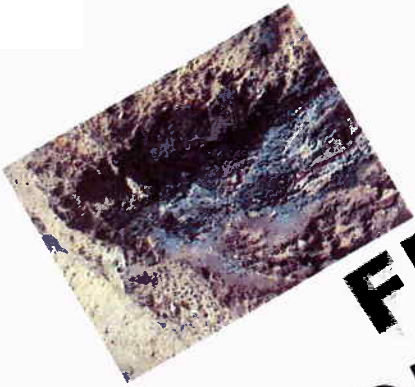
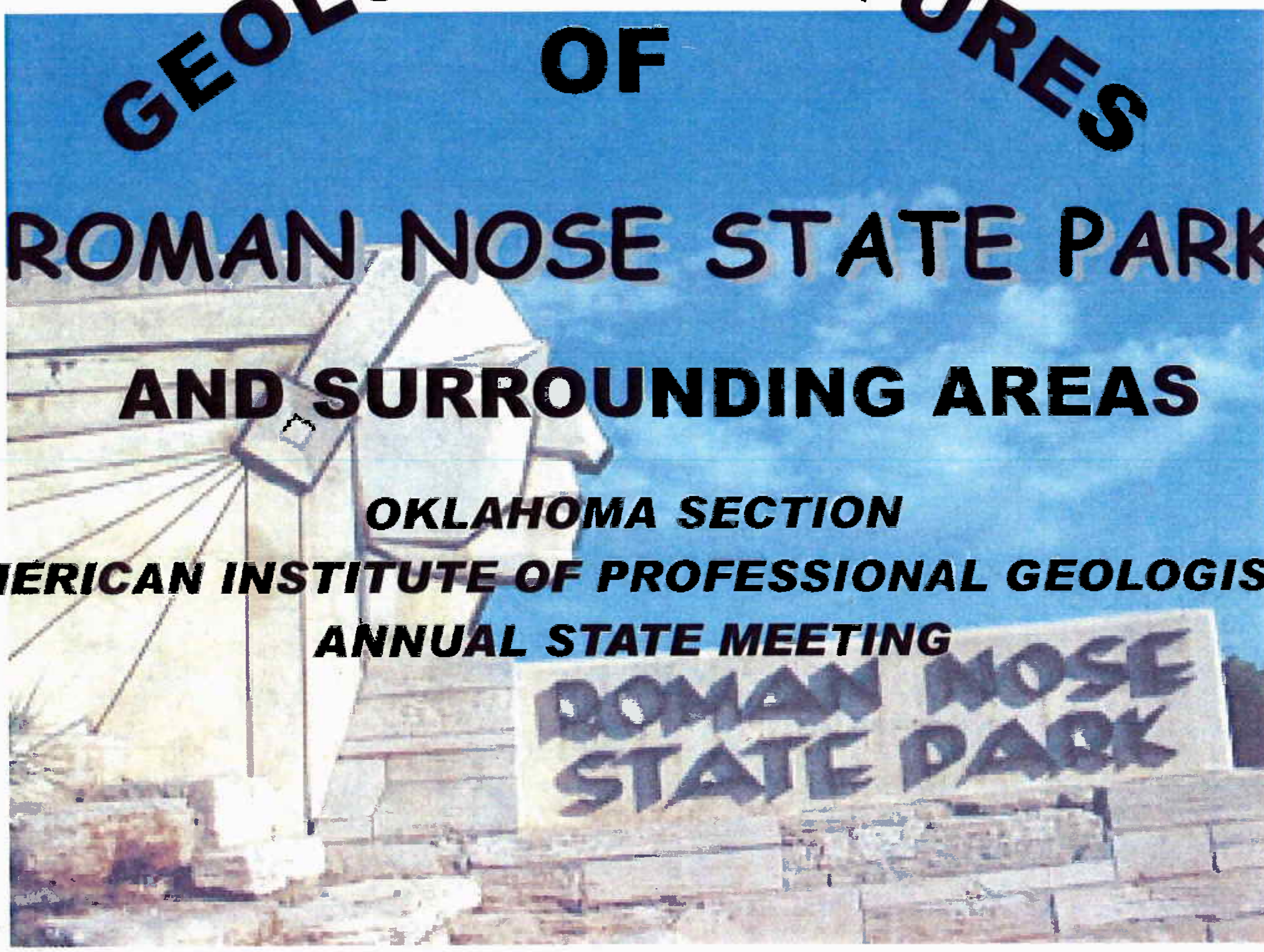
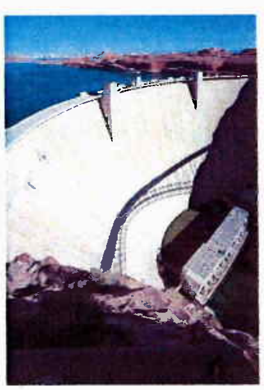


FIELD GUIDE TO GEOLOGIC FEATURES OF ROMAN NOSE STATE PARK AND SURROUNDING AREAS

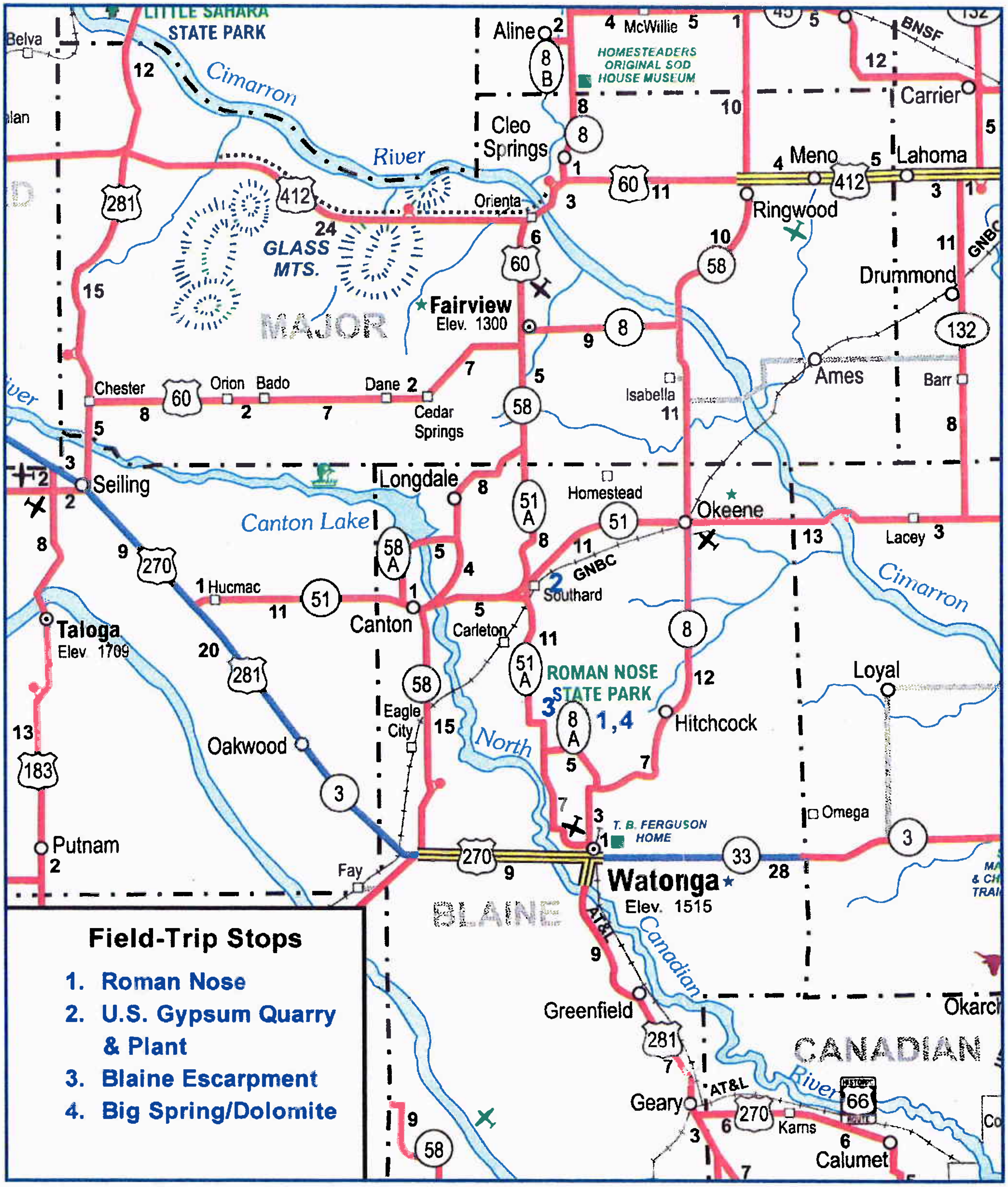


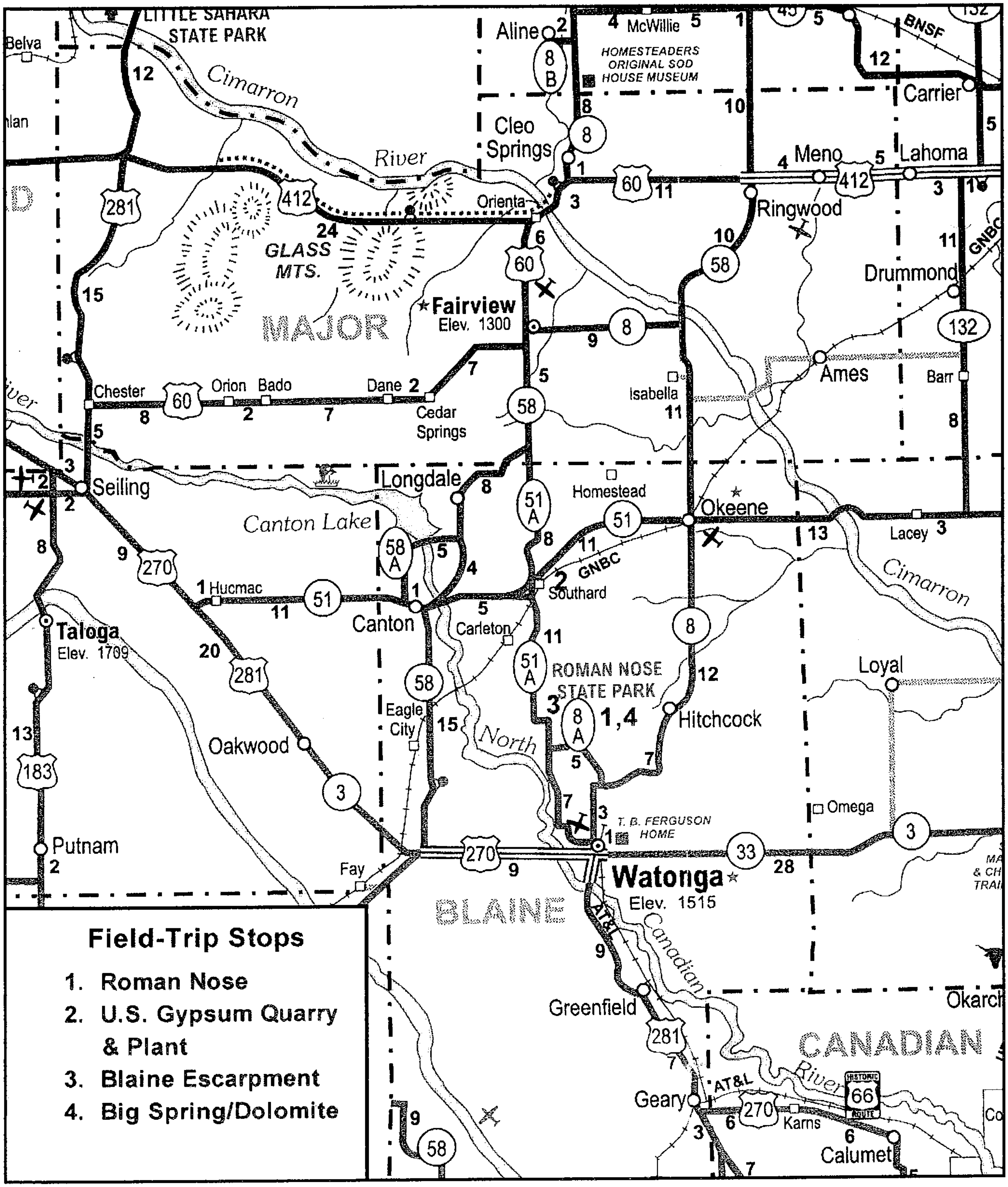
OKLAHOMA SECTION
AMERICAN INSTITUTE OF PROFESSIONAL GEOLOGISTS
ANNUAL STATE MEETING



FRIDAY, MAY 2 - SUNDAY, MAY 4, 2003
ROMAN NOSE STATE PARK

Jim Chaplin
Ken Luza
Luis Rodriguez
OKLAHOMA GEOLOGICAL SURVEY
Open-File Report 15-2003


LITTLE SAHARA STATE PARK
Belva
Cimarron River
GLASS MTS.
MAJOR
Aline
McWillie
HOMESTEADERS ORIGINAL SOD HOUSE MUSEUM
Cleo Springs
Orienta
Meno
Lahoma
Carrier
Ringwood
Drummond
BNSF
GNBC
Fairview
Elev. 1300
Ames
Barr
Isabella
Chester
Orion
Bado
Dane
Cedar Springs
Seiling
Longdale
Homestead
Okeene
Lacey
Canton Lake
Hucmac
Canton
Southard
Carleton
Taloga
Elev. 1709
Eagle City
ROMAN NOSE STATE PARK
Hitchcock
Loyal
Oakwood
North
Omega
T. B. FERGUSON HOME
Putnam
Fay
Watonga
Elev. 1515
BLAINE
AT&L
Canadian River
Greenfield
Okarche
CANADIAN
Geary
Karns
Calumet
Field-Trip Stops
1. Roman Nose
2. U.S. Gypsum Quarry & Plant
3. Blaine Escarpment
4. Big Spring/Dolomite


LITTLE SAHARA STATE PARK
Belva
Cimarron River
GLASS MTS.
MAJOR
Aline
McWillie
HOMESTEADERS ORIGINAL SOD HOUSE MUSEUM
Cleo Springs
Orienta
Fairview
Elev. 1300
Meno
Lahoma
Carrier
Ringwood
Drummond
Ames
Barr
Isabella
Chester
Orion
Bado
Dane
Cedar Springs
Seiling
Longdale
Canton Lake
Homestead
Okeene
Lacey
Southard
GNBC
BNSF
Hucmac
Canton
Carleton
Taloga
Elev. 1709
ROMAN NOSE STATE PARK
1,4
Hitchcock
Loyal
Eagle City
North
Oakwood
Omega
T. B. FERGUSON HOME
Putnam
Fay
Watonga
Elev. 1515
BLAINE
Canadian
AT&L
Greenfield
CANADIAN
River
Geary
Karns
Calumet
Okarch
Field-Trip Stops
1. Roman Nose
2. U.S. Gypsum Quarry & Plant
3. Blaine Escarpment
4. Big Spring/Dolomite

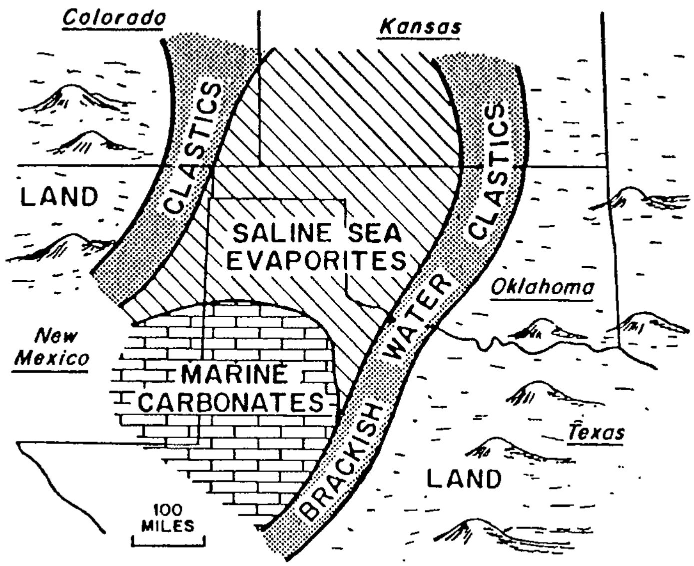


Figure 2. Paleogeography and principal lithofacies in Permian Basin of the southwestern United States during deposition of carbonate/ evaporite / siliciclastic facies of the Flowerpot Shale, Blaine Formation, and Dog Creek Shale. (Johnson, 1972b)

The area is an excellent site to examine cyclic sedimentation in an evaporate-carbonate-redbed sequence. Thick layers of rock salt were originally deposited over wide areas in several Permian formations. Where these formations occur now at or just below the surface, the salt has been largely dissolved by ground water. Overlying strata have collapsed into the cavities formed by this dissolution, causing the beds to dip in various directions at angles of 5° to 20°. In the Salt Plains of northwestern Oklahoma, brines formed from recently dissolved salt beds are now flowing to the surface through layers of porous sandstones and siltstones.

HISTORY OF PARK AREA

The park area has long been a famous camping place for Indians, outlaws, cavalrymen, and settlers, many of whom followed trails along the North Canadian River. The ever-flowing fresh water springs of the park area offered a better supply of water than did the adjacent rivers. The Spaniards were the first white men to cross the region and they found many Indians already along the rivers.

The area that now includes Blaine County was first claimed by Spain in the 1520's, then France, 1600, Spain again, France again in 1800, and finally was purchased by the United States in 1803. The earliest reference to the manufacture of salt in Blaine County was Jesse Chisholm who manufactured salt in the Salt Creek Canyon area before the Civil War and his operation continued until 1867. On March 4, 1868, Chisholm died at the Johnny Lefthand Spring in Blaine County, after eating some bear meat cooked in a brass kettle.

From the 16th to the 18th century the Kiowas, Comanches, Cheyennes, Arapahos, and Osage Indians migrated into this region from the north and northeast. French and Spanish trading activities represented the only white contact with tribes of this area before American acquisition of Louisiana Territory in 1803. Following the Louisiana purchase, the United States created a huge Indian Territory in the central and southern portion of the acquisition and took steps to move these Indians east of the Mississippi to this region. Practically all of present-day Oklahoma was assigned to the Five Civilized Tribes, and by treaty and in some cases by force, the Cherokees, Choctaws, Creeks, Chickasaws, and Seminoles were removed from their historic tribal domains in the east to new homes in the west.

During the Civil War the Five Civilized Tribes, for the most part, supported the Confederacy. As a penalty for this, each tribe was forced by the treaties of 1866 to surrender portions of certain tribal lands in the Indian Territory to the United States. The government then undertook to assign certain portions of these surrendered lands to the various plains tribes which were committed by treaty to accept a given reservation and live thereon. The Blaine County area was assigned to the Cheyenne-Arapaho down to the South Canadian River in 1869. In 1872 the Wichita, Caddo, and Delaware Indians were assigned to the area south of the Canadian River, part of which would include the remainder of Blaine County.

An important Indian battle is the battle of Arickaree or the fight of Beecher Island as it is called. Chief Henry Roman Nose, after whom Roman Nose State Park is named, led 600 Indians, mostly Sioux, Cheyenne, and Arapaho, in the attack against the 51 soldiers stationed on the sand bar island in the stream in 1868. According to U.S. Army records and Cheyenne historians, Roman Nose was killed at Beecher's Island. However, other accounts state Roman Nose returned after the battle to what is now the Roman Nose State Park area and used this area as winter quarters for his people. Roman Nose is believed to have died about 1917 and is buried in the Indian Cemetery one-half mile west of the northwest corner of Watonga.

After 1889, the government adopted the policy of extinguishing Indian tribal title to reservation lands, assigning each tribal member and allotment in severalty, and opening the surplus to settlement. In 1890, prior to opening the Cheyenne-Arapaho reservation the government designated the area that, is now Blaine County north of the South Canadian River as "C" County. With the run of April 19, 1892, the name was changed to Blaine County, after James G. Blaine, a Senator from Maine. The area south of the South Canadian River was opened by lottery in the summer of 1901. Thus Blaine County became a part of Oklahoma Territory. Indian Territory to the east and Oklahoma Territory to the west then combined on November 16, 1907, into Oklahoma, proclaimed the forth-sixth state by President Theodore Roosevelt. During this time, and a little earlier many post offices, stage coach routes, and railroads were established.

The Choctaw, Oklahoma, and Northern Railway Company built a railroad from Geary to Alva in 1902, running through what is now the park area. The Rock Island took it over in 1906 and abandoned it in 1926. The post office of Bickford, just northwest of the park area was established November 2, 1904. This was also the site of the Roman Nose Gypsum Company, now abandoned.

The first oil well in Blaine County was drilled at Darrow in 1906 and went to a depth of 3,300 ft, but was dry and abandoned. The owners would drill awhile and then go into town and promote awhile. When promoting they would place a cedar log in the hole. When the price of shares got down to $1.00 or less, the promoters left Darrow in the dark of night, stating that they couldn't get the stump out of the hole.

The first gypsum (stucco) mill in Oklahoma Territory was the Ruby Stucco Mill near Ferguson. The mill was built in 1902 at the base of a high cliff capped by the Nescatunga Gypsum, which was quarried. Usually ten to twelve men worked in the quarry and twelve to fifteen farmers with four-horse teams took the sacked gypsum to Salton and loaded it on railroad cars.

During and after the Civil War period, this area became famous as the lair for notorious outlaws. These include Quantrill, James brothers, Belle Starr, Younger brothers, Daltons, the Doolin gang, Black-Yeager gang, and Al Jennings. These people took advantage of the unsettled nature of Oklahoma Territory and Indian Territory, using places in these territories for their hideouts. According to local stories only three gangs were in this region in the 1890's. Two of these gangs supposedly have "buried treasure" in the Roman Nose State Park area, the Dalton and the Yeager gangs. The Doolin gang probably operated in the area and it is difficult to know what crime to attribute to what gang. Most of the stories about "buried treasure" originated from the outlaws themselves while they were in jail and the stories may not be reliable. Some of the known hideouts were in caves at the head of Salt Creek Canyon and in Roman Nose State Park.

On June 20, 1935, businessmen from Watonga, Okeene, Hitchcock, Canton, Geary, Greenfield, and rural citizens provided the original $6,000 to purchase 480 acres which formed the park area. Plans were made to develop the park by the National Park Service in cooperation with the Oklahoma Planning and Resources Board. The Civilian Conservation Corps workers constructed the first facilities and in 1937 the park was opened to the public. Some more land was added so that it now covers 540 acres, 22 of which is Lake Boecher, named after Senator Roy Boecher of Kingfisher. Lake Watonga covers 76 acres outside of the park area and is operated by the State Game and Fish Department.

On April 22, 1956, the Oklahoma Planning and Resources Board formally opened the lodge, which is operated by the state. Up to that time $749,000 was spent on the park, and $169,000 on the lodge.

GENERAL GEOLOGIC HISTORY OF REGION

Sedimentary strata of Middle Permian age (Guadalupian-uppermost Leonardian) in the Midcontinent contain a variety of rock types, including carbonates, evaporites, and mixed carbonate / siliciclastic rocks (Fig. 2). These sediments were deposited in a broad cratonic shelf setting which underwent differential subsidence and which was bounded by continental uplands on the east and west and by relatively deep-water seas to the south (Fig. 2). Most Permian formations are thicker to the south, because during Permian time the Anadarko Basin sank (subsided) more rapidly and received more sediment than the northern shelf area. Thus, most Permian rocks in the region were deposited in a shallow epicontinental (inland) sea that extended across the Anadarko Basin and shelf areas to the north. Streams draining land (source) areas to the east and west carried mud, silt, and sand into the epicontinental sea, while currents, waves, and tides distributed the sediment across the sea floor.

Lithofacies are characterized by profound lateral facies changes related to a broad range of depositional environments and processes. Cyclical repetition of lithologies in vertical successions of strata are related to rapid periods of transgressions, regressions, and sea-level stillstands produced by changes in sediment productivity and relative sea level. These changes were probably controlled, at least in part, by both global tectonic instability and polar glaciation.

GEOMORPHOLOGY

Geomorphology (the study of land forms) in the park area shows that the present topography has resulted from differential weathering and erosion of resistant (dolomite / gypsum) and nonresistant (mudstone, shale) rock layers. Horizontal beds of dolomite, gypsum and sandstone resist erosion and cap most of the topographic highs (hills) forming a series of benches (ledges) along the sides of the valleys. Shales and mudstones are less resistant and are deeply eroded to form most of the broad lowlands and canyons.

The park area encompasses two major physiographic (geomorphic) provinces that in general coincide with the outcrop area of the various Permian formations (Fig. 3).

Central Redbed Plains

Characterized by gently rolling hills, and broad, flat plains formed on Permian red shales (Flowerpot Shale), mudstones, and sandstones. Bedrock is locally exposed, but much of the present ground surface consists of a soil of loose Quaternary sediment deposited predominantly by streams and wind.

Cimarron Gypsum Hills

This province encompasses a long, narrow band of escarpments and badlands developed on interbedded Permian gypsums and shales (Blaine and Dog Creek Formations). The principal geomorphic feature in the park area is a northwest-southeast trending escarpment referred to as the "Blaine Escarpment", which overlooks the North Canadian River. The escarpment is held up by resistant gypsum and dolomite ledges. The escarpment in the park area is about 1600 ft (488 m) in elevation with a topographic relief of nearly 300 ft (92 m). It is deeply dissected forming steep valleys such as Cat Canyon and Ruby Mill Canyon. Caverns and sinkholes may develop in areas where ground water has dissolved part of the gypsum.

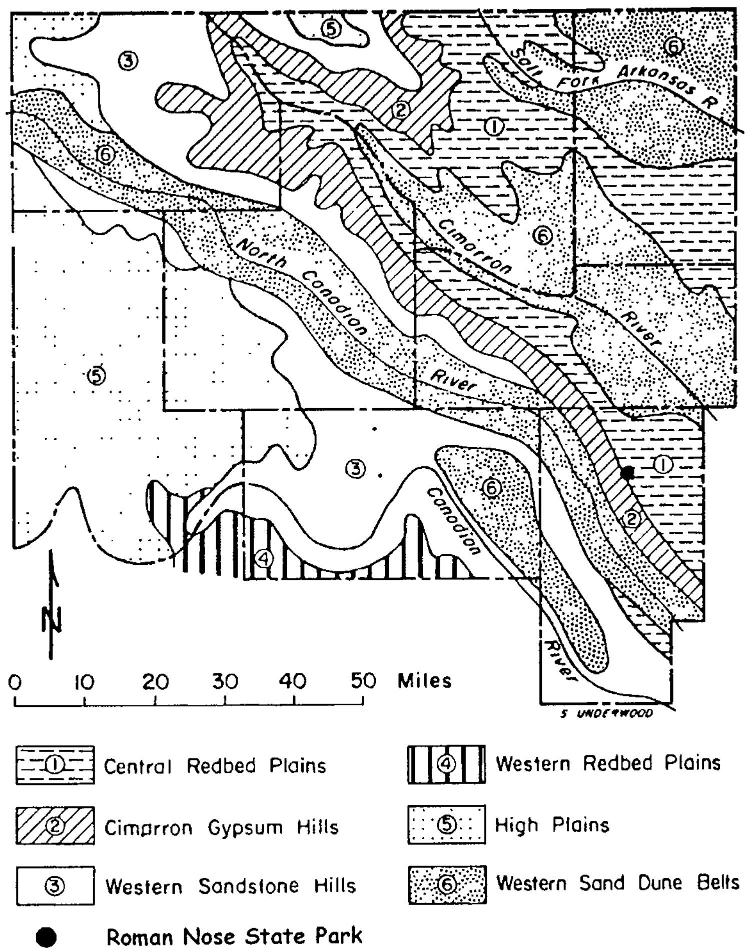


Figure 3. Geomorphic Provinces of northwest Oklahoma. Black dot in Blaine County shows location of Roman Nose State Park (after Johnson, 1972a)

The ridge termed the Gypsum Hills, is the first line of hills if approached from the east. Early settlers, coming westward, called them the first line of hills because they form an unbroken escarpment, extending in a northwestward direction as far as the eye can see.

North Canadian River

The principal drainage in the area of the park is the North Canadian River to the southwest of the park (Fig. 3). The North Canadian River deposits consist of 40 to 100 ft (12 to 31 m) of gravel, sand, silt, and clay, and locally some volcanic ash, deposited at 3 to 5 terrace levels, along either side of the river. On the southwestern side of the river there is a veneer of silt and clay, with some gravel resting upon exposed bedrock.

The gravels are composed of quartzite pebbles and cobbles from the Rocky Mountains. The upper terrace levels contain volcanic ash and Pleistocene dune sands covered with vegetation. The present channel runs entirely upon the Dog Creek Shale. One characteristic feature of the drainage on the northeastern side of the river is the pattern produced by ephemeral and intermittent streams that do not reach the main river. Most of these streams are less than a mile long and end in a small depression or sink. Many sand dunes cover the region and may account for some of this pattern, but recently formed sinkholes also played a major role in their formation. The overlying terrace gravel and sand deposits act as an aquifer, supplying water to the Permian formations below. The water probably dissolved out the gypsum and soluble salts, flowing out eastward in the Blaine escarpment to form gypsum- and salt-water springs at lower elevations.

GENERAL STRATIGRAPHY OF REGION

In most of the park region, Permian rocks are exposed at the surface. They consist of several feet of red shales, mudstones, and sandstones ("redbeds") with relatively thin but conspicuous layers of resistant gypsum and dolomite. Strata dip gently (10 to 30 ft per mile) (1.9 to 5.7 meters per km), to the southwest into the Anadarko Basin and strike north-northwest in the northern part of Blaine County and west-northwest in the southern part of the county.

Outcropping rocks are the Blaine Formation and overlying Dog Creek Shale of Permian age (270 million years ago). Three resistant beds of white gypsum (Medicine Lodge, Nescatunga, Shimer), each 6 to 12 ft (2 to 4 m) thick, are separated by red-brown and light gray shales 25 to 30 ft (8 to 10 m) thick; each gypsum bed is immediately underlain locally by a fossiliferous dolomite bed 1 ft (0.3 m) thick (Fig. 4). Fossils in the dolomites consist dominantly of molds of the pelecypod (bivalve) *Permophorous*. Locally the Altona Dolomite contains ripple marks on its upper surface. Anhydrite, an anhydrous form of calcium sulphate ($CaSO_4$), in layers or lenses 0.5 to 3 ft (0.15-1 m) thick, is present locally in the middle of both the Shimer and Nescatunga Gypsum Members; the anhydrite is light gray and finely crystalline and is both harder (3-3.5) and denser (2.93 g/cc) than the gypsum which can be scratched with the fingernail.

PALEONTOLOGY

Most fossils in the Middle Permian in Kansas, Oklahoma, and Texas occur as casts or molds in thin carbonates (limestones / dolomites) at the base of an evaporite member. The faunas include predominantly the mollusks; in order of decreasing abundance: pelecypods (bivalves), nautiloid cephalopods, ammonoid cephalopods (particularly *Perrinites*), and gastropods. In addition, less common marine invertebrates include brachiopods, bryozoans, one scaphopod, and one crinoid. The nautiloid cephalopods are outstanding for the number of species and genera represented as well as for their size and diversity in development. The ammonoid cephalopod *Perrinites hilli* (Smith) is diagnostic and is useful for the correlation of Middle Permian strata throughout the Permian Basin.

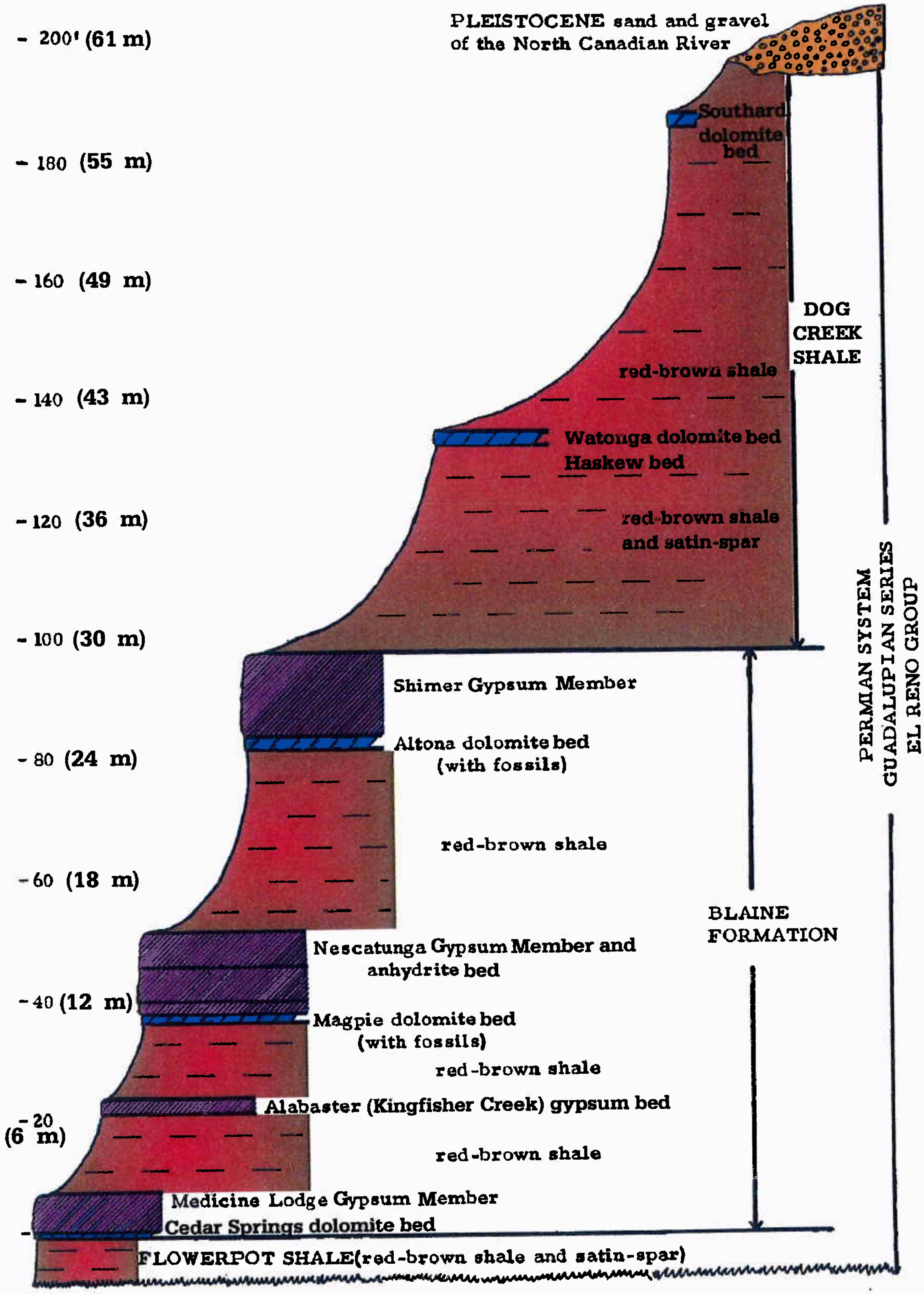


Figure 4. STRATIGRAPHIC FRAMEWORK FOR PERMIAN ROCKS EXPOSED IN THE PARK AND ADJACENT AREAS

DETAILED STRATIGRAPHY OF PARK AREA
(Figure 4)

In the park area, the formation beneath Lake Watonga is called the Flowerpot Shale composed of red to reddish-brown shale and a variety of gypsum called satin-spar (Fig. 4). The next formation above the Flowerpot Shale is called the Blaine Formation. The Blaine Formation consists of about 90 ft (28 m) of unnamed red-brown shales and mudstones, thick gypsum units, and thin dolomite beds, locally fossiliferous. The Medicine Lodge Gypsum is the basal member of the Blaine Formation together with a thin Cedar Springs dolomite bed at the base. About 15 ft (5 m) higher occurs another gypsum bed called the Alabaster (Kingfisher Creek) gypsum bed. The Alabaster Gypsum is separated from an overlying thin dolomite called the Magpie Dolomite by about 15 ft (5 m) of red-brown shale. Immediately above the Magpie is the Nescatunga Gypsum / Anhydrite overlain by about 30-35 ft (9 to 11 m) of unnamed red-brown shales. Above this occurs the Altona Dolomite and overlying Shimer Gypsum of the Blaine Formation. The top of the Shimer Gypsum marks the upper boundary of the Blaine Formation.

The Dog Creek Shale occurs next above the Blaine Formation. It is composed of about 85 ft (26 m) of unnamed, satin-spar bearing red-brown shales with several thin dolomite ledges. The lower dolomite ledge, referred to locally as the Watonga Dolomite, occurs about 30 ft (9 m) above the top of the Shimer Gypsum and forms a flat, high, prairie-like landscape within the park area. The upper ridge, referred to locally as the Southard Dolomite, occurs about 80 ft (25 m) above the top of the Shimer, forming an escarpment or steep-faced ridge west and south of the park area. The top of the Dog Creek Shale is not exposed in this region because it was eroded off by the North Canadian River.

Just west and south of the park area, the North Canadian River gravels and sands are exposed, forming the highest elevations in the area. They were deposited at a time when the river was at a higher elevation during what is termed the Pleistocene Epoch, the last 2 million or so years of earth's history, when much of North America and the Rocky Mountains were under ice. The river valley formed when the river was much larger during the "interglacial stage", which separated the four glacial stages of the Pleistocene ("Ice Age") Epoch. The porous nature of the sand dunes and Pleistocene river sands make the alluvial valleys of the North Canadian and Cimarron Rivers excellent sources of groundwater.

ROADSIDE GEOLOGY OF THE PARK AREA

The entrance gate in the southeastern part of the park area is built upon the lower portion of the Dog Creek Shale. Just after passing northward through the park entrance, a deep ravine can be seen immediately to the east of the road in the Shimer Gypsum. This was used by Chief Roman Nose as a natural stable for his horses.

In ascending the slight hill north of the ravine, where the road forks, the ground surface is relatively flat for some distance. This flat nature is due to an underlying dolomite (Watonga) of the Dog Creek Shale, about 30 ft above the top of the Shimer Gypsum.

At the fork, the northward-bearing road leads to the park proper and the northeastward-bearing road ends at the lodge. The lodge is built upon the Nescatunga Gypsum (Fig. 5) and the prominent cliff above the ridge is formed in the Shimer Gypsum. If you look directly across Boecher Lake from the lodge, one can observe a large red cedar tree, named the Medicine Tree, growing upon the Shimer Gypsum escarpment. Both Boecher and Watonga Lakes are formed in the shale below the Nescatunga Gypsum, in the Medicine Lodge Gypsum, and in the underlying Flowerpot Shale.

Most of the prominent cliffs seen in the park are in the Shimer Gypsum, the Nescatunga becoming prominent only down near the lakes. The area of the springs and swimming pool is surrounded on three sides by the Shimer escarpment. The springs flow from the base of the gypsum and supply the swimming pool with water (Fig. 5). The Altona Dolomite (at the base of the Shimer) is the rock that was used in the construction of the swimming pool, walkways, steps, and parts of many buildings in the park area. The rock was quarried locally just east of the park area.

In passing out of the park to the southwest, the road ascends through the Dog Creek Shale, including both dolomites. Above this occurs the sands and gravels of the North Canadian River, deposited during the Pleistocene Epoch. Many ancient sand dunes can be observed above these gravels and sands. In proceeding westward to State Highway 51A, it should be noticed that there is a natural westward slope of the land toward the North Canadian River, indicating that the ancient river channel has had a net shift from east to west throughout its history.

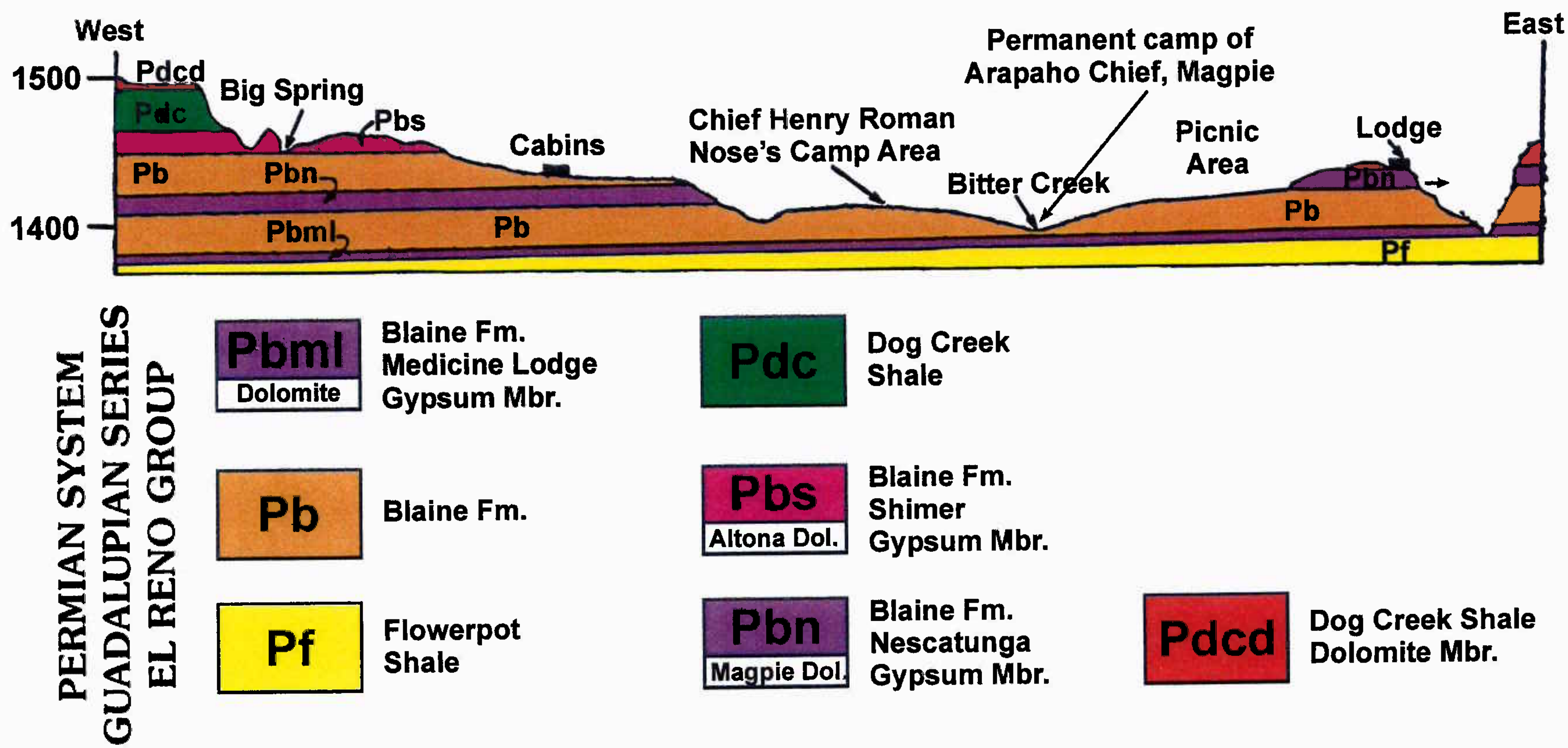


FIGURE 5. GEOLOGIC CROSS-SECTION (WEST TO EAST) OF ROMAN NOSE STATE PARK BLAINE COUNTY, OKLAHOMA (modified from Fay, 1959)

MODERN PERITIDAL (SHORELINE) ENVIRONMENTS

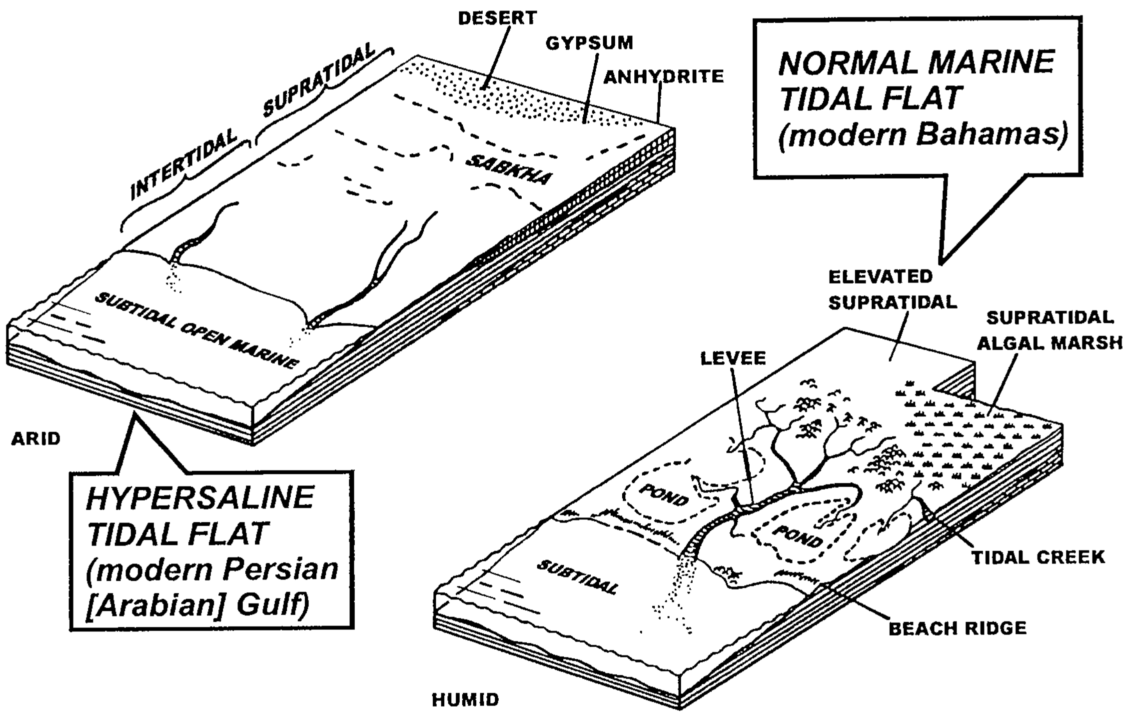


FIGURE 6. CARBONATE TIDAL FLATS

Peritidal ("peri" means around or near, "tidal" relates to tides)

I. SUBTIDAL FACIES OR ZONE
   - Permanently submerged; ranges from low energy, lagoonal environments to higher energy shoals.
   - Semimonthly neap tides may briefly expose the shallowest portions.
   - Shelly, bioturbated lime mud.
   - Cover of sediment-stabilizing sea grasses
   - Low-relief protective oolite shoals in higher-energy settings.

II. INTERTIDAL OR LITTORAL FACIES OR ZONE
   - Lies between normal low and high-tide levels
   - Submerged on a diurnal or semidiurnal basis
   - Often subdivided into outer, middle, and inner tidal flats
   - Outermost zone thoroughly bioturbated (crabs, shrimps, gastropods, worms, and fish).
   - Usually covered at low tide with an ephemeral microbial ("algal") mat serving as abundant food source for grazing organisms
   - May be fronted seaward by beaches of bioclastic sand winnowed from creeks and ponds or adjacent seafloor during storm events
   - Microbial mat cover in the inner tidal zone, exhibits different morphologies (polygonal, wrinkled, crenulated, smooth, etc.) reflecting

the frequency and duration of subaerial exposure and the salinity of tidal waters.

A. PONDS AND CREEKS

- Brackish or hypersaline water; stressed environment
- Especially common in more humid climates
- Restricted biota adapted to fluctuating salinities (e.g. gastropods, small bivalves, shrimps, ostracodes, polychaete worms, etc.)
- Low species diversity, high numbers of individuals
- Permanently submerged tidal creeks or channels.
  - Conduits for tidal flooding and draining.
  - Least common in arid settings.
  - Several meters deep and tens of meters wide.
  - Lag of semilithified intraclasts.
  - Creeks migrate laterally.
  - Creeks bordered by supratidal levees that protrude above high-tide level; microbially laminated.

III. SUPRATIDAL FACIES OR ZONE

- Positioned above normal high tide
- Flooded only during storms and semimonthly spring tides
- May become evaporitic in semiarid and arid climates, and for these supratidal flats the Arabic word "sabkha" has been adopted by sedimentologists
- Covered by microbial mats of filamentous cyanobacteria often shrunken into desiccation polygons and commonly dislodged into chips or intraclasts
- May contain coarser sediment intercalations that reflect deposition by exceptional storm events
- Beds and nodules of gypsum/anhydrite in arid settings
- Landward parts grade into eolian deposits, soils, or freshwater marshes and lakes in humid settings
- Lithified polygonal microbial crusts (mats) may be thrust into "tepee" structures by episodic groundwater discharge
- Much of the microbially laminated sediment shows fenestral fabric

SEDIMENTOLOGY

Permian sedimentation consists of a succession of lithofacies making up an evaporite cycle. The cycle (sequence of evaporite precipitation) usually begins with the formation of a thin dolomite bed at the base, followed by a gypsum layer which in turn is normally overlain by a thick layer of salt (halite) (Fig 7). However, salt (halite) beds which normally cap the evaporite cycle in the normal order of precipitation from sea water, may be absent and replaced by a relatively thick sequence of siliciclastics composed of reddish-brown shale/mudstone interbedded with thin greenish-gray shale/mudstone beds. The cycles may be repeated several times throughout the stratigraphic section, but often are incomplete.

Some possible explanations for the absence of salt in the cycles may be: 1) in some places normal precipitation was interrupted by an influx of less concentrated saline water, 2) at other places certain chemicals were depleted from the sea water before precipitation began, 3)the more soluble units (salt and perhaps gypsum) were deposited but were dissolved later, 4) periods of evaporation were too short, and elsewhere, 5) evaporite / carbonate precipitation was interrupted by an influx of siliciclastics. The stratigraphic record of ancient peritidal carbonates tends to be one of persistent repetition of the basic meter-scale, shallowing-upward succession, imparting a characteristic "cyclic" or perhaps, more appropriately, "rhythmic" appearance to the strata. (Fig 8)

EVAPORITE GEOCHEMISTRY

Gypsum is a normal evaporation product of marine water. It can easily be precipitated by evaporating sea water to 19% of its original volume. Common salt (NaCl) begins to precipitate when the original volume has been reduced to 5%. Therefore about 0.4 ft (12 cm) of gypsum can be formed from 1,000 ft (305 m) of sea water, thus a bed of gypsum 15 ft (5 m) thick would require a column of water 37,500 ft (11,430 m) thick. Considering the water depth during deposition of the Blaine Formation was probably never more than 50 to 200 ft (16 to 61 m), and probably much less, and because salt occurs only in traces, a constant reflux of marine waters from the open ocean to the south (New Mexico area) is required to bring in calcium sulphate and at the same time remove salt. This may, in part, explain the origin of the Blaine County evaporites.

Traces of salt are present in outcropping gypsums and anhydrites of the Blaine Formation. Higher concentrations are found in subsurface beds as evidenced from cores. At shallow depths and on the outcrop most of the salt has been leached away by groundwater.

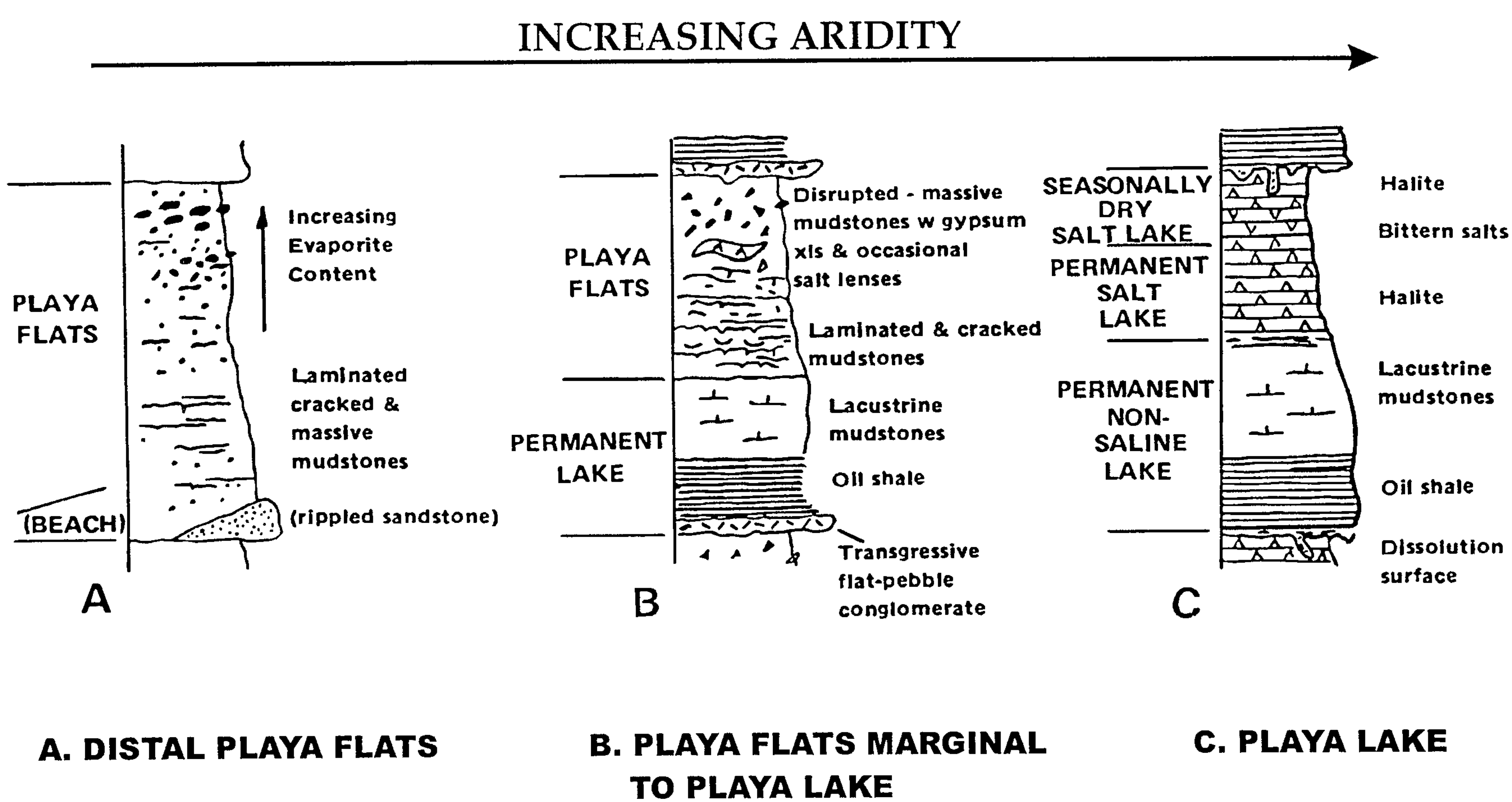
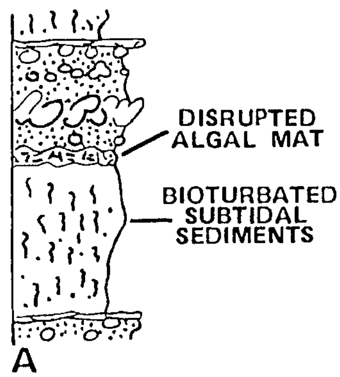
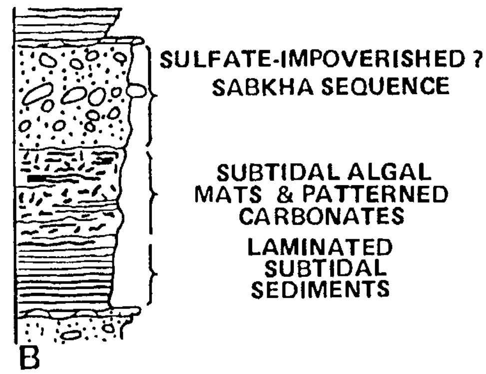


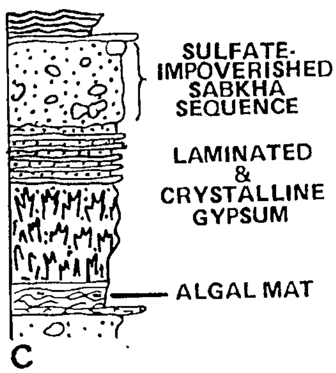
FIGURE 7. HYPOTHETICAL CYCLES REFLECTING INCREASING ARIDITY (After Walker, 1981.)



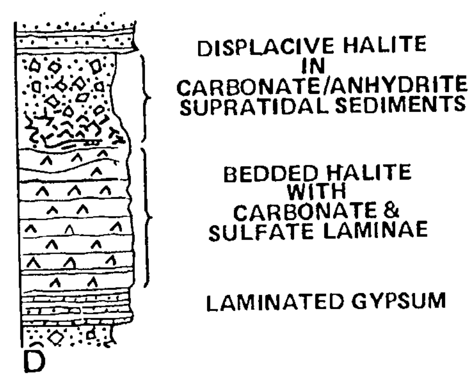
A **Marginal to a normal marine to slightly hypersaline water body.**



B **Marginal to a hypersaline water body within which sulphates are bacterially reduced**



C **Marginal water body precipitates and preserves gypsum**



D **Marginal water body is salt-precipitating; supratidal sequence largely composed of displacive (and replacive?) halite.**

FIGURE 8.HYPOTHETICAL SHOALING-UPWARD CYCLES
(After Walker, 1981.)

ENVIRONMENTAL GEOLOGY

Locally, large blocks of gypsum have fallen from the main ledges and rest on slopes composed of underlying shales. One large rockfall in December, 1971 brought a block of Shimer Gypsum weighing about 150,000 pounds (68,000 kg) down to the road on the north side of the lake, 0.1 mi (0.16 km) northeast of the riding stables. The rockfall occurred after a heavy rain when the gypsum block was sufficiently undercut by shale erosion, and joints or slippage planes in the underlying shale were sufficiently "lubricated" by water.

The only certified surface hazardous-waste (non-radioactive) disposal site in Oklahoma is in central Major County about 40 miles (64 km) northwest of the park area. It is developed on the Flowerpot Shale, which is virtually impermeable to groundwater flow.

The top of the Blaine Formation is not an absolutely planar surface but is rather irregular, due largely to the fact that in many places the gypsum or halite in the subsurface, has partly dissolved and the overlying shale has collapsed 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 partially collapsed caves) and caverns characterize these areas (Fig. 9).

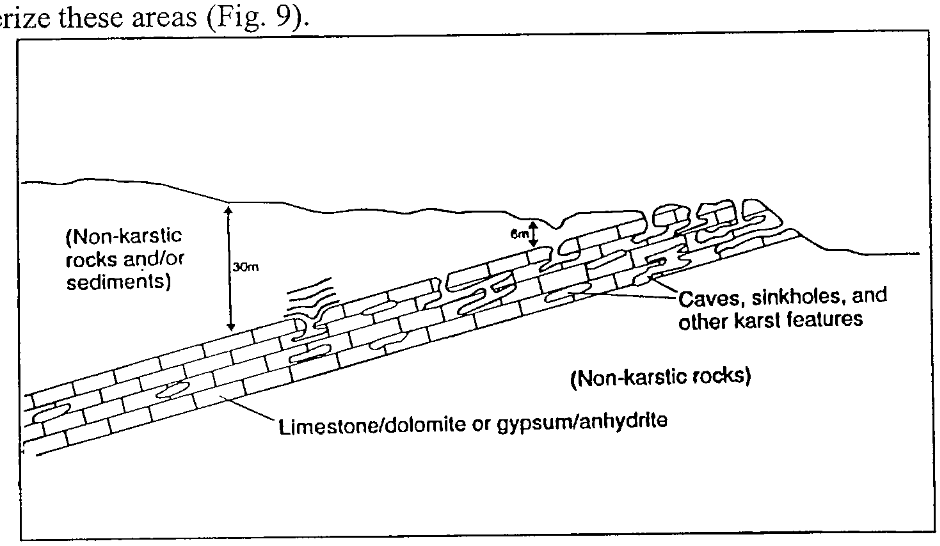


FIGURE 9. Schematic diagram showing karst features as surface features and in the subsurface. (from Johnson and Quinlan, 1995).

Here, karst features have developed on gypsum beds; in other parts of northwest Oklahoma, similar features have developed over shallowly buried salt deposits. Salt (halite) is highly soluble, more soluble than any other rock in the Permian succession of western Oklahoma and adjacent areas. Hydrogeologic studies show that natural dissolution of bedded rock salt occurs at shallow depths at many places in western Oklahoma and adjacent areas. Fresh and saline groundwater moves not only laterally through aquifers, such as sandstone or cavernous gypsum, dolomite, or salt, but also moves vertically through fractures, sinkholes, and collapse features. When dissolution occurs, the resulting collapse, subsidence, and fracturing of overlying rock causes a greater vertical permeability along joints and openings. Therefore, salt dissolution can produce a self-perpetuating cycle: dissolution causes cavern development and then land subsidence, with the resulting disrupted rock having a greater vertical permeability that allows increased water percolation and additional salt dissolution.

PETROLEUM

In 1956, Blaine County became the sixty-sixth county in Oklahoma known to have commercial petroleum production. Gas was discovered in the field area, now named Northwest Okeene, in the northern part of the county. Gas produced is from Late Mississippian limestones at depths ranging from 7,500 to 7,900 ft (2,286 to 2,408 m).

Prior to 1945, some sixteen shallow holes, ranging in depth from 1,000 to 5,550 ft (0.3 to 1.7 km). and with a total footage amounting to approximately 30,000 ft (9,144 m), were drilled in the county. Most of them did not fully penetrate the Permian section, but some were drilled into Late Pennsylvanian rocks. The earliest test was drilled at Darrow in 1906 in sec. 20, T.19N, R.11W.

STOP 1
GOLF COURSE PULLOUT
OVERVIEW OF THE STRATIGRAPHY, GENERAL GEOLOGY, AND TOPOGRAPHIC EXPRESSION OF ROMAN NOSE STATE PARK

(SE ¼ sec.24, T.17N, R.12W, Watonga Lake quadrangle map).

The park is located regionally on the east side of the broad Permian Basin evaporite region of southwestern United States (Fig. 2). Permian-age rocks are well exposed in essentially horizontal layers (dips of 10-30 ft per mi; 1.9 to 5.7 m per km) causing their outcrop pattern to coincide with specific topographic contour lines throughout the park.

The present topography has resulted from differential weathering and erosion of resistant dolomites and gypsum beds capping most of the topographic highs (hills) and nonresistant mudstones and shales forming the broad lowlands and valleys (Cimarron Gypsum Hills Physiographic Province). Horizontal beds of dolomite and gypsum form a series of benches or ledges along the sides or the valleys. The northwest-southeast trending Blaine escarpment held up by resistant gypsum and dolomite ledges has been deeply dissected resulting in a topographic relief of more than 200 ft (61 m) in the park area. Steep valleys such as Cat Canyon to the northeast are the result of stream dissection of redbeds associated with the Blaine escarpment.

Most of the prominent cliffs or ledges in the park are in the Shimer Gypsum, the Nescatunga Gypsum becoming prominent only down near the lakes. The lodge is built upon the Nescatunga Gypsum. Both Boecher and Watonga Lakes are formed in the unnamed shales below the Nescatunga Gypsum, in the Medicine Lodge Gypsum, and in the underlying Flowerpot Shale.

The tributary drainages directly to the east (right) are part of Bitter Creek which was dammed to form Watonga and Boecher Lakes. Bitter Creek is underlain by unnamed redbeds of the Blaine Formation.

STOP 2
U.S. GYPSUM PLANT
SOUTHARD, OKLAHOMA
(NW ¼ sec. 10, T.18N., R.12W., Southard 7.5' quadrangle map)

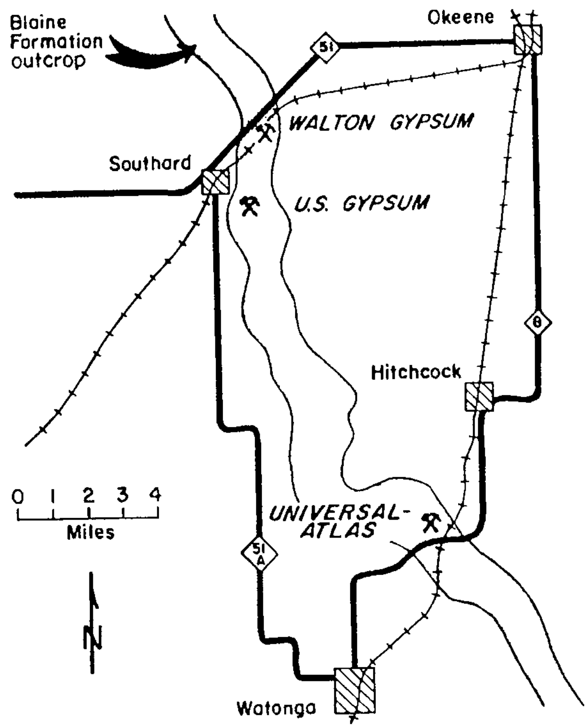


Figure 10. Location map showing some gypsum quarry sites in Blaine County. (After Johnson, 1972a)

Blaine County is the center for gypsum mining in Oklahoma. Development of these deposits began early (1894), because this is one of the few places in Oklahoma where thick gypsum layers are located adjacent to railroads. Also, these gypsum deposits are closer than any others to a large market area in eastern Oklahoma, as well as in much of Missouri, Arkansas, Louisiana, and east Texas.

The Southard Plant of the United States Gypsum Company is part of the largest gypsum-producing organizations in the world, with home offices in Chicago and with several plants of various kinds in the United States and Canada. Organized in 1902 through consolidations of several smaller companies, U.S. Gypsum in 1912 purchased the plant and property of G.H. Southard, and since 1912 has been the largest single gypsum producer in Oklahoma. All the production in Blaine County is now obtained by open-pit quarrying, although before 1948 the U.S. Gypsum Company mined the Shimer and

Nescatunga gypsum ledges underground by the double-entry room-and-pillar method, and at an earlier date the Nescatunga gypsum ledge was mined underground by the Universal Atlas Company. The Shimer Gypsum was mined underground on the Southard property for about 25 years. The rooms were 22 ft (7 m) wide and 7 ft (2 m) high; they were separated by 10-ft-square (0.93 m-square) pillars which were robbed 2 ft (0.61 m) on a side when the workings were abandoned. After being shot, the broken stone was hand loaded and hauled out by mules. In later stages, machine mining was introduced and 30-ft (9 m) rooms were cut.

The two principal economic gypsum beds being mined are the Shimer and Nescatunga Members of the Blaine Formation of Permian age (Fig.4). Each gypsum bed is 10 to 15 ft (3 to 5 m). thick and is 97 to 99 percent pure gypsum ($CaSO_4 \cdot 2H_2O$). Impurities are anhydrite (0.1 to 0.5 percent), dolomite (0.3 to 2.0 percent), strontium sulfate (0.2 to 0.3 percent) and sand and clay (0.1 to 0.3 percent).

Favorable quarry sites in these gypsum beds are determined by geologic, topographic, and economic factors. One of the chief factors is the thickness of shale overburden at a particular location, because this determines the amount of scraping (economic factor) that needs to be done and influences the distribution of anhydrite within the gypsum bed (geologic factor). Although gypsum ($CaSO_4 \cdot 2H_2O$) and anhydrite ($CaSO_4$) are closely related rock types, more than 5 to 10 percent anhydrite in gypsum makes the rock unusable. For most purposes, gypsum is derived by hydration (combining with water) of anhydrite at or near the surface of the ground, and the hydration process is generally incomplete in this area where 30 ft (9 m). or more of shale overlies and protects the bed. Thus, gypsum can generally be mined along a band or bench 100 to 700 ft (30 to 213 m). wide before encountering residual anhydrite layers beneath thick overburden.

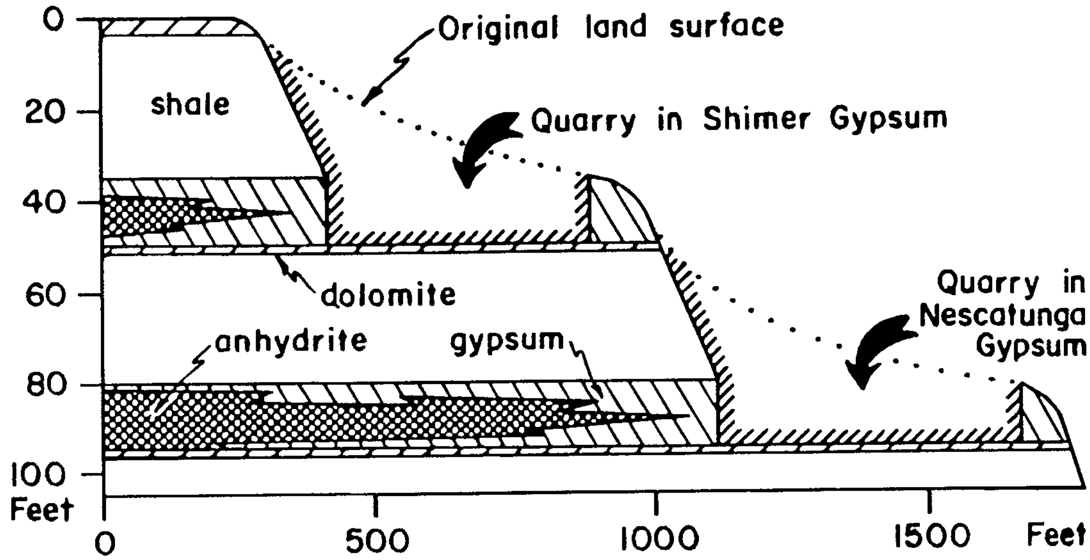


Figure 11. Schematic cross section showing relationship between topography, lithology, and quarrying in Shimer and Nescatunga Gypsum beds of Blaine County. (From Johnson, 1972a)

Gypsum is primarily used to make wallboard (sheetrock) although additional uses include: oil well cements, fillers in foods, toothpaste, paper, and paint pigments; laths, sheathing, various plasters, retarder in Portland cement, soil conditioner (ground gypsum), road metal, pharmaceutical products such as fillers and binders in aspirin and other pills, as a yeast activator in brewing beer, and as a moister absorbent in bread and pizza dough; agricultural products such as a carrier for insecticides, pesticides, and herbicides, and as a supplement in animal feeds.

Oklahoma ranks first among the United States in crude production of gypsum, with about 2.6 million metric tons produced annually by 14 companies in 9 western counties. Total gypsum resources in Oklahoma are estimated at 48 billion short tons. These resources are well suited for open-pit mining or quarrying, because, 1) gypsum typically forms hills in the semiarid climate of western Oklahoma, and 2) the gypsum layers are nearly horizontal, without major folds or faults.

Enormous resources of high-purity Permian gypsum crop out in western Oklahoma. Blaine formation gypsums are 5-30 ft (2 to 9 m) thick and 95-99% pure in the northwest and southwest, and the Cloud Chief gypsum of Washita-Caddo Counties is 25-100 ft (8 to 30 m) thick and 92-97% pure. Anhydrite crops out only locally, but is present underground where overburden is 25-100 ft (8 to 30 m). thick, or more.

Names have been given to several distinct varieties of gypsum:
Alabaster – compact, fine grained, gypsum with a smooth, even-textured appearance.
Selenite – gypsum occurring as transparent or translucent crystals or plates; colorless.
"Satin spar" – refers to white veins of fibrous gypsum crystals; silky luster.

GENERAL STRATIGRAPHY

Shimer Gypsum

- 15-ft (5 m) thick; principal worked ledge on property
- White massive gypsum; purity of 95% or greater
- Quarries in the three-mile length of Shimer Gypsum workings have ranges in width from 100 ft. to 700 ft (30 to 213 m), averaging 350 ft (107 m).
- Thickness of overburden ranges up to 30 ft (9 m), averaging about 20 ft (6 m).
- Mined underground on the Southard property for about 25 years.

Nescatunga Gypsum

- Second gypsum ledge worked by U.S. Gypsum Company.
- First gypsum bed below the Shimer and is separated from it by 30 ft (9 m). of shale.
- Among the purest (98.7%) commercially worked gypsum deposits in the world.
- 8 to 15 ft (2 to 5 m). thick ledge of high-purity white gypsum.
- Underlain by 7 ft (2 m). of anhydrite just below the quarry floor.
- Worked underground by the room-and-pillar method in the 1920's and 1930's.

The gypsum beds are quite variable both in thickness and distribution. A rule-of-thumb used for quarrying in the Southard area is that if there is 5 ft (1.52 m). or more of original overburden above gypsum, the underlying gypsum is probably present in its entire thickness. However, if there is less than 5 ft (1.52 m) of original overburden, the gypsum may be cavernous and unworkable.

SALT CREEK CANYON

(secs. 22, 23, and 24, T.18N., R.12W., Southard 7.5' quadrangle map)

In the region the gypsum beds of the Blaine Formation form distinctive ledges that are resistant to weathering and erosion. These ledges extend the length of the outcrop of the Blaine Formation and form the geomorphic province named the Cimarron Gypsum Hills of northwestern Oklahoma. The non-resistant Flowerpot Shale erodes more rapidly than the gypsum, leaving an escarpment that is several hundred feet high in places. The topographic relief of the escarpment at Salt Creek Canyon is about 200 ft (61 m). The Shimer Gypsum caps the hill on the left and the prominent Nescatunga Gypsum forms the next lower ledge about 40 ft (12 m) below the Shimer ledge. The Medicine Lodge Gypsum is barely visible. Many isolated buttes capped by gypsum are present in this area, some of them being named, such as Mount Henquent (SW ¼ sec 30, T.18N, R.11W).

We are looking southeast from the top of the east-facing Blaine escarpment. Many salt and gypsum springs flow from this escarpment, the water probably coming from the gravel and sand of the overlying North Canadian River deposits, and the gypsum and salt being supplied by the Dog Creek, Blaine, and Flowerpot Formations.

STOP 3

STRATIGRAPHY OF THE DOG CREEK, BLAINE, AND FLOWERPOT FORMATIONS
TYPE REFERENCE (STANDARD) SECTION FOR THE BLAINE FORMATION

Exposures along an east-west section line road about 2.5 miles (4 km) north of Roman Nose State Park and 1 mile (1.6 km) east of State Highway 51A along the southern boundaries of secs. 1 and 2, T.17N, R.12W, (Watonga Lake quadrangle map)

This stop provides excellent opportunity to examine cyclic sedimentation in an evaporite-carbonate-redbed sequence. The type section for the Blaine Formation was designated by Fay (1962, p.33) as the rocks exposed along State Highway 33, about 7 miles (11.3 km) east of Watonga, Blaine County, Oklahoma, in the southern part of sec. 19 and northern part of sec. 30, and SW ¼ sec. 20, T.16N, R.10W, (Watonga SE quadrangle map). At that time the entire formation was exposed, but today the section is poorly exposed. Therefore, exposures along an east-west section line road about 2.5 miles (4 km) north of Roman Nose State Park and 1 mile (1.6 km) east of State Highway 51A along the southern boundaries of secs. 1 and 2, T.17N, R.12W, (Watonga Lake quadrangle map) is herein designated as a type reference (standard) section for the Blaine Formation.

Going from west to east along the section line road, exposures include Pleistocene terrace deposits, Dog Creek Shale (Southard and Watonga Dolomite Members), Blaine Formation (Shimer, Nescatunga, and Medicine Lodge Gypsum Members) and the Flowerpot Shale. The section is well exposed along the Blaine escarpment, a major geomorphological feature that separates the drainages of the North Canadian River to the southwest from the Cimarron River to the northeast.

TYPE LOCALITY – The place at which a stratigraphic unit (such as a formation or member) is typically displayed and from which it derives its name. It contains the type section, and is contained within the type area (Table 1).

TYPE SECTION – The original sequence of strata as first described or originally recognized for a given locality or area. It serves as an objective standard with which spatially separated parts of the stratigraphic unit (formation, member, etc.) may be compared, and it is preferably in an area where the unit shows maximum thickness and is completely exposed (or at least shows top and bottom). Type sections for rock-stratigraphic units can never be changed; there is only one type section (Table 1).

REFERENCE SECTION – A rock section, or group of sections, designated to supplement the type section, or sometimes to supplant it (as where the type section is no longer exposed), and to afford a standard for correlation for a certain part of the geologic column; e.g. an auxiliary section of particular regional or facies significance, established through correlation with the type section, and from which lateral extension of the boundary horizons may be made more readily than from the type section.

STANDARD SECTION – A reference section showing as complete as possible a sequence of all the strata in a certain area, in their correct order, and thus affording a standard for correlation. It supplements (and sometimes supplants) the type section.

TABLE 1 - DESIGNATED TYPE LOCALITIES AND TYPE SECTIONS FOR THE PERMIAN (GUADALUPIAN SERIES) EL RENO GROUP-ROMAN NOSE STATE PARK AREA, BLAINE COUNTY, OKLAHOMA

Stratigraphic Unit	Type Locality	Type Section
DOG CREEK SHALE	South of Lake City, Barber County, Kansas, in secs. 4 & 9, T.32S., R.14W.	State Highway 160, in $N^1/_2N^1/_2$ sec. 9, T.32S., R.14W., Barber County, Kansas.
Southard Dolomite Bed	Southard, Oklahoma area, Tps. 18 & 19N., R.12W., north-central Blaine County, Oklahoma.	On and near State Highway 51A in $SW^1/_4SW^1/_4$ sec. 10, T.18N., R.12W., one mile south of Southard, northern Blaine County, Oklahoma.
Watonga Dolomite Bed	Area east and northeast of Watonga, Blaine County, Oklahoma, in T.16N., Rs. 10 & 11W.	On state Highway 33, about 7 miles east of Watonga, in $SW^1/_4SW^1/_4$ sec. 19, T.16N., R.10W., and $SE^1/_4SE^1/_4$ sec. 24, T.16N., R.11W., Blaine County, Oklahoma.
Haskew Bed	Haskew Township and surrounding areas in T.25N., Rs. 18-19W., Woodward County, Oklahoma.	$SW^1/_4SW^1/_4SW^1/_4$ sec. 6, T.25N., R.18W., just east of State Highway 50 in a creek bank, Woodward County, Oklahoma.
BLAINE FORMATION	Area of Roman Nose State Park and Salt Creek Canyon in central to north-central Blaine County, Oklahoma.	State Highway 33, about 7 miles east of Watonga, Blaine County, Oklahoma, in the southern part of sec. 19 and northern part of sec. 30, and $SW^1/_4$ sec. 20, T.16N., R.10W.
Shimer Gypsum Member	Shimer Township, through which Cave Creek flows, now Tps. 33, 34, 35 S., R.17W., Comanche County, Kansas.	No type section has been designated.
Altona Dolomite Bed	Southwestern Kingfisher County and southeastern Blaine County, Oklahoma, especially southwest of Altona in the Gypsum Hills escarpment.	On State Highway 33, seven miles east of Watonga, Oklahoma, southern part of sec, 30, T.16N., R.10W., Blaine County, Oklahoma.

TABLE 1 (Cont.) - DESIGNATED TYPE LOCALITIES AND TYPE SECTIONS FOR THE PERMIAN (GUADALUPIAN SERIES) EL RENO GROUP-ROMAN NOSE STATE PARK AREA, BLAINE COUNTY, OKLAHOMA

Stratigraphic Unit	Type Locality	Type Section
Nescatunga Gypsum Member	Lower reaches of Nescatunga Creek, T.34S., R.17W., southeastern Comanche County, Kansas.	No type section has been designated.
Magpie Dolomite Bed	Roman Nose State Park, sec. 24, T.17N., R.12W, Blaine County, Oklahoma.	On State Highway 33, about seven miles east of Watonga, in the southern part of sec. 19 and northern part of sec. 30, T.16N., R.10W., Blaine County, Oklahoma.
Alabaster (Kingfisher Creek) Gypsum Bed	Southeastern Blaine County, especially Tps. 15 & 16N., R.10W.	On State Highway 33 and outcrops just north and south of the road, especially in SE $^1/_4$SE $^1/_4$ sec. 19, T.16N., R. 10W., Blaine County, Oklahoma.
Medicine Lodge Gypsum Member	Northern Barber County, Kansas, along the Medicine River Valley and the area southwest of Medicine Lodge.	No type section has been designated.
Cedar Springs Dolomite Bed	Southern Major County, Oklahoma, in T.20N., R.12W., especially along Sand Creek.	High bluff along east bank of Sand Creek in NW $^1/_4$ sec. 20, T.20N., R.12W., southern Major County, Oklahoma.
FLOWERPOT SHALE	Flowerpot Mound, at the divide between east Cedar Creek and west Cedar Creek, near the center of SW $^1/_4$ sec. 26, T.32S., R.13W., 8 miles southwest of Medicine Lodge, Barber County, Kansas.	No type section has been designated.

DETAILED STRATIGRAPHY
(See Table 1, page 25 for type locality and type section designations)

Pleistocene

Alluvium and salt plains

Consists predominantly of gravels, sands, silts, and clays along floodplains and low terraces of rivers; locally covered by sand dunes and other wind-blown sediments; salt plains occur along Salt Creek.

Terrace Deposits

High terrace deposits consist principally of gravel and sand deposits at several levels along former stream courses, locally covered by sand dunes; includes rare volcanic ash locally.

Permian

Guadalupian Series

El Reno Group

Dog Creek Shale (157-200 ft; 48 to 61 m)

Red-brown blocky clay shale containing thin beds of greenish-gray siltstone and silty dolomite; lower 20-35 ft (6 to 11 m) contains much wavy-bedded satin spar gypsum.

Southard Dolomite Bed (3-4 in; 8 to 10 cm)

Dolomite, light-gray, dense, silty, massive to laminated; underlain by dolomite and greenish-gray indurated shale; occurs about 80 ft (24 m) above the base of the Dog Creek Shale; forms a mappable escarpment throughout most of Blaine County.

Unnamed Shales

Watonga Dolomite Bed (3-7 ft; 1 to 2 m)

Dolomite and interbedded dolomitic shales and siltstones; occurs about 25 to 40 ft (8 to 12 m) above the base.

Unnamed Shales

Haskew Bed (4 ft; 1 m)

Gypsum, shale, and gypsiferous siltstone approximately 4 ft (1 m) above the base.

Unnamed Shales

Blaine Formation (75-100 ft; 23 to 30 m)

Thick beds of white gypsum interbedded with red-brown and greenish-gray shale with thin beds of dolomite.

Shimer Gypsum Member (7-22 ft; 2 to 7 m)

Gypsum, white, fine-to coarsely-crystalline, dense to porous; upper surface wavy bedded; forms massive white ledge.

Altona Dolomite Bed (0.75-1.0 ft; 23 to 30 cm)

Dolomite, yellowish-gray, finely-crystalline, oolitic, locally crossbedded, rippled, and mudcracked; weathers to a box-work appearance; locally contains molds of the clam *Permophorus* and other fossils.

Unnamed Shales

Nescatunga Gypsum Member (7-15 ft; 2 to 5 m)

Gypsum and anhydrite, white to gray, massive; overlain by red-brown and greenish-gray shales; anhydrite, light gray, fibrous, occurs in middle and is approximately 9 ft (3 m) thick in Salt Creek Canyon area; weathering of anhydrite produces a white ribbon-like pattern; forms an escarpment throughout Blaine County.

Magpie Dolomite Bed (0.5-1.5 ft; 15 to 46 cm)

Dolomite, light-gray, finely-crystalline, oolitic, fossiliferous; non-oolitic at base; locally contains molds of clam *Permophorous*; underlain by thin light greenish-gray silty clay shale.

Unnamed Shales

Kingfisher Creek Gypsum Bed (Alabaster Gypsum) (1-3 ft; 0.3 to 1.0 m)

Gypsum, white, well-indurated, alabaster-like, mottled greenish-gray and pale pink, with many thin clay shale and selenite seams; underlain by reddish-brown shale with numerous seams and veins of satin spar.

Unnamed Shales

Medicine Lodge Gypsum Member (4-7 ft; 1.2 to 2 m)

Gypsum, white, compact to porous, fine-to coarsely-crystalline banded gypsum; mottled moderate reddish-brown to pale pink; contains many reddish-brown clay shale seams in its upper part.

Cedar Springs Dolomite Bed (9 in; 23 cm)

Dolomite, light gray, fine grained, oolitic, massive; base of Blaine Formation.

Unnamed Shales

Flowerpot Shale (450 ft; 132 m)

Upper 50 ft (15 m) –	impure gypsum beds, dolomites, siltstones, shales
40 ft (12 m) –	silty clay shale with little or no gypsum, dolomite, or siltstone
160 ft (49 m)–	alternating beds of reddish-brown gypsiferous shales and light greenish-gray siltstones; lower 115 ft (35 m) grades southward into mudstone, conglomerate, sandstone, siltstone, and silty clay shale; locally conglomerates and sandstones may contain bones of reptiles and/or amphibians; forms valleys of badlands-type topography.
Lower 180 ft (55 m) –	Reddish-brown silty clay with a few thin light greenish-gray siltstone beds.

DISCUSSION

Exposures at this stop demonstrate the overall cyclicity of supratidal (sabkha) and mud-rich tidal flat systems characteristic of much of the Blaine Formation. The Blaine Formation consists of a succession of dominantly red and greenish-gray mudstones/shales interstratified with numerous regionally continuous beds of dolomite and gypsum. Mudstone and dolomite lithofacies represent transgressive mud-rich tidal-flat systems, whereas nodular and bedded gypsum and gypsiferous mudstone lithofacies record supratidal (sabkha) deposits.

STOP 4
GROUND WATER
BIG SPRING

(NE ¼ SE ¼ sec. 23, T.17N, R.12W. Watonga Lake quadrangle map.)

Ground water is emitted at the surface through several natural springs near the picnic area in the west end of the park. Major springs, such as Big Spring, Middle Spring, and Little Spring, all issue from the base of the Shimer Gypsum (Fig. 5). Rain water entering the ground farther south and west moves through karstic cavities and crevices in gypsum and dolomite until it emerges at the springs.

The water is highly gypsiferous because it is actively dissolving the rock gypsum and enlarging underground caverns. The combined flow from the three major springs is generally 600 to 800 gallons (2,400 to 3,200 liters) per minute, and one set of measurements in 1958 recorded a flow of 80, 175, and 365 gpm (320, 700, and 1,460 lpm) from Little, Middle, and Big Springs, respectively. The water for Big Spring probably comes from the overlying North Canadian Pleistocene terrace deposits, dissolving the gypsum and forming caves. It is reported that this cave extends back almost one-fourth mile. The spring fluctuates in flow seasonally.

ALTONA DOLOMITE

A short walk from the springs to the swimming pool area will provide an opportunity to examine blocks of the Altona Dolomite (base of the Shimer Gypsum) used in the construction of the swimming pool, walkways, steps, and parts of many buildings in the park area. The rock was quarried locally just east of the park area. Close examination of the dolomite blocks will reveal some superb sedimentary structures / features including mudcracks, crossbedding, gypsum nodules, ripple marks, oolites, and perhaps molds of the clam *Permophorus.*

REFERENCES

Clifton, R. L., 1942, Invertebrate faunas from the Blaine and the Dog Creek Formations of the Permian Leonard Series: Journal of Paleontology , v.16, p.685-699.

Einsele, G., 1992, Sedimentary basins-evolution, facies, and sediment budget: Springer – Verlag Publisher: p. 77-93; 109-121; 242-263.

Fay, R. O., 1959, Guide to Roman Nose State Park: Oklahoma Geological Survey, Guidebook 9, 31p.

Fay, R. O., 1961, The Blaine and related formations of northwestern Oklahoma and Kansas: University of Kansas, unpublished Ph.D. dissertation, 423p.

Fay, R. O., Ham, W. E., Bado, J. T., and Jordan, L., 1962, Geology and mineral resources, Blaine County: Oklahoma Geological Survey Bulletin 89, 258p.

Fay, R. O., 1964, The Blaine and related formations of northwestern Oklahoma and southern Kansas: Oklahoma Geological Survey Bulletin 98, 238p.

Hardie, L. A., and Eugster, H. P., 1971, The depositional environment of marine evaporites; a case for shallow, clastic accumulation: Sedimentology, v. 16, p. 187-220.

Johnson, K. S., 1972a, Guidebook for geologic field trips in Oklahoma; Book II, northwestern Oklahoma: Oklahoma Geological Survey, Educational Publication 3, 42p.

Johnson, K. S., 1972b, Gypsum and salt resources in Oklahoma: Industrial Minerals no. 62, p. 33-39.

Johnson, K. S., 1988, Evaporites and red beds in Roman Nose State Park, northwestern Oklahoma: Geological Society of America Centennial Field Guide – South-central Section, p. 83-84

Johnson, K.S., and Quinlan, J. F., 1995, Regional mapping of karst terrains in order to avoid potential environmental problems: Cave and Karst Science, v. 21, no. 2, p. 37-39.

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, 76p.

Kendall, A. C., 1978, Facies Models II; continental and supratidal (Sabkha) evaporites: Geoscience Canada, v.5, p. 66-78.

Leeder, M., 1999, Sedimentology and sedimentary basins: Blackwell Science, Inc. Publisher, p. 340-356; 414-443.

Lewis, D.W., and McConchie, D., 1994, Practical sedimentology: Chapman and Hall Publisher, p. 165-185; 186-201.

Mack, G. H., and Dinterman, P. A., 2002, Depositional environments and paleogeography of the Lower Permian (Leonardian) Yeso and correlative formations in New Mexico: The Mountain Geologist, v. 39, no. 4, p. 75-88.

Reading, H.G., (ed.), 1996, Sedimentary environments-processes, facies, and stratigraphy: Blackwell Science, Inc., Publisher, p. 83-124; 281-394.

Shearman, D. J., 1971, Marine evaporites; the calcium sulfate facies: American Society of Petroleum Geologists, Seminar, University of Calgary, 65p.

Walker, R. G., 1981, Facies Models; Geoscience Canada, Reprint Series 1, Geological Association of Canada , p. 105-119; 145-157; 159-174.