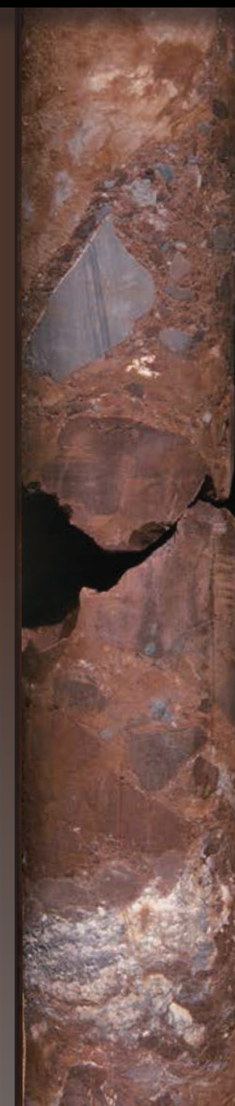
OKLAHOMA GEOLOGICAL SURVEY 1908 OGS

OKLAHOMA GEOLOGY NOTES

VOLUME 76, NO. 3 JULY-SEPTEMBER 2017

Evaporite Karst and Collapse Breccia in Permian Strata, Canton Lake Dam, Blaine County, Oklahoma

INSIDE ON PAGE 5



ALSO:

Geologist Pick

SELENITE CRYSTALS IN THE GREAT SALT PLAINS

Inside on page 20

OKLAHOMA GEOLOGICAL SURVEY

Dr. Jeremy Boak, *Director*

Editor
Ted Satterfield

Cartography Manager
James Anderson

GIS Specialist
Russell Standridge

Copy Center Manager
Richard Murray

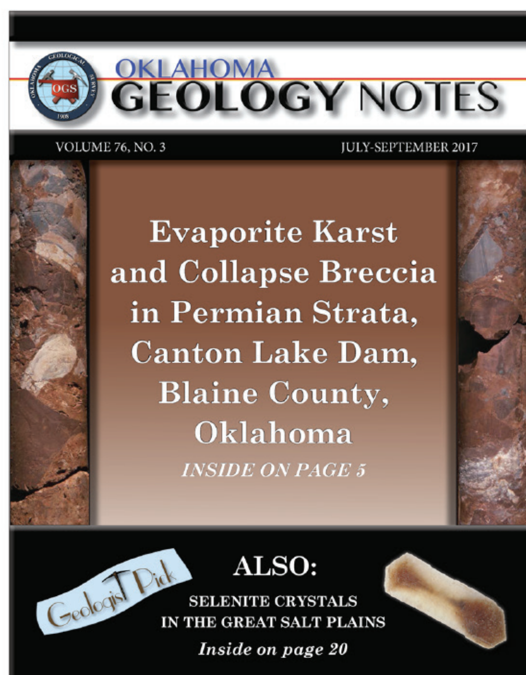
This publication, printed by the Oklahoma Geological Survey, Norman, Oklahoma, is issued by the Oklahoma Geological Survey as authorized by Title 70, Oklahoma Statutes 1981, Section 3310, and Title 74, Oklahoma Statutes 1981, Sections 231—238

The Oklahoma Geological Survey is a state agency for research and public service, mandated in the State Constitution to study Oklahoma's land, water, mineral and energy resources and to promote wise use and sound environmental practices.

IN THIS ISSUE

Retired OGS geologist, Ken Johnson, writes about evaporite karst and collapse breccia at the Canton Lake Dam site in northwest Oklahoma. — ***Page 5***

In the first "Geologist Pick" column, OGS geologist Stacey Evans discusses the selenite crystals that can be found in the Great Salt Plains. — ***Page 20***



Cover Designed by Ted Satterfield

From The Director

Remnants of Ancient Seas, Potential Hazards, Potential Resources

This issue of the Oklahoma Geology Notes looks at two different occurrences of a feature that regularly surprises residents of Oklahoma not familiar with geologic history – the remnants of seas that once flooded Oklahoma hundreds of millions of years ago. Along with the more familiar layers of sandstone, shale and limestone, the evaporation of portions of those seas left substantial deposits of various salt minerals – mainly gypsum ($CaSO_4$ – a critical ingredient in drywall construction) and halite (NaCl– common table salt).

Retired OGS geologist and associate director, Ken Johnson, writes about the dissolution of beds of halite and the jumbled rock that resulted from collapse of the overlying sedimentary rocks (called breccia, from the Italian for "broken") in the Canton Lake Dam area. Evaluating the risks of further collapse was an essential part of building the dam, and of subsequent inspections, and led to drilling boreholes in the 1940s, 1970s, 1990s, and 2000s. Ken's research through the years involved investigating many areas of karst features. (Karst is the geologic term for areas where limestone, gypsum, halite, or other soluble minerals have been dissolved, resulting in breccias, sinkholes, caves, and other features.) He was also part of the team evaluating the risks at Canton Dam in 2002-2003. Periodic checking of previous geologists' work is a recurring task at the Oklahoma Geological Survey, and provides the assurance that the infrastructure we depend upon will last for its design life. As events at California's Oroville Dam this year illustrate, nature can sometimes throw us a curve, so that periodic reconsideration of the assumptions and data, and further characterization, may be a necessary part of avoiding crucial failures.

Also, OGS geologist Stacey Evans writes a Geologist Pick column about one of her favorite geological features in Oklahoma: the hourglass selenite (a generally clear and well-crystallized form of gypsum) crystals that can be found in the Great Salt Plains, located northwest of Enid. These crystals are forming today from briny groundwater that seeps upward from the Hennessey Group to the surface of the Great Salt Plains.

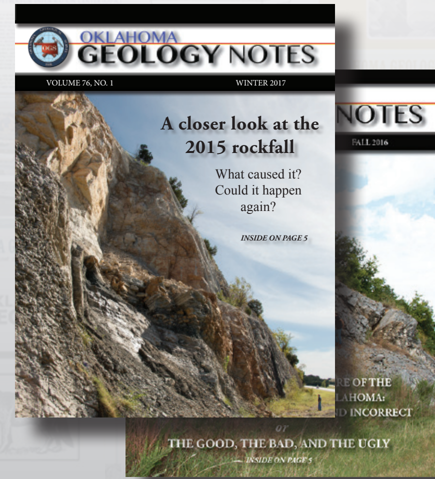
Jeremy Boak
OGS Director

Both the halite that caused the breccia in western Oklahoma, and the gypsum reprecipitating in northwest Oklahoma constitute potential resources that warrant periodic investigation as industrial demand evolves through time, as well as potential sources of hazards, and are subjects of the Survey's continuing mission to investigate the geology of the state.

The Geologist Pick column will be a recurring series in the Notes, where our earth scientists have the opportunity to share some of their favorite geological features in Oklahoma, which we intend to make accessible to the general public as well as interesting to our readers who are professional geologists.

The Survey said goodbye to several employees since our last Notes, including Stan Krukowski, Brittany Pritchett, Steven Holloway, and Ella Walker. We are grateful for their contributions to our work. We also welcomed Molly Yunker and Bill Greenwood to the Survey, and look forward to working with them to meet the challenges ahead of us.

Subscribe to the Oklahoma Geology Notes



The Notes is now available in both digital and print formats. The digital version is FREE, and subscribers will be sent an email the moment it's available.

The print version will cost $12 annually.

Sign Up Today!

OKLAHOMA
GEOLOGY NOTES

Mail Payments to:
Oklahoma Geological Survey
The University of Oklahoma
Sarkeys Energy Center
100 E. Boyd, Room N-131
Norman, OK 73019-0628

SUBSCRIBE TODAY!

☐ 1 YEAR for **$12**

MAKE CHECKS PAYABLE TO:
Oklahoma Geological Survey

NAME (PLEASE PRINT) ______________________

ADDRESS ______________________

CITY ____________ STATE ____________ ZIP ____________

PHONE NUMBER ______________________

EMAIL ADDRESS ______________________

Evaporite Karst and Collapse Breccia in Permian Strata, Canton Lake Dam, Blaine County, Oklahoma

by Kenneth S. Johnson
Retired Geologist, Oklahoma Geological Survey

ABSTRACT

Cores drilled at the Canton Lake Dam site in northwest Oklahoma contain about 90 to 100 feet of brecciated rock in the Permian Dog Creek Shale. The breccia consists of angular fragments of shale, siltstone, sandstone, dolomite, and gypsum that range in size from 0.1 to about 6 inches across, and they are surrounded by, and recemented in, a matrix of clay, shale, or sandstone. The Dog Creek breccia results from dissolution of underlying or interbedded layers of salt that originally existed in the area, and the removal of salt has caused the remaining strata to be disrupted, to collapse, and to be brecciated. Beds of rock salt are present at this stratigraphic level between 45 and 60 miles to the southwest, in the deep part of the Anadarko Basin; however, north of the known limits of these salt deposits the younger Permian and Cretaceous strata (normally flat-lying, or gently dipping at less than 1 degree) are commonly chaotic collapse blocks or masses that locally dip at angles of up to 25 degrees. It is clear that some of the salt beds in the Anadarko Basin originally extended far beyond their present limits.

REGIONAL GEOLOGY

Canton Lake is located in northwest Oklahoma, on the north flank of the Anadarko Basin—a major depositional and structural basin (Fig. 1). Rocks exposed and in shallow subsurface at the Canton Lake Dam site are Permian red-brown shales and sandstones ("red beds"), and, at depths below about 125 feet, layers of gypsum, dolomite, and shale.

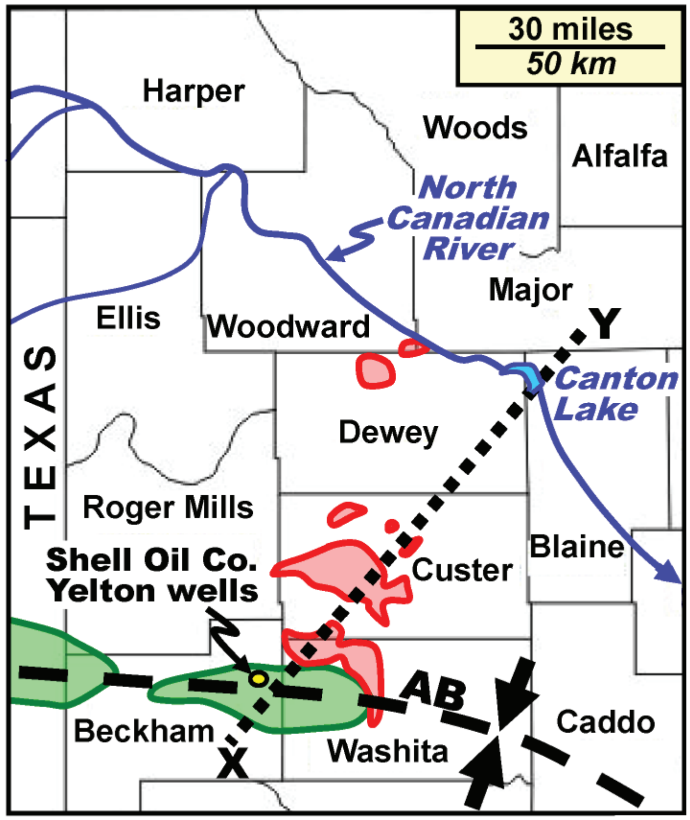


Figure 1. Map of northwest Oklahoma showing: 1) axis of the Anadarko Basin (AB); 2) areas still underlain by the Yelton salt (green); 3) location of Shell Oil Co. Yelton wells (see Fig. 2); 4) areas with multiple collapse blocks of Cretaceous rocks in Washita, Custer, and Dewey Counties (red); 5) Canton Lake, where breccia was encountered in Permian strata during dam construction; and 6) cross section X---Y line (see Fig. 3).

Principal formations in the area are (in ascending order): 1) Blaine Formation, consisting of about 75 feet of interbedded gypsum, dolomite, and red-brown shale; 2) Dog Creek Shale, consisting of about 175–200 feet of red-brown shale, with thin interbeds of siltstone, gray shale, dolomite, and gypsum; and 3) Marlow Formation, consisting of about

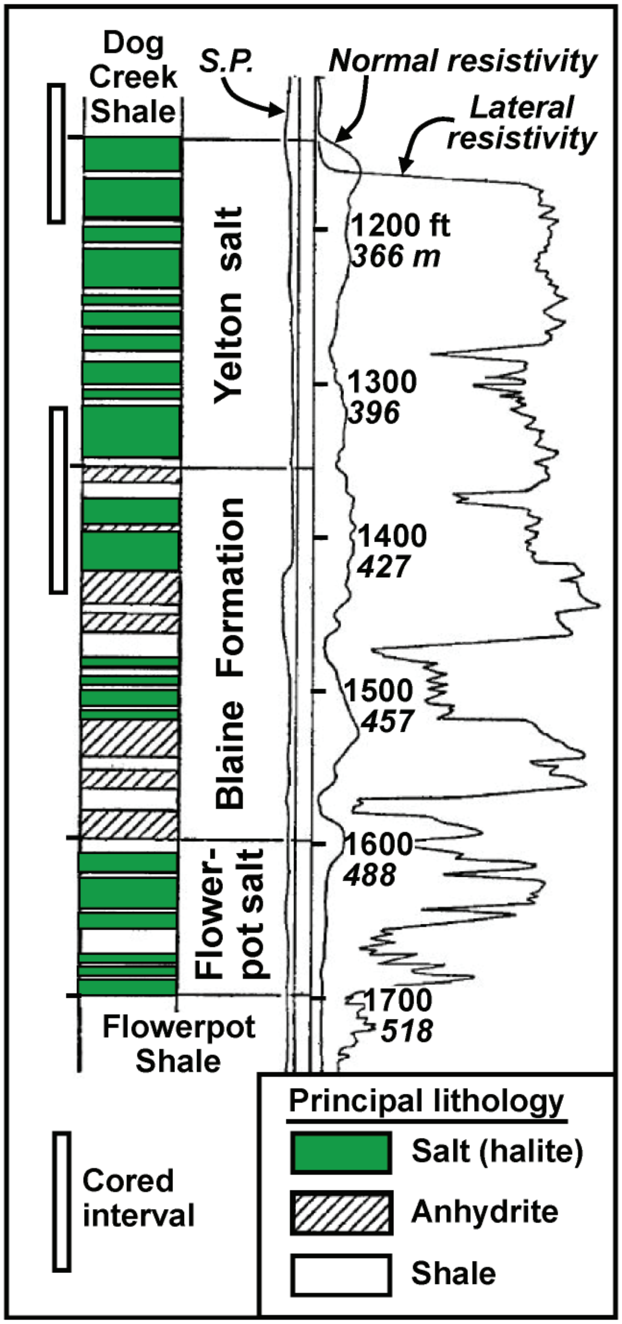


Figure 2. Salt beds are fully developed in the Blaine Formation and associated strata in the deep part of the Anadarko Basin. Lithology based on cores and log interpretation of Shell Oil Co. wells #1 Yelton and LPG-#1 Yelton, sec. 15, T.10N., R.21W., Beckham County, Oklahoma. After Jordan and Vosburg (1963).

120 feet of orange-brown sandstone and siltstone (Fay and others, 1962; Fay, 1964; Johnson, 1972). Strata here dip gently to the southwest, into the Anadarko Basin, at a rate of 50 feet/mile (about 0.5 degrees).

Permian rocks in the region were deposited in a shallow inland sea that extended across the Anadarko Basin and its northern shelf (Johnson, 2003b). Most formations are thicker to the south, because the basin sank more rapidly and received more sediment than the northern shelf area. Between 45 and 60 miles to the southwest of Canton, in the deep part of the Anadarko Basin, several hundred feet of layered rock salt (halite) is present within the Blaine and Dog Creek Formations (Johnson, 1963, 2013; Jordan and Vosburg, 1963) (Fig. 2), but these salts are absent in the region around Canton Lake (Figs. 1, 3). Beds of anhydrite in the Blaine Formation in the deep subsurface are hydrated to gypsum in outcrops and at shallow depths in the Canton Lake area.

Overlying the Permian bedrock at Canton Lake are Quaternary (Pleistocene and Holocene) deposits that generally are 10–100 feet thick and consist mainly of unconsolidated sand, gravel, and clay deposited by major rivers and streams that flow from northwest to southeast across the region. Commonly these sediments are buff, tan, brown, and pale reddish brown, and their lighter color and lack of cementation readily distinguishes them from the underlying Permian red beds.

SITE EXPLORATION

Subsurface conditions at the spillway of the dam on Canton Lake were explored several times in the past. Initial exploration was in 1940 when the dam was being planned and designed. Owing to World War II, completion of the dam was delayed until 1948. Because stability of the spillway structure was questioned during periodic inspections in 1973 and later years, additional exploration occurred in 1979, in 1995–1996, and in 2002–2003. Note: "spillway," in this report, refers to the primary spillway, completed in 1948; a secondary spillway, just southwest of the primary spillway, was constructed in 2014 and has no bearing upon this report.

Exploration in 1940

For planning and design of Canton Dam, 71 core borings were drilled (some to depths of 500 feet) along the dam and in the spillway area (U.S. Engineer Office, 1940). At least 12 of the cores were drilled into, or completely through, the Blaine For-

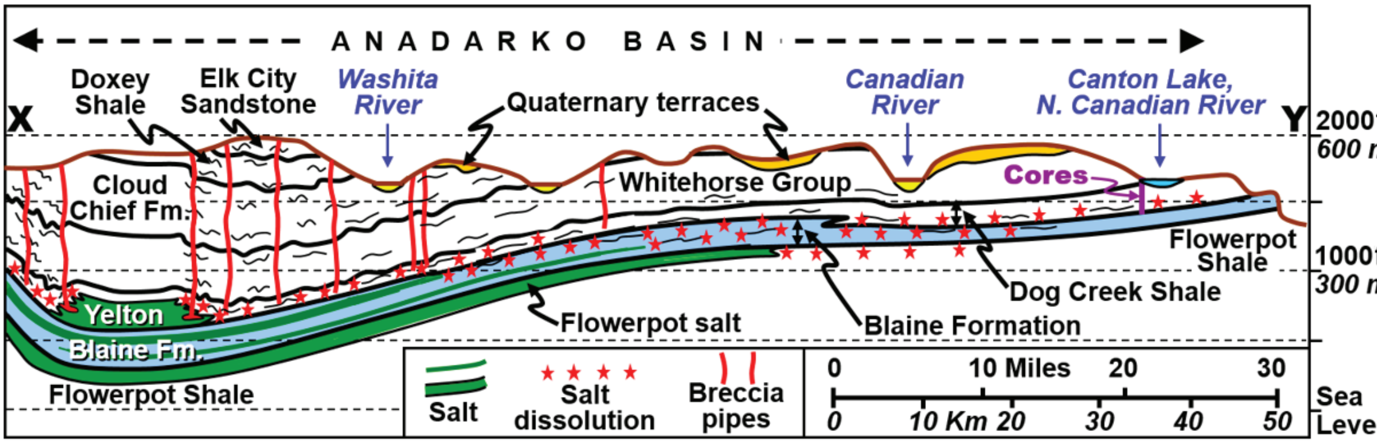


Figure 3. Cross section X---Y from axis of Anadarko Basin (left) to the northern shelf area (right). Permian salt units, still present in the deep subsurface, are dissolved at shallower depths, causing brecciation and collapse of overlying strata. Breccia pipes, shown schematically, locally reach the present land surface and contain blocks of Permian and Cretaceous strata. Location of cross section shown in Figure 1.

mation to evaluate the possibility of solution cavities in the Blaine gypsum beds or in deeper strata. The possibility of solution caverns was raised because most of the Dog Creek Shale in these cores was disrupted and brecciated: the rock consisted of fragments of shale and other rocks recemented in a matrix of shale, siltstone, or sandstone. Also, 241 auger holes were drilled (some up to 60 feet deep), mostly in Quaternary deposits, but also into the lower Marlow Formation and the upper part of the Dog Creek Shale.

Major geologic concerns at that time were: 1) the apparent softness of near-surface, red-bed clays, shales, and siltstones in the Dog Creek Shale; 2) brecciation of rock in the Dog Creek Shale; and 3) the possibility of open cavities in the underlying Blaine gypsum beds or other soluble rocks that might underlie the dam and spillway. These concerns were alleviated during drilling and testing: 1) although the uppermost, weathered Dog Creek strata generally are soft, they grade down into more compact, consolidated, and cemented strata at depth; 2) brecciated material encountered in the cores is recompacted and recemented, and the rock apparently is as consolidated as the unbrecciated material; and 3) no open cavities were found in the Blaine gypsum beds, and no deposits of rock salt (or open cavities formed by dissolution of rock salt) were found in Dog Creek, Blaine, or Flowerpot strata in any part of the project area. Geologic conditions and considerations during 1940 are discussed in the report by U.S. Engineer Office (1940).

Exploration in 1979 and 1995–1996

During these two periods of exploration, a number of borings were drilled in and near the spillway. These borings only penetrated the Dog Creek Shale, and went to depths of between 32 and 65 feet. Most of the Dog Creek cores were described as being moderately hard to hard shale, although in two cores the top 6 feet were described as soft to moderately hard shale. Much of the rock was fractured, and much of the core was broken up, mechanically. Slickensides were described in several cores.

Exploration in 2002–2003

In the last exploration program, the US Army Corps of Engineers (USACE) retained MACTEC Engineering and Consulting, Inc. (previously Law Engineering and Environmental Services, Inc.), and me (as consulting geologist) to determine bedrock conditions beneath the spillway. Subsurface conditions at Canton Dam spillway were explored between December 16, 2002, and February 5, 2003 (Law Engineering and Environmental Services, 2003). Six vertical boreholes were drilled with a BK-66 truck-mounted drill rig, equipped for wireline coring (Figs. 4, 5). Hollow-stem augers (6 5/8-inch ID) were advanced to the top of coring depth, and then rock was cored using a PQ-sized core barrel (recovered cores were about 3.35 inches

Figure 4. Aerial view of primary spillway on Canton Dam, looking north. Also shown is drill rig for borehole BL–2 (arrow) on left spillway abutment, and stilling basin at base of spillway.

in diameter). Borings were logged by a Law (now MACTEC) geological engineer and geologist, Heather Balven, and me.

Three borings (BL–1, 2, and 3) were located on the left (northeast) abutment of the spillway, and three borings (BL–4, 5, and 6) were on the right (southwest) abutment. Borings on each abutment were about 40 feet apart, and the surface elevation of all borings was about 1,600 feet above sea level. Four borings were drilled to depths of 140–145 feet below ground level, and penetrated most of the Dog Creek Shale. The other two, the deeper borings (one on each abutment), were drilled to depths of 182 feet (boring BL–2) and 190 feet (BL–5); they cored to the base of the Dog Creek Shale, and penetrated 4 feet into the underlying Shimer Gypsum Bed of the Blaine Formation (Fig. 6).

In all six borings, the upper part of the Dog Creek Shale consisted mainly of fairly well-bedded and relatively undisturbed clayey shale or silt, down to depths of 48 to 90 feet (elevations of 1,552 to 1,510 feet). Below those depths, most of the Dog Creek core consisted of brecciated shale, siltstone, and sandstone, with fragments of shale or other rock embedded in a matrix of shale, siltstone, or sandstone.

Personnel involved with the program in 2002–2003 included Shannon Hudson with LAW, who served as project manager in charge of coordinating all field efforts, and Heather Balven with LAW, who was responsible for observation of field work and documentation of field findings. Mohawk Drilling, Inc., performed drilling and coring services for the geotechnical borings. Randy Mead, Dam Safety Project Manager with the USACE, served as our main point of contact and was involved with all aspects of the project. I appreciate very much the work and cooperation of all who were involved in this phase of exploration.

Figure 5. View of primary spillway on Canton Dam and drill rig (on left) for borehole BL–2 on left spillway abutment. View looking to the southwest.

SITE GEOLOGY

Permian bedrock formations present at the site are (in ascending order) the Blaine Formation, Dog Creek Shale, and Marlow Formation. During dam construction, about 60–90 feet of basal Marlow and upper Dog Creek strata were excavated to establish the foundation for the spillway. The Dog Creek Shale directly underlies the spillway, and it extends down from the stilling basin for about 150 feet to the top of the Blaine Formation (Fig. 6). These bedrock formations locally are overlain by Quaternary alluvium and terrace deposits.

Blaine Formation

The Blaine Formation beneath Canton Dam consists of three gypsum beds separated by shales. Information on the Blaine is based upon 12 deep borings drilled through the entire Blaine in 1940, and 2 borings (BL–2 and BL–5) drilled 4 feet into the top of the Blaine in 2002–2003. Seven of the deep borings were drilled in the spillway itself, and in those holes the top of the Blaine (the top of the Shimer gypsum bed) is about 150–165 feet below the base of the spillway (Fig. 6).

Total thickness of the Blaine Formation is 73–78 feet beneath the spillway, and the thickness of each of the gypsum beds and shales of the Blaine is fairly uniform (based upon deep borings in 1940); this indicates that probably there has been little or no dissolution of the Blaine gypsum beds. The Shimer gypsum bed ranges in thickness from 14–16 feet, and averages 15 feet. The elevation of the top of the Shimer bed is 1,423 feet under the left spillway abutment (BL–2), and is 1,413 feet under the right spillway abutment (BL–5) (Fig. 6); the abutments are about 1,000 feet apart. Therefore, the Blaine dips to the southwest at a rate of 10 feet per 1,000 feet, or about 50 feet per mile (about 0.5 degrees).

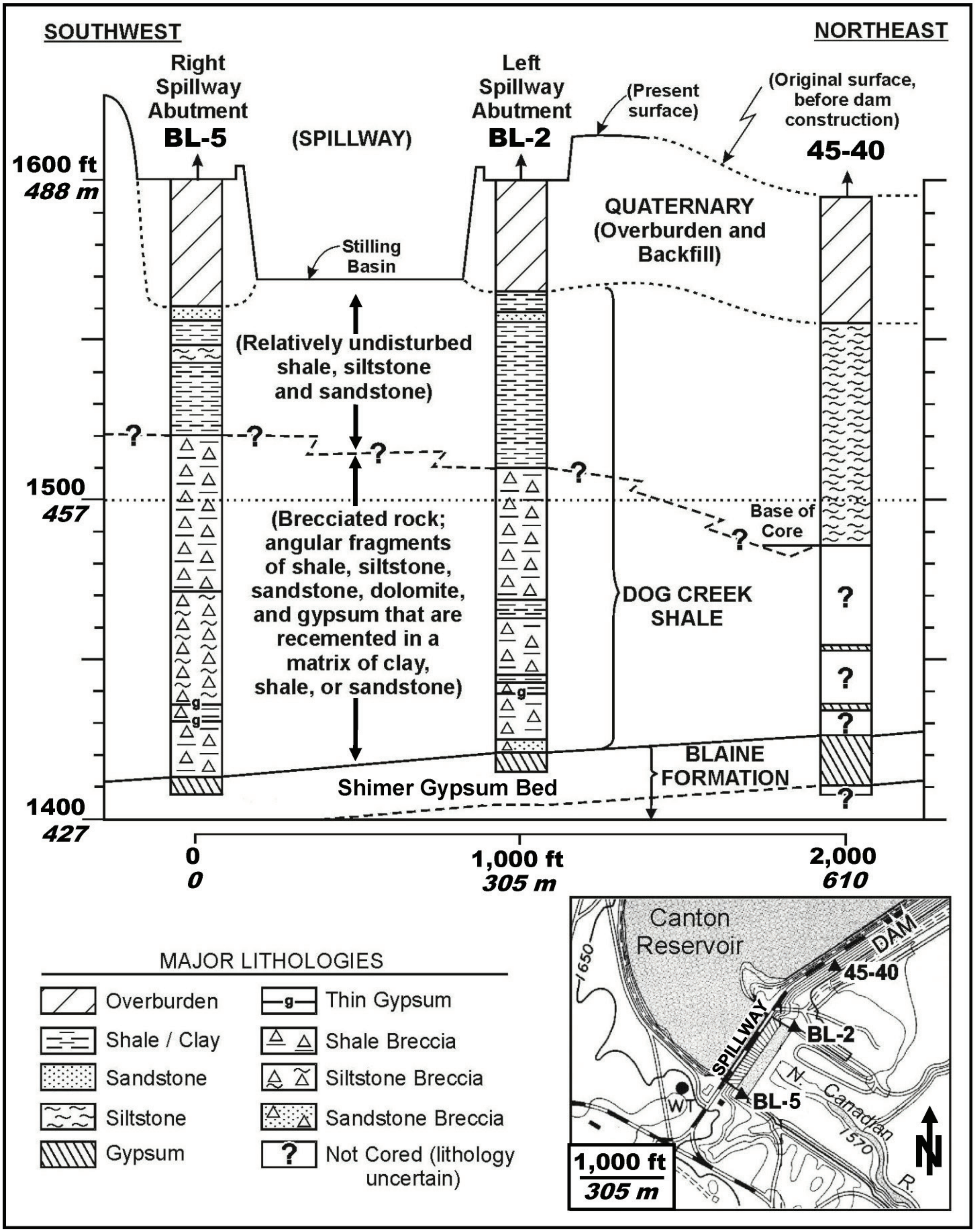


Figure 6. Cross section showing major lithologies beneath Canton Dam and spillway. View looking upstream, to the northwest. Boreholes BL–2 and BL–5 drilled in 2002–2003; borehole 45–40 is borehole #45 drilled in 1940 (before the dam was constructed). Location map shows present dam, primary spillway, and reservoir.

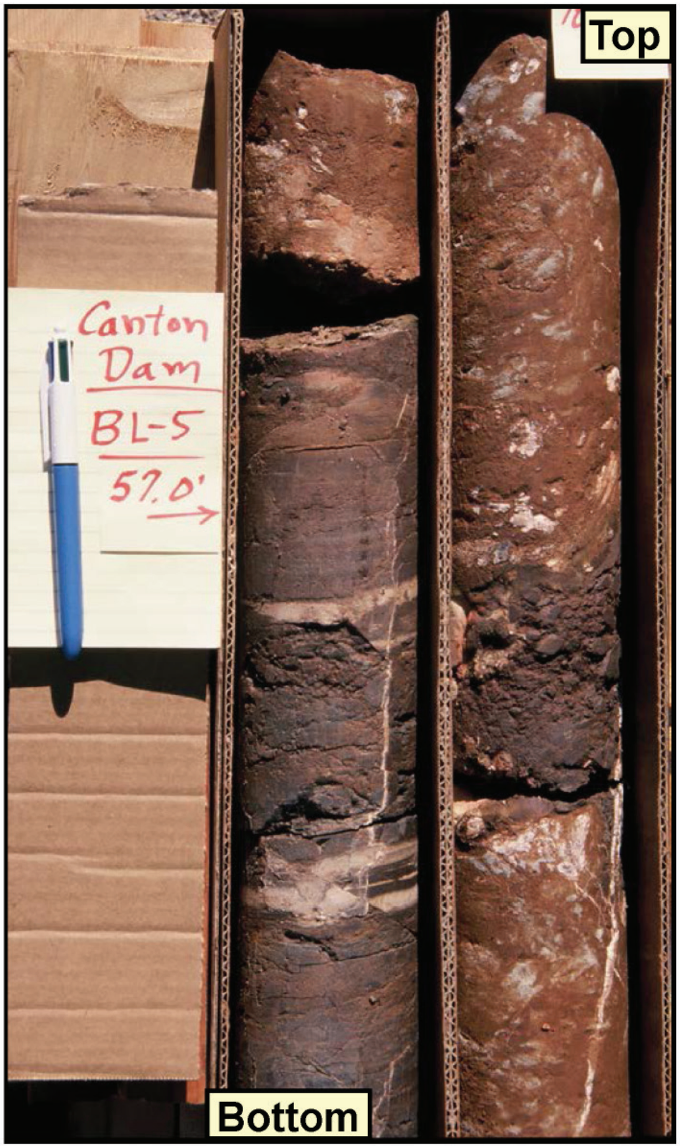


Figure 7. Core of Dog Creek Shale in borehole BL–5 on right spillway abutment. Core shows both fairly well-bedded and relatively undisturbed brown-gray shale (on left), and mottled red-brown and light-gray shale and siltstone with some small fragments of other rock types (on right). Length of pen is about 6 inches (about 15 cm).

Some of the cores drilled in 1940 were originally described as containing caved and brecciated red beds between the Blaine gypsums. This suggests that originally there may have been some soluble rock (such as salt) in the Blaine Formation at Canton Dam, but no salt exists now; any salt that may have been present has been totally dissolved. Unfortunately, cores of these "caved and brecciated" red beds between the Blaine gypsums have been discarded, so it is uncertain whether the rock was truly brecciated, how severely it may have been brecciated, or if it was material that caved during the drilling process. The only beds of soluble rock now present beneath the spillway are the Blaine gypsum beds. Dissolution of Blaine gypsum and dolomite beds is not a likely cause of brecciation because the gypsum beds are uniformly thick in the area, and there is no evidence or reports of gypsum dissolution or cavities in the numerous cores that were drilled in 1940, or later. Dolomite beds in the Blaine Formation are at the base of each of the gypsum beds, and are only 0.1 to 1.5 feet thick in the area (Fay and others, 1962); even if they were dissolved, their removal could not contribute to any significant brecciation in younger strata.

Several of the Blaine gypsum beds in the deep Anadarko Basin (Figs. 2, 3) do not extend as far north as the Canton area; the upper gypsums grade laterally into shale on the north flank of the basin. Therefore, the Shimer gypsum, defined as the top of the Blaine near Canton, is equivalent to a gypsum bed just above the middle of the Blaine in the Yelton wells (at a depth of about 1,450–60 feet in Fig. 2), based upon regional studies of the Blaine Formation throughout western Oklahoma (Johnson, 1967, plate II)

Dog Creek Shale—Brecciated Rock

All borings drilled in the several phases of exploration penetrated some or all of the Dog Creek Shale at the site. Deep borings drilled to the base of the Dog Creek included 12 of the holes in 1940 and 2 holes in 2002–2003. Descriptions of the 1940 cores, and geologic reports prepared at that time, refer to most of the lower Dog Creek strata as being "caved and brecciated material," and this is identical to the current characterization of the lower Dog Creek Shale. Most of the following discussion is based upon examination of cores drilled in 2002–2003.

The thickness of the Dog Creek Shale is about 180 feet at the spillway. However, the top of the formation is eroded or excavated at the site, and only the lower 150 feet of shale are present beneath the base of the spillway and the stilling basin (the elevation of the stilling basin is about 1,570 feet, and the base of the Dog Creek is at 1,423 feet and 1,413 feet, respectively, beneath the left and right spillway abutment).

The Dog Creek Shale is mainly reddish-brown shale, with thin layers of gray shale, siltstone, gypsum, and dolomite, and scattered veins of stain-spar gypsum. The shale is blocky and non-fissile, contains varying amounts of silt and sand mixed in the shale, and would be referred to as a "mudstone" by some geologists.

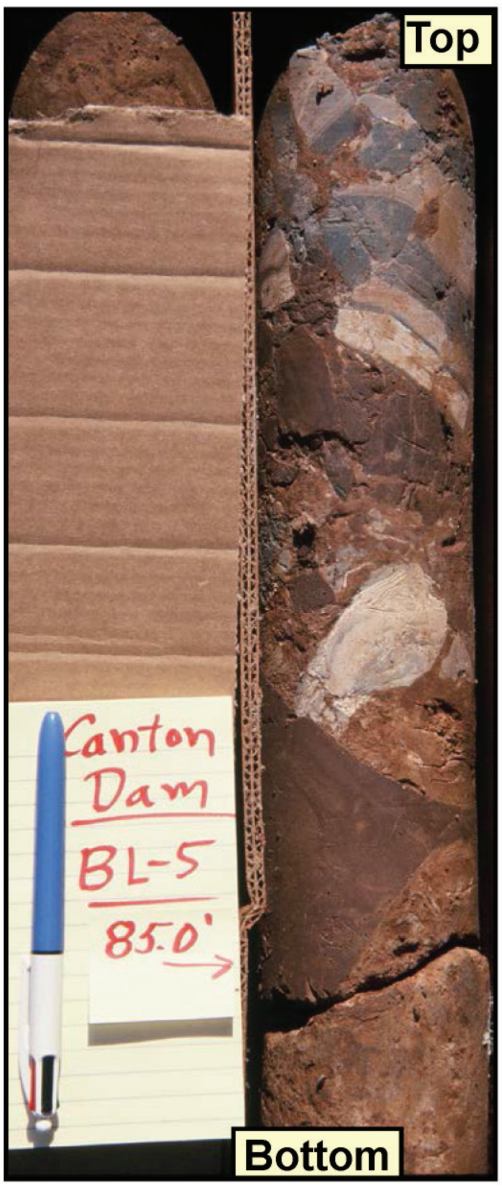


Figure 8. Core of brecciated Dog Creek Shale in borehole BL–5 on right spillway abutment. Angular fragments of red-brown and gray shale and dolomite are recemented in a matrix of red-brown shale, clay, and sandstone.

Brecciated rock is one of the most striking features of the Dog Creek Shale at Canton Dam and spillway (Figs. 7–11), and it undoubtedly results from cave-ins due to karst processes (the dissolution of soluble rock). The breccia consists of angular fragments of shale, siltstone, sandstone, dolomite, and gypsum that are surrounded by a matrix of clay, shale, or sandstone (Figs. 7–11). The fragments or clasts, which in the cores range in size from 0.1 inch to about 6 inches across, have been recemented in the matrix, and the resulting rock mass appears as competent as the non-brecciated shale. At the base of the Dog Creek Shale, the rock is only mildly brecciated (Fig. 12).

Breccia was described in the Dog Creek Shale in almost all the borings of 1940, and was observed and confirmed in all the borings of 2002–2003. The top of the brecciated zone is not uniform beneath the spillway. In the borings of 1940 and of 2002–2003, breccia was first encountered typically at elevations of 1,540–1,560 feet, but it ranged from 1,510–1,605 feet. However, once the top of the breccia was reached, almost all the underlying Dog Creek Shale was brecciated. The brecciated zone is about 90–100 feet thick in boreholes BL–2 and 5 (Fig. 6).

It is likely that dissolution of highly soluble, subsurface layers of rock salt (Yelton salt, and/or salts in the upper part of the Blaine Formation in the deep Anadarko Basin; Fig. 2) is the explanation for brecciated Dog Creek Shale beneath the Canton Lake Dam site. The Yelton salt is regarded as a facies of the lower part of the Dog Creek Shale in the deep Anadarko Basin (Johnson, 1963, 1967; Jordan and Vosburg, 1963). Although now absent from the Canton Dam area, the Yelton salt and salts in the Blaine Formation are present between 45 and 60 miles to the southwest, in deeper parts of the Anadarko Basin (Fig. 3). Salt beds in the Yelton and Blaine have been dissolved where they were at shallow depths on the north flank of the Anadarko Basin (Fig. 3), and this has resulted in brecciation, disrupted bedding, and collapse structures in the overlying strata. The collapse structures include overlying Permian strata as well as scattered masses of Cretaceous strata that once mantled most of the Anadarko Basin.

Although the Blaine Formation and lower Dog Creek strata crop out only 5 miles to the northeast of the Canton Dam spillway, field studies in that area report no evidence of brecciation in outcrops of either formation (Fay and others, 1962; Fay, 1964). It appears that salt beds that were dissolved and resulted in breccia at Canton Dam did not extend the extra 5 miles to present-day outcrops, or that that the salt beds were so thin in

LEFT: Figure 9. Core of brecciated Dog Creek Shale in borehole BL–2 on left spillway abutment. Angular fragments of red-brown and gray shale, siltstone, dolomite, and gypsum are recemented in a matrix of red-brown shale and clay. **RIGHT: Figure 10.** Core of brecciated Dog Creek Shale in borehole BL–2 on left spillway abutment. Angular fragments of red-brown and gray siltstone and shale are recemented in a matrix of red-brown shale and clay.

that area that their removal caused no discernable collapse and brecciation.

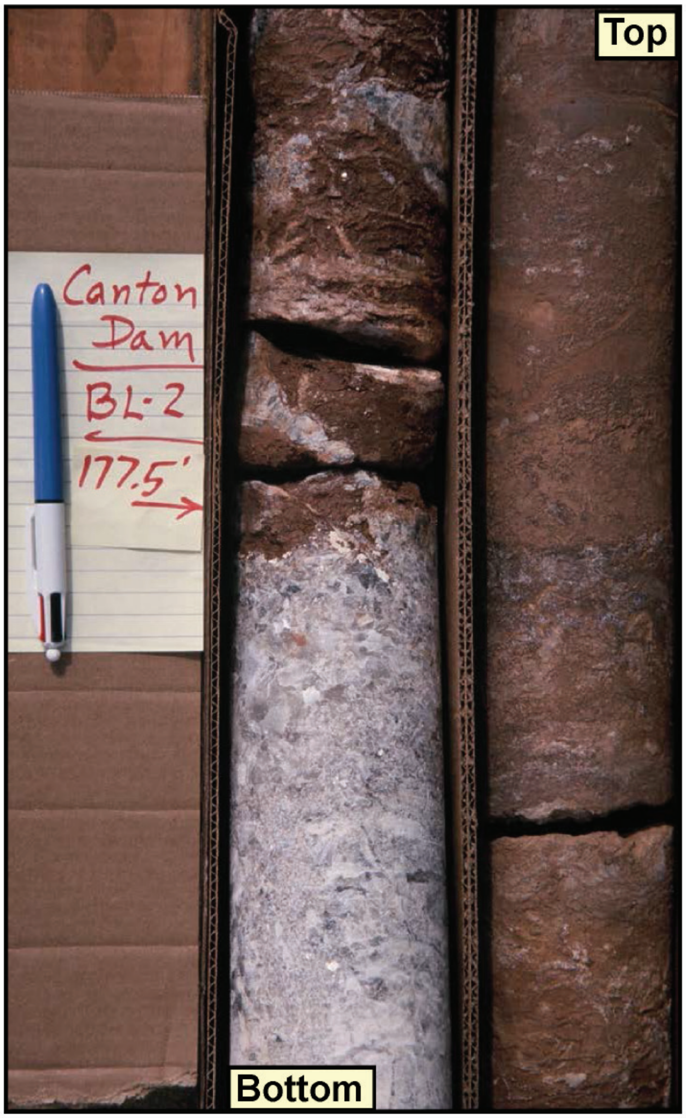
Distribution of collapsed blocks of Cretaceous strata in northwest Oklahoma is clearly associated with areas where the Yelton and/or Blaine salts have been dissolved (Johnson, 1963, 2013; Suneson, 2012). The relationship between collapsed Permian and Cretaceous strata and the distribution of the Yelton salt is shown clearly in the Canute–Burns Flat area of northwest Washita County (Fig. 13). Mapping of the surface geology by Richardson (1970), and later by Johnson (2013), shows the distribution of the collapsed blocks of Permian and Cretaceous strata, and their locations are directly related to the present-day limits of the Yelton salt on the north side of the Anadarko Basin.

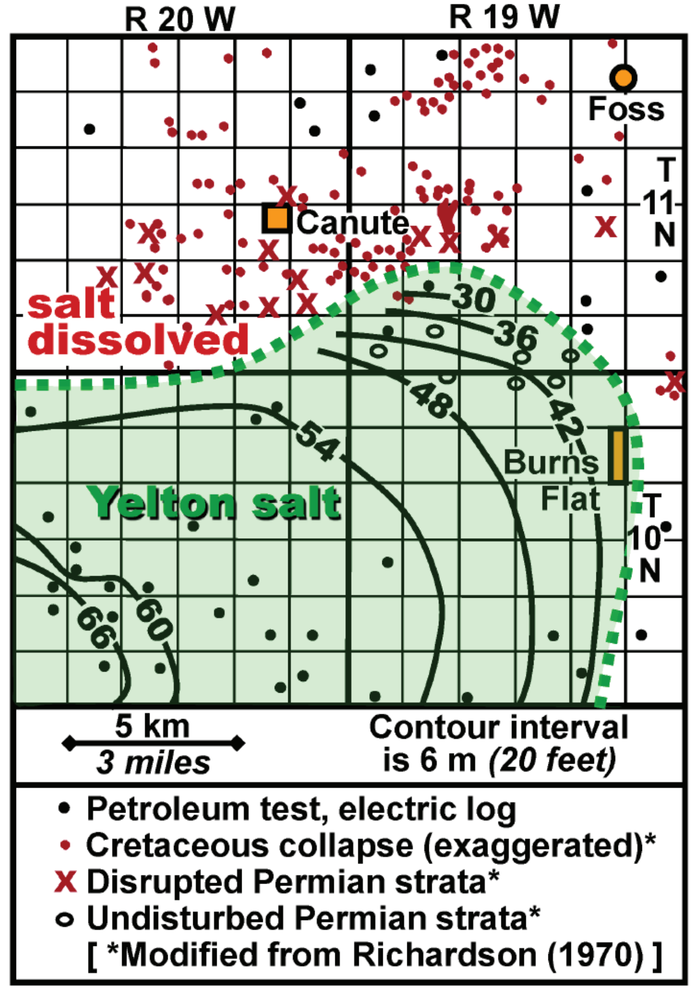
Recognition that many of the collapse structures are due to salt dissolution and collapse (and not gypsum dissolution) occurred when Johnson (1963, p. 90) noted: "Where the Yelton salt is known to be present in subsurface, outcropping strata in the overlying Cloud Chief, Doxey, and Elk City are undisturbed and dip at angles of but 1 or 2 degrees. At several places where the salt is known to be ab-

Figure 11. Three boxes containing 13 feet of core from borehole BL–3, drilled 40 feet from BL–2 on left spillway abutment. Top is 132.0 feet, and bottom is 145.0 feet. Core shows brecciated Dog Creek Shale, with fragments of shale, siltstone, dolomite, and gypsum that are recemented in a matrix of clay, shale, and sandstone.

sent…the surface beds are highly disturbed and dip in all directions at angles up to 25 degrees."

Yelton salt is dissolved on the north flank of the Anadarko Basin (Fig. 3), and this caused subsidence and collapse of overlying strata. The Yelton is about 150–220 feet thick in the southwest quarter of the Canute–Burns Flat study area, and it thins,





LEFT: **Figure 12.** Core in borehole BL–2 showing contact of Dog Creek Shale upon Blaine Formation. Mildly brecciated Dog Creek strata (on right and upper left) overlie white gypsum (lower left) at top of Shimer Gypsum Bed of Blaine Formation. RIGHT: **Figure 13.** Thickness of Yelton salt showing salt-dissolution area and collapse of overlying strata in the Canute-Burns Flat area of northwest Washita County, Oklahoma. Cretaceous collapse structures are mostly less than 1 acre (0.4 hectare). Modified from Johnson (2013).

by dissolution, both to the north and to the east (Fig. 13). The Yelton salt is completely missing beneath collapse features in the northern and far eastern parts of the Canute–Burns Flat area, and Suneson (2012) describes excellent exposures of collapsed blocks of Cretaceous sandstone and limestone in Custer County, just 6 miles northeast of Canute.

Typical karst features are not currently visible in outcrops at Canton Dam. However, photographs (taken in 1946) of the excavated right abutment of the spillway show that upper Dog Creek strata and the base of the overlying Marlow Formation are disrupted and undulate as much as 20–30 feet within short distances. Such undulations, which look like subsidence, collapse, and sinkhole features, are the surface and near-surface results of dissolution, collapse, and brecciation of rocks in the lower part of the Dog Creek Shale. These undulating strata are now concealed by soil, vegetation, rip rap, and the dam and reservoir.

It is likely that a moderate amount of bedded rock salt (the Yelton salt and/or salts in the upper half of the Blaine Formation in the Yelton wells; Fig. 2) originally existed in the lower part of the Dog Creek Shale beneath Canton Dam. The salt was dissolved by ground water some time in the geologic past, resulting in fracturing, subsidence, and brecciation of interbedded and overlying materials that

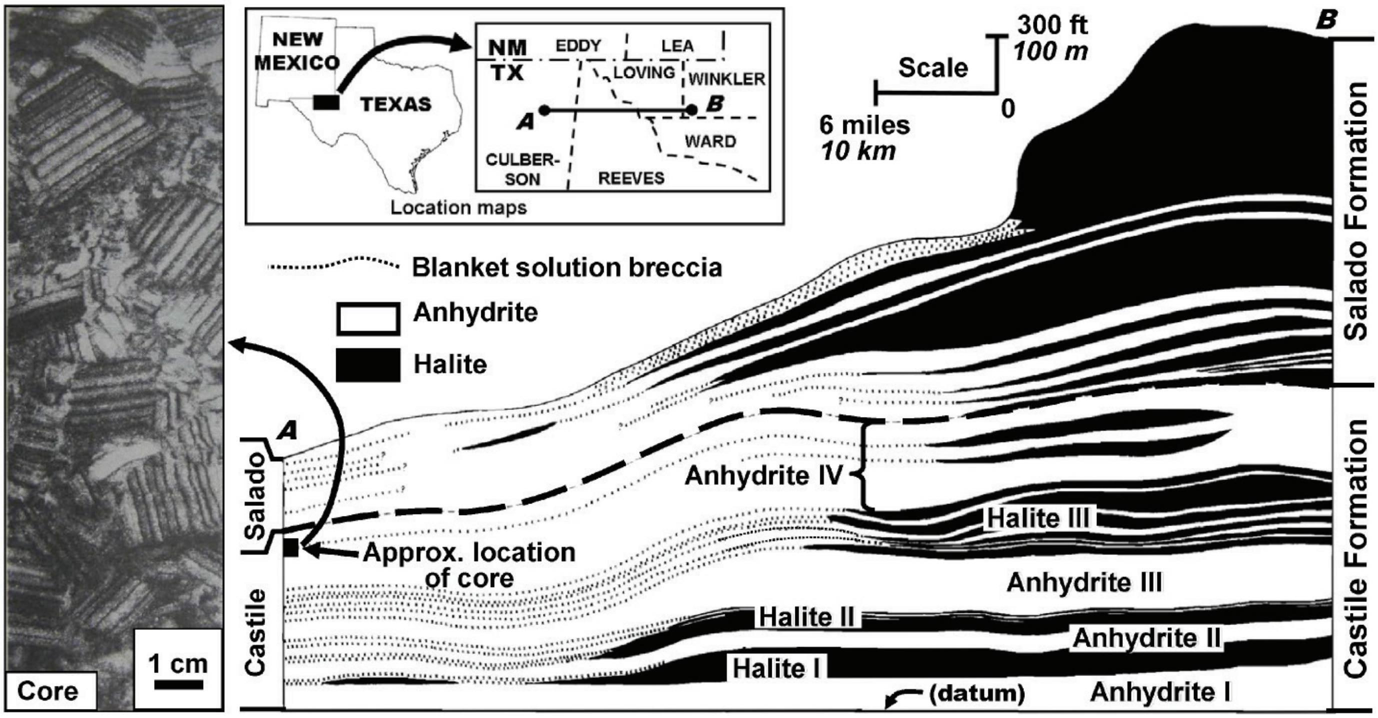


Figure 14. Schematic stratigraphic cross section A-B of Castile and Salado Formations in Delaware Basin of west Texas showing "blanket solution breccia" units where salt beds are dissolved towards the west, in the shallower, up-dip portion of the basin. On the left is part of a core showing collapse breccia caused by dissolution of salt and resultant collapse of overlying strata in the upper part of Anhydrite IV. Modified from Anderson and others (1972).

collapsed into the underground cavities and voids (a process described by Johnson, 2003a). Eventually, the broken fragments of shale and interbedded or overlying siltstone, sandstone, dolomite, and gypsum were reconsolidated as brecciated rock. The clay, shale, and fine-grained sand making up the matrix around the clasts most likely were deposited from ground water that flowed around the fragments and through voids, during or shortly after brecciation.

There is no evidence that Yelton or Blaine Formation salts now exist in the subsurface beneath Canton Dam, or at any location in the region. Obviously, the salt dissolution and brecciation occurred long ago, and the clasts and matrix in the Dog Creek Shale at Canton Dam have been completely recemented into competent rock. Although dissolution of gypsum is also known to be responsible for caving of overlying beds and formation of breccias in some parts of northwest Oklahoma, the underlying Blaine gypsum beds here appear to be undisturbed, intact, and non-karstic. Therefore, dissolution of preexisting Yelton and/or upper Blaine salt beds (not the Blaine gypsum beds) is regarded as the cause for brecciation in the Dog Creek Shale beneath Canton Dam.

Brecciation due to salt dissolution at Canton Dam is similar to what is shown in the classic work by Anderson and others (1972, 1978), wherein they correlated specific breccia beds in the Castile Formation with salt-dissolution horizons in deeper parts of the Delaware Basin of West Texas (Fig. 14).

Marlow Formation

The Marlow Formation has been eroded (or excavated) from the spillway, although the basal layers of the Marlow probably are present in the upper part of the right (southwest) abutment of the spillway. Marlow sandstones and siltstones typically are very fine grained, orange brown to red brown, and unconsolidated (weakly cemented or friable). Some of the sandstone and siltstone clasts and matrix making up the Dog Creek breccia may have collapsed and/or flowed down into the Dog Creek from the Marlow Formation during the period of brecciation.

Quaternary Deposits

Quaternary sediments locally overlie Permian bedrock at and near Canton Dam. They consist of sand, gravel, and clay alluvium and terrace deposits of the North Canadian River and its tributaries. These sediments were derived by weathering and erosion of nearby Permian rocks, or of other rocks and sediments located farther west. Commonly they are buff, tan, brown, and pale reddish brown. Quaternary deposits typically are loose, friable, and lack cementation. They range from 22–65 feet thick in borings drilled in 1940, but in most borings they are 30–40 feet thick.

SUMMARY

In the Canton Dam area, the lower part of the Permian Dog Creek Shale has been disrupted and brecciated. Angular fragments of shale, siltstone, sandstone, dolomite, and gypsum range in size from 0.1 to about 6 inches across; the clasts are surrounded by, and recemented in, a matrix of clay, shale, or sandstone. The Dog Creek breccia results from dissolution of underlying or interbedded layers of salt that originally existed in the area, and removal of the salt has caused the remaining strata to be disrupted, to collapse, and to be brecciated. Salt beds are still present at this stratigraphic level between 45 and 60 miles to the southwest, in the deep part of the Anadarko Basin. However, north of the known limits of these salts, rocks of Permian and Cretaceous age are commonly chaotic collapse blocks or masses that locally dip at angles of up to 25 degrees. It is clear that salt beds in the Anadarko Basin originally extended far beyond their present limits.

REFERENCES

Anderson, R.Y., Dean, W.E., Jr., Kirkland, D.W., and Snider, H.I., 1972, Permian Castile varved evaporite sequence, west Texas and New Mexico: Geological Society of America Bulletin, v. 83, no. 1, p. 59–86.

Anderson, R.Y., Kietzke, K.K., and Rhodes, D.J., 1978, Development of the dissolution breccias, northern Delaware Basin, New Mexico and Texas, in Austin, G.S., compiler, Geology and mineral deposits of Ochoan rocks in Delaware Basin and adjacent areas: New Mexico Bureau of Mines and Mineral Resources, Circular 159, p. 47–52.

Fay, R.O., 1964, The Blaine and related formations of northwestern Oklahoma and southern Kansas: Oklahoma Geological Survey Bulletin 98, 238 p. http://ogs.ou.edu/docs/bulletins/B98.pdf

Fay, R.O.; Ham, W.E.; Bado, J.T.; and Jordan, L., 1962, Geology and mineral resources of Blaine County, Oklahoma: Oklahoma Geological Survey Bulletin 89, 252 p. http://ogs.ou.edu/docs/bulletins/B89.pdf

Johnson, K.S., 1963, Salt in the El Reno Group (Permian), Elk City area, Beckham and Washita Counties, Oklahoma: University of Oklahoma, Biennial Geological Symposium, 8th, Proceedings, p. 79–92.

Johnson, K.S., 1967, Stratigraphy of the Permian Blaine Formation and associated strata in southwestern Oklahoma: unpublished Ph.D. Dissertation, University of Illinois, 247 p.

Johnson, K.S., 1972, Northwest Oklahoma, Book 2 of Guidebook for geologic field trips in Oklahoma: Oklahoma Geological Survey Educational Publication 3, 42 p. http://ogs.ou.edu/docs/educationalpublications/EP3.pdf

Johnson, K.S., 2003a, Evaporite karst problems in the United States, in K.S. Johnson and J.T. Neal, eds., Evaporite karst and engineering/environmental problems in the United States: Oklahoma Geological Survey Circular 109, p. 1–20. http://www.ogs.ou.edu/pubsscanned/Circulars/circular109.pdf

Johnson, K.S., 2003b, Evaporite karst in the Permian Blaine Formation and associated strata of western Oklahoma, in K.S. Johnson and J.T. Neal, eds., Evaporite karst and engineering/environmental problems in the United States: Oklahoma Geological Survey Circular 109, p. 41–55. http://www.ogs.ou.edu/pubsscanned/Circulars/circular109.pdf

Johnson, K.S., 2013, Salt karst and collapse structures in the Anadarko Basin of Oklahoma and Texas, in L. Land, D.H. Doctor, and J.B. Stephenson, eds., Sinkholes and the engineering and environmental impacts of karst–Proceedings of the thirteenth multidisciplinary conference, Carlsbad, NM, May 6 through 10, 2013: National Cave and Karst Research Institute, Carlsbad, NM, p. 103-112. http://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=1118&context=sinkhole_2013

Jordan, L.; and Vosburg, D.L., 1963, Permian salt and associated evaporites in the Anadarko Basin of the western Oklahoma–Texas Panhandle region: Oklahoma Geological Survey Bulletin 102, 76 p. http://ogs.ou.edu/docs/bulletins/B102.pdf

Law Engineering and Environmental Services, 2003, Report of field anchor study; dam safety assurance field anchor study, Canton Dam, Canton, Oklahoma: Report to U.S. Army Corps of Engineers by Law Engineering and environmental Services, Inc., Contract No. DACW56-00-D-1004, Task Order 20, Modification No. 2, 17 p., plus Appendices.

Richardson, J.L., 1970, Areal geology of western Washita County, Oklahoma: unpublished MS thesis, University of Oklahoma, 67 p.

Suneson, Neil H., 2012, Custer County oysters: Oklahoma City Geological Society, Shale Shaker, Vol. 62, No. 6, p. 422–429. http://www.ogs.ou.edu/pdf/ShaleShakerOYSTERS2012.pdf

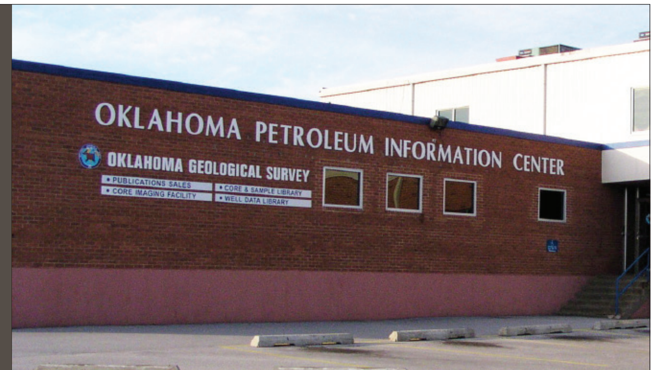
U.S. Engineer Office (now U.S. Army Corps of Engineers), 1940, Definite project report, Canton Dam and Reservoir, North Canadian River, Oklahoma: U.S. Engineer Office, Tulsa, Oklahoma, Appendix II–Geology, 12 p. Also, Appendix II Supplement, Report on geologic conditions, by Edward B. Burwell, Jr., Senior Geologist.

About the Author

Ken grew up in New York City, but earned a BS and MS in Geology at The University of Oklahoma, and then his Ph.D. in Geology at the University of Illinois. From 1961–1999 he was a research geologist for the Oklahoma Geological Survey (OGS), and was Associate Director of OGS from 1978–1999. Major research interests for OGS were Permian geology, economic geology, evaporite deposits (especially evaporite karst), and environmental geology. Ken has published more than 270 articles, books, maps, and abstracts, and he organized, chaired, and edited more than 20 OGS symposia or workshops dealing with petroleum geology and/or regional geology of Oklahoma and the Southern Midcontinent. He still consults on geology, mineral resources, evaporite karst, and environmental problems in Oklahoma and surrounding states.

Ken is a Senior Fellow of the Geological Society of America, an Honorary Member of the Oklahoma City Geological Society, a recipient of the Living Legend Award by the Oklahoma Geological Foundation, and with the Association of American State Geologists he is both an Honorary Associate and recipient of a Distinguished Service Award.

OKLAHOMA PETROLEUM INFORMATION CENTER



"Bringing Together Drill Cores, Well Logs, Well Data, Publications And Services."

Activities and Services

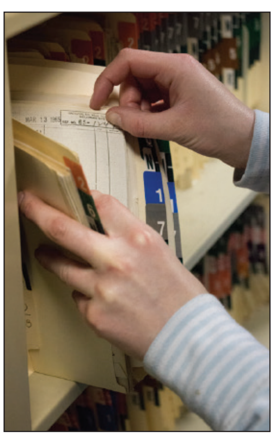
The Oklahoma Geological Survey's Oklahoma Petroleum Information Center (OPIC) is a 192,916 square-foot facility that houses approximately 500,000 boxes of core and cuttings from Oklahoma and elsewhere; an extensive repository of Oklahoma petroleum data; and the Geological Survey's publication sales office.

The OPIC facility is open Monday through Friday from 8AM to 5PM.

Core and Sample Facility

As Oklahoma seeks to maximize the recovery of oil and gas from new, existing, and shut-in wells, these data resources play an ever more important role.

In addition to being a valuable source of information for hydrocarbon exploration and production activities, OPIC's collections are used in many other ways. In particular, the use and appreciation of these materials is increasing because they are a major resource for groundwater studies, land-use change analyses, CO_2 sequestration research, archaeological investigation, and environmental studies.



Well Data Library

The OGS Well Data Library is the State's official repository for full-scale (5 inches to 100 feet) paper logs from more than 450,000 wells, with new logs added daily. In addition to hard copy logs, a backup collection of logs is available on microfiche as well.

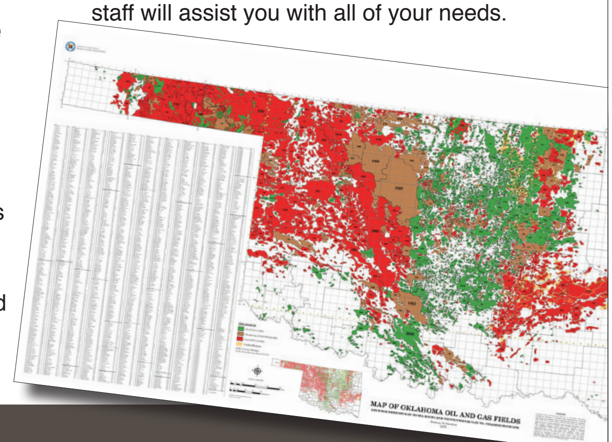
Also in the collection are 126,000 strip logs dating from the 1890s which have been recently digitized. In addition, the library maintains a hard copy of 1002A completion reports from 1904 to the 1990s; multiple sets of scout tickets; completion cards for Oklahoma wells; and hard copies of aerial photos dating from 1934-1986 that are filed by county, township and range.

Publication Sales Office

The Oklahoma Geological Survey's Publication Sales Office is also located at OPIC. There you can purchase any USGS 7.5 minute quadrangle map of the state, a variety of other USGS maps and all inprint maps and publications produced by the OGS, representing nearly a century's worth of research and mapping.

OGS publications are used by hikers, campers, hunters, school and scout groups, those who enjoy outdoor activities. We have a resource room especially for K-12 teachers, which provides free access to rocks, minerals, fossils, and curricula for classroom use. OPIC is a resource for public officials planning highways and facilities, as well as those engaged in urban planning, water development, alternative energy, and other projects for economic development and civic improvement.

Our friendly and knowledgeable OPIC staff will assist you with all of your needs.



OKLAHOMA PETROLEUM INFORMATION CENTER
OGS PUBLICATION SALES OFFICE
405-325-1299 2020 Industrial Blvd. Norman, OK 73069-8512

Geologist Pick

Selenite Crystals in the Great Salt Plains

by Stacey Evans | OGS Geologist

One of my favorite geological features in Oklahoma is the hourglass selenite crystals found in the Great Salt Plains National Wildlife Refuge in northern Oklahoma. The Refuge, as well as the Great Salt Plains State Park, is located in central Alfalfa County, about an hour's drive northwest of Enid, OK (Figure 1). The unique hourglass-shaped inclusions are found only in Oklahoma, and the hourglass selenite was made the Oklahoma State Crystal in 2005.

Selenite is a variety of gypsum that grows as large crystals with well-formed faces. It is a sulfate mineral formed from calcium and sulfate plus water ($CaSO_4 \cdot 2H_20$). (Fun Fact: another common sulfate mineral is barite, which has another special Oklahoma form – the rose rock.) The Great Salt Plains are formed by naturally occurring brines seeping up from the Permian Hennessey Group and through the overlying Quaternary sediments. While this process, and the resulting salt flats, occurs at many locations in northern Texas, Kansas, and Oklahoma, the Great Salt Plains is the largest at around 25 mi^2

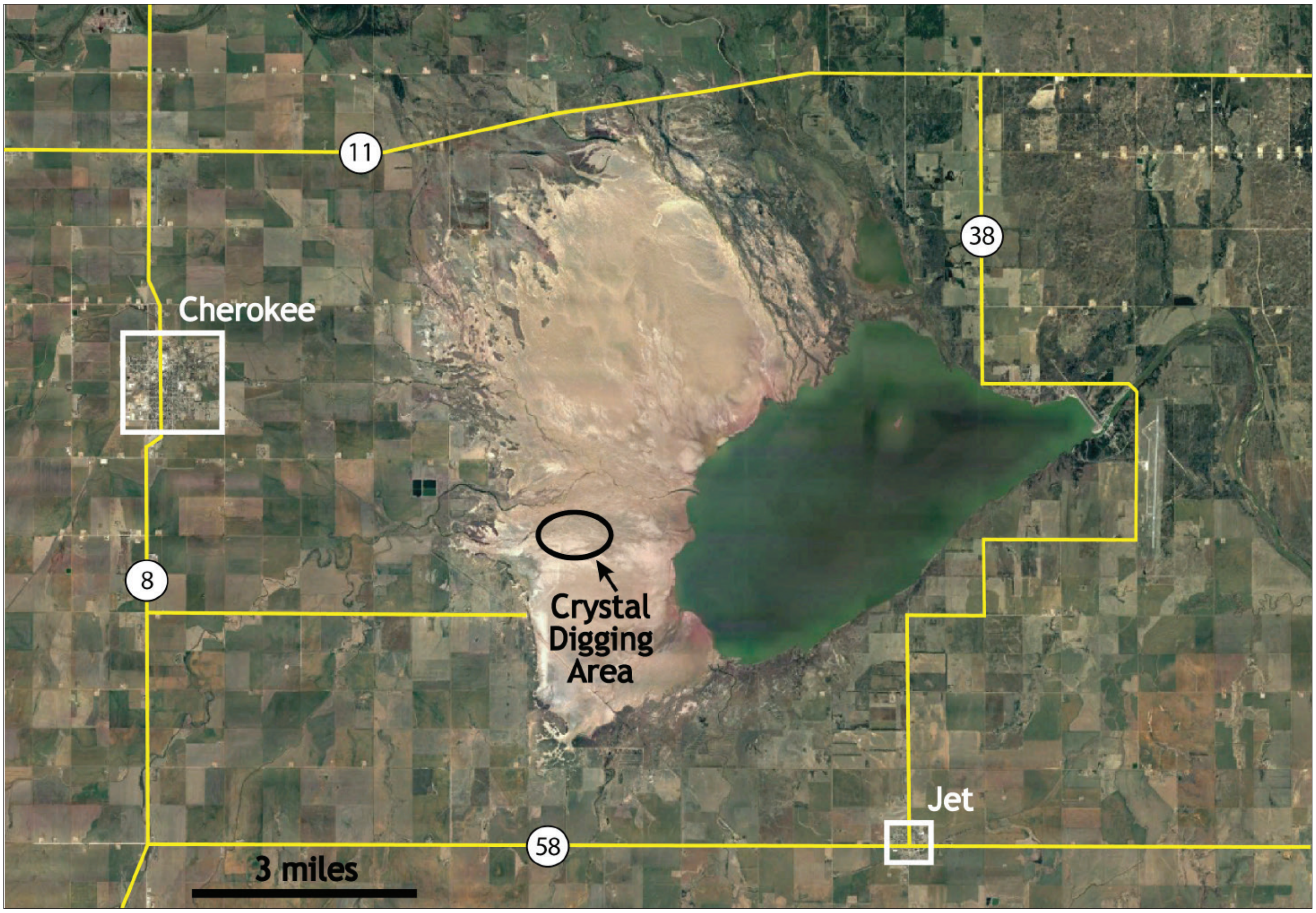


Figure 1. This map shows the location where the hourglass selenite, the Oklahoma State Crystal, can be found.

(Johnson, 1972). The brines seeping up to the surface are enriched in calcium and sulfate; as the water nears the surface and begins to evaporate, this enrichment increases until the selenite precipitates.

What I love most about the hourglass selenite is the thought that these crystals grow SO FAST that the surrounding sand, silt, and clay can't get out of the way. Most of the time, "fast" in a geologic sense means 10s-100s of thousands years, but there's a new batch of these crystals growing and making hourglasses all the time! The formation of the distinct

hourglass shape has to do with anisotropic growth rates and bond strengths. Selenite crystals grow much more quickly in their long dimension than in the narrow

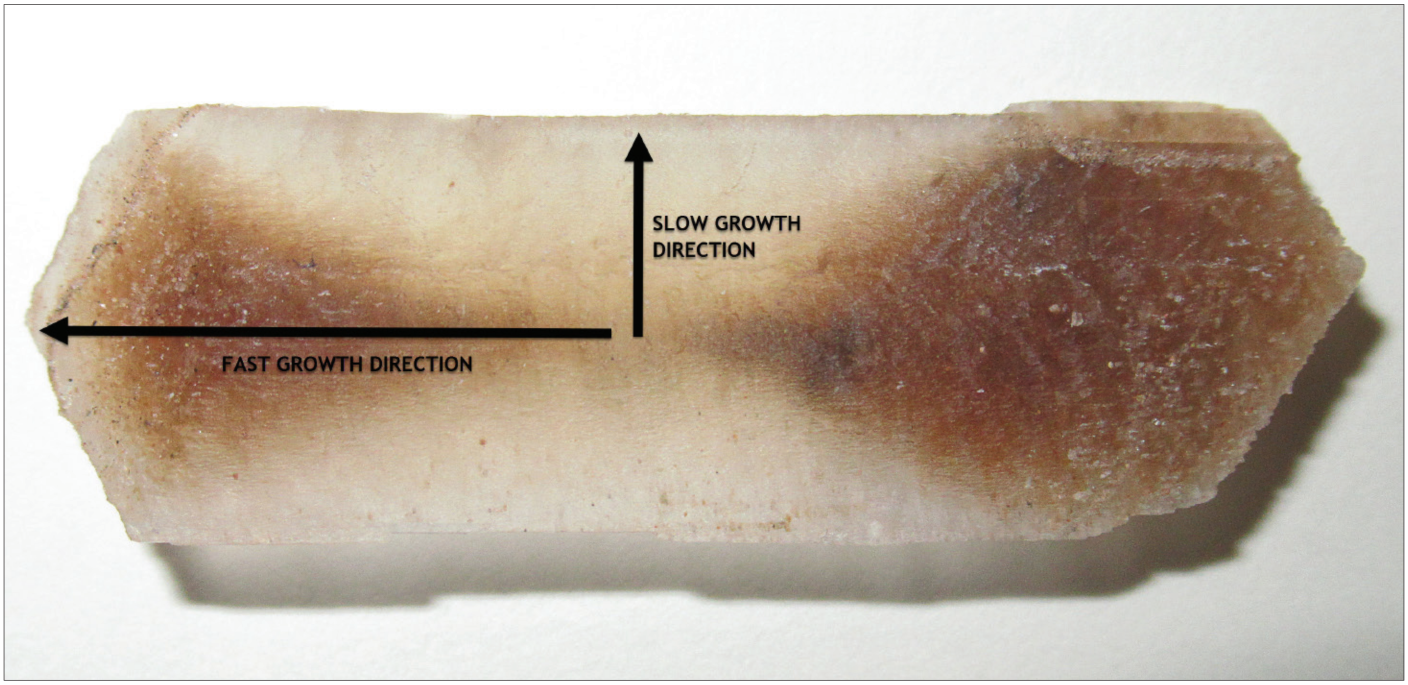


Figure 2. An up-close look at the an hourglass selenite crystal found in the Great Salt Plains.

dimension (Figure 2). As the ends rapidly lengthen, the loose surrounding material gets included. The faces on the narrow dimension, in contrast, grow slowly enough that they can push the loose material out of the way, and thus that portion of the crystal remains clear. It also appears that the bonds between molecules on the narrow dimension is so strong that as each new layer of molecules is added, the surrounding material is pushed away, while the weaker bonds on the ends do not (Johnson, 1972).

The best part about the selenite crystals is how easy it is to go out and collect some of your own! The crystal digging site is open from April 1 – October 15, from sunrise to sunset. No permit is required for crystal digging, and collectors are allowed to take up to 10 pounds of crystals plus an

additional large cluster, for personal use only. Selenite grows as individual bladed crystals (up to 7 inches) or as intergrown clusters. Most crystals are located within two feet of the surface so only a relatively shallow hole is required. There's no way to tell exactly where the crystals will be, so a few will likely get crunched during the digging. Once your hole has reached wet sand, you simply splash water against the sides of the hole to wash away the loose sediment and expose the selenite crystals. The crystals are fragile when they are wet and fresh out of the ground. They need to be handled gently and left somewhere safe to dry. My personal method for crystal hunting includes changing location pretty frequently. I have little patience, and if I don't find some awesome crystals in the first random spot I try, I'm off to the next one! It is pretty hard to find a spot that ***doesn't*** have some crystals, though, and it's very easy to go home with a lot of really nice samples.

The selenite crystals at the Great Salt Plains is a unique Oklahoma geologic feature that I think everyone should experience!

REFERENCES

Johnson, K.S., 1972, Guidebook for geologic field trips in Oklahoma, Book 2, Northwest Oklahoma: Oklahoma Geological Survey Educational Publication 3, 42 p.

About the Author

Stacey Evans joined the Oklahoma Geological Survey as a Research Geologist in late 2014. She is involved in many different areas of research at the OGS, with recent projects including researching petroleum-producing plays, surface mapping, and investigating potential fluid pathways in the Arbuckle Group and basement rocks.

Stacey received both a B.S. (2008) and an M.S. (2011) in Geology from the University of Oklahoma. During that time she did field work in Nevada, Colorado, Missouri, Wyoming, and Scotland.

Prior to joining the OGS, Stacey gained experience as a petroleum geologist working in the Anadarko Basin, the Permian Basin, and the Gulf of Mexico shelf. Other professional interests include sedimentology, diagenesis, and paleomagnetism.

Oklahoma Geological Survey
The University of Oklahoma
Mewbourne College of Earth & Energy
100 E. Boyd, Room N-131
Norman, Oklahoma 73019-1001

Non-Profit Organization
U.S. Postage
PAID
University of Oklahoma

How old are Oklahoma's Mountain Ranges?

This is a question OGS geologists are asked frequently, from both the public and professional geologists. Neil Suneson and Thomas Stanley of the OGS provide some answers to this commonly asked question.