THE GEOLOGY OF THE

GYPSUM HILLS

IN WOODWARD AND MAJOR

COUNTIES, OKLAHOMA

AN INTRODUCTION
AND
FIELD-TRIP GUIDE

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THE GEOLOGY OF THE GYPSUM HILLS IN WOODWARD AND MAJOR COUNTIES, OKLAHOMA

AN INTRODUCTION AND FIELD-TRIP GUIDE

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Boiling Springs State Park, Woodward, Oklahoma
May 30, 1998

THE GEOLOGY OF THE GYPSUM HILLS

IN WOODWARD AND MAJOR COUNTIES, OKLAHOMA

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The Geology of Boiling Springs State Park

The following description of the geology of Boiling Springs State Park is from Johnson (1972). The only information one might add to this description is the origin of the spring water. Most likely, rainwater that falls on the very porous unconsolidated sand northeast of the North Canadian River seeps into the ground until it reaches the local bedrock, in this case, the Marlow Formation or Doe Creek Lentil of the Marlow Formation. These rocks are less porous than the overlying sand, so the water either "collects" on top of the bedrock or just within the bedrock and flows down the hydrologic gradient, which generally mimics the topography and is toward the river. Where the topography intersects this riverward-moving groundwater, a spring forms.

Woodward County Site 2: Boiling Springs State Park

Access: Boiling Springs State Park is open all year and has full camping and picnic facilities. For assistance and information, contact the Park Superintendent. Boiling Springs State Park, Woodward (telephone: 256-7664).

Site location: secs. 23 and 24, T. 23 N., R. 20 W.

Topographic map: Woodward NE (7½').

References: Myers and others (1969), Riley (1961).

Boiling Springs State Park, on State Highway 34C between Woodward and Mooreland (fig. 50), consists of 820 acres covered by alluvial and terrace sand deposits and several exposures of resistant Permian sandy limestones. Fresh water issues from natural springs at several places in the park. In the main spring, ground water issues from reddish-brown limestone covered by several feet of loose sand, and as the water works its way up through the sand it

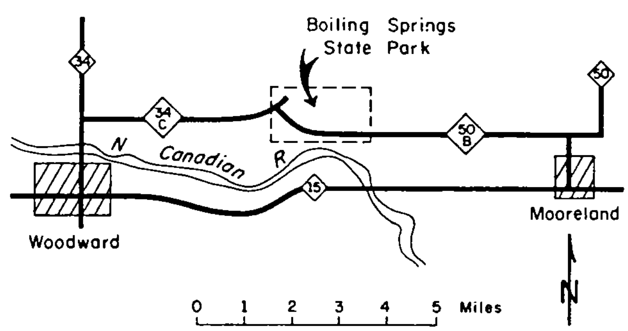


Figure 50. Location map for Woodward County site 2, Boiling Springs State Park.

churns it, giving the appearance of boiling. Bedrock is exposed in a small rock ledge just below the footpath 50 feet northwest of the pavilion that houses Boiling Spring. The water is of excellent quality, but the quantity has been reduced to about one-third of its yield in years past: the spring now yields about 30 gallons per minute. This lower yield may reflect increased withdrawal of ground water to the north for irrigation purposes.

The bedrock aquifer carrying ground water to most of the springs is fine-crystalline, crossbedded, sandy limestone exposed in 4-foot-high ledges at several places in the picnic area. Some layers and lenses of sandstone are present. Both horizontal bedding and crossbedding are well defined. Crossbeds dip about 10° toward the east and northeast. The limestone is the same unit that is exposed at Woods County site 3, west of Alva, and is called the Doe Creek Lentil of the Marlow Formation (fig. 51).

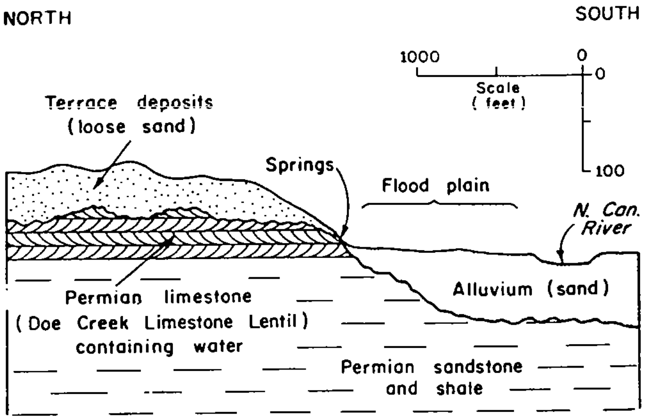


Figure 51. Schematic cross section through Boiling Springs State Park.

Small natural springs issue from this limestone at several other places in the park. At location C (see map, fig. 52), in the west roadcut 200 feet north of the intersection, a small spring yields 5 to 10 gallons of water per minute. Exposed above the bedrock spring are 20 feet of fine- to coarse-grained sand with alternating buff and light-gray layers. In contrast to these light colors is 1 foot of dark-brown and dark-gray sand in the bottom of a small tributary which enters the road ditch 40 feet south of the spring. The dark color results from a high concentration of decaying organic material at the bottom of the stream.

Stone used in buildings and retaining walls in the park was obtained locally. Large blocks of reddish-brown stone are from the Doe Creek Limestone bed in the park area, whereas the light-gray dolomite blocks (Day Creek Dolomite) were brought in from outcrops southeast of Woodward.

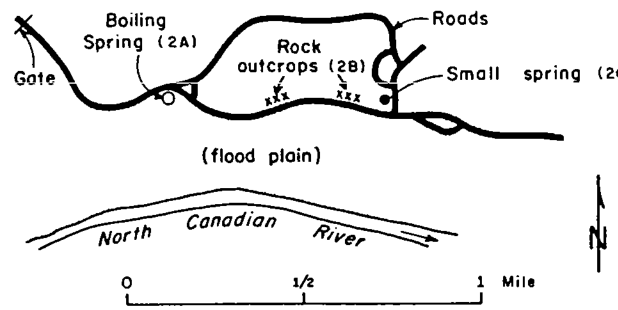


Figure 52. Map of principal features and locations in Boiling Springs State Park.

Low areas along and south of the road from the picnic area eastward are part of the modern flood plain of the North Canadian River. This area has been flooded several times since 1900. Sand covering the higher areas to the north are Pleistocene terrace deposits laid down when the North Canadian River was higher and north of its present location.

Drive east out of Boiling Springs State Park and then south to Mooreland. In Mooreland, drive east on US Hwy. 412. The road log begins at the intersection of OK Hwy. 50 and US Hwy. 412 in Mooreland.

0.0. Intersection of OK Hwy. 50 and US Hwy. 412 in Mooreland, Oklahoma.

4.0. Just east of Curtis, Oklahoma. Rolling STOP 1.

PLEISTOCENE AND HOLOCENE ALLUVIAL DEPOSITS AND SAND DUNES OF THE NORTH CANADIAN RIVER

The two major rivers flowing through Woodward County are the North Canadian River and Cimarron River. These rivers flow from the northwest to southeast; the fact that their alluvial valleys are so much larger than the rivers themselves suggests the valleys may only be indirectly related to the present-day rivers. This is, in fact, the case. The river valleys formed when the rivers were much larger during the "interglacial periods" which separated the four glacial periods of the Pleistocene "Ice Age". Obviously, rivers originating in the Rocky Mountains would carry more glacial meltwater and sediment during the relatively warm interglacial periods than when the water was locked up as glacial ice.

Another interesting observation concerning the alluvial valleys of the North Canadian and Cimarron River is that the rivers themselves seem to hug the southwest side of the valleys. Most of the alluvium (river silt, sand, and gravel; and dune sand) for both rivers is northeast of the river and Permian bedrock bounds the rivers to the southwest (Fig. 1). Over time, and although the rivers always flowed to the southeast, the rivers migrated to the southwest. This is due to the fact that the strata in this part of Oklahoma are tilted very gently to the south or southwest (Fig. 1), into the deep, natural-gas-producing Anadarko Basin. The rivers tend to migrate down the dip of the strata, abandoning former courses and leaving behind their alluvium as relatively high terrace deposits well above modern-day floodplain deposits (Fig. 2).

During the Pleistocene, most of the prevailing winds in this part of Oklahoma were from the southwest. As a result, much of the alluvium was reworked into sand dunes on the northeast side of the valleys. Some of the stabilized (vegetated) sand dunes can be seen on the upper parts of the broad alluvial valley of the North Canadian River just east of Mooreland. Active sand dunes are a popular recreation spot for ORVs at Little Sahara State Park just north of the Cimarron River.

The porous nature of the sand dunes and Pleistocene river sand make the alluvial valleys of the North Canadian and Cimarron Rivers excellent sources of groundwater.

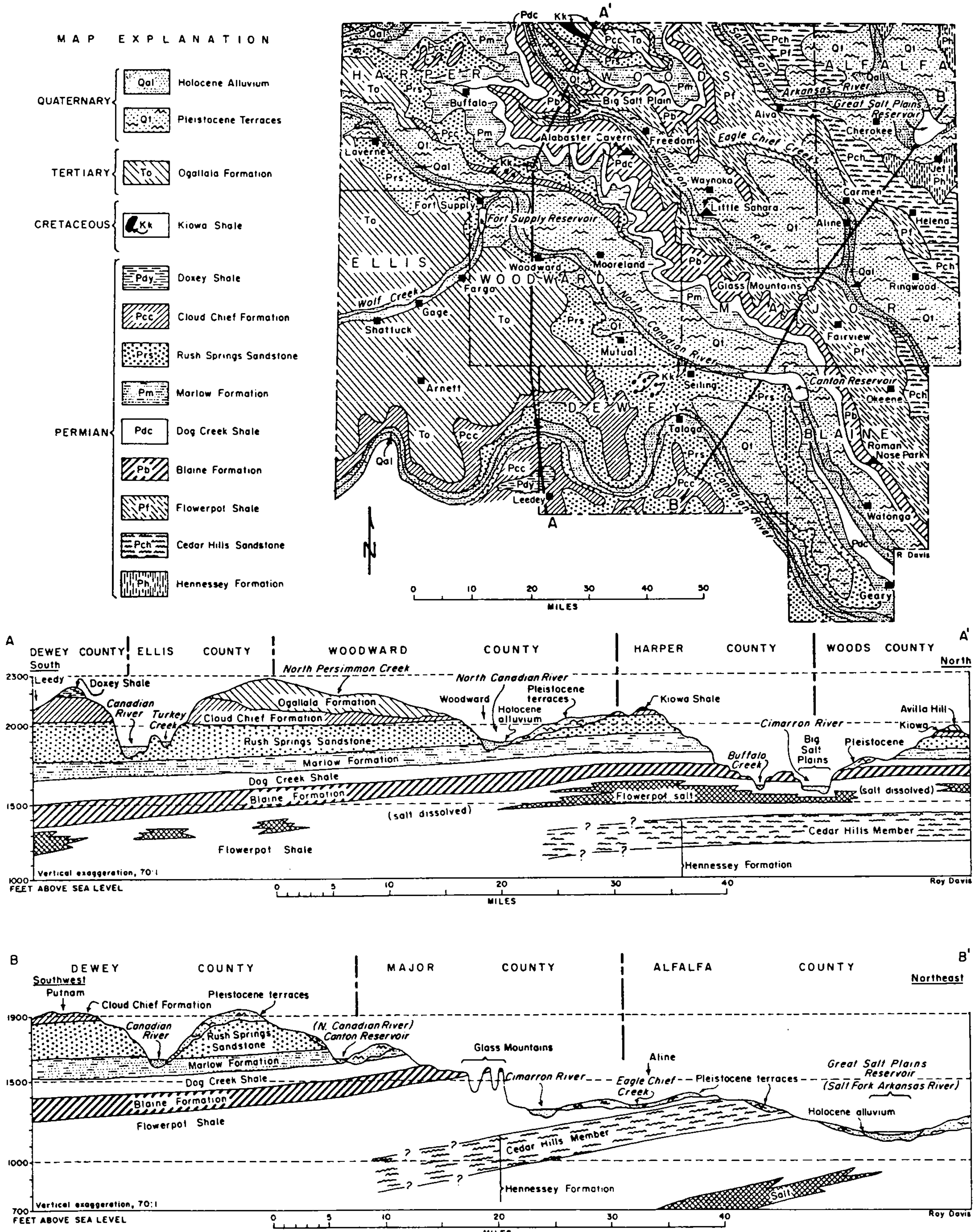


Figure *1* Generalized geologic map and cross sections of northwest Oklahoma. Map shows areas of outcrop for each formation exposed in the region, and cross sections show subsurface extension of these formations. (FROM JOHNSON, 1972, p. 8)

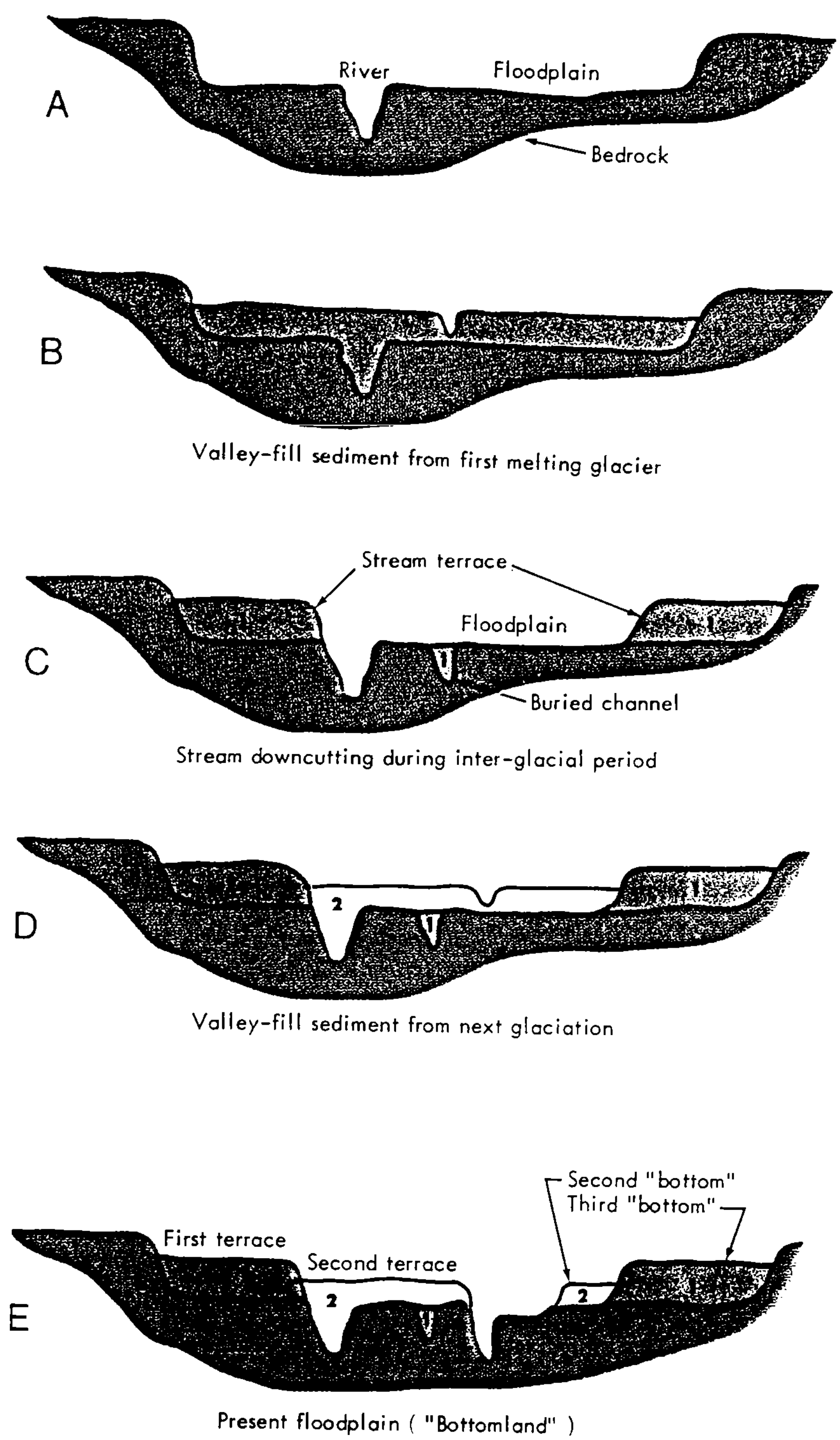


Fig. 2. Cross-section of a stream valley showing development of terraces during the Pleistocene (from Wilson, 1978, p. 46)

6.9. Just before gentle right bend in road. Rolling STOP 2.

MARLOW FORMATION

On the left (north) side of the road are the first outcrops of the Permian bedrock along the field-trip route. The very soft, easily eroded sandstone is the Marlow Formation (Fig. 3). The Permian period of the Earth's history lasted from about 250 to 290 million years ago; all the rocks we will see on this field trip are within what is known as the Guadalupian Series, a subdivision of the Permian, which lasted from about 255 to 270 million years ago.

The formation that overlies the Marlow is the Rush Springs Sandstone (Fig. 3). The Rush Springs makes its first appearance from beneath the alluvium of the North Canadian River just north of Hwy. 412. Unlike the Marlow, which is relatively soft, the Rush Springs is quite hard and resistant to erosion; as a result, where a considerable thickness is exposed, it forms a bold cliff. The Rush Springs Sandstone is beautifully exposed in Red Rock Canyon State Park (see Suneson and Johnson, 1996).

Although subtle, the outcrop of Marlow represents the beginning of our descent into the Cimarron River valley. You may have noticed that since leaving Boiling Springs which is along the edge of the North Canadian River, we have been rising ever so slightly. Highway 412 now begins a rather (in Oklahoma terms!) precipitous drop. At Boiling Springs, the elevation of the Canadian River is 1850 ft; where Hwy. 281 crosses the Cimarron River just north of Stop 6 the elevation of the Cimarron River is 1390 ft. These relations are (cleverly) shown on Fig. 4. Slowly, but irrevocably, streams flowing northeast into the Cimarron River will erode back into the Marlow in a process known as "headware erosion". In other words, the heads of the streams will slowly migrate to the southwest. Eventually, they will connect with the North Canadian River in a different process known as "stream piracy". The North Canadian will make a sharp bend to the northeast down the stream that pirated it and flow into the Cimarron River. The North Canadian River below the point of capture will become dry.

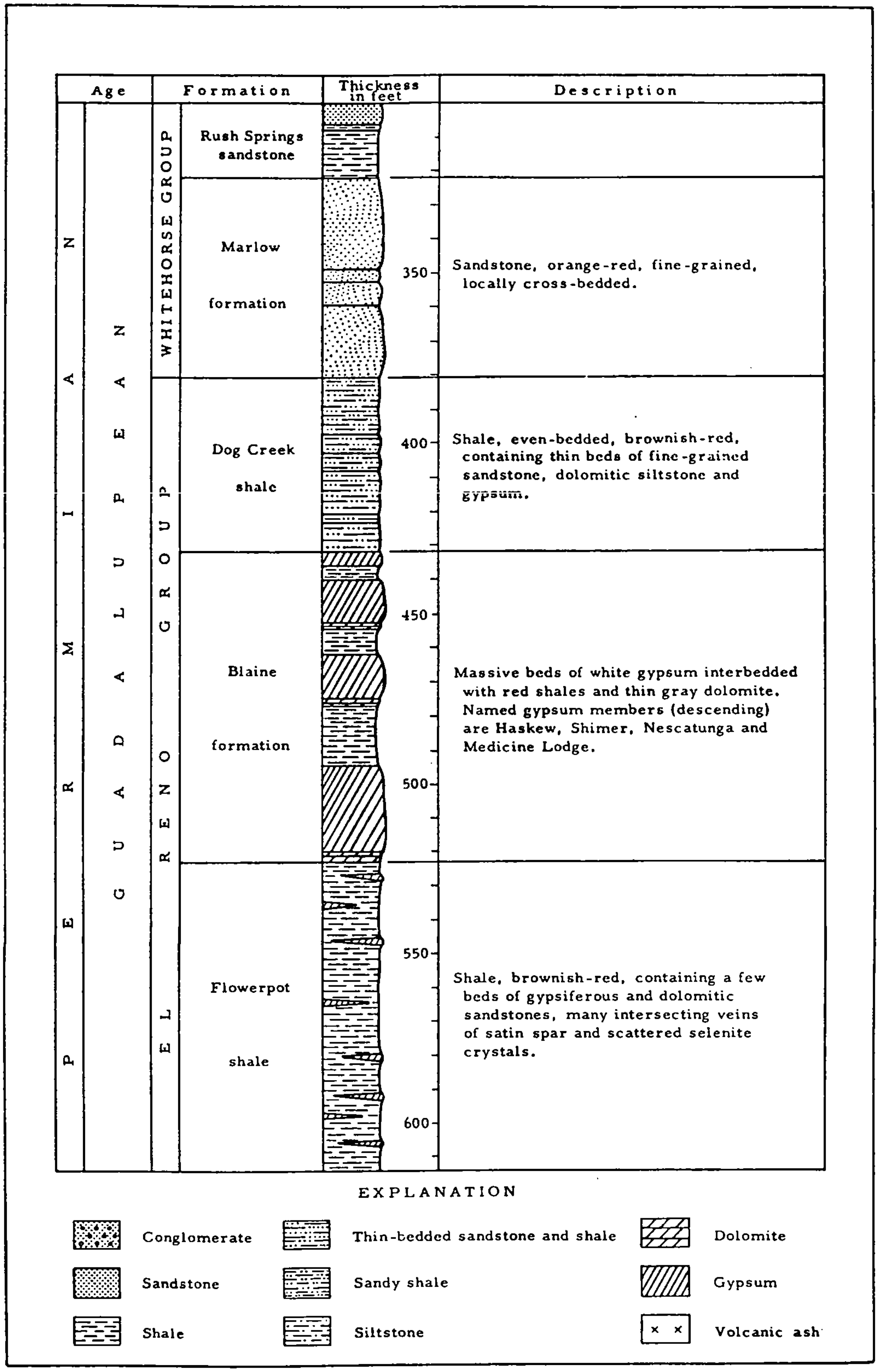


Fig. 3. Stratigraphic column of Permian strata along US Hwy. 412 east of Woodward, Oklahoma. Note that the Rush Springs Sandstone crops out just north of the highway.

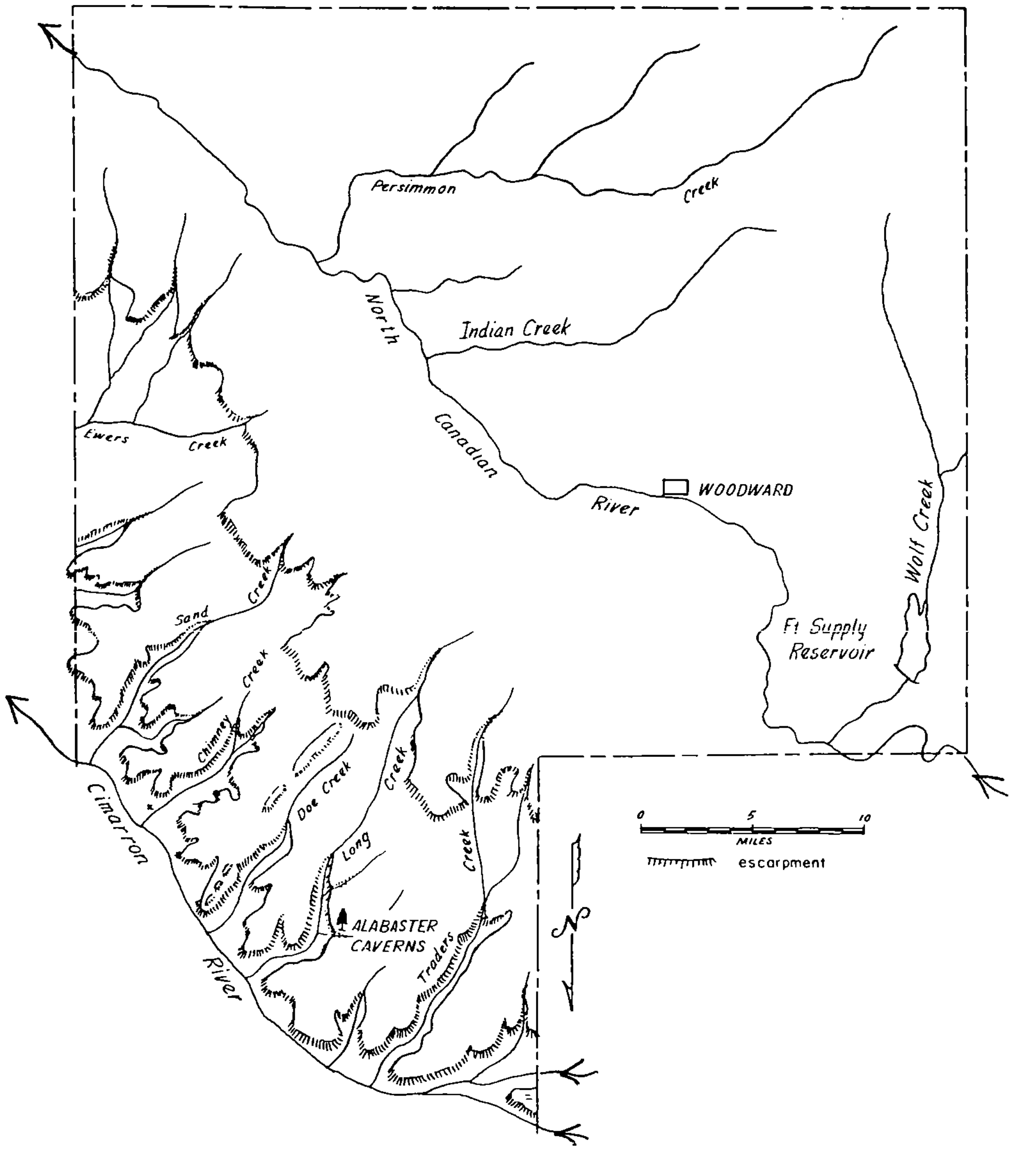


Figure 4. Physiographic diagram of Woodward County showing escarpment features of the area. Note that the map is oriented with north toward the bottom.

7.9. Rolling STOP 3.

DOG CREEK SHALE

Note that the color of the bedrock has changed. Whereas the Marlow Formation was a relatively bright reddish orange, the rocks exposed on the right (south) side of the road are multi-colored - reddish, purplish, and whitish. In addition, walking on these "rocks" after a rainstorm is quite different than walking on the Marlow. The Dog Creek Shale becomes a "goo" when wet; evidence for this are the deep ruts in many of the local ranchers' fields. The shale is very fine-grained, almost a mud, and rain falling on it does not penetrate very far into the subsurface. In contrast, the Marlow is a relatively permeable sandstone; rain falling on it quickly disappears and becomes part of the groundwater.

But like the Marlow, the Dog Creek Shale is easily eroded - even more so than the Marlow. As a result, the Dog Creek tends to form to large flat areas except where it is immediately capped by more resistant units.

11.6. Road to Cedarvale to right (south). Recalibrate odometer if necessary.

Note the long flat area lying to the east along the route of the highway. This area is underlain by Dog Creek Shale which is very soft and subject to erosion.

13.6. Cross Woodward County - Major County line.

Note the patches of white showing up in the fields on the left (north) and right (south) sides of the highway. These white patches are gypsum and mark the top of the Blaine Formation (Fig. 3). The top of the Blaine is not an absolutely planar surface but is rather irregular, due largely to the fact that in many places the gypsum has partly dissolved and the overlying shale has fallen into the depressions. The partly dissolved gypsum forms a distinctive land surface known as "karst topography". Karst topography typically develops in humid climates in areas with limestone bedrock. Sinkholes (closed surface depressions over party collapsed caves) and caverns characterize these areas (Fig. 5). Here, karst features have developed on gypsum beds; in other parts of northwest Oklahoma, similar features have developed over shallowly buried salt deposits (Fig. 6).

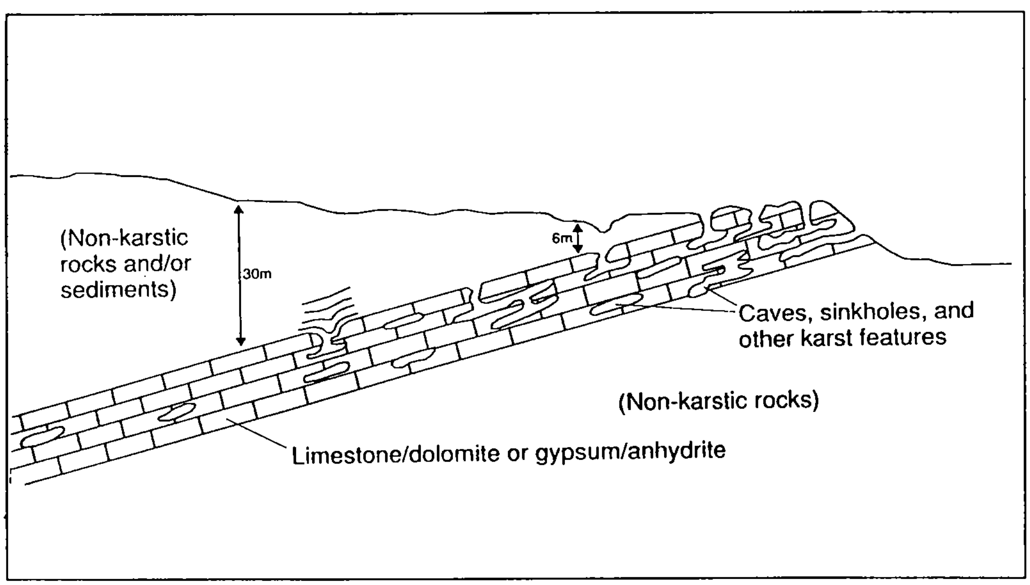


Fig. 5. Schematic diagram showing karst features as surface features and in the subsurface (from Johnson and Quinlan, 1995).

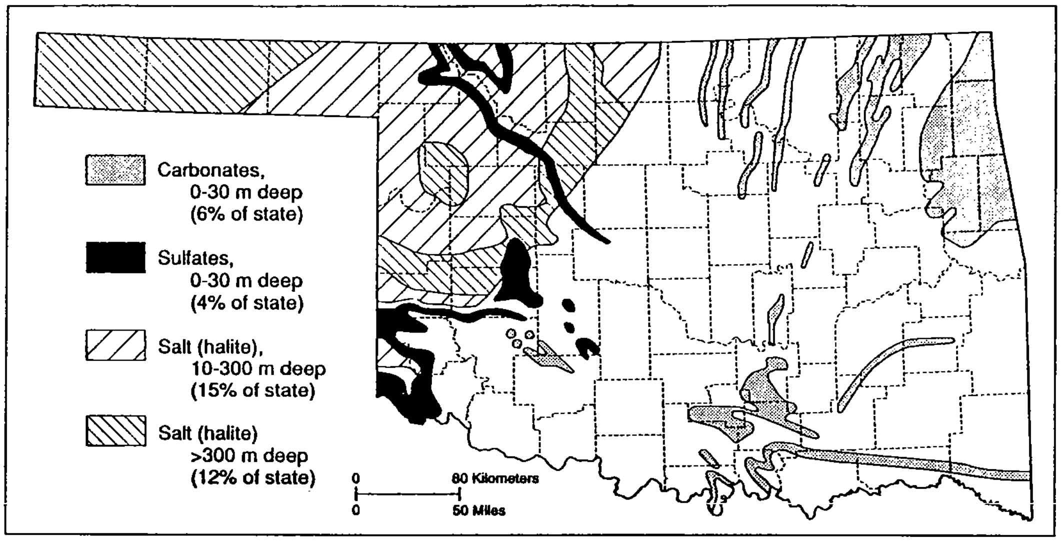


Fig. 6. Map showing general distribution of karst terranes in Oklahoma (from Johnson and Quinlan, 1995). The long northwest-trending black line in northwestern Oklahoma marks where the Blaine Formation is 0 to 30 m deep. The term "carbonates" refers to limestone and minor dolomite; "sulfates" refers to gypsum.

14.6. Turn left (north) on road to Belva. Drive 3 miles to top of escarpment. On the way, note the extremely irregular topography that has developed on the gypsum. In one place (left/west side of road) a small cave has formed in the gypsum.

17.6. STOP 4.

MEDICINE LODGE GYPSUM MEMBER OF BLAINE FORMATION

This is an excellent place to view the Cimarron River Valley. The sand dunes of Little Sahara State Park are about 8 miles to the northeast. We will talk more about the evolution of the landscape at Stop 7.

This is also an excellent opportunity to examine the contact between the Blaine Formation and the underlying Flowerpot Shale (Fig. 3). In this area, the Blaine Formation consists of four relatively thick gypsum beds separated by three beds composed mostly of shale. The names of the gypsum beds are, from oldest to youngest, the Medicine Lodge, Nescatunga, Shimer, and Haskew. Geologists define the base of the Medicine Lodge gypsum as the base of the Blaine, and the top of the Haskew as the top of the Blaine (Fig. 3). This is an outcrop of the Medicine Lodge gypsum and the roadcut provides an opportunity to few a cross-section of the contact between the Blaine and Flowerpot.

Note the following features in the outcrop:

1. The white mineral is gypsum; it has a hardness of 2 (on Moh's hardness scale, which ranges from 1 = talc to 10 = diamond) and can be easily scratched with your fingernail. Gypsum can be other colors (gray, red, brown, green) depending on impurities. There are three varieties of gypsum. Alabaster is a fine-grained massive variety that can be carved and polished and made into sculptures. It is the principal rock type at Alabaster Caverns. Selenite is a clear, colorless crystal that is commonly mistaken for isinglass, a variety of mica, which formerly was used in oven windows. Selenite crystals with sand inclusions in the shape of an hourglass are a popular collector's item at Great Salt Plains near Jet, Oklahoma. Satin spar is a fibrous gypsum with a silky luster. What kinds of gypsum do you see in this outcrop?

2. Walk up on top of the outcrop. Note the very irregular surface of the gypsum; in some places, it almost looks as though "plates" of gypsum have been pushed up at their edges. In some places near here, the "plates" have been pushed up to a degree that a very small "cavelet" has formed beneath the plates. These are favorite hiding places for snakes and is one reason why this area abounds in snakes. Another mineral known as anhydrite is commonly associated with gypsum. The chemical composition of anhydrite ($CaSO_4$) differs only slightly from that of gypsum ($CaSO_4 . 2H_2O$), anhydrite being the anhydrous (without water) version of gypsum. When anhydrite is exposed to the air it absorbs water; this causes the crystal structure to expand which forces the altered rock (gypsum) to pull away from the surrounding material.

3. Note the extremely "disorganized" nature of the contact between the Medicine Lodge gypsum and the Flowerpot Shale. The gypsum is quite soluble (consider the sinkholes and caves we passed along the road to here) whereas the shale is not. Groundwater will infiltrate fractures in the gypsum, dissolving some of it along the way, until it hits the shale. At this point the groundwater may travel laterally, perhaps dissolving more gypsum along the way. The overlying weight of the remaining, undissolved gypsum will cause blocks to collapse onto the shale which, being relatively soft, will deform around the blocks. We saw a similar, but reverse, example at mile 13.6, but there shale that overlied the gypsum filled in depressions formed by dissolution.

4. Look carefully at the gypsum and you will see several small down-to-the-valley "faults". As the Flowerpot continues to erode with every Oklahoma thunderstorm, the Medicine Lodge ledge becomes more unstable and undercut. Eventually, the ledge begins to break down, but most of the blocks do not spall off the ledge in spectacular boulder-rolls downslope. Most gradually "peel" or "slide" off the ledge and slowly slide downhill, perhaps a few inches per year or per rainstorm. The first step in this "sliding" process is the formation of small "faults" at the edge of the ledge.

Return to US Hwy. 412

19.6. Turn left (east) on US Hwy. 412. Drive 1.3 miles to the first (westernmost) of two large outcrops on the right (south) side of the highway.

20.9. STOP 5.

CONTACT BETWEEN THE FLOWERPOT SHALE AND BLAINE FORMATION

Is this outcrop the Blaine Formation or the Flowerpot Shale? Based on our discussion at Stop 4, this must be the Flowerpot because of the predominance of shale. But careful examination of the shale reveals innumerable thin beds of gypsum. What would be the effect if one of these thin gypsum beds thickened enough to become a ledge former; perhaps even thick enough that geologists would want to give it a name? Would this thick gypsum bed be considered the base of the Blaine? Definition of the tops and bottoms of different formations is not always clear-cut, especially considering that formations thicken and thin (sometimes down to zero ft thick), and sometimes the predominant rock type in a formation can change.

An interesting feature of this outcrop, as well as the Flowerpot in most places, is the complete absence of fossils. This observation, and evidence discussed at Stop 7, suggests the Flowerpot was deposited in an environment not conducive to abundant life.

Continue east on US Hwy. 412.

22.6. Intersection with US Hwy. 281. Turn north. Drive 2.1 miles.

24.7. STOP 6.

FLOWERPOT SHALE

This is an excellent opportunity to note how the Flowerpot Shale weathers. Except for the brownish red color, you might almost mistake these sparsely vegetated muddy-looking hills for the Badlands of South Dakota. In fact, geologists recognize this kind of topography as "badlands-type" topography and it forms, in South Dakota as well as here, in poorly consolidated shale under moderately arid conditions. The Painted Desert in Arizona is another example of "badlands-type" topography.

One feature of the Flowerpot Shale that is visible from a distance as well as up close are the colored bands. The overall color of the shale is brownish red, but throughout the shale at irregular intervals and of varying thicknesses are bands of bluish gray shale. The reddish color in the shale comes from the mineral hematite (Fe_2O_3), which those of you who are chemically advantaged will recognize as iron oxide, or rust. It takes only 1 to 2 percent hematite in the shale to give it its distinctive color. In constrast, the bluish gray shale contains no iron. Geologists believe that at one time the mud that is now bluish gray contained iron, but it also contained more organic material than the adjacent beds (now reddish). The presence of organic material resulted in a geochemically reducing environment; in such an environment, iron oxide is more easily dissolved in groundwater and removed from the rock layer. An oxidizing environment prevailed in those layers with no organic material; iron oxide minerals were stable, did not dissolve, and remained in the rock.

Note the thin beds of gypsum in the shale at this outcrop. These are very similar to those noted at Stop 5. But also note that some of the gypsum "beds" are not horizontal; some, in fact, are nearly vertical, and clearly cut across the different shale beds. These gypsum "beds" are actually veinlets that fill subvertical fractures in the shale. The origin of this gypsum must be secondary; it formed well after the mud was consolidated to rock and the rock was able to sustain fractures. Much of the gypsum that is horizontal was probably deposited as thin layers between episodes of mud deposition. This gypsum is primary.

Look at the top of the outcrop on the south side of the highway. There is a very coarse-grained layer (in fact, so coarse-grained it contains boulders) of colluvium. The mechanical breakdown of the resistant gypsum layers in the overlying Blaine Formation, the separation of gypsum blocks from their home outcrops, and the slow migration of those blocks down-slope as a relatively thin veneer of coarse material over the shale, is the primary erosional process of "slope retreat". The coarse material that mantles the shale in many places is known as "colluvium".

Return to US Hwy. 412.

26.8. Turn left (east) on US Hwy. 412. Drive 3.2 miles.

30.0. STOP 7.

TOPOGRAPHIC EXPRESSION OF FLOWERPOT SHALE AND BLAINE ESCARPMENT

This view to the east is of the expansive Cimarron River valley. The river is a couple of miles to the north and the highway approximately follows the course of the river. As discussed at Stop 1, the southwest bank of the Cimarron River is bedrock, in this case, Flowerpot Shale, while the northeast bank is sand, gravel, and reworked sand (dunes) of the Pleistocene floodplain.

An interesting, but little studied, part of the Pleistocene history of this part of Oklahoma can also be viewed here. Note the long, sloping surfaces that descend from the ledges of the Medicine Lodge gypsum. In some cases the slopes extend all the way up to the gypsum; in other cases, the slopes appear to start part-way down; and in still other cases, there are only the vaguest remnants of slopes down in the river valley. Where the slopes are complete, they are steepest at the top and gradually become more gentle downslope. In all cases, these slopes are dissected by modern streams. Geomorphologists (geologists who study landforms and landform development) call the top of the ledge the "shoulder", the steep part of the slope the "backslope", and the very gently tilted bottom of the slope the "footslope".

Obviously, these slopes developed at some time in the past, probably during the Pleistocene. The material that makes up the slopes is probably similar to the colluvium that capped the Flowerpot at Stop 6. Was this material deposited during periods of relatively high or low rainfall? Can we say anything about the seasonal nature of the rainfall - did most of the rain fall as "gully-washers" or more soaking, gentle rains? Consider the origin of the material that makes up the slopes in terms that the slopes are now being actively eroded. Most of the rain that falls in this part of Oklahoma comes as relatively brief, but severe, thunderstorms.

Northwest Oklahoma during the Permian, however, was much different. The key to interpreting the Permian (specifically, the Guadalupian) history of this part of Oklahoma are the gypsum beds. Gypsum (and anhydrite) are only deposited in hypersaline seas in arid climates. In addition, the older to younger sequence of thin gypsum beds in shale (Flowerpot), alternating thick gypsum beds and shale (Blaine), shale (Dog Creek), and sandstone (Marlow) records details of the geologic history.

One of the better descriptions of the Permian geology of northwestern Oklahoma is given by Johnson (1972) and is quoted here:

"Permian rocks are exposed at the surface in most of the region. They consist of several thousand feet of red shales and sandstones ("red beds") with relatively thin but conspicuous layers of resistant gypsum and dolomite. Strata dip gently (10 to 30 feet per mile) to the south into the Anadarko basin (Fig. 1, cross sections). Most Permian formations are thicker to the south, because during Permian time the Anadarko basin sank more rapidly and received more sediment than the northern shelf area.

"Most Permian rocks in the region were deposited in a shallow inland sea that extended across the Anadarko basin and shelf areas to the north (Fig. 7). Streams draining land areas to the east carried mud, silt, and sand to the seashore, while currents and tides spread this sediment across the sea floor.

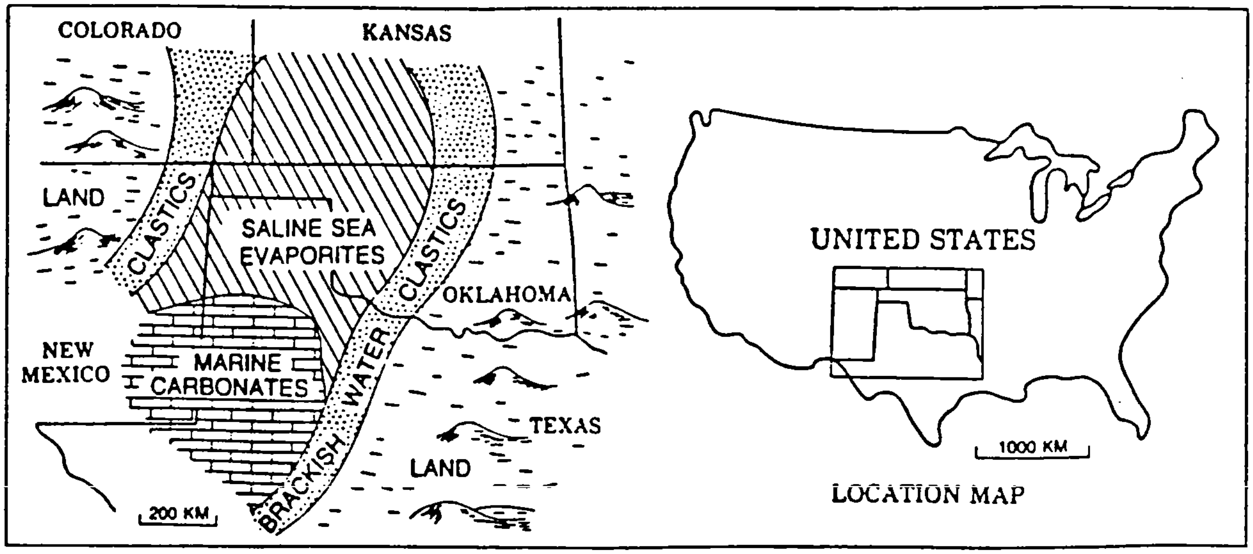


Fig. 7. Paleogeography of the Permian Basin of the southwestern U.S. during deposition of the Blaine Formation and Flowerpot Shale. Also shown are the principal rock types deposited in the different environments.

"The concentration of dissolved solids in the sea water was raised periodically to the point at which a series of "evaporite" rocks (dolomite, gypsum, and salt) was precipitated on the sea floor. The sequence of evaporite precipitation began with the formation of a thin layer of dolomite; next a thick layer of gypsum was deposited; and finally a thick layer of salt covered the rest. The complete sequence is not found everywhere in the region: at some places normal precipitation was interrupted by an influx of less concentrated water; at other places certain chemicals were depleted from the sea water before precipitation started; and elsewhere the more soluble units (salt and perhaps gypsum) were deposited but were dissolved later."

And some notes from Myers and others (1969):

"In early Middle Permian time, the sea was approximately 500 to 600 miles wide and extended across eastern New Mexico, western Texas, and western Oklahoma into Kansas. Eastern Oklahoma was a land area of low relief, and streams flowing from this area into the sea carried fine clastics. ...

"Sea level fluctuated repeatedly during part of Permian time. While the rocks of the Blaine Formation were being deposited, world-wide rises of sea level deepened the Permian sea in Oklahoma and were followed by periods of stillstand before the sea level declined. During those periods when the sea level was static, evaporation of the water increased the concentration of dissolved solids and brought about the precipitation of (evaporites). As the sea level declined, the precipitated deposits were covered by shales. This cycle of rise, stillstand, and fall of the sea level occurred at least four times and produced the alternating succession of gypsum and shale that characterizes the Blaine Formation.

"Eventually all the water disappeared, and streams flowing into the basin spread hundreds of feet of red muds (Dog Creek Shale) and sands (Marlow) over its desert floor. For a time, extensive sand dunes (Rush Springs) covered part of Oklahoma. ..."

END OF ROAD LOG AND FIELD TRIP

Thank you for attending the annual meeting of the Oklahoma Chapter of The Natural Conservancy. We hope you have enjoyed this brief overview of the geology of the Gypsum Hills. Our discussion has taken us from the shallow evaporite seas of the Permian to rivers formed during the interglacial periods of the Ice Age. We've discussed headward erosion and the likelihood that one day, the Cimarron River will capture the North Canadian. We've collected gypsum and seen the evidence for gypsum dissolution and karst development throughout the Blaine escarpment.

Several non-technical books have been written on the geology of this part of the State and are listed in the References. Two of the most popular are Johnson (1972) and Myers and others (1969). These may be ordered from the Oklahoma Geological Survey at 1- (800) 330-3996 for $2.00 and $1.00, respectively. If you have any additional questions about the geology of Oklahoma, contact the Survey at the above toll-free number or access us through our web site: http://www.ou.edu/special/ogs-pttc/.

Please drive safely on your way home after the meeting.

DID YOU KNOW THAT?

Alabaster Caverns is the largest commercial gypsum cave in North America?

The longest gypsum cave in the world outside of Russia is Jester Cave in Greer County, Oklahoma. Over 33,000 ft of passageways have been mapped in the cave. Like Alabaster Caverns, it is in the Blaine Formation.

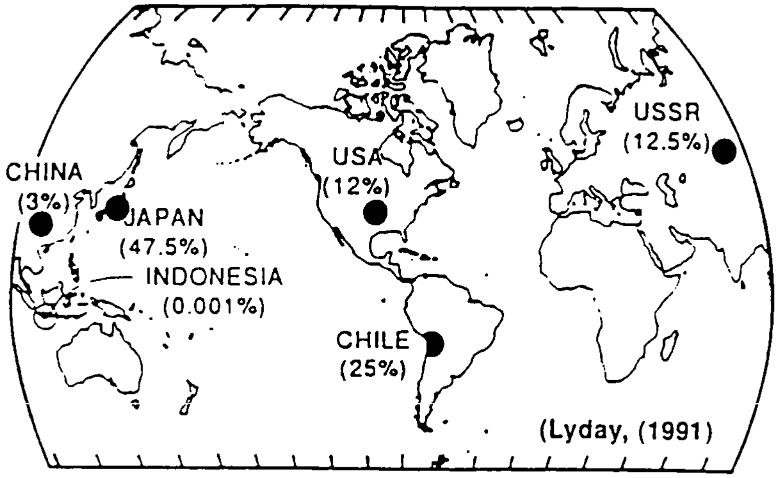
Little Sahara State Park includes the largest active sand dune field in Oklahoma.

All U.S. production of iodine is by three companies in the Woodward area. These are Woodward Iodine Corporation, Iochem Corporation, and American Brine Resources. Wells produce iodine-rich brine from about 7500 feet deep in the subsurface. Iodine production near Woodward is about 2 million pounds annually, which is about 25% of U.S. demand and represents about 12% of world production (1990).

Gypsum is an $18-million industry in Oklahoma and is quarried extensively in the northwest part of the State. It has many uses (Sharpe and Schroeder, 1998):

- Agricultural - soil amendment; calcium supplement in animal feeds, other.
- Gypsum wallboard - common, fire-resistant, and water-resistant varieties.
- Industrial gypsum plasters - art and casting, pottery and ceramic, moulding and tooling, crayons, wall patching.
- Industrial gypsum cements - oil-well cement; high-strength statuary; high-strength tooling; fiber-reinforced architectural; patching for roads, bridges, runways, and floors.
- Food and pharmaceutical - filler and binder in aspirin and other medicines, yeast activator in brewing of beer, moisture absorbent in bread and pizza dough. (Have you had your gypsum today?)
- Portland cement retarder - ground with clinker to control setting time.

The only certified surface hazardous-waste (non-radioactive) disposal site in Oklahoma is just northeast of Stop 7. It is developed on the Flowerpot Shale, which is virtually impermeable to groundwater flow.



COUNTRIES PRODUCING IODINE AND PERCENTAGE OF WORLD PRODUCTION (1990)

USES OF IODINE

FIRST USED IN EARLY 1900s FOR GOITER, AS A DISINFECTANT FOR CUTS AND ABRASIONS, AND FOR SANITATION.

1. CATALYSTS: TO PRODUCE ACETIC ACID, BUTADIENE, AND POLYMERS.
2. STABILIZERS: PROCESSING OF NYLON (FOR TIRE CORD AND CARPETS), ROSINS, AND WOOD PRODUCTS.
3. ANIMAL FEEDS: IODIZED SALT AND OTHER COMPOUNDS REDUCE LIVESTOCK AILMENTS (25% OF U.S. USE).
4. DISINFECTANTS: A GERMICIDE USED IN DAIRIES, LABORATORIES, FOOD-PROCESSING PLANTS, DISH WASHING, SWIMMING POOLS, AND WATER SUPPLIES.
5. PHARMACEUTICALS: RADIOPAQUE MEDIA (X-RAYS), COUGH MEDICINE, AND MAKING AMPHETAMINE.
6. PHOTOGRAPHY: SILVER IODIDE IN NEGATIVE EMULSIONS, AND AMMONIUM IODIDE IN DEVELOPERS.
7. COLORANTS: RED COLORING IN SOFT DRINKS, GELATIN DESERTS, ICINGS, AND PET FOODS; RED DYES ON COTTON, HALF-SILK, AND STRAW.

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