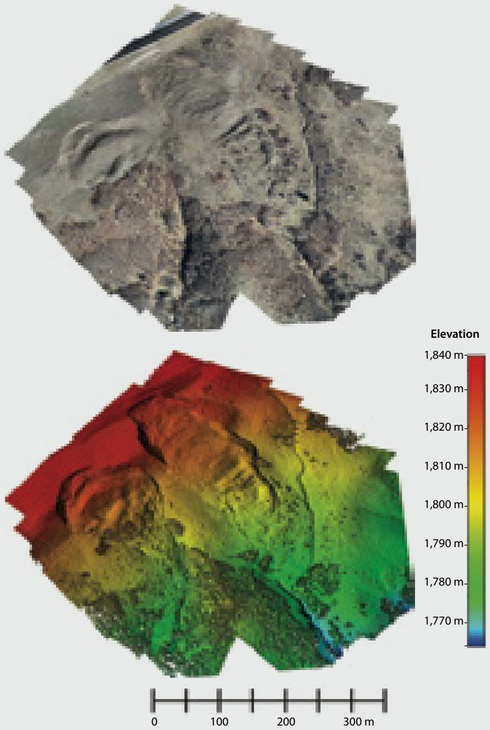
by Christian L. Hardwick

An increasingly used technology tool in many job and research fields is the small unmanned aerial system (sUAS). A sUAS includes the aircraft (drone), the pilot on the ground, and the electronics system (radio, laptop, etc.) that connects them. A sUAS can optimize data collection workflows, lower costs, and reduce risk to staff in hazardous areas. The Utah Geological Survey (UGS) has added a quadcopter sUAS to its tool box to assist geoscientists with fieldwork. This addition is part of the new Department of Natural Resources (DNR) sUAS program which regulates and manages the operation of this modern-age tool among its divisions.

A sUAS can be used for many things including live video streaming during reconnaissance, search and rescue operations, and capturing images used in aerial mapping projects. The rapid data acquisition that a sUAS provides allows us to more easily survey large areas and to carry out repeat measurements where long-term monitoring is needed. The collection of high-resolution photographs allows us to create detailed orthomosaic maps (several images stitched together) that can aid in the identification of features that may be undiscovered by crews on the ground or unresolved by high-altitude surveys. When photographs are acquired appropriately during the survey, they can be used to create three-dimensional (3D) models of the study area, allowing us to better understand both geologic and man-made structures as well as the geometry of the land. Thermal imaging sensors can also be used with sUAS to help locate thermal anomalies in potential geothermal areas, locate vegetation lineaments that could indicate subsurface features such as faults, and identify hidden water features in hydrogeologic studies.

HENRY, the UGS sUAS quadcopter. Specifications and features of HENRY include a 20-megapixel camera, 20-minute average flight time per battery in planned missions, 5-direction obstacle avoidance, maximum speed of 45 MPH, and a maximum range of 7 km (4.2 miles).

The UGS has used sUAS in several projects over the past year. Near Lakeside, Utah, high-resolution orthomosaic maps were created and are being used for detailed mapping of lacustrine facies (rocks formed in a lake setting) along the west shore of Great Salt Lake, an area with abundant microbialites (remnants of microbial communities) as well as large-scale travertine and tufa mounds. In Mona, Utah, a high-resolution orthomosaic map in conjunction with a 3D model was used to generate a bathymetry map of Mona Reservoir to investigate relationships between the water level and amount of water in the reservoir. The active Waste Dump landslide along Utah Highway 167 was surveyed to create a 3D model which will assist in the long-term monitoring of the landslide as well as help characterize landslide movement.



Waste Dump landslide aerial survey ortho-mosaic and 3D terrain model. Survey details include 25 minutes of flight time, 481 photos acquired, and 2 hours of computer processing.

Each of these examples presented logistical challenges whether it was the sheer size of the study area, poor access/ground conditions, hazardous environments for staff, or perhaps all the above. The sUAS has become an especially vital tool for geologic hazard analysis. Flights over active landslides enable better mapping and provide safer conditions for geologists studying the event. With the sUAS rapid deployment and processing, the system can provide a timeline of change for landslides as they grow and evolve, providing crucial data for those making public safety decisions. Additional mapping of other hazards, such as fault lines, rockfalls, fissures, and flooding can also benefit from sUAS applications.

The new sUAS is helping the UGS expand its field-data acquisition capabilities. Traditional field-mapping methods are improved by increasing field efficiency, staff safety, and expanding coverage to areas that may have been left out previously due to access, budget and/or time constraints.

Utah Mining Districts at Your Fingertips

by Ken Krahulec

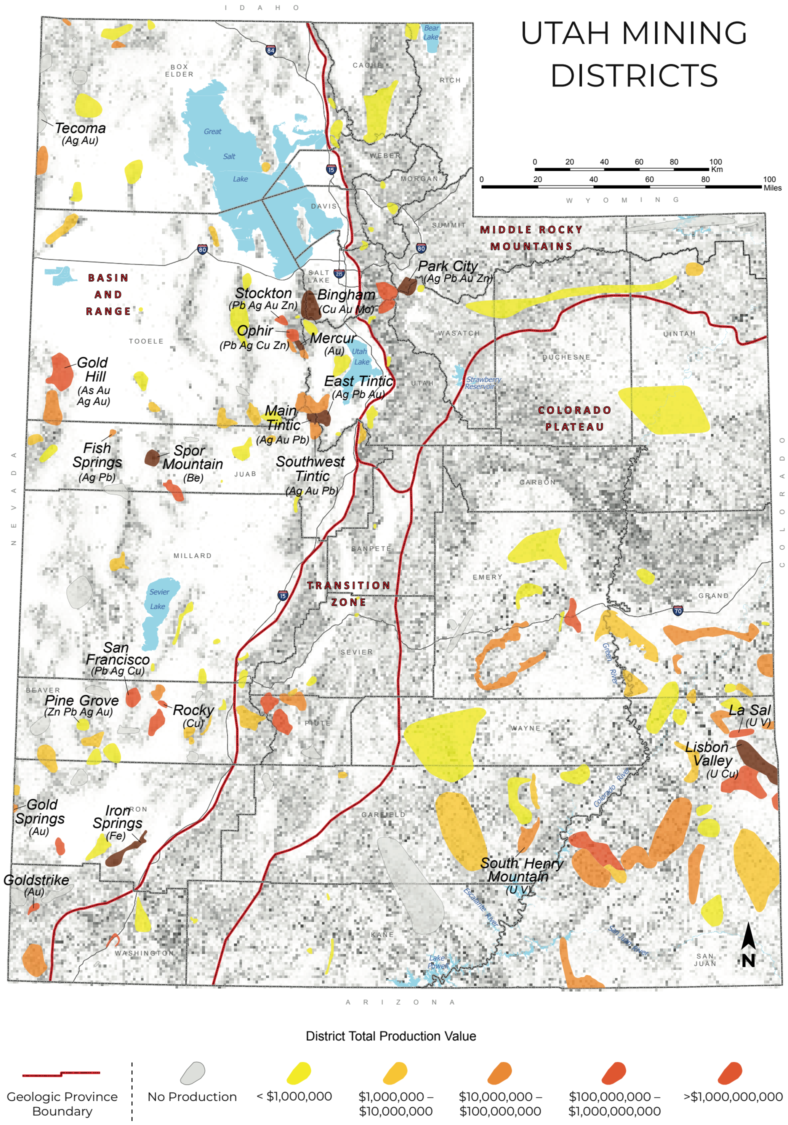
New Utah Geological Survey Products

The Utah Geological Survey (UGS) has produced two new up-to-date, web-available products on the mining districts of Utah. The first is an interactive web page (https://geology.utah.gov/apps/blm_mineral/) that allows you to explore Utah's 185 mining districts and learn about the metallic resources of each district, what metals were produced, when the district produced, and the estimated total production value of each district based on recent average metal prices. A particularly useful component to this interactive map is a one-page summary of each district that includes information on history, metals produced, production significance, most important mines, recognized ore deposit types, and geological setting. The summaries also provide a few key references to get the interested reader started on researching more detailed information about the district's geology and ore deposits. The U.S. Bureau of Land Management helped fund the development of this web page.

The second new product is UGS Open-File Report 695 (https://ugspub.nr.utah.gov/publications/open_file_reports/ofr-695.pdf) which has all 185 one-page mining district summaries along with introductory information and an overview of the importance of Utah's metal production. A 1:1,000,000-scale map of Utah displays all the mining districts and represents the first update to the Utah mining district map since 1983. On the map, each district is color-coded to the total district production value, ranging from zero to greater than $1 billion, and labeled with the district name and primary mineral commodities produced. Appendices list the 38 ore deposit types recognized in the state, chemical formulas of over 200 minerals found in Utah, and abbreviations for the chemical elements used in the text.

The Utah mining districts report includes some interesting findings and statistical information:

- Utah is the third largest metal producing state in the U.S., behind Arizona and Nevada, in terms of total historical production.
- For the major base and precious metals, Utah ranks second in the U.S. in the historical production of copper and silver, third in lead, fifth in gold, and ninth in zinc.
- Historically, Utah is the largest beryllium and magnesium producing state in the U.S., as well as second largest vanadium, third largest molybdenum and uranium, and fourth largest iron producer.
- Utah's total historical metal production value, at recent estimated metal prices, is approximately $217 billion.
- Utah's most valuable metals in decreasing order of importance are copper, gold, molybdenum, silver, lead, iron, zinc, uranium, beryllium, vanadium, manganese, and tungsten.



Utah Mining Summary

The Bingham mining district in the Oquirrh Mountains of southwestern Salt Lake County is, by far, Utah's most significant mining district. The Bingham Canyon open-pit mine is recognized as the first open-pit porphyry copper mine in the world, and porphyry copper mines are currently the world's most important copper producers. Bingham is also the most productive mining district in the U.S. The district has sustained production for over 150 years, and Bingham's total historical production value is approximately $174 billion and accounts for about 80 percent of Utah's total historical production value.

The other most productive Utah districts that have over $1 billion of metal production at current metal prices include Park City (2), Main Tintic (3), Iron Springs (4), East Tintic (5), Mercur (6), Spor Mountain (7), and Lisbon Valley (8). Rounding out the top 10 but with less than $1 billion in production value are the San Francisco (9) and Ophir (10) districts.

Currently, the Bingham, Spor Mountain, Lisbon Valley, and Rocky districts all have mines in production. In addition, districts having significant ore reserves or subeconomic resources include the Bingham, Southwest Tintic, Pine Grove, Spor Mountain, Stockton, Iron Springs, Goldstrike, Tecoma, Gold Springs, Fish Springs, East Tintic, Rocky, Lisbon Valley, La Sal, and South Henry Mountain districts. Furthermore, Bingham, Goldstrike, Gold Springs, Rocky, San Francisco, Fish Springs, Southwest Tintic, and Gold Hill all have ongoing mineral exploration programs.

Another significant fact about Utah mining is that the Spor Mountain district in Juab County currently accounts for about 70 percent of the world's beryllium production, as it has for the past three or four decades. This fact is particularly notable because beryllium is on the U.S. Department of the Interior's list of 35 mineral commodities (released in May 2018) deemed critical to the U.S.

Other metals found in Utah on the Interior's critical minerals list include rhenium, platinum, palladium, uranium, and vanadium. Bingham is the U.S.'s second largest producer of rhenium and also produces minor amounts of platinum and palladium. Utah has historically been an important producer of uranium and vanadium from sandstone-hosted deposits on the Colorado Plateau in southeastern Utah; however, these operations are currently on standby due to low prices. Recent increases in vanadium prices due to rapidly rising demand may change this situation.

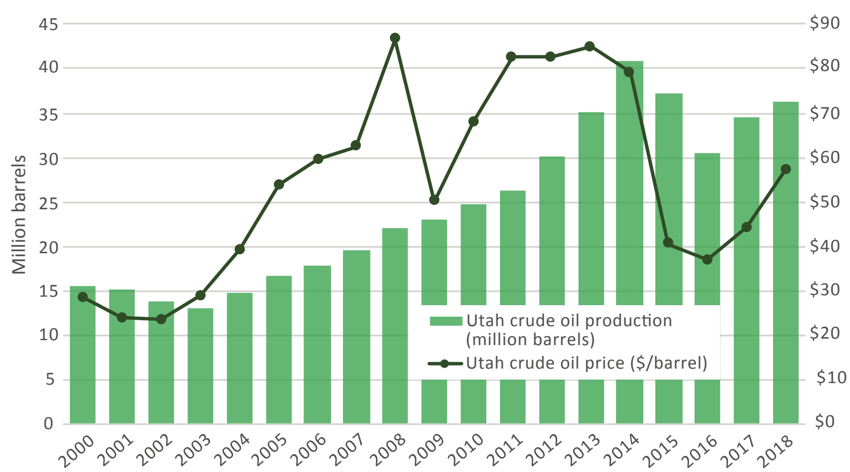
As this summary suggests, Utah's metallic deposits and mining history are significant. Given the importance of metals in our modern society and the reserves and resources available in the state, metallic mining should continue to be an important contributor to the Utah economy, potentially including future opportunities for rural Utah communities. Our hope is that the new interactive web page and open-file report will prove useful as up-to-date, accessible, and user-friendly introductions and guides to metallic ore deposits of Utah for public, industry, and government users.

ENERGY NEWS

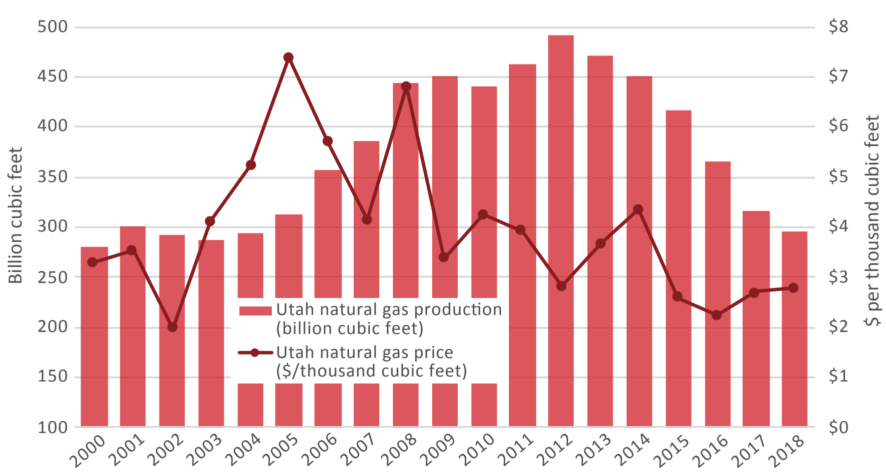
The Benefits of Oil and Gas Production to the State of Utah and Its Citizens—How Things Work!

by Thomas C. Chidsey, Jr.

Over the past decade, Utah has consistently ranked about 10th and 13th in domestic oil and gas production, respectively, in spite of the price collapses that began in 2014. In 2018, over 36 million barrels of oil and 295 billion cubic feet of gas was produced from more than 11,000 wells in Utah. Revenue to Utah and its citizens from oil and gas production varies depending on market prices, land ownership, and the amount produced. A decrease in prices results in less drilling activity and thus a decrease in production. In addition, as oil and gas fields mature, production naturally decreases along with revenue.



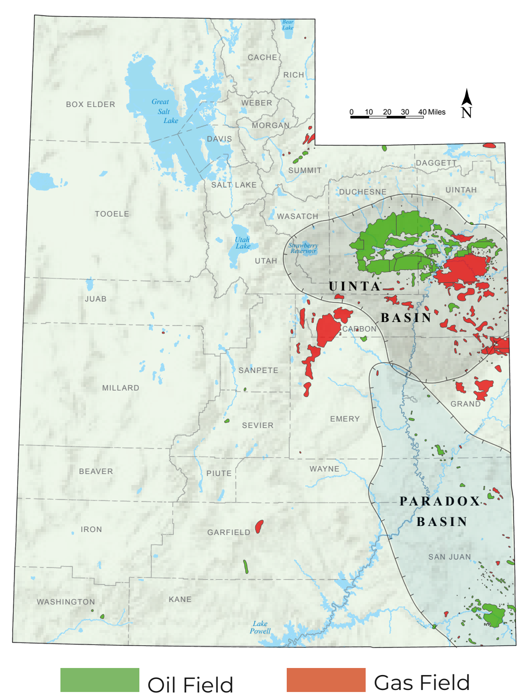
Utah oil production and prices, 2000–2018. Data from U.S. Energy Information Administration; Utah Division of Oil, Gas and Mining.



Utah gas production and prices, 2000–2018. Data from U.S. Energy Information Administration; Utah Division of Oil, Gas and Mining.

Land Ownership

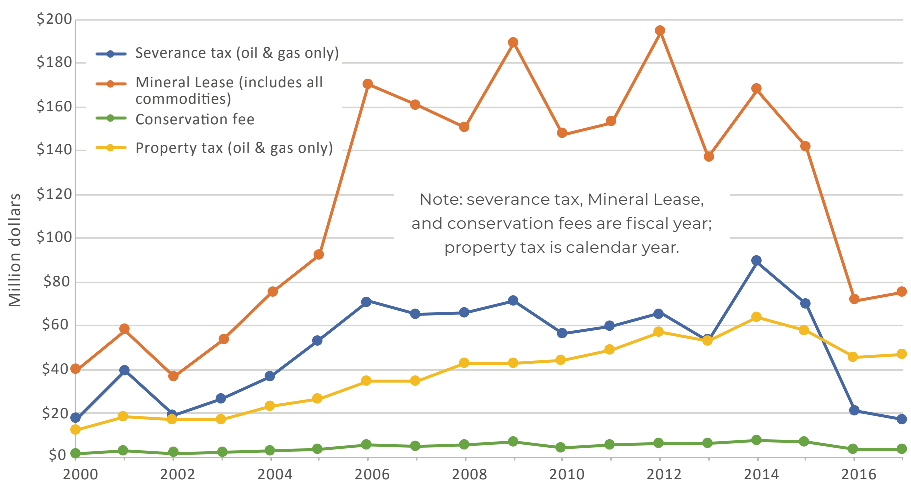
About two-thirds (67 percent) of the lands in Utah are owned by the federal government including National Parks, National Monuments, National Recreation Areas, National Historical Sites, National Forests, Military Reservations, and the Bureau of Land Management (BLM). Other lands in Utah are owned by Native American tribes, the State (including State Parks, Sovereign Lands [the beds of major waterways and lakes, for example the Green and Colorado Rivers, and Great Salt Lake], and School Trust Lands), and private entities (ranches, farms, etc.). The School and Institutional Trust Lands Administration (SITLA) is an independent state agency that manages 4.5 million acres of Utah lands, of which over 1 million acres are currently leased for oil and gas exploration for the exclusive benefit of Utah's schools and 11 other beneficiaries. Most of Utah's oil and gas production comes from BLM and tribal lands in the Uinta and Paradox Basins of eastern and southeastern Utah, respectively.



Oil and gas fields map of Utah.

Oil and Gas Royalties

Oil and gas royalties are the cash value paid by a lessee (usually an oil company) to a lessor (the landowner or whoever has acquired possession of the royalty rights) based on a percentage of gross production from the property, free and clear of all costs. Currently, the federal government charges a royalty of 12.5 to 19.6 percent for oil and 9.2 to 12.5 percent for gas extracted from public lands (based on the composition, quality, etc. of the produced crude oil and gas); some royalty agreements with other landowners may be as high as 25 percent. After an oil company discovers oil or gas on federal (or state or private) lands, subsequent wells are drilled to develop and produce the resource. Once production starts, royalties begin to be paid to the landowner(s). For example, if a new well produces 100 barrels of oil per day, and the current market price is $50 per barrel that particular month, then the cash flow would be 100 x $50 or $5,000 per day. The landowner (such as the BLM), who requires a 12.5 percent royalty payment on that production, would receive $625 per day ($5,000 x 0.125).



Tax collections on oil and gas production and activities in Utah, and total Mineral Lease disbursements, 2000–2017. Data from Utah State Tax Commission.

A question often asked: "Does Utah and its citizens get anything out of oil and gas production on federal lands?" The answer is an emphatic yes! Forty-two to forty-five percent of the royalty payment from oil and gas production (as well as coal, industrial minerals, gilsonite, geothermal, etc.) on federal lands comprise what are called Mineral Lease disbursements and are divided up among several state agencies and counties. For example, the Utah Department of Transportation receives 40 percent of the royalty, a number of counties split 32 percent, and the rest goes to other state entities including the Utah Geological Survey (UGS). In the example discussed above, Utah would receive $262.50 (42 percent) per day from that one hypothetical well. As total oil and gas production and prices fluctuate, so does the royalty revenue to Utah, ranging from as much as $155 million when oil was over $112 per barrel in 2011 to $64 million when oil dropped to a low of $29 per barrel in 2016. The UGS receives 2.25 percent of the state's part of this payment, which amounts to one-fifth (20 percent) of the UGS's annual budget and thus is a critical source of funding that is often difficult to predict. Utah schools received about $28.7 million from oil and gas activities on SITLA lands for the 2018 fiscal year. Like many states, Utah also charges a severance tax (3 to 5 percent; $9 million in 2017) and a conservation fee (0.2 percent; $3.3 million in 2017) based on the value of the oil and gas produced and saved, sold, or transported from the field where it is produced. Finally, Utah charges property taxes on oil and gas facilities; this amounted to $47 million in 2017.

Some may remember the old 1960s TV comedy *The Beverly Hillbillies*. Royalty payments turned the poor mountaineer, Jed Clampett, into a millionaire when "black gold" was discovered on his land! In reality, royalty payments to private landowners can be very large or very small and especially complicated. The mineral rights under a ranch or farm, for example, may be divided up (and not always equally) among multiple family members or heirs several generations removed from the property; all are entitled to monthly royalty checks. Wells may produce for 30 years or longer. In addition, many old oil wells are often classified as stripper wells, producing 15 barrels or less per day. Yet royalty payments will continue to be paid to those owners as long as the wells produce. Ten barrels per day x $50 per barrel x 12.5 percent royalty = $62.50 per day. Divide that up among perhaps dozens of people entitled to a share of the royalty and few will be moving to Beverly Hills. Throw in the variations in oil and gas prices as well as changes in production, and oil companies often have to employ large numbers of accountants to handle the monthly royalty payments from hundreds of wells.

Leasing and Subsurface Mineral Rights

Before an oil company drills a well, it must first lease the land from the owner of the subsurface mineral rights. Leasing is usually done after extensive geologic, geophysical, and economic evaluations of an area—subsurface mapping, acquiring seismic data, analyzing cores and well logs, determining the hydrocarbon source and reservoir rocks, estimating dry hole risks and resource potential, and the costs associated with its development (exploration programs, drilling, production wells, and infrastructure such as pipelines). Acquired leases owned by the federal and state government are often obtained through a bidding process. The price per acre varies from less than $10 to $1,000s depending on whether or not the land is within a relatively inactive area, a “hot” new exploration play, or if oil and gas prices are high or low; these monies are also a source of revenue for the federal and state governments. The company may hold on to the lease anywhere from three to ten years after which it goes back to the landowner and can be offered again to interested companies. If production is achieved, the company retains the lease as long as their wells produce (referred to as a lease “held by production,” i.e., HBP). Companies usually try to acquire large blocks of leased acreage to cover their drilling prospects although some pick up small leases just to be “part of the action.” Finally, companies sometimes reduce their risk by forming units or “farming out” a share of their leases and drilling costs with other companies while retaining an interest in any production that may occur.

Private landowners lease the mineral right under their lands differently than the federal and state governments. Typically, landowners are approached by the oil company or its hired representative, called a landman, who may make a monetary offer, called a “Bonus,” to lease the mineral rights. The price per acre and duration of the lease are usually similar to those owned by the state and federal government; however, small leases may receive smaller offers because companies usually try to tie up larger lease blocks of acreage. As is most often the case, oil and gas are not found under a property, and the only money that the landowner receives will be that from leasing the mineral rights. If oil or gas is discovered under a lease, even a small one, the mineral owner is still entitled to their proportional share (royalty) of the estimated resource being “drained” un-

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Glad You Asked!

What are Those Blue Ponds Near Moab?

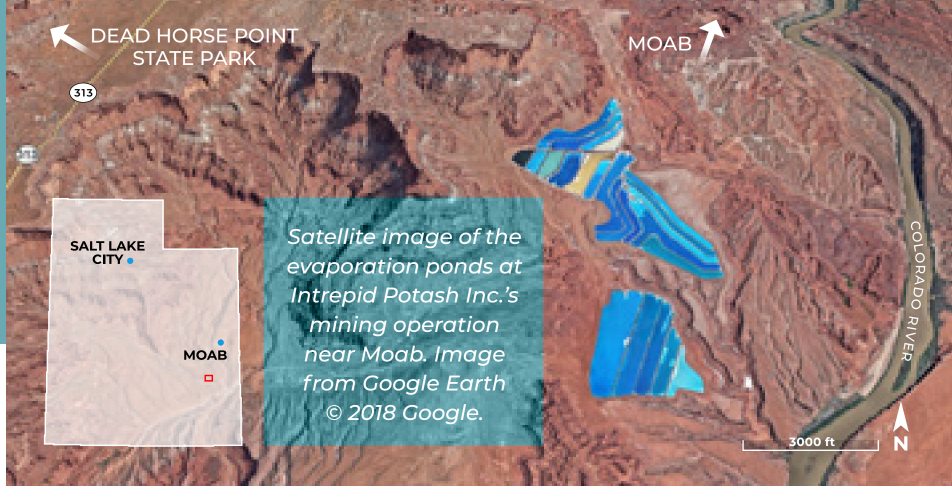
by Stephanie Carney

If you have ever visited Dead Horse Point State Park, you may have noticed bright blue ponds glistening off to the east. These are not a mirage but are solar evaporation ponds used in the process of mining potash. The mine is currently owned and operated by Intrepid Potash Inc., and the ponds cover about 400 acres of land 20 miles southwest of Moab.

Potash, a water-soluble potassium salt, is solution mined from the Paradox Formation more than 3,000 feet below the ground. Water from the Colorado River is injected down through a well into the potash-bearing strata, where it dissolves the salts. The resulting brine is extracted from a different well and pumped into the evaporation ponds. Blue dye is added to the water to enhance evaporation. The dye increases the absorption of sunlight and therefore increases the rate of evaporation. As evaporation progresses, the ponds become shallower and turn shades of light blue while the potash precipitates out of solution and is deposited on the bottom of the pond. The ponds turn a tannish brown color when nearly all the water has evaporated and the potash is ready to be harvested.

“Potash” is a general term that refers to a variety of potassium salts, such as potassium chloride (KCl), that are mainly used in fertilizer products, but also in the production of soap, glass, ceramics, and batteries. Historically, the term refers to potassium carbonate (KCO_3), which is obtained by combining ash from burned plant material (usually hardwood trees) with water in large iron pots. Through evaporating and leaching of the “pot ash,” a residue of potassium carbonate is left behind that historically was used in the process of making soap or glass and ceramic products as early as A.D. 500. In North America in the 17th and 18th centuries, potash became an important industrial chemical and agricultural commodity. Large asheries were built to process the timber cleared and burned by settlers as they expanded westward across the U.S. By the mid-19th century, however, asheries became obsolete after a large deposit of natural potash was discovered in Germany and the birth of potash mining began. Natural potash deposits occur all over the world, but the largest reserves are in Canada. Other significant deposits are in Russia, Belarus, China, Israel, Jordan, and the U.S.

Sylvite from Intrepid's potash mine, Moab, Utah.

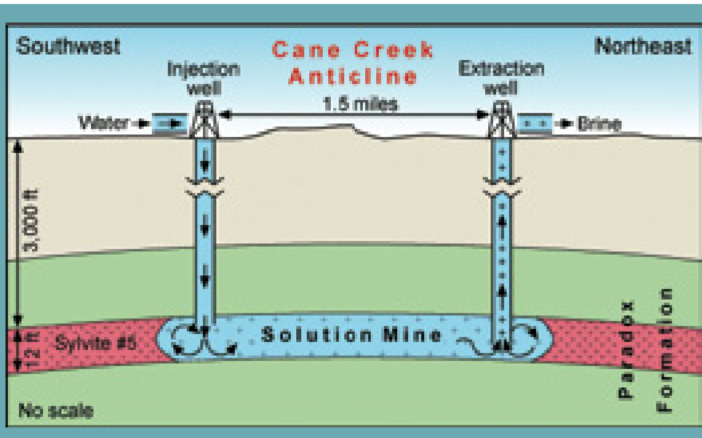


Satellite image of the evaporation ponds at Intrepid Potash Inc.'s mining operation near Moab. Image from Google Earth © 2018 Google.

Paleogeographic map of Utah during the Pennsylvanian period, approximately 308 million years ago, showing the Paradox Basin as an embayment to a western ocean (map modified from Ancient Landscapes of the Colorado Plateau *by Ron Blakey and Wayne Ranney).*

The potash mined near Moab is from the Pennsylvanian-age Paradox Formation, which was deposited between 315 and 310 million years ago in the Paradox Basin. During the Pennsylvanian period, the basin was an embayment to a large ocean and experienced cycles of open-marine conditions with freely circulating ocean water and restricted-marine conditions where access to the open ocean was blocked. During open-marine conditions, layers of shale, siltstone, limestone, and dolomite were deposited. When the basin was closed, the hot and dry climate during this time led to high rates of evaporation, and layers of salt were deposited. The salt is mostly halite ($NaCl$), but layers of sylvite (KCl) and carnallite ($KMgCl_3{\cdot}6H_2O$) were also deposited. Geologists have identified at least 29 cycles in the Paradox Formation, each represented by a specific sequence of sedimentary and evaporite rock layers, though only 18 cycles are known to contain potash minerals and only a few of those may have economically viable deposits. Individual salt deposits can be up to 1,000 feet thick in some places in the basin. Under the pressure of overlying strata, salt becomes ductile and because it is less dense than other rocks, it moves upward creating folds and diapirs. The Cane Creek anticline, in which the Intrepid potash mine is located, is a large, broad fold created by salt moving upward and bowing the rock layers above it. The potash mined by Intrepid is from Paradox Formation salt cycles number 5 and 9, which occur near the top of the formation. The salt is about 200 feet thick in cycle 5 and about 150 feet thick in cycle 9. The mined potash zone within each cycle, however, is much thinner, typically less than 10 feet thick.

Though the cyclic deposits of the Paradox Formation were discovered in the 1920s, it was not until the mid-1950s during exploration for oil and natural gas that a potential economic potash resource was discovered within the Cane Creek anticline. By the early 1960s, the Texas Gulf Sulfur Company had built an underground mine and began room-and-pillar mining the potash from cycle number 5. Before operations began in 1964, however, an explosion of methane gas trapped 23 men, 18 of which were killed, during construction of the mine.



Schematic diagram of solution mining at Intrepid Potash Inc.'s Moab operation.

Because of hazardous gas pockets, high mine temperatures, and the thin, contorted, and difficult-to-mine potash layer, the operation was converted to solution mining in 1970.

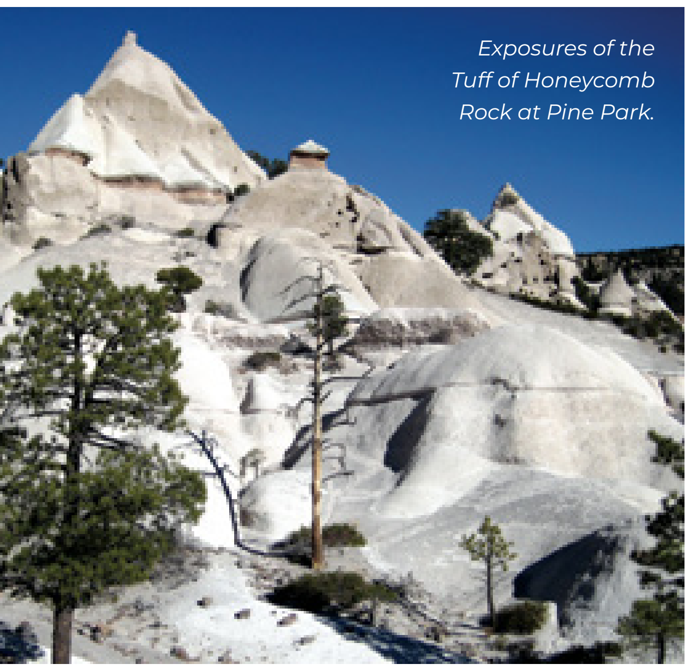
The U.S. Geological Survey estimates that the Paradox Basin contains around 2 billion tons of potash resource, though depth to the resource (more than 5,000 feet in some areas) and complex geology have made exploration for economic deposits challenging. The current market price for potassium chloride, the most commonly produced form of potash, is about $200 per short ton, but price has been quite variable in the last decade. Intrepid's capacity is about 100,000 short tons per year of potassium chloride, from their Moab operation, which is the only potash mine in the basin. Intrepid's Moab operation along with two other operations in other parts of Utah (see *Survey Notes*, v. 44, no. 3, p. 1-3) produced 444,000 short tons of potash in 2017 (which includes both potassium chloride and potassium sulfate), the value of which was approximately $210 million. Utah and New Mexico are the only two states that currently produce potash. Because potassium is an essential nutrient for life and there is no substitute, potash mining in Utah likely has a bright and long future.

GeoSights

Pine Park and the Ancient Supervolcanoes of Southwestern Utah

by Lance Weaver

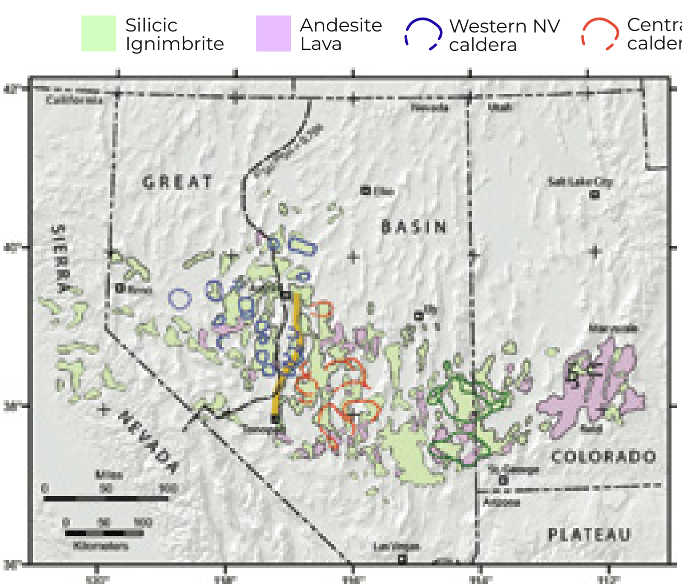
Hidden in a remote corner of Washington County is a fascinating place nearly forgotten among the other attractions of southern Utah. The scenic Pine Park area exposes intriguing volcanic deposits that reveal the story of the largest volcanic eruptions in Utah's geologic history. Although the beautiful exposures outcrop in only a small area, the eruptions that produced the volcanic deposits in this part of Utah were some of the largest in Earth's history.



Exposures of the Tuff of Honeycomb Rock at Pine Park.

Pine Park is located approximately 20 miles (32 km) southwest of Enterprise in the southwest corner of Utah. It is one of several attractions located on the upper Beaver Dam Wash. The region supports a high-desert forest of juniper, pinyon, and large ponderosa pine trees, which thrive in the well-drained volcanic soils. The main attractions in Pine Park are bright white volcanic ash-flow tuff exposures that form a landscape of hoodoos, pyramid- and mushroom-shaped domes, and undulating slickrock basins. Many of these vistas resemble the hoodoos and knobs of the better-known Goblin Valley State Park of central Utah, or the Toadstools area near Lake Powell's Wahweap Bay. However, instead of the familiar sandstone and claystone of Utah's Colorado Plateau, these spires have eroded from thick deposits of white volcanic ash-flow tuff known as the Tuff of Honeycomb Rock. An ash-flow tuff is a type of rock made of volcanic ash, rock, and gases derived from explosive volcanic eruptions.

A few miles to the west down Pine Park Canyon, at Beaver Dam State Park in Nevada, the same types of ash-flow tuff deposits create scenic vistas like those of Pine Park. These two attractions showcase just a small piece of the voluminous ash-flow tuff deposits that blanket the region. Called "supervolcanoes" or "super-eruptions" because of their immense size, these types of eruptions tend to leave behind massive, often miles-wide, craters called calderas instead of the typical pyramid-shaped cones of stratovolcanoes. A caldera's large, cauldron-like hollow or valley forms after magma erupts and the ground surface above the magma chamber collapses.



Miocene- to Oligocene-age (12 to 36 million years ago) supervolcanoes, caldera complexes, and volcanic deposits, which stretch from south-central and western Utah through Nevada and eastern California. From Best and others, 2013, Geosphere article: https://doi.org/10.1130/GES00945.1

Pine Park lies at the edge of the ancient Pine Park caldera—one of dozens of calderas spanning from southwestern Utah, across central Nevada, to the border of eastern California. These supervolcanoes were active between 12 and 36 million years ago, when Utah was home to rhinoceros, camels, tortoises, and palm trees. Although the Tuff of Honeycomb Rock that outcrops at Pine Park is locally derived from a smaller ancient caldera, many of the ash-flow tuffs in the area are derived from the nearby Indian Peak–Caliente caldera complex, formed by some of the largest ancient super-eruptions in North America. Geologists have found deposits 2.5 miles

(4 km) thick that are believed to have come from a single incredible eruption from the Indian Peak–Caliente caldera complex 30 million years ago. Over 1,300 cubic miles (5,400 km³) of volcanic materials have been found from this eruption spanning from central Utah to central Nevada and from Fillmore, Utah, on the north to Cedar City, Utah, on the south—over 1,000 times the volume of material ejected during the 1980 Mount St. Helens eruption (about 1 cubic mile [4 km³]). And this caldera was only one of up to 20 calderas in the region.

Since the eruption of the volcanoes that created the deposits of Pine Park, extension of the Earth's crust across the Basin and Range Province has torn apart much of western Utah and has vastly altered the landscape and drainages. Without geologists studying the thick volcanic deposits such as those exposed at Pine Park, people may have never known the extent to which ancient volcanoes altered the landscape of this part of southern Utah.

HOW TO GET THERE:

To get to Pine Park, head west on Main Street from the town of Enterprise, Utah, toward Panaca on State Route 219. Continue past the signs pointing to Enterprise Reservoir. After a few miles the paved road will transition to a nicely graded dirt road. After driving 12.6 miles from Enterprise, take a left on Forest Service Road 001 (White Rocks Road) and continue west-southwest 9.5 miles. Along the last mile, the road becomes rougher and turns sharply to the southeast and snakes its way down into the valley. The road ends at a creek and primitive campsite. There are no bathroom or potable water facilities.

GPS Coordinates: 37° 31' 19.4" N 114° 01' 22.5" W

Teacher's Corner

EARTH SCIENCE WEEK: October 7–10, 2019

Hands-on Activities for School Groups

Come celebrate Earth Science Week with the Utah Geological Survey! This popular annual event features educational activities that are particularly suited for the 4th and 5th grades, where earth science concepts are taught as outlined in the Utah Science Core Curriculum standards. Earth Science Week activities take place at the Utah Core Research Center in Salt Lake City and include panning for "gold," identifying rocks and minerals, experimenting with erosion and deposition on a stream table, and examining dinosaur bones and other fossils.

Groups are scheduled for 1½-hour sessions. Reservations typically fill early; to inquire about an available time slot for your group, contact Jim Davis at 801-537-3300.

Launched by the American Geosciences Institute (AGI) in 1998, Earth Science Week is an international event highlighting the vital role earth sciences play in society's use of natural resources and interaction with the environment.

For more information, please visit our web page at https://geology.utah.gov/teachers/earth-science-week/.

SURVEY NEWS

Left to right: Department of Natural Resources Executive Director Mike Styler, Hellmut Doelling, Geologic Mapping Program Manager Grant Willis, Lt. Governor Spencer J. Cox.

DISTINGUISHED SERVICE AWARD

In December 2018 **Hellmut Doelling** was presented with the Governor's Distinguished Service Award for an amazing 65 years of service to the Utah Geological Survey (UGS) and State of Utah. Hellmut started his long career in 1953 when the UGS's (then the Utah Geological and Mineralogical Survey) first director hired him part-time as a student draftsman—Harry Truman was president at the time! He worked for 8 years as a draftsman, then for nearly 30 years as a staff geologist, Economic Geology Program manager, and Mapping Program manager. Following his partial retirement in 1994, he worked as a part-time geologic mapper until 2003, and since then has been a volunteer geologic mapper. Today, at 88 years old, he continues mapping. In his early career, he explored and described nearly every uranium mine in the state; he has probably been inside more Utah mines than any other person. He also published papers on copper, aragonite, gypsum, fluorspar, tar sands, variscite, industrial minerals, diatomaceous earth, phosphate, and methane. In the late 1960s, Hellmut secured funds to study, inventory, and encourage development of Utah coal, and he walked and measured nearly every coal seam in the state. The result was the three-volume Utah Coal Monograph, the leading document on Utah coal for over 40 years. Hellmut has authored or coauthored more than 225 geologic maps and nearly 300 UGS publications. In short, Hellmut has devoted his entire life to Utah geology. In 2012, in recognition of his contributions to Utah geology, the dinosaur *Yurgovichia doellingi* was named after him.

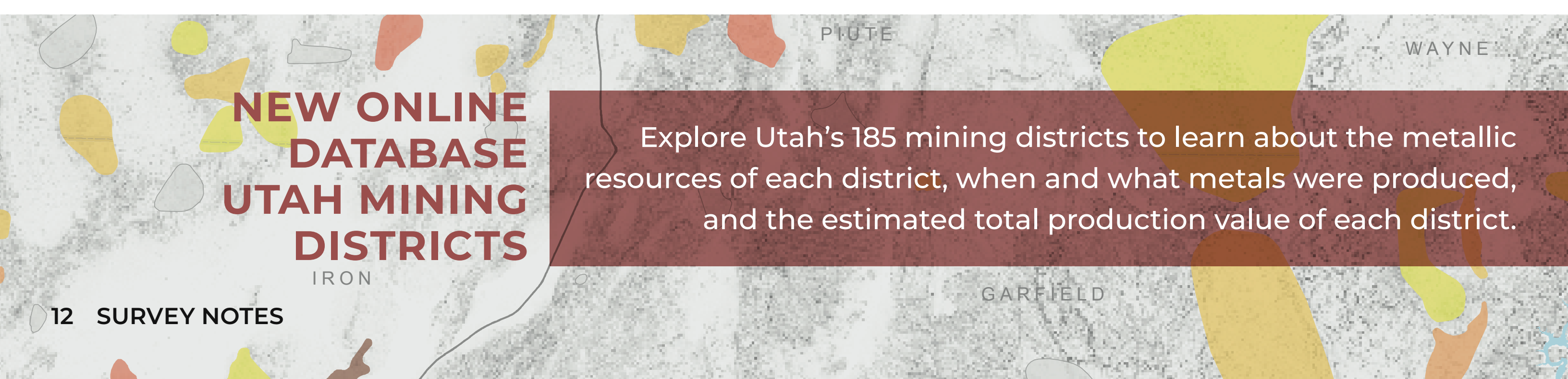
NEW EMPLOYEE NEWS

The Energy and Minerals Program welcomes **Stephanie Mills** as the new metals geologist. Stephanie received her B.S. from the University of Texas and her Ph.D. from Monash University in Australia. She has over seven years of experience working in minerals exploration in Australia and the U.S. Stephanie replaces **Ken Krahulec**, who retired from the UGS in December.

Pete Goodwin has recently joined the Groundwater Program as a wetland mapper. Pete received his B.A. in Biology from Bates College in Maine and previously worked as a wetland intern with the UGS in 2014. Welcome back Pete!

IN MEMORIAM

Archie D. Smith, former geologist with the Utah Geological and Mineral Survey from 1977 to 1989, passed away from natural causes at his home on January 16, 2019. Archie held various leadership positions including manager of the Economic Geology Program and created much of the organization that still exists here today. Archie leaves behind his beloved wife of 65 years, Barbara, and will be missed by all.



NEW ONLINE DATABASE UTAH MINING DISTRICTS

Explore Utah's 185 mining districts to learn about the metallic resources of each district, when and what metals were produced, and the estimated total production value of each district.

RECENT OUTSIDE PUBLICATIONS BY UGS AUTHORS

Age of a Pliocene basin fill along the Sevier River, southwestern Utah, U.S.A., based on fossil rodents, by W.W. Korth, J.G. Eaton, and **R.F. Biek**: Rocky Mountain Geology, v. 53, no. 2, p. 129–136, https://doi.org/10.24872/rmg-journal.53.2.129.

Controls of geothermal resources and hydrothermal activity in the Sevier thermal belt based on fluid geochemistry, by S.F. Simmons, **S. Kirby**, R. Allis, P. Wannamaker, and J. Moore: Proceedings of the 43rd Workshop on Geothermal Reservoir Engineering, Stanford University, California, SGP-TR-214, 10 p.

Update on the geoscientific understanding of the Utah FORGE site, by S.F. Simmons, **S. Kirby**, J. Bartley, R. Allis, **E. Kleber**, **T. Knudsen**, J. Miler, **C. Hardwick**, K. Rahilly, T. Fischer, C. Jones, and J. Moore: Proceedings of the 43rd Workshop on Geothermal Reservoir Engineering, Stanford University, California, SGP-TR-214, 10 p.

Systematic error and uncertain carbon dioxide emissions from U.S. power plants, by **J.C. Quick** and E. Marland, *in* Journal of the Air & Waste Management Association, https://doi.org/10.1080/10962247.2019.1578702.

Domes, rings, ridges, and polygons—characteristics of microbialites from Utah's Great Salt Lake, by **M.D. Vanden Berg**: The Sedimentary Record, v. 17, no. 1, p. 4–10.

https://geology.utah.gov/apps/blm_mineral/

ENERGY NEWS *continued from pg 8*

der the land no matter if a well is actually on the surface of the property or not. Finally, some landowners may not be aware of what mineral rights they own or do not own. They may own all or a portion of the subsurface mineral rights, or if they only own the surface rights, then they get nothing from leasing or production. This situation may occur if previous landowners sold the surface property (a farm or ranch, for example) but retained the subsurface mineral rights, or sold a percentage of the rights to a third party—all independently of how many times the surface ownership changes hands over the years. For example, a farmer may own a 640-acre section (1 square mile) of land but they own the mineral rights to only 320 acres at 100 percent and 40 acres under another part at 50 percent with all remaining mineral rights owned by someone else. However, the surface landowner still has rights even if they do not own the subsurface mineral rights, especially if the oil company conducts exploration or development activities on their land, such as shooting seismic lines, drilling, or building pipelines. The landowner can negotiate reasonable "damage" fees for these activities. For instance, when shooting a seismic line, shallow-depth shot holes may be drilled in an area of interest. Explosive charges are set off in shot holes that create seismic waves, which bounce off the subsurface layers of rock to give a better picture of the geologic structure below. The landowner may receive $300 to $500 in damage fees per hole.

Covenant oil field, east of Richfield, Sevier County, Utah. The subsurface mineral rights in the field are owned by the BLM, SITLA, and a private entity.

If a landowner is unsure of the mineral rights, the local county clerk's office can usually help. When contacted by a landman representing an oil company about leasing the mineral rights, a landowner should consider hiring an attorney who specializes in oil and gas leasing. In addition, numerous websites are available with helpful information, advice, and negotiating guidance on leasing. Landowners may also want to know about the geology of their land especially pertaining to oil and gas. Although the UGS cannot specifically evaluate individual properties (hired geologic consultants can, however), we can answer general questions and recommend our numerous publications on oil and gas resources, plays, etc. (see Public Information Series 71, "Utah Oil and Gas," and Bulletin 137, "Major Oil Plays in Utah and Vicinity," for example) that are available for free from our website at https://geology.utah.gov/map-pub/publications/.

Oil and Gas Revenue—The Bottom Line

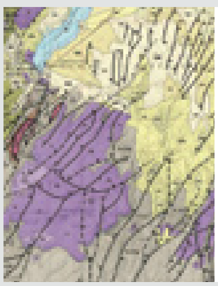
Revenue from oil and gas production and leasing can be a double-edged sword to Utah and its citizens. When prices are high, the state has more funds for education, roads, and other services. At the same time, high oil prices affect the gas pump. When prices are low, the revenue and its benefits to the state consequentially fall but it becomes cheaper to fill up our vehicles. Ultimately, however, the fact that Utah is rich in oil and gas resources is of great benefit to the state and its citizens, now and well into the future.

UTAH GEOLOGICAL SURVEY
1594 W North Temple, Suite 3110
PO Box 146100
Salt Lake City, UT 84114-6100

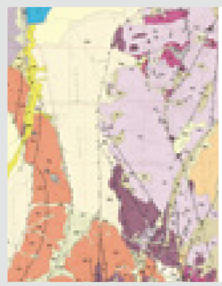
Address service requested
Survey Notes

NEW PUBLICATIONS

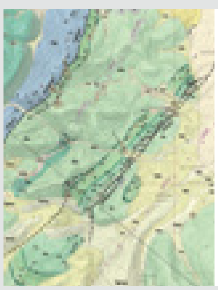
Available for download at ***geology.utah.gov*** *or for purchase at* ***utahmapstore.com***.



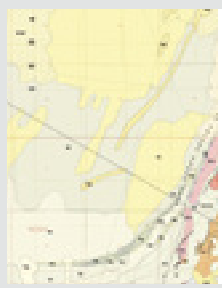
Interim geologic map of the southwestern quarter of the Beaver 30' x 60' quadrangle, Beaver, Iron, and Garfield Counties, Utah, by Peter D. Rowley, Robert F. Biek, David B. Hacker, Garrett S. Vice, Robert E. McDonald, David J. Maxwell, Zachary D. Smith, Charles G. Cunningham, Thomas A. Steven, John J. Anderson, E. Bart Ekren, Michael N. Machette, and Bruce R. Wardlaw, 18 p., 1 pl., **OFR-686DM**



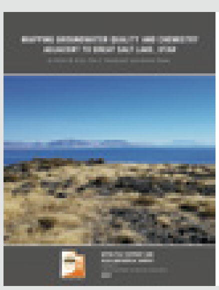
Interim geologic map of the Burrville quadrangle, Sevier and Piute Counties, Utah, by Grant C. Willis and Hellmut H. Doelling, 19 p., 1 pl., scale 1:24,000, **OFR-696**



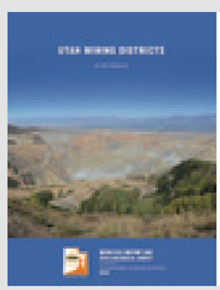
Interim geologic map of the Park City West Quadrangle, Summit and Wasatch Counties, Utah, by Robert F. Biek, W. Adolph Yonkee, and William D. Loughlin, 20 p., 2 pl., scale 1:24,000, **OFR-697DM**



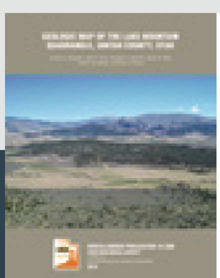
Interim geologic map of the Goshen Pass quadrangle, Utah County, Utah, by Adam P. McKean, 15 p., 2 pl., scale 1:24,000, **OFR-694DM**



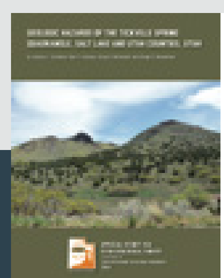
Mapping groundwater quality and chemistry adjacent to Great Salt Lake, Utah, by Stefan M. Kirby, Paul C. Inkenbrandt, and Andrew Rupke, 19 p., GIS database, **OFR-699**



Mining Districts of Utah, by Ken Krahulec, 191 p.,1 pl., scale 1:1,000,000, **OFR-695**



Geologic map of the Lake Mountain quadrangle, Uintah County, Utah, by Bart J. Kowallis, John E. Hunt, Douglas A. Sprinkel, Skyler B. May, Todd D. Bradfield, and Kent D. Brown, 13 p., 2 pl., scale 1:24,000, ISBN 978-1-55791-949-6, **MP-18-2DM**



Geologic Hazards of the Tickville Spring quadrangle, Salt Lake and Utah Counties, Utah, by Jessica J. Castleton, Ben A. Erickson, Greg N. McDonald, and Gregg S. Beukelman, 25 p., 10 pl., ISBN 978-1-55791-950-2, **SS-163**

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