Geologic Field Trips In Northwest Oklahoma

Oklahoma Geological Survey Educational Publication 3

OKLAHOMA GEOLOGICAL SURVEY
Charles J. Mankin, *Director*
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Guidebook for Geologic Field Trips in Oklahoma

Book II: Northwest Oklahoma

Kenneth S. Johnson

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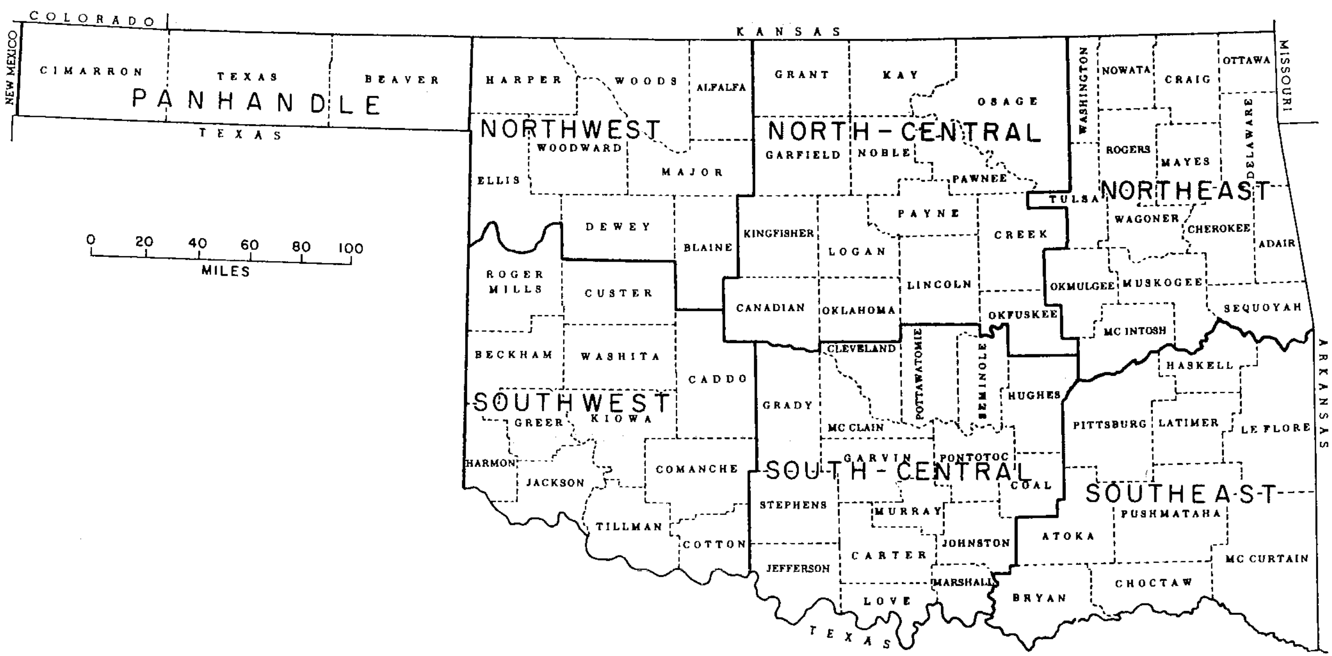
Cover Description

Aerial view of gypsum and shale in "Blaine Escarpment" overlooking Cimarron River south of Freedom.



Outline of seven regions in Oklahoma for which separate geologic guidebooks are being prepared.

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PREFACE

Guidebooks of this series will be prepared and distributed by the Oklahoma Geological Survey in cooperation with the National Science Foundation, the Oklahoma Curriculum Improvement Commission, plus the Instructional Division and the Curriculum Section of The Oklahoma State Department of Education. Compilation and preparation of material are financed through a grant from the National Science Foundation (Grant GW-5726), and publication is made possible by funds from Title V, Section 503, of the Elementary and Secondary Education Act of 1965 through The Oklahoma State Department of Education.

Guidebooks are being released as "preliminary versions" so that the changes and additions that users recommend can be incorporated in a final printing. Field-trip guidebooks are being printed by The Oklahoma State Department of Education and will be issued free within the Oklahoma school system as they are completed. Distribution will be in the region covered by the report and in adjacent areas.

Please send comments and recommendations for improvement of guidebooks to: Editor, Oklahoma Geological Survey, 830 Van Vleet Oval, Room 163, Norman, Oklahoma 73069. A limited supply of preliminary guidebooks is available; copies can be purchased from the Oklahoma Geological Survey. Oklahoma teachers who have not received a free copy can obtain one from: Director of Curriculum, The State Department of Education, Lincoln Plaza, Oklahoma City, Oklahoma 73105.

Geologic information presented in this series is intended to give the teacher sufficient background to direct student field studies, although it may also be used directly by students in preparation for field trips. The introductory guidebook (Johnson, 1971) contains a nontechnical discussion of the geologic history of Oklahoma along with general information and suggestions on pre-trip planning, the responsibilities of leading a field trip, safety precautions, and recommended student activities in investigating each site. The current guidebook of northwest Oklahoma contains a discussion of the regional geology as well as detailed descriptions of the local geology at 26 selected sites (fig. 1). In addition, information is provided on viewing oil and gas wells. Sources of supplementary information are listed for each site, as is the quadrangle name of the topographic map covering each.

Many of the references cited can be examined at the following public libraries in or near the region: Carnegie Public Library, 402 N. Independence, Enid; Phillips University Library, Enid; Northwestern State College, Alva. Additional assistance or information on geologic information in the region is available through local museums, libraries, professional geologists, rockhounds, Soil Conservation Service Personnel, construction companies, and stone or monument processors.

Methods of field study are explained in more detail in the Earth Science Curriculum Project Field Guides prepared by the American Geological Institute and the National Science Foundation. Readers are referred to field guides on rock weathering (Boyer, 1971), soils (Foth and Jacobs, 1971), layered rocks (Freeman, 1971), fossils (Beerbower, 1971), beaches (Hoyt, 1971), and lakes (Verduin, 1971), which should be particularly useful for northwest Oklahoma.

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Dr. William D. Carr, Chairman
Oklahoma Curriculum Improvement Commission
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Oklahoma City, Oklahoma

Mr. Frank Conaway, Principal
Aline-Cleo Elementary School
Cleo Springs, Oklahoma

Mr. Earl Cross
Director, State-Federal Programs, and
Assistant State Superintendent
State Department of Education
Oklahoma City, Oklahoma

Mr. Roy D. Davis, Cartographer
Oklahoma Geological Survey
Norman, Oklahoma

Mr. Stanley Dixon, Superintendent
Okeene Public Schools
Okeene, Oklahoma

Mrs. Marie Elkins
Woodward Elementary Schools
Woodward, Oklahoma

Dr. Robert O. Fay, Geologist
Oklahoma Geological Survey
Norman, Oklahoma

Miss Peggy Gill, Special Assistant
Oklahoma Curriculum Improvement Commission
State Department of Education
Oklahoma City, Oklahoma

Dr. Joe Glover, Superintendent
Woodward Public Schools
Woodward, Oklahoma

Mrs. George Goetzinger
Woodward Elementary Schools
Woodward, Oklahoma

Mr. Dean Hubbard, Earth Science Teacher
Cherokee High School
Cherokee, Oklahoma

Mr. Loren L. Johnson, Principal
Okeene Junior and Senior High Schools
Okeene, Oklahoma

Dr. David B. Kitts, Professor of Geology
School of Geology and Geophysics
The University of Oklahoma
Norman, Oklahoma

Mr. Conrad Knox, Science Teacher
Alva High School
Alva, Oklahoma

Dr. Charles J. Mankin, Director
Oklahoma Geological Survey
Norman, Oklahoma

Mr. Larry McKinney
Specialist for Math and Science
Curriculum Section
State Department of Education
Oklahoma City, Oklahoma

Dr. Arthur J. Myers
Associate Professor of Geology
School of Geology and Geophysics
The University of Oklahoma
Norman, Oklahoma

Mr. David M. Patrick
U.S. Army Corps of Engineers
Waterway Experiment Station
Vicksburg, Mississippi

Mr. Howard Potts
Specialist for Ecology
Curriculum Section
State Department of Education
Oklahoma City, Oklahoma

Mr. Gene Scovel, Earth Science Teacher
Buffalo High School
Buffalo, Oklahoma

Mr. Keith Stone
Specialist for Social Studies
Curriculum Section
State Department of Education
Oklahoma City, Oklahoma

Mr. Ralph Strete
Associate Professor of Geology
Northwestern State College
Alva, Oklahoma

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Okeene School
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Guidebook for Geologic Field Trips in Oklahoma
Book II: Northwest Oklahoma

Kenneth S. Johnson[1]

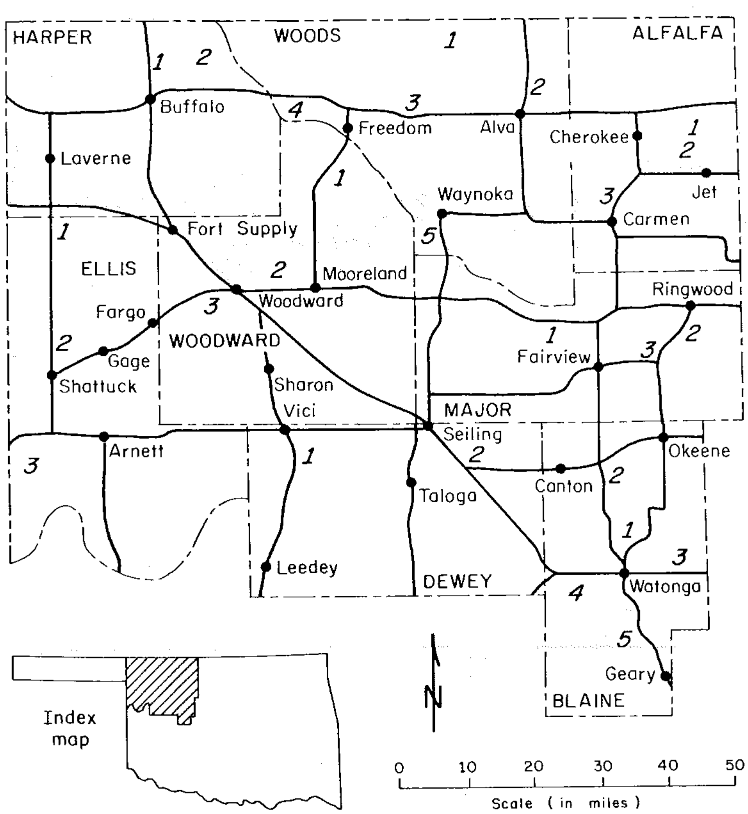
GENERAL GEOLOGY OF NORTHWEST OKLAHOMA

Northwest Oklahoma, an area of simple but interesting geology, consists of an eight-county region where a series of sites for conducting geologic field trips have been selected (fig. 1). Rocks are well exposed in most areas, owing to sparse vegetation and a thin soil cover, and the network of section-line roads permits access to most outcrops. Included among the geologic materials in the region are: common rocks such as sandstone, siltstone, shale, conglomerate, gypsum, anhydrite, limestone, dolomite, volcanic ash, and a variety of gravels eroded from the Rocky Mountains; minerals such as selenite, satin spar, salt crystals, aragonite, agate, and petrified wood; and fossil clams, snails, and oysters plus the bones of large and small vertebrate animals.

Principal mineral resources now being developed are petroleum, gypsum, salt, bentonite, volcanic ash, clays, and sand and gravel (Johnson, 1969). Oil and gas are produced at depths of 5,000 to 12,000 feet from many fields in each county.

Outcropping rocks are all of sedimentary origin and include deposits of Permian, Cretaceous, Tertiary, and Quaternary age (figs. 2 and 3). The general history of Oklahoma during each of these geologic time periods is summarized in Book I of this guidebook series (Johnson, 1971).

[1]Geologist, Oklahoma Geological Survey.



COUNTY	SITE	DESCRIPTION
Alfalfa	1	Great Salt Plains
	2	Selenite crystals
	3	Red beds and gypsum
Blaine	1	Roman Nose State Park
	2	Gypsum quarries
	3	Gypsum, dolomite, gravel
	4	Trench Canyon
	5	Red Hill at Greenfield
Dewey	1	Bentonite mine
	2	Red beds, dolomite, collapse
Ellis	1	Gravel and collapse
	2	Flattop Hill-caliche
	3	Lake Vincent
Harper	1	Gravel, dolomite, fossils
	2	Fossil snails
Major	1	Glass Mountains
	2	Fossil snails
	3	Shale pit
Woods	1	Volcanic ash
	2	Sand and gravel pits
	3	Red beds and fossils
	4	Big Salt Plain
	5	Little Sahara sand dunes
Woodward	1	Alabaster Caverns State Park
	2	Boiling Springs State Park
	3	Caliche deposit
Many Sites		Oil and gas wells

Figure 1. Location of field-trip sites by county and principal highways in northwest Oklahoma.

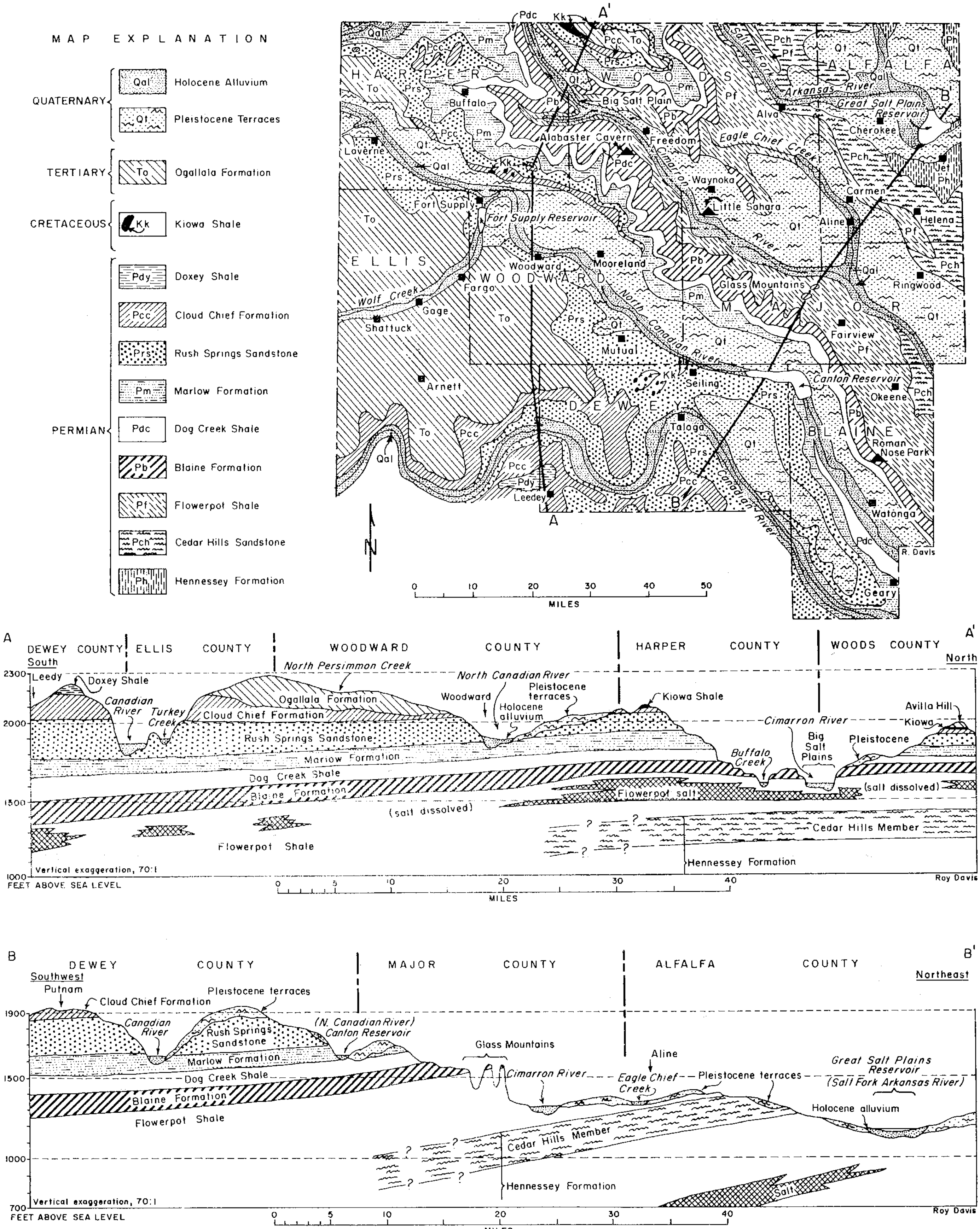
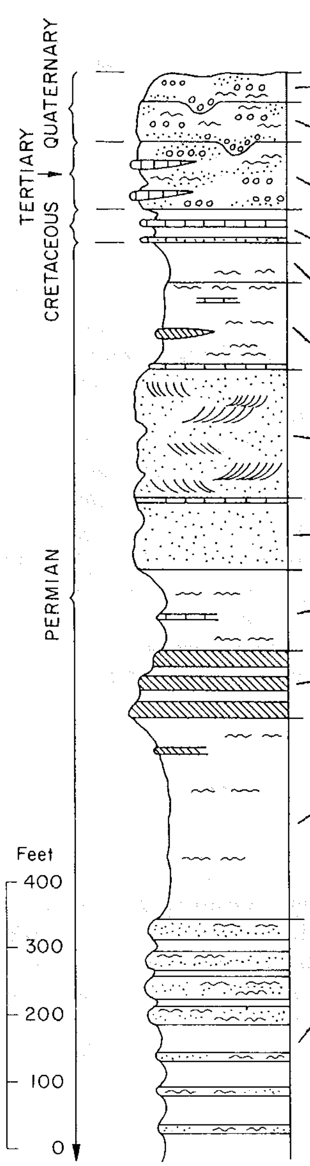


Figure 2. Generalized geologic map and cross sections of northwest Oklahoma. Map shows areas of outcrop for each formation exposed in the region, and cross sections show subsurface extension of these formations.



FORMATION NAME	GENERAL DESCRIPTION OF ROCKS	THICKNESS (feet)
Holocene alluvium	Loose sand, silt, clay, and gravel in channels and flood plains of today's streams and rivers; tan, buff, brown.	5-20 (streams) 20-100 (rivers)
Pleistocene terraces	Loose sand, silt, clay, and gravel left at higher elevations of earlier streams and rivers; tan, buff, brown.	10-100
Ogallala Formation	Loose sand, silt, clay, and gravel with layers of limestone and caliche; gray, tan, yellow, white, pink.	50-200
Kiowa Shale	Shale beds 2-30 feet thick with layers of limestone and sandstone 0.2-3 feet thick; gray, black, tan, yellow-brown.	10-60
Doxey Shale	Red-brown shale with thin beds of siltstone.	50-75
Cloud Chief Formation	Red-brown shale with thin beds of siltstone, dolomite, and gypsum.	75 (north) 175 (south)
Rush Springs Sandstone	Orange-brown sandstone with a few thin beds of gypsum and dolomite; large-scale crossbeds in sandstone.	75 (north) 250 (south)
Marlow Formation	Orange-brown sandstone with several thin beds of gypsum and dolomite.	100-120
Dog Creek Shale	Red-brown shale with thin layers of dolomite, gypsum, and green-gray shale.	50 (north) 200 (south)
Blaine Formation	Three beds of white gypsum, 10-30 feet thick, separated by red-brown shales 10-25 feet thick.	80-100
Flowerpot Shale	Red-brown shale with thin layers of gypsum, dolomite, and green-gray shale; upper part contains thick beds of rock salt back from outcrop to west and southwest.	225 (north) 450 (south)
Hennessey Shale	Red-brown shale interbedded with red-brown, orange-brown, and light-gray siltstone and sandstone; beds are 1-20 feet thick; top 200 feet, mostly siltstone and sandstone, is called Cedar Hills Member.	700

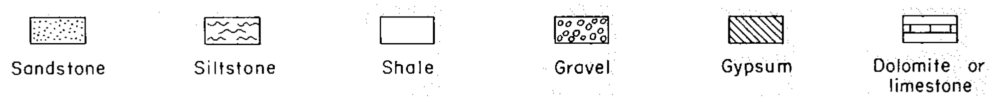


Figure 3. Generalized diagram and description of outcropping rocks in northwest Oklahoma. Oldest rocks are at the bottom and youngest are at the top.

Permian Rocks

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. 2, 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 (Johnson, 1971, figs. 11, 12). 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.

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 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.

Dolomite beds in the region are typically 0.5 foot to 4.0 feet thick, light gray or tan, and cap benches or mesas owing to their hardness and resistance to erosion. Locally, they contain bedding planes covered with poorly preserved fossils (chiefly clam shells).

Gypsum is typically white to light gray and occurs in layers 1 to 30 feet thick. It is a moderately soluble rock, but in this semiarid region it generally resists erosion and caps many bluffs and benches. Locally, however, the solution of gypsum by ground water has caused an intricate network of caves and sinkholes (Myers and others, 1969). Names have been given to several distinct varieties of gypsum (fig. 4): "alabaster" is compact, fine-grained gypsum that has a smooth, even-textured appearance; "selenite" is gypsum occurring as transparent or translucent crystals or plates; and "satin spar" refers to white veins of fibrous gypsum crystals.

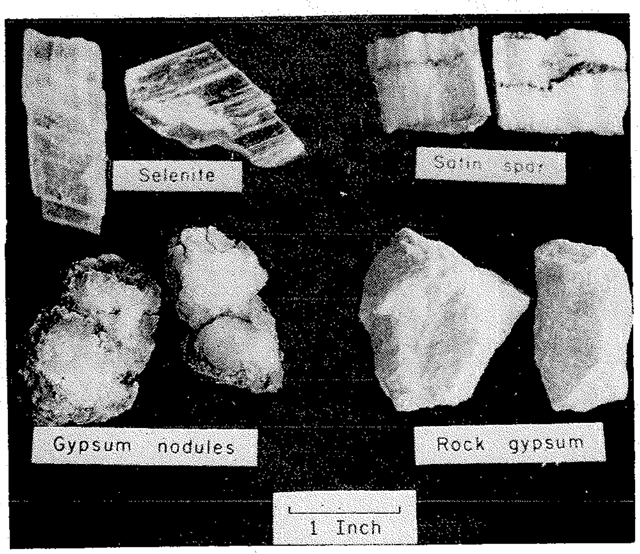


Figure 4. Varieties of gypsum.

Thick layers of rock salt were originally deposited over wide areas in several Permian formations (Jordan and Vosburg, 1963). Where these formations are now at or just below the surface, the salt has been largely dissolved by ground water (fig. 2, cross sections). Overlying strata have collapsed into the cavities formed by this dissolution, causing them to dip in various directions at angles of 5° to 20°. These collapse structures are common in the western half of the region. In the salt plains of northwest Oklahoma, brine formed from recently dissolved salt beds is now flowing to the surface through layers of porous sandstone and siltstone.

One of the most striking properties of Permian rocks is their red color. It results from a thin coating of oxidized iron minerals (chiefly hematite) that stains individual grains or particles of the rock. Ferric oxide (Fe_2O_3) generally makes up only 2 to 5 percent of the rock. Greenish-gray layers of rock have a similar or slightly lower iron content, but iron in minerals and compounds making up these layers is present mainly as ferrous iron (FeO). Coarse-grained rocks, such as siltstone and sandstone, are generally a lighter color than the shales, owing to (1) a lower percentage of iron oxide and (2) the presence of light-colored quartz grains constituting most of the rock's surface area. Probably most Permian muds and sands of the region were red when deposited. Color changes to green or gray occurred just after deposition in some layers because of the chemical composition at the depositional site, particularly because of the presence of decaying organic matter; in other instances the color change occurred later, as a result of the circulation of underground water.

Cretaceous Rocks

Fossiliferous Cretaceous rocks are preserved only in scattered small areas (fig. 2), and consist mainly of blocks and masses that collapsed because of the formation of large cavities in underlying salt beds. Most of the rock is gray, black, and yellowish-brown shale, but the shales are interbedded with thin layers of tan limestone and sandstone that commonly contain fossil oysters, clams, snails, and ammonites (fig. 5).

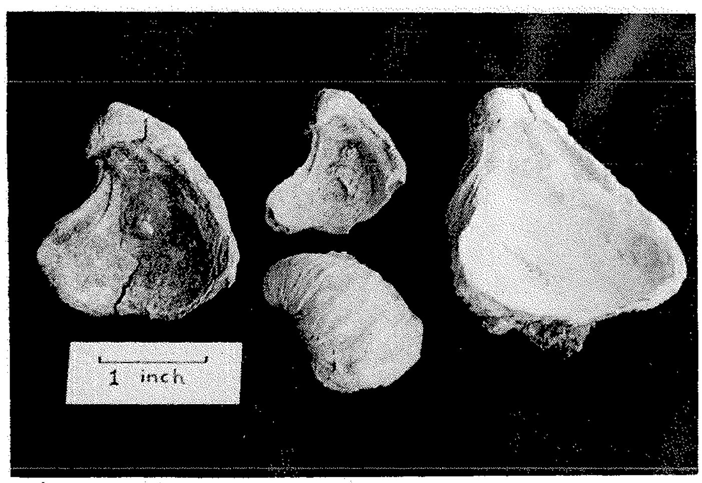


Figure 5. Cretaceous pelecypod (oyster) shells.

Tertiary Deposits

Tertiary deposits are widespread in the southwest part of the region and in an outlying area of Woods County (fig. 2). They consist of sands, silts, clays, and gravels that are locally cemented and resistant, interbedded with layers of limestone and caliche. The sediments are commonly gray, tan, yellow, white, or pink and are most easily distinguished from the underlying "red beds" by their color.

All Tertiary sediments of the region are grouped together in the Ogallala Formation. The formation originally blanketed the entire region, but erosion reduced it to present outcrops. It is commonly 50 to 200 feet thick. The contact with underlying rock units is rarely exposed, because it is covered by loose material eroded from the poorly cemented Ogallala.

Being soft and porous, the Ogallala easily soaks up rainfall: hence, there are few well-developed drainage systems across the formation and the unit is an excellent aquifer for fresh ground water throughout the High Plains.

The Ogallala was deposited by rivers, streams, and lakes draining the Rocky Mountains, and therefore its gravels include an assortment of the more resistant igneous and metamorphic rocks native to the mountains of Colorado and northern New Mexico. Both vertebrate fossils (bones and teeth) and invertebrate fossils (snails and clams) have been found at scattered localities, as well as fossil seeds and leaves.

Quaternary Deposits

Quaternary deposits of the region are generally 10 to 100 feet thick and consist mainly of sand, gravel, and clay eroded from nearby Permian rocks, from the High Plains Ogallala Formation, or from other rocks and sediments farther west. Pleistocene (the "Great Ice Age") and Holocene (or Recent) sediments are rarely cemented. They commonly are buff, tan, brown, and pale reddish brown, and thus they resemble some Ogallala deposits. Most Quaternary material was deposited by major rivers and streams flowing to the east and southeast across the region (Fay, 1959b; Myers, 1962). Coarse-grained sediment (gravel and sand) was deposited mainly in the channels of modern and ancient rivers, whereas fine-grained sediment (clay and silt) was laid down either on flood plains of rivers or in shallow temporary lakes and ponds. Locally these deposits contain the bones of large vertebrates (elephants, horses, camels, and turtles), the bones of small vertebrates, petrified wood (fig. 6), and the shells of small snails and clams.

When a river shifts its position or cuts deeply into underlying rocks, the original flood-plain or alluvial deposits are left behind as terraces marking the earlier location and elevation of the stream. Pleistocene terrace deposits in the region are now 50, 100, or even 300 feet above modern flood plains. The oldest terraces normally are those that are highest above and farthest from the modern rivers.

Most terrace deposits in northwest Oklahoma are on the north side of major rivers: they were left behind as Pleistocene rivers cut laterally to the southwest, following the direction of gently dipping rock layers. In addition, the prevailing southwesterly winds have aided in heaping well-sorted fine- and medium-grained alluvial sand into dunes north of the rivers.

Virtually all the rivers and major streams of the region are now flowing upon 10 to 50 feet of alluvium that fills deep valleys previously cut into the bedrock. The original bedrock valleys were probably excavated some 10,000 to 50,000 years ago during a period of greater rainfall and runoff associated with the last major stage of continental glaciation in North America. Reduced rainfall and other climatic changes since then have reduced the streams' erosive energy; the streams have therefore deposited part of their load, partially filling the bedrock valleys.

Volcanic ash, the finest material blown into the air from explosive volcanoes, is widely scattered in Pleistocene deposits of western, central, and east-central Oklahoma, and nearly 20 separate deposits have been reported in northwest Oklahoma (Burwell and Ham, 1949). The volcanic ash is believed to have come from volcanoes erupting in some part of the Rocky Mountains during the Pleistocene Epoch (no volcanoes existed in Oklahoma at that time). Rapid cooling during violent eruption causes tiny fragments of molten matter to form volcanic glass. The glass shards or dust were carried eastward by the winds and settled out over a vast area in Oklahoma and surrounding states. Much of the ash was quickly eroded from upland areas and carried away by local streams. The ash deposits now found in western Oklahoma appear to be associated with high river terraces and show evidence of deposition in quiet water, suggesting that they were formed as the ash settled from the air into temporary lakes on the flood

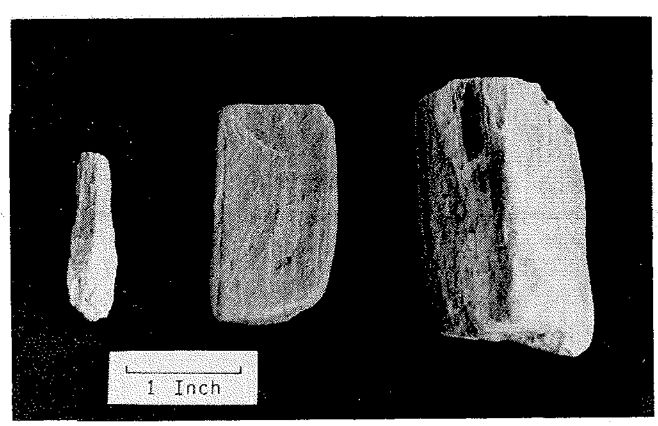


Figure 6. Samples of petrified wood.

plains of rivers. Some additional concentration of ash is attributable to local runoff into the lakes. The presence in some locations of fresh-water snails in associated clays supports this hypothesis of quiet-water deposition.

Geomorphology

Geomorphology (the study of landforms) in northwestern Oklahoma shows that the present topography has resulted from differential weathering of resistant and nonresistant rock layers. Horizontal beds of dolomite, gypsum, and sandstone resist erosion and cap most of the topographic highs, whereas shales are least resistant and are deeply eroded to form most of the broad lowlands. Contrasting landforms include rolling plains, steep escarpments, badlands, hummocky sand dunes, and flat featureless plains. The region has been subdivided into six geomorphic provinces (fig. 7), each of which is characterized by similar landforms resulting from erosion of somewhat uniform rocks and sediments. These geomorphic provinces, described below, generally coincide with the outcrop areas of various formations as shown on the geologic map (fig. 2).

Central Redbed Plains.– Gently rolling hills and broad, flat plains formed on Permian red shales and sandstones (Flowerpot Shale, Cedar Hills Sandstone, and Hennessey Shale, fig. 2) characterize this province. Bedrock is locally exposed, but much of the present surface is a moderate-to-deep soil of loose Quaternary sediment that was deposited on bedrock by small streams, slope wash, and wind.

Cimarron Gypsum Hills.– This area encompasses a long, narrow band of escarpments and badlands developed on interbedded Permian gypsums and shales (Blaine and Dog Creek formations, fig. 2). The principal escarpment (referred to as the "Blaine Escarpment") faces northeast, overlooking the Cimarron River, and is deeply dissected. Several benches of resistant gypsum and dolomite, in addition to as much as 250 feet of the underlying Flowerpot Shale in bluffs of the Glass Mountains area, are exposed (fig. 2, cross section B). Caverns and sinkholes are abundant in areas where ground water has dissolved part of the gypsum.

High Plains.– A featureless, relatively flat upland surface formed mainly on Tertiary sands, gravels, and clays (Ogallala Formation, fig. 2) describes this province. The area is deeply dissected along rivers and major streams, but tributary streams and creeks are scarce because most rainfall soaks into the ground and does not run off. Relief is greatest along the edge of the High Plains, where streams flowing onto the red beds cut back into the Ogallala by headward erosion.

Western Redbed Plains.– Permian red sandstones and shales form gently rolling hills in uplands above the Canadian River (Doxey and Cloud Chief formations, fig. 2) in this region. The surface is partly mantled by moderately deep soil composed of loose Quaternary sediment deposited by small streams, wind, and slope wash.

Western Sand Dune Belts.– These hummocky or lumpy fields of sand dunes are located typically on the north side of major rivers (Quaternary deposits, fig. 2). Most dunes are stabilized by a covering of grass or bushes, but some are barren and are still shifting. Part of the sand is blown from present flood plains by prevailing southwesterly winds, and part is reworked from terrace deposits left behind as the rivers cut laterally to the southwest. Few streams cross these belts, because rainfall easily infiltrates the highly porous loose sands.

Western Sandstone Hills.– These gently rolling hills and steep-walled canyons are formed on flat-lying, soft red sandstones (Rush Springs and Marlow formations, fig. 2). Soils are generally thin. Porous sandstones soak up much of the rainfall and are an excellent source of ground water.

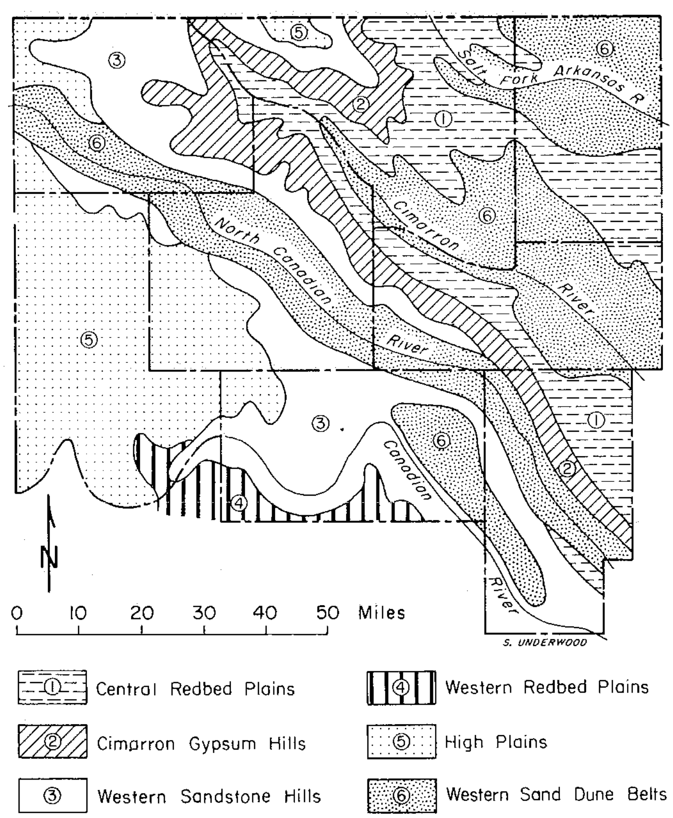


Figure 7. Geomorphic provinces of northwest Oklahoma.

Subsurface Rocks

Sedimentary rocks deposited during each geologic period of the Paleozoic Era underlie northwest Oklahoma. The thickness of these sediments increases markedly to the south toward the axis of the Anadarko basin; they are 7,000–8,000 feet thick at the Kansas line on the north and more than 20,000 feet thick on the south (fig. 8).

Subsurface Permian rocks are mostly red beds similar to those on the outcrop: shale predominates, but thick sequences of interbedded salt, anhydrite, and shale are evident from records of oil and gas wells drilled in the region. Pennsylvanian rocks are mostly gray shales and limestones with some interbedded sandstone. The Mississippian strata are almost entirely limestone in the northern part of the region, but southward toward the Anadarko basin approximately half the rock is interbedded gray shale. Silurian and Devonian limestone and dolomite underlie all but the northern part of the region: the black Woodford Shale of Mississippian-Devonian age overlies these limestones and extends northward into Kansas. Cambrian and Ordovician rocks are mostly dolomite with some beds of sandstone and shale. Beneath this thick sequence of sedimentary rocks is a "basement" of Precambrian granites (fig. 8), whose eroded surface dips down sharply into the Anadarko basin.

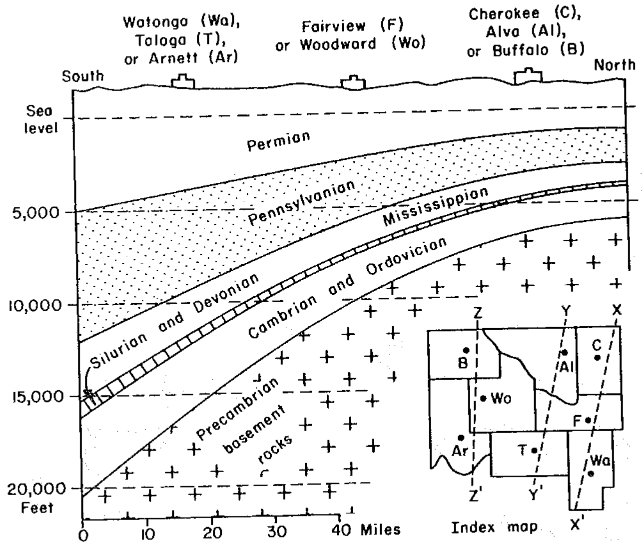


Figure 8. Generalized north-south cross section through northwest Oklahoma, showing that formations thicken and dip southward into the Anadarko basin. Cross section is the same whether drawn along line XX', line YY', or line ZZ'.

FIELD-TRIP SITES

Alfalfa County

Alfalfa County Site 1: Great Salt Plains

Access: Free access is permitted at all times to the salt flats in the vicinity of the observation tower 6 miles east of Cherokee and to the dam and State park area in the east (including picnic tables and camping facilities). For access to selenite crystal collecting area, see description of Alfalfa County site 2.

Site location: parts of Ts 26 and 27 N., Rs 9 and 10 W.

Topographic maps: Cherokee S (7½'); Cherokee N (7½'); Jet (7½'); and Manchester SW (7½') (four 7½' maps are needed to cover entire area).

References: Ward (1961a), Davis (1968).

Great Salt Plains comprises a flat, featureless surface covering about 25 square miles in east-central Alfalfa County (fig. 9). It is made up of loose Quaternary deposits saturated with natural brine, which is now seeping up from underlying Permian rocks. During parts of 1968, 1969, and 1970, the U.S. Army Corps of Engineers made a study of ground-water conditions and brine emissions in the area, and much of the following description is based upon this work.

The Quaternary deposits forming the salt plains are generally 10 to 25 feet thick. They consist of alluvial and lacustrine (lake-bottom) sediments that were laid down upon, and now conceal, an irregular bedrock surface that was eroded by streams and rivers, probably 10,000 to 50,000 years ago. These sediments occur in thin layers that were deposited over large areas of the salt plains (1) by streams which, in time of flood, spread their water and sediment load in a fanlike manner upon reaching the salt flats; (2) in intermittent lakes formed when water was backed up temporarily behind the narrow (0.5-mile-wide) water gap through which the Salt Fork of the Arkansas River leaves the salt plains; and (3) by wind, which tends to redistribute sediment and bevel surface irregularities. The present surface appears horizontal, but it does in fact slope toward the reservoir at a rate of 4 to 8 feet per mile.

Salt water is moving laterally and upward under artesian conditions through several porous sandstone aquifers in the bedrock (Hennessey Formation) and is being discharged into the bottom of Quaternary deposits that cover the bedrock (fig. 10). Natural brine in the bedrock aquifers and in Quaternary sediments has a sodium chloride content generally ranging from about 150 to 250 grams per kilogram (g/kg) of brine, or about 15 to 25 percent by weight. The only other ions in significant concentration are

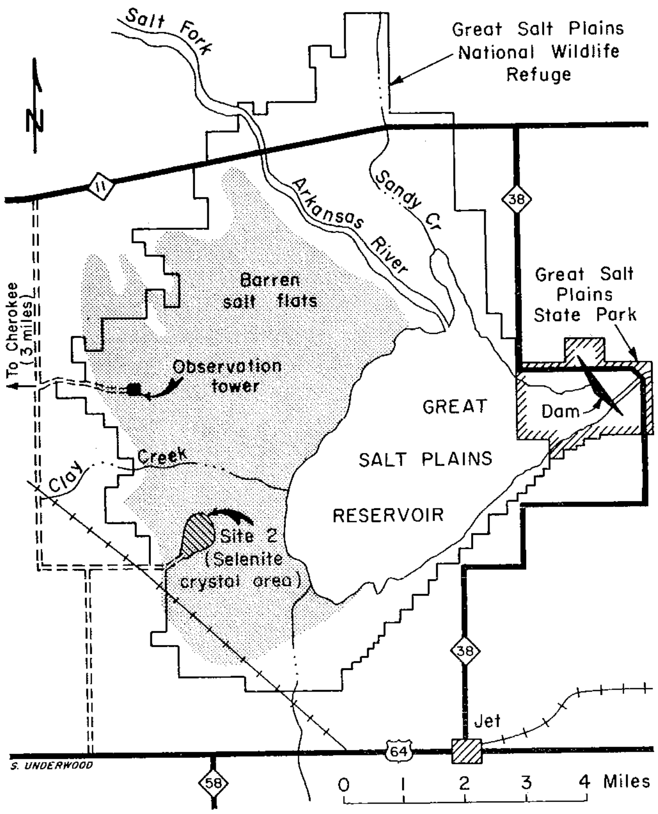


Figure 9. Location map for Alfalfa County sites 1 and 2, Great Salt Plains.

calcium (0.15 g/kg), magnesium (0.1 g/kg), and sulfate (0.7 g/kg). A thin crust of salt forms on the plains, usually after several days of dry weather. The salt is precipitated as water is evaporated from brine drawn to the surface of the salt flats by capillary action. (For a description of formation of selenite crystals on the Great Salt Plains, see Alfalfa County site 2.)

The origin of the brine is uncertain. Apparently, fresh water seeps into the ground at an unknown location north or west of the salt plains, moves downdip or laterally through porous sandstones and fractures in the Permian bedrock, dissolves salt from underground deposits of rock salt or salty strata, and eventually returns to the surface beneath the salt plain. The most probable sources of salt are thin layers of rock salt at a depth of 300 to 400 feet beneath the plain (these strata are deeper and thicker farther west and southwest) or small salt crystals and finely disseminated salt masses that are present in small quantities in porous sandstones through which the ground water moves.

The dam that created Great Salt Plains Reservoir was completed in 1941. The lake covers approximately 14 square miles of land that was once part of the salt plain. The water is less than 15 feet deep in most places but is nearly 20 feet deep at the eastern end near the dam. At this end, particularly just below the dam, there are excellent exposures of flat-lying Hennessey sandstones and shales similar to the rocks covered by the salt plains. Layers of shale are reddish brown, whereas layers of coarser grained siltstone and sandstone are, respectively, orange brown and light gray.

Salinity of water in the lake is normally 2 to 15 grams of dissolved salts per kilogram of water. Although the water definitely tastes salty, its dissolved-solids content is considerably less than the 30 g/kg found in normal sea water. The lake reaches higher salinities when brief but heavy rains on the adjacent salt flats wash the salt crust into the lake or when the lake volume is greatly reduced through evaporation while the amount of salt in the lake remains the same or increases. Salinity of the lake water is diluted when large quantities of fresh water flow into the reservoir. Although the salinity varies, the amount of salt (NaCl) that flows out of the reservoir through the Salt Fork of the Arkansas River averages about 3,000 tons per day.

Much attention has been focused on this area recently because of the adverse effect of these brines on water quality downstream from the salt plains. A better understanding of the origin and movement of brine can lead to more effective containment or control of emissions which now restrict use of large quantities of water flowing from the reservoir. One measure receiving serious consideration involves rechanneling the Salt Fork of the Arkansas River around the salt plains and the reservoir, allowing the dam to impound and isolate permanently brine and any water which flows across the salt flats.

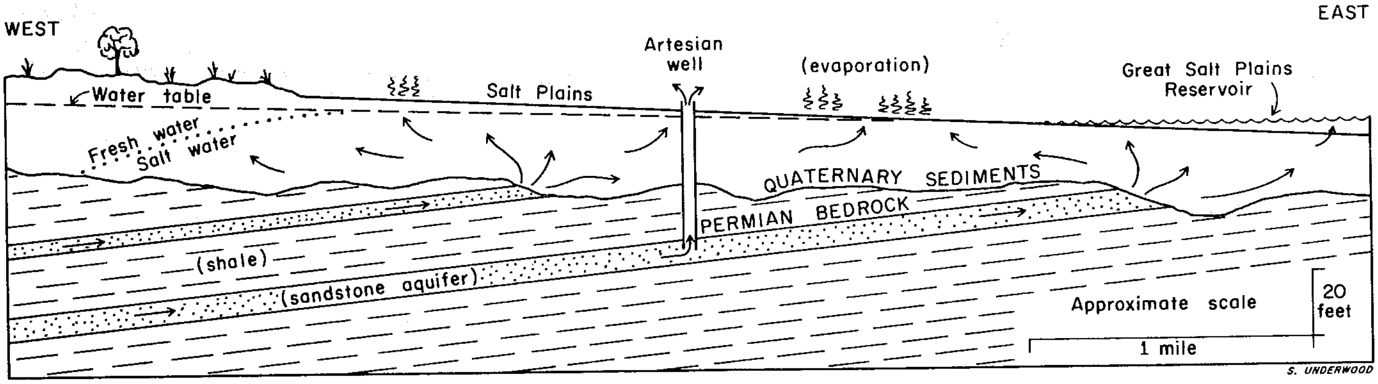


Figure 10. Schematic cross section showing movement of salt water (arrows) from layers of permeable bedrock into overlying Quaternary sediments at Great Salt Plains.

Alfalfa County Site 2: Selenite crystals

Access: Free access to the selenite crystal area is permitted only through one gate, which is unlocked 8 a.m. to 5 p.m. on Saturdays, Sundays, or holidays from April 1 to October 15 each year. To reach the gate, go 6 miles west of Jet on U.S. Highway 64, then go north on dirt road for 3 miles, then travel 1 mile east on dirt road across railroad tracks (fig. 9). The crystal area is one mile northeast of the gate and can be reached safely by driving across the salt flats.

Site location: sec. 22, T. 26 N., R. 10 W.

Topographic map: Cherokee S (7½').

References: Davis (1968), Vickers (1969).

Of special interest at Great Salt Plains (see Alfalfa County site 1) are the unique hourglass selenite crystals which can be collected during certain times of the year. The ground water here is highly mineralized; concentrations of sodium chloride (150 to 250 g/kg of water), calcium (0.15 g/kg), and sulfate (0.7 g/kg) are already near saturation level. Owing to the high dissolved-solids content of the water and the high rate of evaporation in the area, salt and gypsum crystals are continually precipitated on and just below the surface of the salt plains.

Selenite, a variety of gypsum, is a hydrous calcium sulfate ($CaSO_4 \cdot 2H_2O$). It forms at Great Salt Plains when the concentration of Ca and SO_4 in brine becomes so great that the mineral is precipitated. Brine flowing up from the underlying bedrock already contains a high concentration of Ca and SO_4 in solution, but these ions are further concentrated near the top of the loose Quaternary sediments when water in the brine is evaporated (only the water evaporates, and dissolved salts are left behind).

The interior of the crystals contains a ghostlike hourglass form consisting of sand, silt, and clay particles incorporated within the crystal as it grows (fig. 11). The brown color is acquired with the sediment enclosed in the crystal, as a result of the presence of iron oxide. As a crystal grows, loose particles are enveloped or included only at the ends, whereas particles adjacent to the sides of the crystal are merely pushed aside. The reason for this is not clearly understood, but it appears that the bond between molecules forming the smooth faces along the sides of the crystal is so strong that each new layer of molecules added forces foreign particles away from the crystal. On the other hand, the bond between molecules along crystal faces developing at the ends is not strong enough to push foreign matter aside, and therefore new layers envelop the particles.

Crystals are formed just below the surface, seldom more than 2 feet deep, and only in those few parts of the salt plains where the gypsum and salt concentrations in the brine are favorable for selenite precipitation. The selenite occurs as individual crystals and in clusters, with some individual crystals reaching 7 inches long and complete clusters weighing as much as 38 pounds. Crystals can enclose sticks, rocks, bones, and cockleburs that are part of the host sediment.

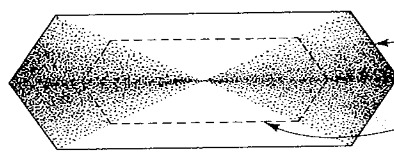


Figure 11. Drawing of hourglass selenite crystal illustrating two stages of growth.

From May 1966 to May 1969, members of the Enid Gem and Mineral Society conducted a study of the shapes and growth rates of selenite crystals they had "planted" on the Great Salt Plains. Their investigation was done in cooperation with the U.S. Department of the Interior's Great Salt Plains National Wildlife Refuge. Results of the study indicate that under favorable climatic conditions (cool, wet springs and hot, dry summers) crystals can grow as much as 26 percent larger within a year. The quality of crystals depends in part on grain size of the host sediment, with the clearest crystals forming in clay and more cloudy ones forming in silt and sand.

One prolific area of the Great Salt Plains has been set aside as a place where the public may dig for crystals during certain times of the year (fig. 9). A brochure from the Great Salt Plains National Wildlife Refuge recommends the following procedures. Dig a hole about 2 feet across and 2 feet deep; allow it to fill with water that seeps in from below (you may need to bring your own water to have a sufficient supply); splash water against the sides of the hole and gently wash the soil away from the crystals until they are free. At first the crystals are very fragile and must be gently placed where the sun and wind will dry them; when dry, they are quite hard and can be handled with normal care.

Owing to hazardous conditions on some parts of the plains, cars should be driven to the digging area on the salt flats only along prescribed lanes. Also, the white salt surface increases the possibility of sunburn, so sunglasses and protective clothing should be worn. Be sure to wash the salt water off all equipment and tools to prevent corrosion.

Alfalfa County Site 3: Red beds and gypsum

Access: The property is owned by Vencil "Corky" Green, Carmen (telephone: 987-2373), who lives 0.6 mile east and 0.1 mile south of the site. Enter the site through gate on south side of road 1.1 miles west of highway. Close the gate behind you.

Site location: NW¼ sec. 31, T. 25 N., R. 11 W.

Topographic map: Carmen (7½').

References: None, but Fay (1965) describes the Cedar Hills Member to the west in Woods County.

North of Carmen (fig. 2), the upper part of the Hennessey Formation consists of alternating layers of siltstone and shale containing nodules and thin veins of gypsum. Locally, the Quaternary sediments contain large fragments of bone. At site 3 (fig. 12) about 50 feet of Permian bedrock is exposed 1,000 feet southwest of the windmill, which is located 500 feet south of the gate.

Four bands of light-gray siltstone, each 0.5 to 1.5 feet thick, can be traced for 500 feet along the outcrop. The lower gray bands are overlain successively by orange-brown silty shale and red-brown shale. The top gray band is overlain by 10 to 15 feet of orange-brown coarse-grained siltstone and very fine-grained sandstone. The thick orange-brown bed is typical of the upper part (called the Cedar Hills Sandstone Member) of the Hennessey Formation. Alternating hard and soft layers in this bed show up through differential erosion.

Below the banded sequence is 20 feet of gypsiferous shale and siltstone. Gypsum occurs as thin veins of white or reddish satin spar and as white nodules of alabaster. Satin spar may have been formed at any time after deposition of the shale, whereas the alabaster nodules developed shortly after deposition of the shale while it was still mud. Some gypsum nodules have incorporated minor amounts of gray shale and have acquired its color.

Erosion processes are well demonstrated in the gullies being cut into the shale. Rain water does not soak into the impermeable shale but instead runs off and erodes small bits of weathered and loosened shale. The channel of the main creek draining the area is lined with these bits of shale and with scattered gypsum nodules weathered from the bedrock.

Much of the bedrock in the broad valley is covered by 3 to 10 feet of Quaternary alluvium and colluvium (sediment washed down slope from higher elevations) through which the creek is now cutting. Several scattered pieces of bone from unknown animals are visible in Quaternary sediments in the small box canyon near the fence in the west. The age of the bone is not certain, but it is probably about 5,000 to 10,000 years old. Owing to the scarcity of bones at this locality, please don't remove any; that way others can also examine them.

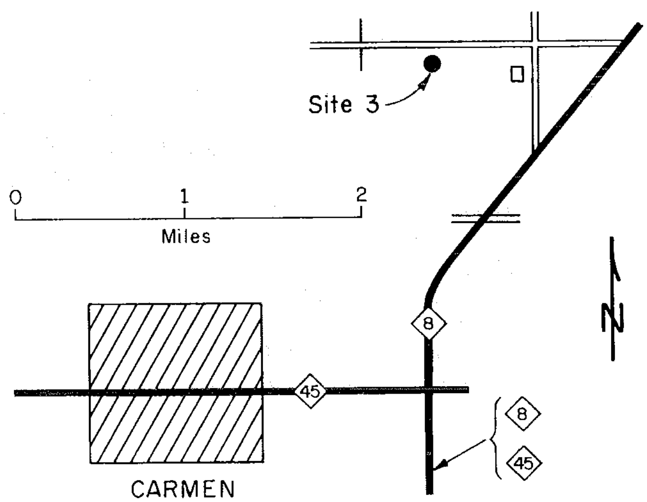


Figure 12. Location map for Alfalfa County site 3.

Blaine County

Blaine County Site 1: Roman Nose State Park

Access: Roman Nose State Park is free to the public at all times and provides picnic, water, and toilet facilities. The park contains a resort lodge and cottages. For information and access to the springs and other areas partially closed during winter months (Oct. 1 to early April), contact the Park Superintendent, Roman Nose State Park, Box 227, Watonga (telephone: 623-4215 or 623-5923).

Site location: secs. 23 and 24, T. 17 N., R. 12 W.

Topographic map: Watonga NW (7½'), in preparation.

References: Fay (1959a, 1964), Fay and others (1962).

Roman Nose State Park (fig. 13) comprises 540 acres of scenic land where layers of gypsum, dolomite, and shale are well exposed and where fresh water flows from three natural springs. The park is an excellent site for examining rock layering, weathering, differential erosion of hard and

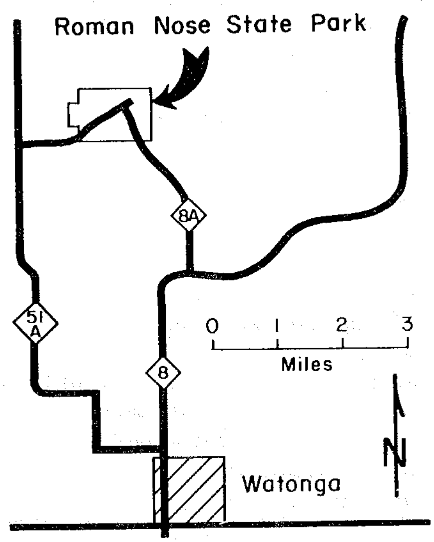


Figure 13. Location map for Blaine County site 1, at Roman Nose State Park.

soft strata, and the effects of bedrock geology on the flora and fauna of an area. It should be noted, however, that the geology along the entire Cimarron Gypsum Hills province is similar to that described here, and many other sites could be used for a similar examination. The description that follows is based upon a comprehensive report on the history, geology, botany, and zoology of the park prepared by Robert O. Fay (1959a).

Outcropping rocks are the Blaine Formation and overlying Dog Creek Shale of Permian age (fig. 14). Three resistant beds of white gypsum (each 6 to 13 feet thick) are separated by red-brown and light-gray shales 25 to 30 feet thick, and each gypsum bed is immediately underlain by a fossiliferous dolomite bed 1 foot thick (see cross section). Fossils in the dolomites are molds of pelecypods (clams), and belong to the genus *Permophorus* (Fay and others, 1962, p. 39). Locally the Altona Dolomite contains ripple marks on its upper surface. Anhydrite, an anhydrous form of calcium sulfate, in layers or lenses 0.5 to 4 feet 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 and denser than the gypsum.

The succession or cycle of rock types making up an "evaporite" series is well exposed. Dolomite, arbitrarily considered the base of a cycle, is overlain by gypsum, next by a thick unit of red-brown shale with thin interbeds of green-gray shale and gypsum. At the top is a thin layer of green-gray shale. Salt, which normally follows gypsum in the order of precipitation and should occur between the gypsum and red-brown shale, either was not deposited because of an interruption in evaporation of sea water or was deposited and has since been dissolved by ground water. The former explanation is more likely to be correct in this area. The cycle is repeated several times in the Blaine Formation, and a more incomplete cycle is seen in the Dog Creek Shale, where even the thick gypsums were not deposited.

Two prominent ledges of thick white gypsum are easily seen in the eastern part of the park near the lake; the lower ledge (upon which the resort lodge is built) is the Nescatunga Gypsum, and the upper ledge (above the roof of the lodge) is the Shimer Gypsum. About 25 feet above the Shimer Gypsum is 5 feet of interbedded light-gray dolomite and dark-gray shale (Watonga Dolomite) that caps the highest hills in the park. The Shimer Gypsum and the Watonga Dolomite are easily recognized and can be identified throughout the park, whereas the Nescatunga Gypsum is conspicuous only in the east near the lake. The youngest (highest) beds of the Dog Creek Shale are not exposed in the area: they were eroded by the North Canadian River when it flowed across the park area and was at a higher elevation than it is now. Pleistocene sands and gravels deposited upon that eroded surface have been largely reworked by wind into a hummocky sand-dune surface that is now stabilized by vegetation.

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

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. Rain water entering the ground farther

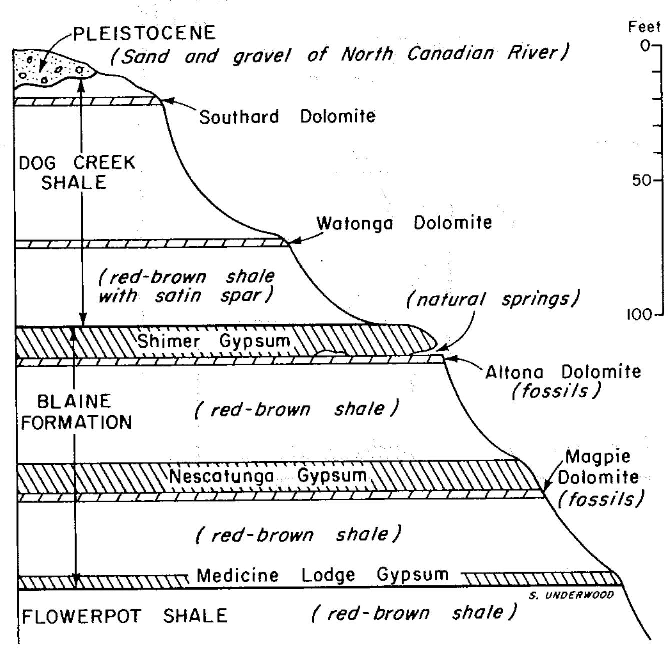


Figure 14. Stratigraphic column of rocks exposed in Roman Nose State Park and adjacent areas.

south and west moves through small holes and crevices in layers of soluble gypsum and dolomite until it emerges at the springs. The water is gypsiferous because it is actively dissolving the rock and enlarging underground caverns and caves; these processes are identical to those which earlier formed Alabaster Cavern (see Woodward County site 1). The combined flow from the three springs is generally 600 to 800 gallons per minute (gpm), and one set of measurements in 1958 recorded a flow of 80, 175, and 365 gpm from Little, Middle, and Big Spring, respectively.

Blaine County Site 2: Gypsum quarries

Access: Contact the plant manager at any of the three mines.

Site location: U.S. Gypsum – secs. 10, 11, 15, T. 18 N., R. 12 W.; Universal Atlas – sec. 27, T. 17 N., R. 11 W.; Walton Gypsum – sec. 35, T. 19 N., R. 12 W.

Topographic map: U.S. Gypsum and Walton Gypsum– Southard (7½'), in preparation; Universal Atlas– Watonga NE (7½'), in preparation.

References: Fay (1964), Fay and others (1962).

Blaine County is the center for gypsum mining in Oklahoma. Average annual gypsum production in Oklahoma from 1965 to 1970 was about 850,000 tons, approximately two-thirds of which came from Blaine County. Three companies are currently mining gypsum in the area: U.S. Gypsum Company, the largest of the three, at Southard; Universal Atlas Cement Company, 5 miles northeast of Watonga; and Walton Gypsum Company, 1 mile northeast of Southard (fig. 15). Nearly 15 million tons of gypsum has been mined in Blaine County since Statehood (1907), and the remaining reserve in the county is about 280 million tons.

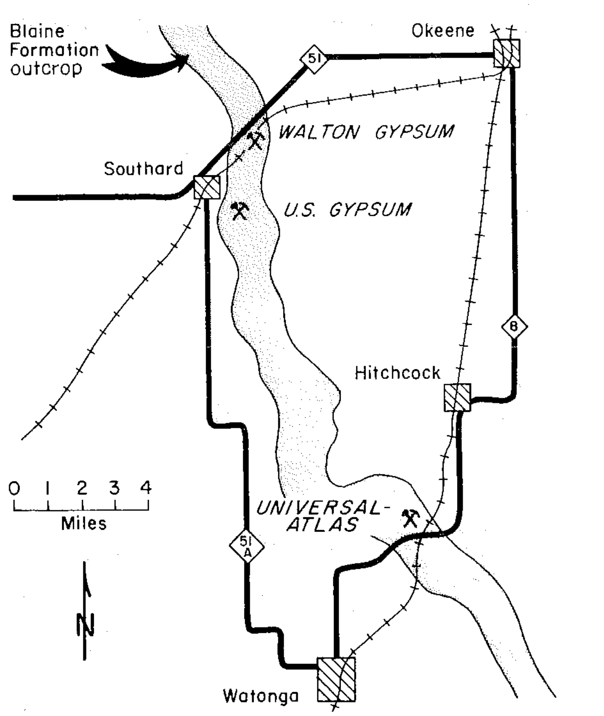


Figure 15. Location map for Blaine County site 2, gypsum quarries.

Development of these deposits began early, 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 central and eastern Oklahoma, as well as in much of Missouri, Arkansas, Louisiana, and east Texas.

The two principal economic gypsum beds being mined are the Shimer and Nescatunga Members of the Blaine Formation of Permian age (fig. 16). Each bed is 10 to 15 feet thick and is 97 to 99 percent pure gypsum ($CaSO_4 \cdot 2H_2O$). Impurities are anhydrite (0.1–0.5 percent), dolomite (0.3–2.0 percent), strontium sulfate (0.2–0.3 percent), and sand and clay (0.1–0.3 percent).

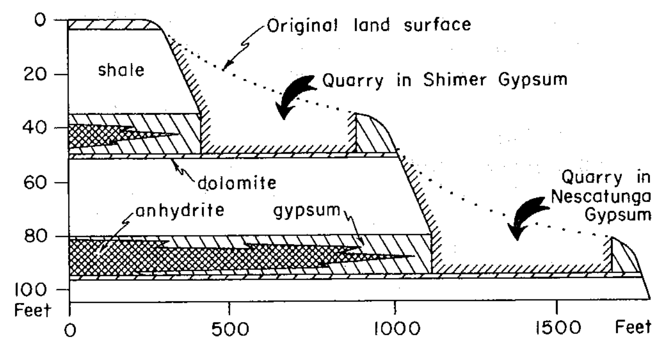


Figure 16. Schematic cross section showing relationship between topography, lithology, and quarrying in Shimer and Nescatunga Gypsum beds of Blaine County.

In mining operations typified by those of U.S. Gypsum Company, the first step is scraping away the red shale overlying the gypsum. Rock layers here are nearly horizontal (they dip west-southwest at 15 to 20 feet per mile) and are not faulted, so there is little difficulty in exposing a smooth surface at the top of the bed. After the surface is scraped, vertical blast holes are drilled from the top of the ledge and horizontal holes are drilled near the base of the quarry face, just above the underlying dolomite. Explosives are set off in both types of holes almost simultaneously, breaking the stone into small enough pieces that secondary shooting is rarely needed. Broken stone is loaded into dump trucks and hauled to the nearby plant. The eroded or outcropping edge of a gypsum bed is generally too weathered and contains too many clay-filled solution cavities for economic recovery of gypsum, and thus the thin outer margin is not quarried.

Good 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 that needs to be done and influences the distribution of anhydrite within the gypsum bed. Although gypsum 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 feet or more of shale overlies and protects the bed. Thus, gypsum can generally be mined along a band or bench 100 to 700 feet wide before encountering residual anhydrite layers beneath thick overburden.

Gypsum mined in the county is used in the following ways: U.S. Gypsum Company uses most of its gypsum to make wallboard (sheetrock), although some is made into laths, sheathing, and various plasters; Universal Atlas Cement Company uses all of its stone as a retarder in portland cement; and Walton Gypsum Company sells crushed gypsum as a retarder in portland cement and as ground gypsum for soil conditioner.

Blaine County Site 3: Gypsum, dolomite, gravel

Access: Exposures are in highway roadcuts 5.4 to 6.7 miles east of main highway intersection in southwest Watonga. Dolomite-gypsum exposures are 1.8 miles east of section line road.

Site location: dolomite and gypsum – NE¼ sec. 30, T. 16 N., R. 10 W.; gravel – N½ sec. 25, T. 16 N., R. 11 W.

Topographic map: Watonga SE (7½'), in preparation.

References: Fay and others (1962).

About 6 miles east of Watonga, on the south side of State Highways 3 and 33, are good exposures of gypsum, dolomite, and solution features in the Blaine Formation (fig. 17). One mile farther west are several exposures of Pleistocene terrace deposits resting unconformably upon Dog Creek Shale. Fay and others (1962, p. 202-206) described the rocks along the highway in measured section X.

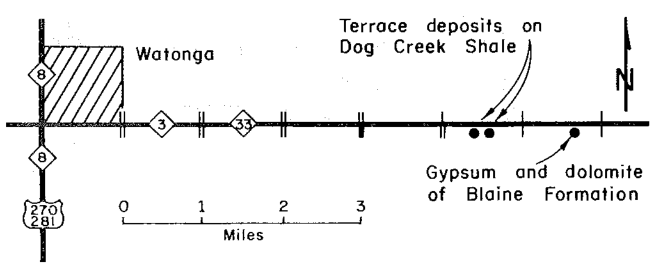


Figure 17. Location map for Blaine County site 3.

The Magpie Dolomite at the base of the gypsum is 1.5 feet thick and is made up almost entirely of oolites (spherical grains) and rounded pellets 0.2 to 0.5 mm in diameter. The bottom and top of the dolomite bed are light gray, whereas the middle part is pinkish brown. Small masses of malachite, a bright-green copper mineral, are scattered in the bottom 2 inches of the bed. At the eastern end of the roadcut large blocks of dolomite have broken loose from the main ledge and are in the process of creeping slowly down the slope.

Directly above the dolomite is 10 feet of Nescatunga Gypsum, which is partly dissolved. In places the upper part of the gypsum bed has collapsed into solution cavities, and elsewhere – particularly at the east end of the roadcut – the once-open cavities are now filled with reddish-brown clay deposited by underground streams that flowed through the cavities. In the bottom 3 feet of the gypsum, irregular masses and stringers of dolomite impart a grayish color to the gypsum. In addition, large crystals of selenite (0.2 to 1.0 inch across) have recrystallized from what was once a finer grained gypsum. About 3 feet above the base are bands of pink, maroon, and white gypsum, and about 6 feet above the base is 1.5 feet of white, faintly banded alabaster. The crisscrossing gray bands in the alabaster mark fractures and beds along which ground water has moved, causing recrystallization of the alabaster to coarser grained selenite. Another exposure of the Nescatunga Gypsum is seen 0.25 mile west of this roadcut.

Pleistocene sand and gravel are well exposed above reddish-brown Dog Creek Shale in south roadcuts 1.1 and 1.4 miles west of the first roadcut described. Yellowish-brown and buff fine- to very coarse-grained sand is mixed with pebbles of quartzite and metamorphic rocks up to 5 inches across. The 2 to 10 feet of sand exposed at the top of these roadcuts is only a thin remnant of what may at one time have been 50 to 100 feet of similar sediment. The basal contact of this Pleistocene deposit with underlying Permian bedrock dips gently to the west and southwest beneath the towns of Watonga and Greenfield. Gravel falling from the Pleistocene deposit has been scattered as a veneer over the Dog Creek Shale in the lower slopes of the roadcuts. Exposure of the shale just beneath this veneer demonstrates that the sand and gravel are merely sliding down the hill. The Dog Creek Shale underlying the Pleistocene terrace deposit is slightly silty reddish-brown shale containing several thin greenish-gray layers.

Blaine County Site 4: Trench Canyon

Access: Enter the property through a gate on the east side of the road 1.9 miles south of the highway, and drive northeast on the trail through the plowed field into the pastureland bordering Trench Canyon. Be sure to close the gate. For permission, see Delmer Bradford, Route 1, Watonga (home phone, 623-4249; office phone, 623-5039). He lives on the south side of U.S. Highways 280 and 271, 1.3 miles west of intersection with State Highways 3, 33, and 8 at Watonga.

Site location: sec. 36, T. 16 N., R. 13 W.

Topographic map: Oakwood (15'); Watonga SW (7½'), in preparation.

References: Fay and others (1962).

Trench Canyon, located about 7 miles west of Watonga (fig. 18), contains excellent exposures of crossbedded Rush Springs Sandstone of Permian age, along with fine examples of potholes and deposits of Quaternary sand and gravel. In one part of the study area the intermittent stream has cut a trench 10 to 20 feet deep and only 1 to 5 feet wide: hence the name Trench Canyon.

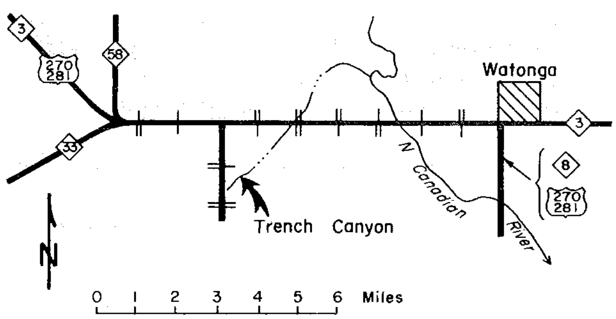


Figure 18. Location map for Blaine County site 4, Trench Canyon.

The outcropping Rush Springs Sandstone is orange brown and is mostly fine grained, although some of the layers are medium and coarse grained. Large-scale crossbedding is one of the most conspicuous characteristics of the Rush Springs at this location. Although most of the crossbed units are only 1 to 5 feet thick, one prominent set of crossbeds (about 1,000 feet upstream from the pond) is 20 feet high, with individual layers extending 50 feet horizontally. These large foreset beds dip 28° toward the south and were undoubtedly formed by the advancing movement of large sand dunes toward the south, much the same as modern dunes at Woods County site 5 are now moving toward the northeast. The direction of dip of crossbeds is not the same in different parts of Trench Canyon and at different levels in the same location; there appears to be no preferred direction of dip, which indicates that the direction of the winds forming these dunes was variable.

The sandstone is friable or soft (because of the small amount of calcite cement) and is porous. Rainfall can easily filter down through the soil into the Rush Springs Formation, making it an excellent aquifer for ground water. Small pits or depressions in the sandstone surface mark the location where plant rootlets have extended down into the sandstone and loosened the sand grains so they can easily be removed by the wind. Light-gray irregular masses of crustose lichens up to 1 foot across encrust the sandstone locally. The lichens secrete a gelatinous substance that cements the sand grains into a rubbery layer approximately 0.1 to 0.2 inch thick.

Potholes are eroded or scoured into the sandstone by the swirling action of water carrying sand grains and gravel. Sand and gravel caught in the flowing water acts as an abrasive and wears down the sides of small channels to smooth, arcuate surfaces. This can be seen in some of the smaller tributary channels leading into the main creek upstream from the pond, and it is especially pronounced along the channel for 1,000 feet or so downstream from the pond. Portions of this downstream section are extremely dangerous: the swirling action of water, sand, and gravel has cut a narrow trench 10 to 20 feet deep into which a student could easily fall and be seriously injured. The hazardous area begins about 100 feet east of the barbed wire fence (500 feet downstream from the dam, fig. 19), and although this is one of the most fascinating parts of the site, the hazards should be carefully examined beforehand to see if it is advisable to bring groups to the trench itself. If so, let students get close to the trench only where it begins to drop off. Farther downstream the footing adjacent to the chasm is more uncertain.

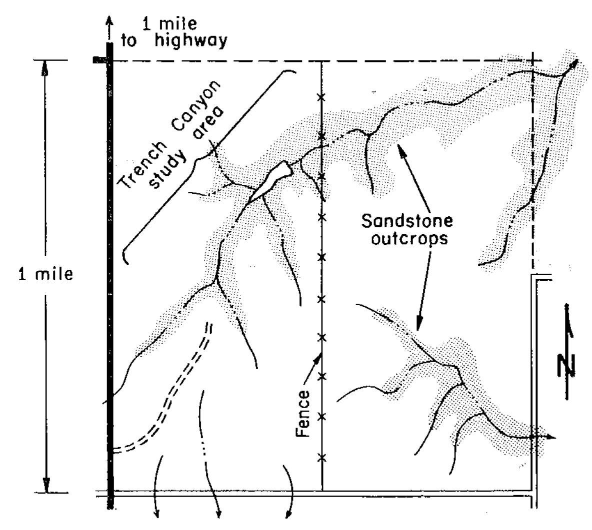


Figure 19. Map of Trench Canyon area.

In the upper banks of some of the tributaries, good exposures of Quaternary terrace deposits laid down by the Canadian River are visible. These Pleistocene deposits are mostly sand with some gravel and clay: they are yellow, whitish brown, or brown and are commonly 5 to 30 feet thick. The youngest sediments at the site are the thin layers of loose sand now being laid down on the floor of the main stream and its tributaries. This sand, consisting of material eroded both from the Rush Springs Sandstone and the overlying terrace deposits, generally has a ripple-marked upper surface and shows small-scale crossbeds in cross section.

Near-vertical fractures and joints are zones of weakness, and as such they are easily eroded and are the lines along which vegetation usually takes root. These are not fault planes, because individual layers of rock can be traced continuously across the fractures without being offset.

In 1955, an earthen dam was put across the main channel and the floor of the pond was sealed with a thin layer of asphalt to prevent loss of water. The pond area was originally bare rock, similar to that just upstream and downstream, but sand carried into the pond filled the pond to such an extent that it had to be dredged in 1970. The spillway on the south side of the dam contains a series of regularly spaced shallow depressions where dynamite charges were set off to blast the rock and create the spillway.

Blaine County Site 5: Red Hill at Greenfield

Access: The land is owned by Mr. Sam Ball, 703 N. Prouty St., Watonga (phone: 623-7755). Enter property through gate 0.3 mile north of house on west side of highway. You may drive on farm road nearly to base of bluffs. Close the gate behind you.

Site location: SE¼ sec. 19 and SW¼ sec. 20, T. 15 N., R. 11 W.

Topographic map: Watonga SW (7½'), in preparation.

References: Fay and others (1962).

Red Hill, a high butte 2 miles northwest of Greenfield (fig. 20), contains excellent exposures of Permian shale, sandstone, and dolomite. Outcrops include the Dog Creek Shale in the lower half of the bluff and sandstones of the Marlow Formation in the top half. The butte is capped by 4 feet of hard dolomite. A good place to examine outcrops is near the group of cedar trees opposite the gate leading into the pasture. Rocks exposed here are described by Fay and others (1962, p. 239-241) in his measured section XX.

Shale in the Dog Creek Formation is reddish brown and slightly silty. Bedding is indicated by two 2-foot-thick layers of light-gray siltstone about 50 and 60 feet below the top of the formation. Shale below one of these siltstones has been quarried for use on a road through the pasture. Some of the shale contains light-gray spots, usually 1 to 4 inches in diameter, with a dark-gray nucleus. The iron oxide in these subspherical spots has been reduced by decay of organic matter or slightly radioactive minerals deposited along with the host shale.

The overlying Marlow Formation is mostly fine-grained orange-brown sandstone, but there are some shale and siltstone layers in the lower part. Bedding is accented by differential rates of weathering and erosion: layers with more cementing minerals between sand grains are hard and stand out in relief, whereas soft layers are more highly eroded. At the base of the Marlow is 4 feet of light-gray fine-grained sandstone. Some geologists believe the base of the Marlow is a regional unconformity, because there are slight undulations of its contact with the underlying shale and because the contrast is sharp between the rock types above and below the contact.

Capping the butte is 4 feet of pink, gray, and white dolomite that is fine to coarse crystalline and has wavy bedding in part. This dolomite, called the Relay Creek Dolomite, is 80 feet above the base of the Marlow. Many small holes (vugs) and channels have been formed by dissolution of the more soluble parts of the rock (perhaps the rock once contained small masses of soluble gypsum). Differential erosion accents layering in the dolomite. Because of its hardness, this rock was quarried some time around 1960 as a source of riprap in building several dams in central Oklahoma.

Atop the butte and several hundred feet back from the edge is a standard triangulation station, located next to a 4-foot-high wooden post. The station is marked B-6-13.

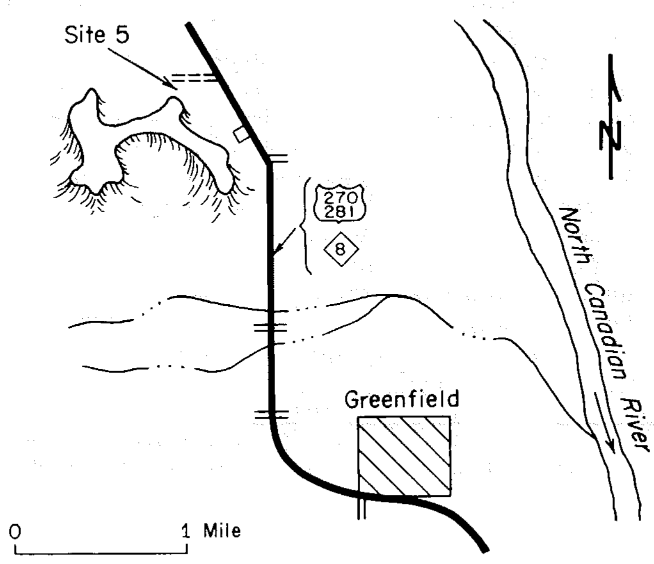


Figure 20. Location map for Blaine County site 5, Red Hill northwest of Greenfield.

The elevation is not stamped on this (and most other stations) because subsequent, more precise surveying may show the presently accepted value to be slightly inaccurate. Knowing precise distances and directions between a series of these triangulation stations throughout the United States insures the accuracy of maps of all parts of the country. Surveyors can measure great distances from prominent hilltops that command unobstructed views.

From atop the hill one can see other buttes to the south and west capped by the Relay Creek Dolomite. To the north and east are the broad, flat lowlands consisting of the flood plain and low terraces of the North Canadian River. Rock layers exposed in the bluff originally extended north and east across what is now the river valley, but they have been eroded from that area as the river cut downward and laterally to the southwest.

Dewey County

Dewey County Site 1: Bentonite mine

Access: The mining company (L.S. Fisher, contractor) is owned by Sam Fisher, Box 602, Woodward (telephone: office 256-3317; home 256-2313). Watch carefully for mining equipment, and be sure to close the gate.

Site location: SE¼ sec. 20, T. 19 N., R. 19 W.

Topographic map: Mutual SW (7½').

References: none.

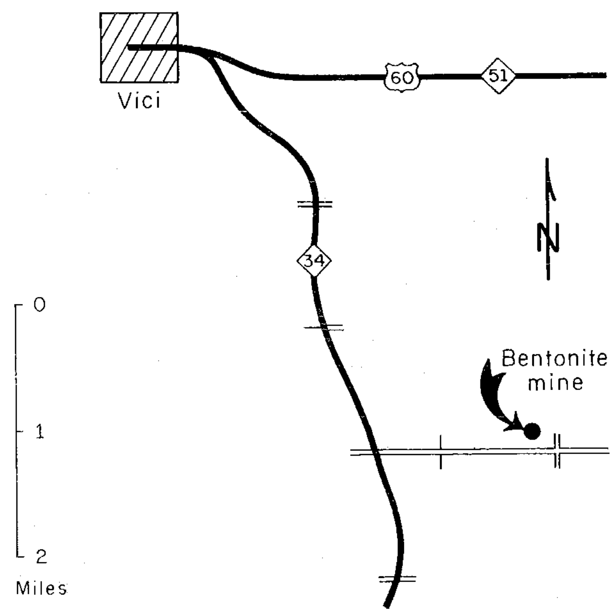


Figure 21. Location map for Dewey County site 1, bentonite mine southeast of Vici.

Bentonite, which is formed by alteration of volcanic ash, is present southeast of Vici in northwest Dewey County (fig. 21). The bentonite is flesh colored or pinkish tan when freshly exposed, but it weathers rapidly to a chalky white color. This particular bentonite has a waxy feel and, unlike the more common types, slakes in water without swelling. The bed is about 3 feet thick and underlies 20 feet of loose sand overburden. The bentonite is of high purity and consists mostly of the clay mineral montmorillonite along with some unaltered volcanic ash and scattered sand grains.

Material at this site was originally ash or dust blown from a volcano (located somewhere in the western United States or Mexico) that erupted during Tertiary time. The ash collected in what was then a shallow lake covering at least several square miles, and it was subsequently buried by alluvial sands. Younger Pleistocene ash deposits of western Oklahoma generally show little evidence of alteration, but in this older Tertiary ash virtually all the glass shards and dust have decomposed and been altered to clay minerals. Other exposures of the bentonite bed are in roadcuts 400 to 800 feet west of the highway along the same dirt road that leads to the mine.

In mining, a bulldozer is used to scrape the overburden from the bentonite and a dragline is used to load bentonite onto trucks driven down to the floor of the pit. The trucks haul bentonite to Camargo, where it is loaded on railroad cars and shipped to Jackson, Mississippi, for use as a desiccant to absorb moisture in packaged goods.

The overlying loose sand is an ancient river deposit. It is tan colored and generally well-sorted, fine- to medium-grained sand. Layering shows up in the walls of the pit, and at a few places crossbeds and disrupted bedding are exposed. Some layers are slightly harder, owing to minor amounts of cement holding the grains together. Fragments of shale scattered in the sand were deposited after having been torn from thin clay layers laid down near the banks of the ancient river.

Dewey County Site 2: Red beds, dolomite, collapse

Access: The field-trip site, at the TV tower 4 miles southeast of Seiling, is owned by Delmer Delong, Seiling (telephone: 922-3348). Mr. Delong lives 0.7 mile northwest of the gate leading to the TV tower. Enter property through the gate, but be sure to close the gate. Do not go near equipment or material around the TV tower.

Site location: SE¼ sec. 23, T. 19 N., R. 16 W.

Topographic map: (none available).

References: Fay (1965, p. 176-177) described these red beds and dolomite in his measured section 16.

Rock exposures on the high hill 4 miles southeast of Seiling (fig. 22) include dolomite and red-brown sandstone and siltstone of the Rush Springs and Cloud Chief formations of Permian age. Although sandstone and siltstone predominate, the dolomite caps most of the high places on the hill and is quite conspicuous. The dolomite, called the Day Creek Bed, is about a foot thick, can be light gray, pink, or white, and locally is recrystallized to finely crystalline calcite. At places the dolomite is laminated, with bands 1 to 2 mm thick. Strata are not horizontal but appear to pitch and roll where they have collapsed as underlying layers of salt and perhaps gypsum have been dissolved.

There are two main areas for examination of rock outcrops: one area southeast of the TV tower and a second area north of the tower. In the first area outcrops of collapsed Day Creek Dolomite and resistant sandstone are evident about 300 feet southeast of the tower, and a deep steep-walled canyon is cut into sandstones several hundred feet farther south. The collapsed sandstone is well cemented along certain layers and along a crisscrossing network of veins, producing a boxwork weathering pattern. Resistant layers and veins stand in bold relief, whereas poorly cemented parts of the rock are easily eroded and are recessed. The deep canyon contains good exposures of massive Rush Springs Sandstone that show bedding only faintly. The channel at the bottom of the canyon is sinuous and swept clean in some of the upper reaches, but farther downstream it is clogged with large boulders of dolomite and well-cemented sandstone eroded from the hill.

The second area of good exposures is near the northernmost knobs on the hill, about 1,200 feet northwest of the TV tower. The Day Creek Bed is vuggy and pitted where more soluble parts of the bed have been dissolved. It caps small bluffs in which the underlying massive-bedded sandstones are exposed. Dolomite has been quarried on a small scale at this site. Locally, it appears that there are 2 similar layers of dolomite (separated by 6 to 8 feet of red beds), but there is only 1 bed – it has been offset or faulted during collapse.

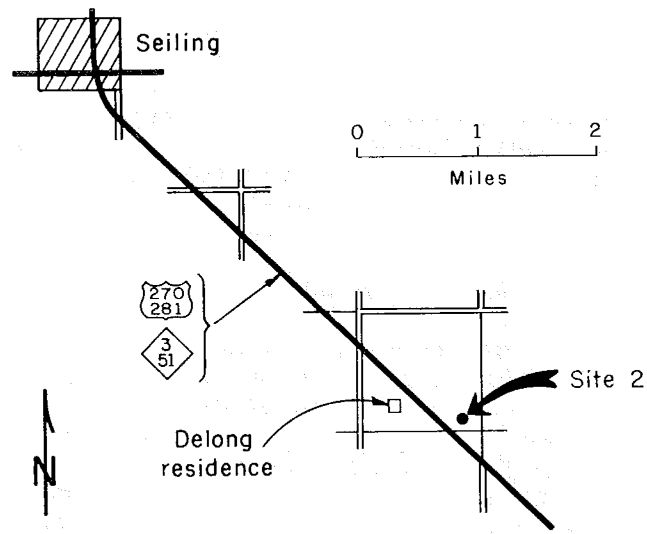


Figure 22. Location map for Dewey County site 2.

In addition to the TV tower, the hilltop is also the site of a U.S. Coast and Geodetic Survey triangulation station, called the Canadian triangulation station. This station is marked by a metal disc in concrete 150 feet southeast of the TV tower. Accurate maps of the region are constructed by establishing precise distances and directions from this station to similar stations 5 to 15 miles away and then locating various local features with respect to them. Two additional reference stations, located about 130 feet north and 130 feet west of the triangulation station, will enable precise reconstruction of the Canadian station if it should be destroyed or moved accidentally.

South and southeast of the site are thick terrace deposits of Quaternary sand and gravel laid down by the Canadian River. The surface of this sand is largely heaped into windblown dunes now stabilized by vegetation. Similar deposits once extended northward over this site but have since been eroded.

Ellis County

Ellis County Site 1: Gravel and collapse

Access: The gravel pit to be studied is owned by Wayne Alexander, Route 3, Laverne (telephone: 921-3228 or 921-3229), who lives south of U.S. Highway 270, 0.3 mile east of the intersection with U.S. 283. For access to the more northerly circular collapse structure west of the section-line road, see George Morey (telephone: 689-2256), who lives 1.3 miles south of May on State Highway 46.

Site location: gravel – SW¼ sec. 3, T. 24 N., R. 25 W.; collapse – SE¼ SE¼ sec. 36, T. 25 N., R. 25 W.

Topographic map: Laverne SE (7½'), in preparation.

References: Kitts (1965), Myers and others (1959).

Gravel and collapse features in the Laverne Formation of Tertiary age (considered a part of the Ogallala Formation by some geologists) are well displayed about 8 miles south of Laverne (fig. 23), where a sand and gravel deposit about 20 to 30 feet thick is being worked for road material. Bedding can be easily studied from the pit: thin layers of dark sand grains accentuate the bedding, and some of the strata are crossbedded.

The deposit being worked, laid down by an ancient river, is primarily gravel mixed with some sand layers, but it also contains balls of slightly hardened clay and silt that were torn from the banks of the river and redeposited. Most of the gravel is fragments of dark-brown or black iron-stained sandstone derived from some unknown source area to the west. Light-colored quartzite and other metamorphic and igneous rocks are also present, along with some oyster shells eroded from Cretaceous formations. Fossil wood may be present in small quantities.

In the top 1 to 3 feet of the pit is a brown soil developed by weathering of gravel and containing scattered pieces of gravel that have not decomposed. The darker brown color of the soil reflects a high organic content due to decaying vegetation. In the southwestern part of the pit sedimentary layers dip to the southwest at an angle of 10° to 15°: this probably reflects collapse of these and underlying strata into cavities formed from dissolution of salt that existed about 400 feet underground.

Fine exposures of collapse features in this area can be seen about 2 miles east and 1 mile north of the gravel pit (fig. 23). Two nearly circular collapse structures are outlined by a layer of white fossiliferous limestone. The hard limestone forms a low bench that dips 15° to 25° toward the center of a small basin approximately 200 feet in diameter. The limestone overlies about 3 feet of light-gray medium-grained sand, and this in turn overlies at least 10 feet of light-brown fine-grained sand. These Tertiary strata were, of course, horizontal when first laid down, but they collapsed into circular sinkholes when the thick layers of salt about 400 feet underground were dissolved. Subsurface salt was dissolved in large areas of Ellis and Harper Counties, causing widespread collapse of Permian red beds and of some Tertiary sediments.

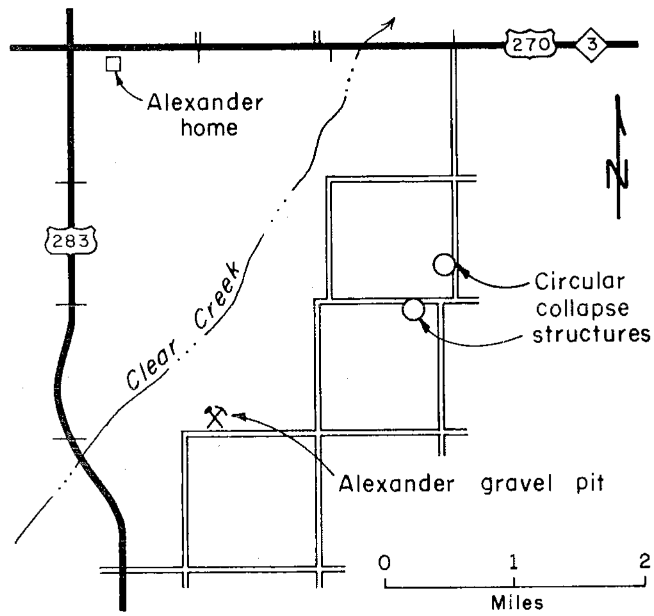


Figure 23. Location map for Ellis County site 1.

Fossils in this limestone are poorly preserved and are microscopic in scale. They consist of the molds or impressions of snails (probably fresh-water snails) about 1 to 3 mm long. The shells have been dissolved, leaving openings as a result. Other small holes in the rock have resulted from plant-root action or from the action of burrowing animals.

The collapse feature is best seen at the more northerly of the two sinkholes. Cross the fence into the field on the west side of the section-line road. Be careful climbing the fence (climb over at the big rock near the top of the hill), because damaged fences will make groups unwelcome in the future.

Ellis County Site 2: Flattop Hill-caliche

Access: Flattop Hill is on land belonging to Allen Schoenhals, who lives 1.5 miles south of Shattuck (telephone: 938-2837).

Site location: W½NE¼ sec. 9, T. 21 N., R. 25 W.

Topographic map: Shattuck (7½').

References: Kitts (1965).

Flattop Hill, 3 miles north of Shattuck on U.S. Highway 283 (fig. 24), is capped by a thick caliche bed of the Ogallala Formation. The bed is about 10 feet thick and is one of the most resistant rock units in the area. Large blocks of the caliche have broken loose from Flattop Hill and rest on the slopes. The stone is white, but it weathers to light gray and is of fairly high purity for caliche, containing only minor amounts of sand and clay (perhaps 10 to 20 percent of the rock). Although caliche is resistant in this semiarid climate, it is a soluble rock, and water has formed many solution cavities.

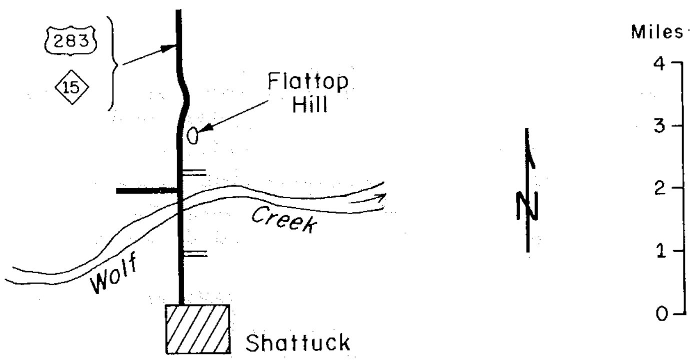


Figure 24. Location map for Ellis County site 2, Flattop Hill.

From atop the hill or from the northern slopes, the bench-forming characteristics of this caliche are conspicuous, especially to the northeast and northwest. Caliche and other layers in the Ogallala of this area are essentially flat lying: that is, the elevation of the caliche bed is approximately the same throughout the area.

Beds of sand underlying the caliche in the Ogallala consist mostly of fine- to medium-grained sand, and all the layers appear to be calcareous. One layer of buff-colored sand forms a conspicuous bench in bluffs to the north and northeast; the bed is 10 feet thick and is about 40 feet below the caliche cap rock. In the lower and middle parts of the roadcut adjacent to Flattop Hill, the sand has been partly changed to caliche by cementation of irregular masses of sand with white calcite. White tubules in the sand mark places where calcite cement has been precipitated around plant rootlets. Topsoil developed on calcareous sand or caliche in this area is brown and is typically only 6 to 12 inches thick.

Just 1 to 2 miles north of Flattop Hill several caliche beds, each 1 to 5 feet thick, are interbedded with sands in the 50 feet of strata overlying the conspicuous buff-colored sand bed.

Ellis County Site 3: Lake Vincent

Access: Free access to Lake Vincent and to the park area is permitted year round, and picnic and toilet facilities are available. Bill McCaslan, Area Manager for the Oklahoma Wildlife Department, Box 664, Shattuck (telephone: 938-2408), can assist in planning activities at Lake Vincent.

Site location: gravel and red beds – sec. 12, T. 18 N., R. 26 W.; volcanic ash – SW¼ sec. 23 and NW¼ sec. 26, T. 18 N., R. 26 W.

Topographic map: Arnett SW (7½'), in preparation.

References: Kitts (1965).

Pleistocene gravels and volcanic ash, as well as bedding features in Permian bedrock, are well exposed in the vicinity of Lake Vincent, located south of Shattuck and southwest of Arnett (fig. 25). The lake, built about 1963, is in a game management area administered by the Oklahoma Wildlife Department.

Gravel in the area is predominantly quartzite, quartz, and assorted metamorphic and igneous rock fragments eroded from the Ogallala Formation (which in turn derived its gravel from the Rocky Mountain region). The gravel occurs in high Pleistocene terrace deposits of the Canadian River. Deposits are generally 50 to 100 feet thick, and their flat-topped surface represents an ancient flood plain that extended about 5 miles north of the present Canadian River. Six feet of white and light-gray volcanic ash is exposed in the roadcut and stream banks several miles south of Lake Vincent; the lower 2 feet of the deposit is partly altered to clay minerals and has a soapy feel (see description of Dewey County site 1 and Woods County site 1).

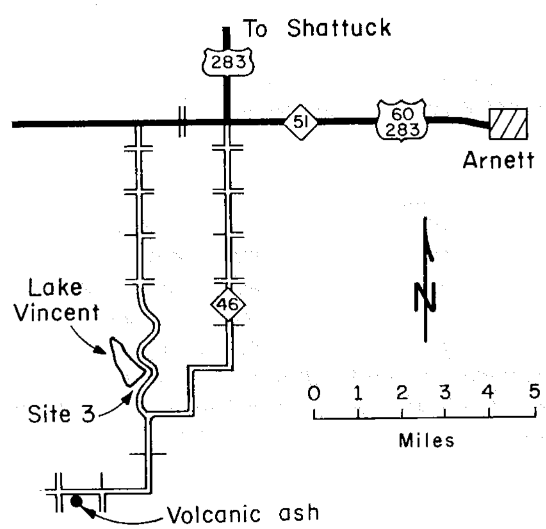


Figure 25. Location map for Ellis County site 3, Lake Vincent area.

Coarse gravel litters most of the slopes in the lake area and makes up thick deposits on hills about 50 feet above the lake level. One particularly good gravel deposit (site 3A, southwest of dam) contains buff-colored sand, gravel, and clay mixed together (fig. 26). Gravel is up to 4 inches across. Screening equipment at this site is used to sort sand and gravel into various sizes for road and construction materials. Some of the gravels have yielded fossil remains of mastodons, horses, and wood, but these finds are rare.

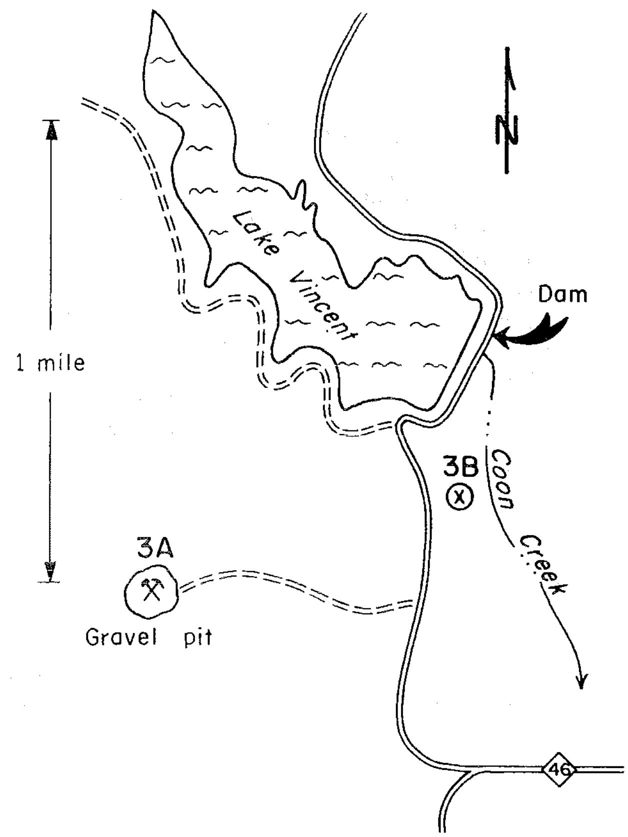


Figure 26. Map of Lake Vincent area showing location of gravel pit (site 3A) and collapsed red beds (site 3B).

Red beds of the Cloud Chief Formation crop out along the water's edge and are particularly well exposed just downstream from the dam. At location 3B (fig. 26) exposed rock is mostly reddish-brown shale with some siltstone and sandstone layers. Contorted bedding and small-scale crossbeds are present in some sandstones (fig. 27). The contorted bedding, shown by tight folding and disruption of stratification, is evidence that some layers of mud and sand slipped or slid after being laid down and before the overlying layer was deposited.

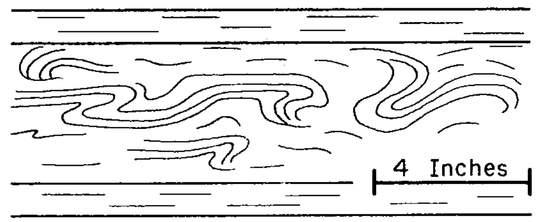


Figure 27. Contorted bedding in red beds at Lake Vincent.

Outcropping red beds dip 10° to 15° in various directions at this site (fig. 28). They have collapsed, along with underlying rocks, into cavities caused by dissolution of salt beds that were once about 500 feet below the surface. Several miles west of the lake, caliche beds in the Ogallala Formation also have collapsed, indicating that at least locally some of the salt was dissolved during or after deposition of the Ogallala.

A brief geologic history of rocks exposed at this site begins with deposition of the red beds in Permian time. Subsequent collapse of red-bed formations occurred when underground salt beds were dissolved, before and during Ogallala time. The Ogallala was laid down over the entire area by rivers and streams draining the Rocky Mountain region. In Pleistocene time, the Canadian River eroded Ogallala sediments from the lake area and deposited thick sands and gravels directly upon red beds. Since that time, the Canadian River has shifted southward to its present location, and modern streams have been cutting through the terraces to expose the red beds once again.

From atop high hills around the lake one can see the Antelope Hills, about 10 miles to the south, and other conspicuous hills that are capped by caliche beds in the Ogallala.

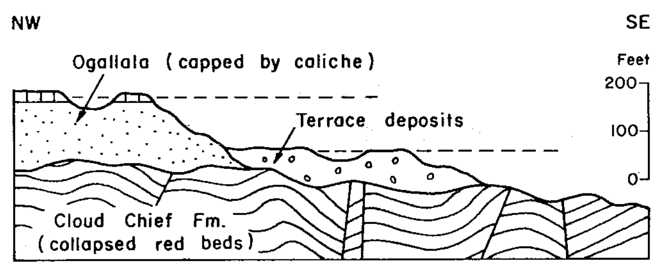


Figure 28. Schematic northwest-southeast cross section (2 miles long) through Lake Vincent area.

Harper County

Harper County Site 1: Gravel, dolomite, fossils

Access: The property is owned by Stewart "Bud" Stinson, Route 2, Buffalo (telephone: 735-2410, after 5:00 p.m.), who lives 1.4 miles north and 0.4 mile east of the intersection of U.S. Highways 183 and 64. The gate to site 1 is 3.4 miles north of that highway intersection. Drive 0.5 mile northeast of the gate on a pasture road to the quarry area. Be sure to close the gate.

Site location: SW¼ sec. 18, T. 28 N., R. 22 W.

Topographic map: Buffalo NE (7½'), in preparation.

References: Myers and others (1959).

At a high hill 4 miles north of Buffalo (fig. 29) a hard layer of Permian dolomite, overlain by thick fossiliferous gravel deposits of the Ogallala Formation of Tertiary age, is exposed. The gravel is occasionally worked for road material. However, no mining equipment is left at the site permanently, so each company must bring its own loading equipment and trucks.

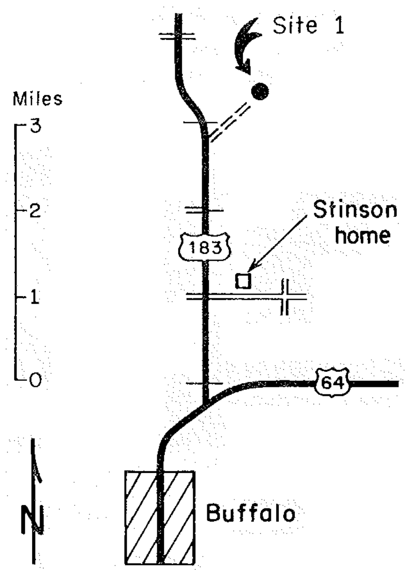


Figure 29. Location map for Harper County site 1.

Atop this hill is the only exposure of Ogallala sediments in this part of the county, which is an outlier of outcrops 10 to 15 miles farther west; the once-continuous sheet of Ogallala sediments that extended between these two areas has since been eroded. The gravel consists of fragments eroded from rocks exposed at the earth's surface in the Tertiary Period. The most common rock fragments are iron-stained sandstones that are black and dark brown. Other fragments are yellow and gray limestones eroded from Cretaceous rocks and a wide assortment of sandstones. Fossil oyster shells, also derived from Cretaceous rocks, are fairly well concentrated in the gravel along with scattered pieces of petrified wood and igneous and metamorphic rocks derived from a source much farther west. The Ogallala is mostly a conglomerate, some of it cemented, although some layers are coarse-grained sand.

The most conspicuous Permian rock in the area is the layer of dolomite that caps prominent ridges below and all around the gravel deposit. The dolomite, called the Day Creek Dolomite, is light gray and white and is about 2 feet thick. It has been quarried at several places in the immediate area to provide riprap for dams and bridges. Chert, a form of quartz (SiO_2), contained in the dolomite is either white, light gray, or bluish gray and occurs as thin layers, as veins, and as small and large irregular masses. It is more resistant than dolomite and hence stands out in relief about 0.1 to 0.5 inch above the surface of the rock. Chert is also distinguishable from dolomite because it cannot be scratched with a knife or nail (dolomite can be scratched) and because it will not effervesce in acid (powdered dolomite will effervesce in acid). The dolomite bed and other strata in the area were originally horizontal, but now they are disrupted and dip as steeply as 20°. These steep dips are the result of collapse of these and underlying rocks into large underground cavities formed when salt beds – originally several hundred feet below the surface – were dissolved. Similar collapse structures can be seen at many places in the southwestern half of the northwest Oklahoma region.

Exposed below the dolomite is 2 feet of light-gray siltstone underlain by 30 feet of orange-brown siltstone. In most of the immediate area the overlying red-brown shale and sandstone are eroded, but at one locality, near some corrugated drainpipe abandoned in the bottom of the main valley, about 30 feet of overlying red-brown Permian sediments is also preserved. Directly above them, and only at this locality, are a few exposures of Cretaceous sediments consisting of olive-brown and yellow-brown shales with thin calcareous sandstone and limestone beds. The Cretaceous sediments are poorly exposed and are disrupted by the collapse, but it appears that nearly 30 feet of strata is preserved (see cross section, fig. 30). Abundant well-preserved fossilized oyster shells are found on the surface of this site: some of them are weathering directly from the 30 feet of Cretaceous strata and some are "reworked" Cretaceous fossils that are coming out of the overlying Ogallala.

Two major unconformities are present at this site, one at the base of the Cretaceous sediments and the other at the base of the Ogallala.

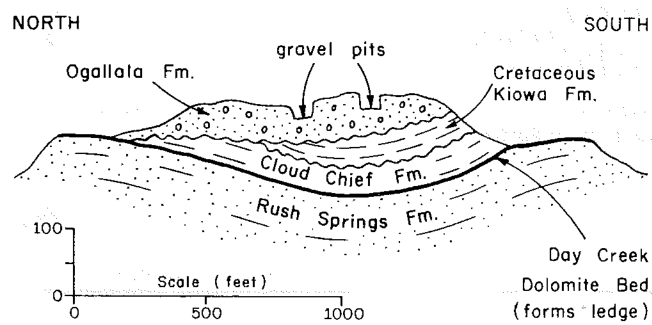


Figure 30. Schematic north-south cross section through Ogallala-capped hill north of Buffalo.

Harper County Site 2: Fossil snails

Access: This property is owned by J.M. Krenz, 408 Northwest Third, Buffalo (telephone: 735-2108). Enter property through the gate 0.7 mile north of section corner. The snail bed is 1,000 feet north-northeast of the gate, just downstream from the pond and near the windmill. Be sure to close the gate.

Site location: NW¼ NW¼ sec. 13, T. 28 N., R. 22 W.

Topographic map: Buffalo NE (7½'), in preparation.

References: Myers (1965), Myers and others (1959), Taylor and Hibbard (1955).

Abundant fossil snail shells occur in a small late Pleistocene lake deposit about 8 miles northeast of Buffalo (fig. 31). The lake deposit consists of light-gray and yellowish-gray silt and clay about 8 to 10 feet thick, exposed for 600 feet along the banks of a small stream. The silt and clay are friable and calcareous. The color of the lake deposit contrasts sharply with surrounding red-brown units of Permian bedrock and Pleistocene sand deposits weathered from the Permian sandstones in the immediate area.

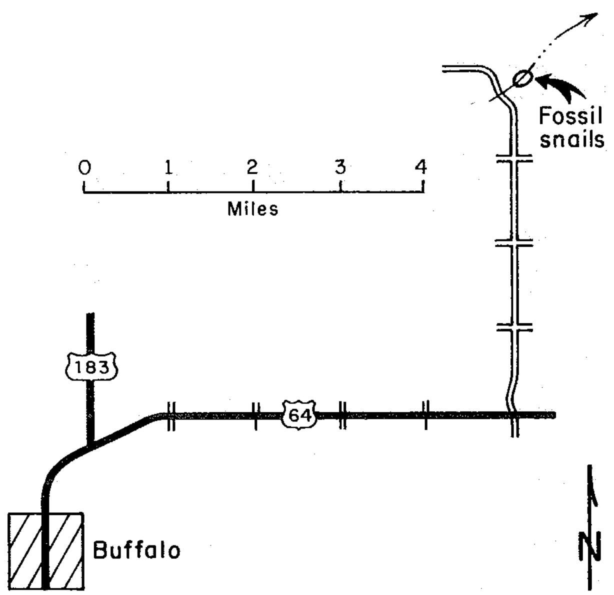


Figure 31. Location map for Harper County site 2, fossil snail site northeast of Buffalo.

Snail shells (fig. 32) at this location are fragile and must be handled with care. The snails were fresh-water inhabitants of a small temporary pond. Some of these species live today, and by knowing their modern habits and habitats we can infer the climate and environment in which they once lived. The climate was cooler and more moist than that of Harper County today; summers were similar to those of North Dakota, and winters were like those of northern Kansas. The age of shells from this locality has been determined by the carbon-14 method of dating: the snails lived and died in this pond about 20,000 to 22,500 years ago (Myers, 1965).

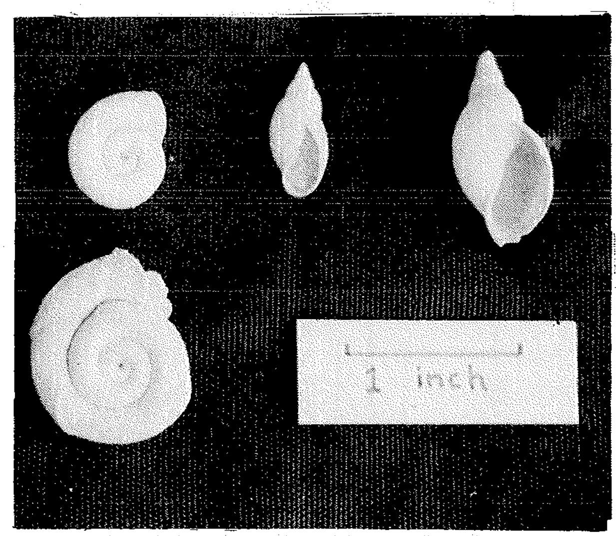


Figure 32. Fossil snail shells from late Pleistocene lake deposit.

Large blocks of white and light-gray gypsum are present farther downstream from the snail deposit. They are located on the east side of a second dam, about 1,000 feet downstream from the windmill. This gypsum is not the same as the Blaine Formation deposits discussed in Blaine County site 2, but is in a younger formation.

Major County

Major County Site 1: Glass Mountains

Access: The site, 6 miles west of Orienta on the north side of State Highway 15, is open to the public. Arrangements must be made with individual landowners if access to private lands adjacent to the highway is desired.

Site location: S½SW¼ sec. 22, T. 22 N., R. 13 W.

Topographic map: Glass Mountains (7½').

References: Fay (1964), Hamilton (1961).

The Glass Mountains are in north-central Major County, about 6 miles west of Orienta (fig. 33), in an area of badlands topography. They are part of the Cimarron Gypsum Hills. Outcropping sedimentary rocks are reddish-brown shales and siltstones of the Flowerpot Formation, capped by a bed of hard gypsum in the overlying Blaine Formation (fig. 34). Stratification is conspicuous because of thin horizontal layers of light-gray shale and the presence of layers containing gypsum nodules and masses.

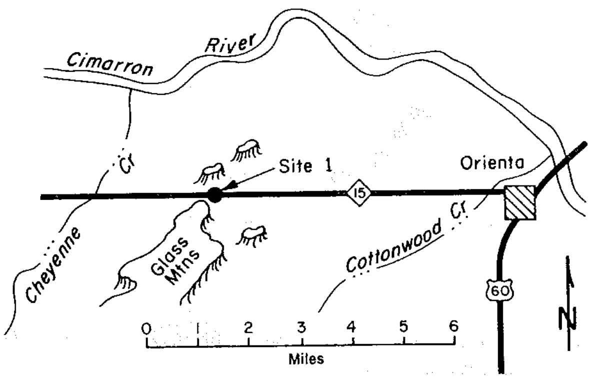


Figure 33. Location map for Major County site 1, Glass Mountains.

Bluff faces and slopes in the area are covered with fragments of various types of gypsum (fig. 4): selenite (as transparent crystals or plates), satin spar (as white veins of "fibrous" crystals), and massive gypsum and alabaster (as white and gray concretionary masses or thin discontinuous layers). Many of these pieces of gypsum look like glass

Figure 34. Aerial view of Glass Mountains capped by white gypsum. View looking northwest across highway.

fragments, especially selenite, and from this characteristic the hills derived their name. Large plates of selenite are commonly mistaken for isinglass (muscovite mica), which was used many years ago for the small windows of ovens.

These hills were first called Glass Mountains in 1873 on a map issued by the U.S. General Land Office, but in 1875 they were labeled "Gloss Mountains" (apparently a draftsman's error) on another map issued by the same agency. A third map, released shortly afterward, reverted to "Glass Mountains," and that name is now most commonly used. The name applies primarily to the area between Cottonwood Creek and Cheyenne Creek in the south half of T. 22 N., R. 13 W., although similar landforms extend farther south and west through much of Major County.

Gypsum crystals and masses in the Flowerpot Formation probably grew within the muds of the sea floor. Water trapped in the muds at and just below the sea floor was saturated with calcium sulfate, and gypsum was precipitated from the water before the mud had completely hardened to shale. The crystals and nodules pushed aside the soft mud as they grew. The process probably resembled that of selenite crystals now growing at Great Salt Plains (Alfalfa County site 1).

Pieces of gypsum are scattered along the slopes of the Glass Mountains, because they are more resistant to weathering and erosion than the host shale. As the slopes are eroded, the clay is washed away and the newly exposed gypsum is left behind.

Overlying the Flowerpot Shale, and capping the prominent mesas, buttes, and escarpments of the area, is the Medicine Lodge Gypsum, the basal gypsum bed of the Blaine Formation. It is white gypsum, about 10 feet thick, with 1 to 2 feet of light-gray to light-brown dolomite at its base. Younger (higher) gypsum beds of the Blaine Formation are still present on some of the buttes, particularly to the southwest.

As much as 250 feet of Flowerpot Shale is exposed in the slopes below the Blaine. Cap-rock gypsum beds and Flowerpot Shale originally extended far to the north and east of their present outcrops, but the Blaine escarpment is gradually being eroded back to the south and southwest. Once the protective cap rock is dissolved or eroded from a given area or butte, the underlying shale is rapidly worn down into irregular landforms such as pinnacles, peaks, ridges, and ravines.

The elevation at the top of the high buttes is about 1,575 feet above sea level, whereas the elevation at the base of the northernmost butte is 1,310–1,320 feet. The elevation of the highway adjacent to the rest stop is 1,418 feet. Just north of the buttes is the broad flood plain of the Cimarron River, which is cutting laterally to the south down the gentle dip of the bedrock. The elevation of the Cimarron River flood plain in this area is 1,260 to 1,270 feet above sea level.

Major County Site 2: Fossil snails

Access: The site is a roadcut on the east side of State Highway 58, 3 miles south of Ringwood and 4.1 miles south of the intersection with U.S. Highway 60. The exposure is just north of the road leading to the Pioneer Gas Products Company plant.

Site location: SW¼SW¼ sec. 34, T. 22 N., R. 10 W.

Topographic map: Fairview SE (7½').

References: None, but another snail occurrence is described in Harper County site 2.

A small deposit of Quaternary sediments 3 miles south of Ringwood along State Highway 58 (fig. 35) contains delicate fossil snail shells. The snails occur in a layer of light-gray and buff clayey sand 1 to 6 feet thick and exposed for 300 feet in roadcuts. The light-gray sand is overlain and underlain by other deposits of fine-grained Quaternary sand deposited by the Cimarron River.

The bed containing snails was probably deposited in standing water, such as a temporary small pond or backwater area on an ancient flood plain. This is suggested by the higher clay content and smaller grain size of sediment in the bed, by the grayish-brown color (which usually indicates a higher organic content), and by the identification of the snails as fresh-water species that preferred living in a shallow pool of standing water.

Fossil snails are commonly 0.2 to 1.0 inch long. They are extremely delicate and therefore must be handled with great care. The snails lived but a short time ago in the geologic time scale (perhaps 10,000 to 50,000 years ago), insufficient time for mineralized waters to harden the shells. A number of genera and species are present in this fauna, and most of them are still represented by living forms.

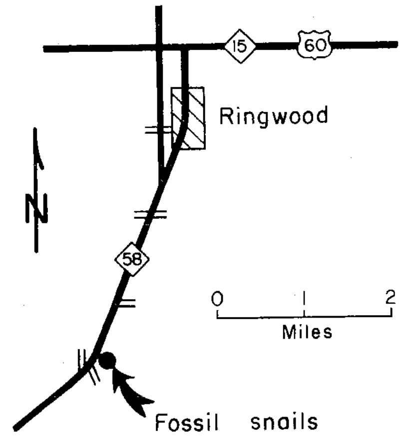


Figure 35. Location map for Major County site 2.

Owing to the limited quantity of fossil snails at this location, please take only what is needed for your collections or for further study. Leave the rest for later groups.

Hard masses or nodules of impure lime ($CaCO_3$) are developing as a weathering product in all sand beds of this exposure. The nodules in the light-colored beds are white or buff in color, whereas those in the orange-brown sand are orange brown.

Major County Site 3: Shale pit

Access: The shale pit is owned by Mark Sproul, Route 1, Isabella (telephone: 822-4927), who lives 0.3 mile west of the pit on the south side of the highway (fig. 36). The shale pit is 8.5 miles east of Fairview (0.5 mile west of the intersection of State Highways 58 and 8) on the north side of the highway. Be sure to close the gate.

Site location: SE¼SW¼ sec. 24, T. 21 N., R. 11 W.

Topographic map: Fairview SE (7½').

References: None.

Excellent exposures of shale and siltstone in the Hennessey Formation can be seen in the Sproul shale pit. Because of loose rock, however, no one should stand or climb near the top or base of high walls in the pit. Examine bedding and other features where the wall is only about 5 feet high or in piles of broken rock away from the face.

The shale contains small masses of calcite crystals, small cavities lined with crystals, and abundant light-gray

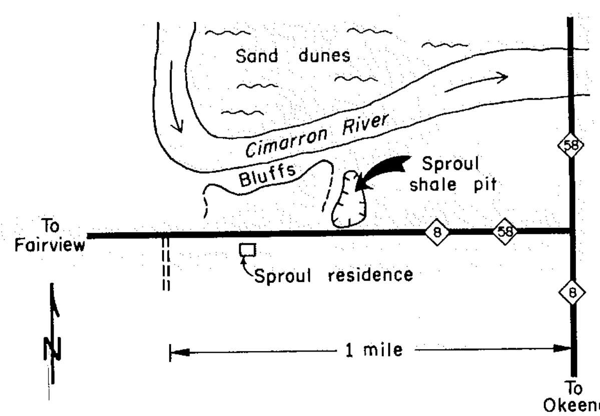


Figure 36. Location map for Major County site 3, Sproul shale pit.

spots with dark-gray nuclei. The shale is reddish brown and rather massive, although horizontal layering in the rock is generally conspicuous because a few light-gray bands of shale accent the bedding. Approximately 35 feet of shale is exposed in the pit and in the high bluffs overlooking the Cimarron River just to the north. Open cavities or vugs in the shale have formed from dissolution of an unknown soluble mineral (probably salt or gypsum) that was originally deposited with the shale. Many of the cavities are now lined with small calcite crystals, and some of the openings have been completely filled with powdery white crystals of calcite.

Light-gray spots are more abundant at this site than at most places in northwest Oklahoma. The gray areas were originally red, like the surrounding rock, but iron in the iron-bearing minerals (chiefly hematite) has been reduced from the ferric to the ferrous state. Most of the spots result from decay of small bits of wood and other organic material deposited with the sediments. Some of the larger spots contain a dark-gray nucleus that is 5 to 10 percent organic matter. Inasmuch as the reduction is generated from a point source, the reduction zone is spherical in shape. This sphericity indicates that reduction took place after the mud had been compacted, for if it had occurred earlier the green spheres would be somewhat flattened. Some fairly large vertical surfaces also are light gray: these surfaces are adjacent to joint or fracture planes along which ground water has moved and reduced the iron oxides.

Overlying the red shale at this location are 10 feet of orange-brown and light-gray siltstone and very fine-grained sandstone typical of the Cedar Hills Sandstone Member of the Hennessey Formation. Although the siltstone and sandstone are friable (crumble easily in the hand), they are still more resistant to weathering and erosion than the underlying shale. The Cimarron River is currently cutting into the shale at the lower parts of the bluff exposures, and periodically large masses of the bank are undercut and fall into the river.

The shale pit, first opened about 30 years ago, provides material for use on dirt roads. Shale is hauled as far as 30 miles and then is laid upon the loose sand of terrace and alluvial deposits along and north of the Cimarron River. Laying 4 to 6 inches of this clay over loose sand makes a suitable all-weather road, and this has been particularly useful in making the oil-field roads which crisscross the sand-dune country north of the river. After years of use and continued road grading, the shale becomes thoroughly mixed with the sand it has been placed upon. A nearby example of this use of clay is on the dirt oil-field roads west of Highway 58, 2 miles north of the bridge over the Cimarron River.

From the pit, and particularly from atop the hill capped by the siltstone, one can see that the Cimarron River is steadily cutting downward and laterally (to the southwest) following the dip of the bedrock. It is leaving behind a wide expanse of Quaternary terrace deposits whose surface is modified by large sand dunes on the north side of the river.

Woods County

Woods County Site 1: Volcanic ash

Access: Drive 0.3 mile west of Cedar Grove Church on gravel road and then walk about 1,500 feet north up the main channel of the stream. The land is owned by Donald White, Route 9, Alva (telephone: 327-2342), who lives 1 mile farther west of the church on the south side of the road. Do not damage the fence, and please close the gate.

Site location: SE¼ sec. 32, T. 29 N., R. 15 W.

Topographic map: Tegarden NE (7½').

References: Fay (1965), Burwell and Ham (1949).

The Alva volcanic-ash deposit, about 15 miles northwest of Alva (fig. 37), shows interesting relationships to overlying and underlying sediments and is also in a good area for collecting gypsum crystals and a wide variety of gravels. Dust-sized ash blown from volcanoes in New Mexico settled in this area during Pleistocene time. The ash was then eroded from surrounding uplands and accumulated in a small depression. The ash, exposed in the upper part of the east valley wall, is white and consists of 90- to 95-percent dust-sized pieces of glass (glass shards), and 5- to 10-percent sand grains and clay. The sand grains, predominantly quartz, and clay were eroded from nearby areas and transported to the site along with the ash. Much of the deposit exhibits horizontal bedding, which suggests deposition in relatively still water, but the presence of coarse sand grains, crossbedding, and irregular bedding features indicates at least some moderate currents. The ash deposit is saucer shaped in cross section: the top of the bed is at the same elevation throughout the exposure, and the base rises in elevation at the north and south end toward the top of the bed (see cross section, fig. 38). Near the top of the deposit, ash is mixed with a large amount of pinkish shale and sand.

Directly underneath the ash is several feet of pinkish-brown, slightly lithified coarse-grained sandstone and red-brown fine-grained sand of slightly older Pleistocene age. These Pleistocene sands in turn overlie red shales of the Flowerpot Formation of Permian age. At the west end of the deposit the ash rests directly upon weathered Flowerpot Shale, and both the ash and the shale are truncated unconformably by 3 to 6 feet of brown Pleistocene sand containing some gravel and clay. This

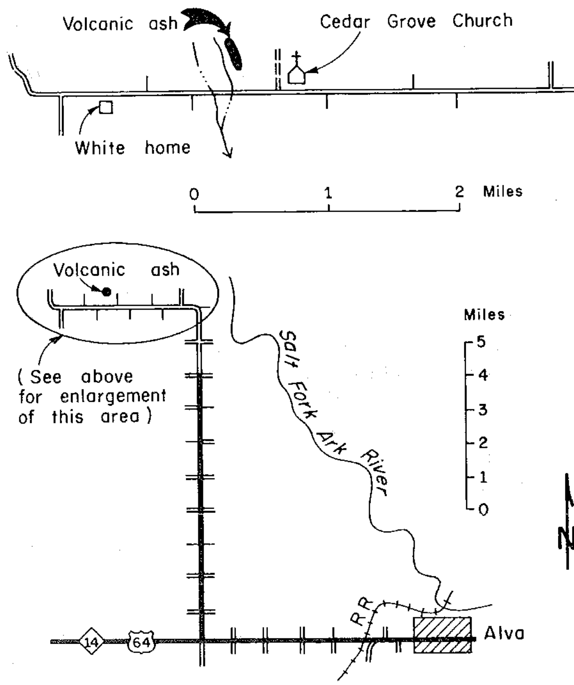


Figure 37. Location map for Woods County site 1.

brown top sand is the latest or youngest Pleistocene deposit at the site.

A summary of the Pleistocene history of this site begins with erosion of the Flowerpot Shale by the ancestral Salt Fork of the Arkansas River and deposition of coarse basal sand upon the Flowerpot. A depression was then scoured in this sand by the river or one of its tributaries and was soon filled with ash and some locally derived sand and clay. At a later time, perhaps not long afterward, the topmost sand was deposited across (1) eroded Flowerpot on the north, (2) the ash deposit in the central part, and (3) the coarse basal sand on the south. The original thickness of this topmost sand is unknown, but it has now been eroded to a bare 3 to 6 feet in outcrops.

The Flowerpot in these exposures is predominantly reddish-brown shale. Stratification is evident because shale layers alternate with bands of light-gray siltstone and very fine-grained sandstone. A 1-inch-thick light-gray dolomite weathers to small plates (about 1 to 2 inches across) at several places. Flowerpot strata near the road and along the road for 2 miles west of this site contain abundant crystals of selenite and thin veins of satin spar.

Light-colored gravel scattered on the slopes and in the floor of the valley are typically quartzites, granites, schists, and various forms of quartz, notably chert and chalcedony. The dark-gray, brown, and black gravel is predominantly iron-stained sandstone. Scattered pieces of petrified wood and fossilized bones are also present.

From atop the hills, high bluffs of red Flowerpot Shale, capped by a hard layer of white gypsum at the base of the Blaine Formation, are visible about 4 miles to the west.

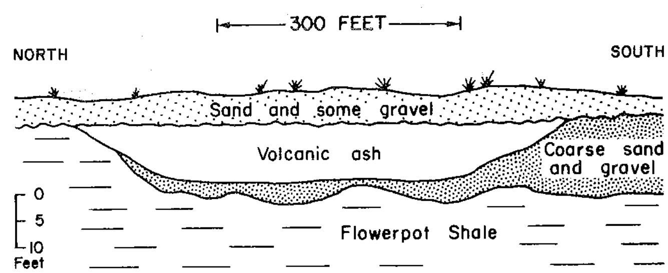


Figure 38. Schematic cross section showing the relationship of volcanic ash at Woods County site 1 to underlying and overlying sediments.

Woods County Site 2: Sand and gravel pits

Access: Mr. Paul Koppitz, Box 185, Alva, Oklahoma (phone: 327-0277), lives 0.5 mile south of his pit on the east side of U.S. Highway 281. Alva Concrete and Materials Company has offices at 108 N. College, Alva (phone: 327-2281).

Site location: Alva Concrete and Materials – SE¼ sec. 1, T. 27 N., R. 14 W.; Koppitz pit – NW¼ sec. 7, T. 27 N., R. 13 W.

Topographic map: Alva (7½').

References: Fay (1965).

Sand and gravel terrace deposits, laid down by the Salt Fork of the Arkansas River in Pleistocene time, are now being worked by several companies just north of Alva (fig. 39). These terrace deposits cap a 1-mile-wide hilltop that extends 6 miles north-northwest from the gravel pits. Although the origin and general character of material at the two pits herein described are similar, the "mining" methods differ: one pit (owned by Koppitz) uses conventional methods, whereas the other (Alva Concrete and Materials) is a dredging operation.

Poorly sorted loose sand predominates at both locations. Grain size ranges from very fine to very coarse sand, and there are also admixtures of clay and gravel. Gravel is usually well rounded and is up to 4 inches across. Light-colored gravel is mostly quartz, quartzite, granite, and other igneous and metamorphic rock fragments; dark-colored gravel is almost entirely composed of well-cemented iron-bearing sandstone fragments. Pieces of silicified (petrified) bone and wood have also been found. Stratification, including crossbedding, is well displayed in some of the faces of both pits. Bedding is accented by alternating layers of light and dark sand grains. Bedrock, exposed in highway roadcuts just to the south, is red-brown

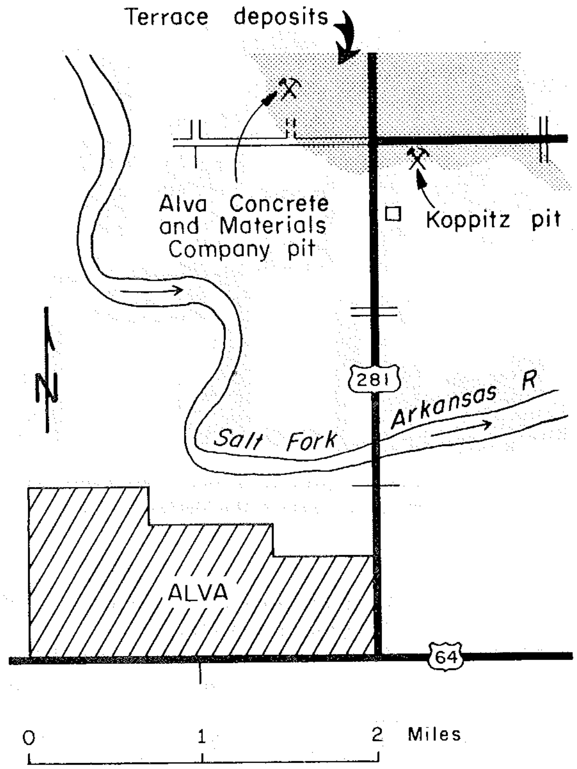


Figure 39. Location map for Woods County site 2.

sandstone, siltstone, and shale of the Cedar Hills Sandstone Member of the Hennessey Formation.

In the Koppitz pit, sand is scraped up by a front-end loader and is either put directly onto trucks or is blended with hot tar into ready-mix asphalt. Tar makes up only 5 to 10 percent of the final asphalt mixture, but it is needed to bind the sand and gravel together. Crushed stone (light-gray limestone), in piles north of the mixer, has been trucked 100 to 150 miles from Ponca City, the Arbuckle Mountains, or the Wichita Mountains for use as aggregate in the asphalt. These three areas are the nearest major sources of limestone, and stone such as this must be hauled in even though it costs $3 to $5 per ton just for transporting it to Alva.

The Alva Concrete and Materials Company pit started as a conventional scraping operation but switched over to dredging when the pit was deepened enough to reach the water table. The full thickness of sand is about 25 feet, and the water in the pit is as much as 10 feet deep in places. A mixture of water, sand, and gravel is dredged or sucked from the floor of the pit using a 6-inch electric pump. The intake end has a grill which prevents material larger than 4.5 inches from entering the pipe. Gravel is then removed from the mixture by running it through a screen that will pass only minus 3/8-inch material. The remaining sand is used in making concrete and masonry blocks and as mortar sand. Student groups may also visit the company plant in Alva where concrete blocks and other construction materials are being processed and manufactured.

Woods County Site 3: Red beds and fossils

Access: The land at this site is owned by George Smithson, Route 8, Alva (telephone: 327-2488), whose ranch is at the base of the bluffs several thousand feet north of U.S. Highway 64. Drive north on the section-line road toward his house, and park vehicles in the vicinity of the large metal shed. Enter the hill area through a gate at the north end of the road you just came in on. Close the gate behind you.

Site location: SE¼ sec. 20, T. 27 N., R. 16 W.

Topographic map: Tegarden (7½').

References: Fay (1965), Riley (1961).

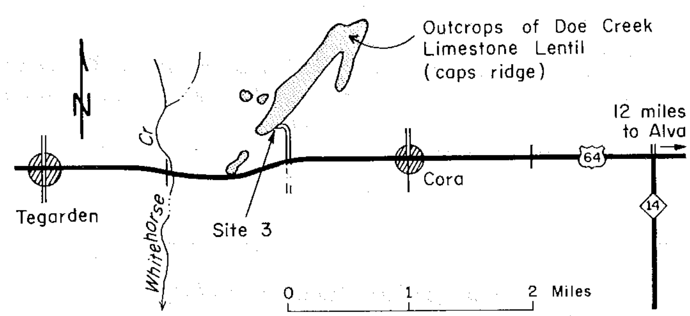


Figure 40. Location map for Woods County site 3.

A number of small but prominent buttes along U.S. Highway 64, 15 miles west of Alva (fig. 40) are capped by a bed of resistant sandy limestone, the Doe Creek Limestone Lentil of the Marlow Formation (Permian), that contains poorly preserved fossils. It is pinkish to orange-brown in color and is conspicuously crossbedded, with crossbeds generally dipping toward the north and northeast. The limestone is medium grained with floating, well-rounded, coarse to very coarse sand grains making up about 5 to 10 percent of the rock in most places. Fragments of reddish-brown mudstone or very fine-grained limestone are incorporated locally within the Doe Creek Limestone: these fragments, torn up from nearby sites during deposition of the Doe Creek were moved a short distance before incorporation; otherwise, they would have been completely broken up during transportation.

With only casual examination, the Doe Creek appears to be sandstone rather than limestone. Coarse sand grains are easily recognized under magnification, but most of the remaining rock (generally more than 65 percent) is calcite in the form of whole and fragmented fossils, oolites, and finely crystalline calcite grains. Some layers and lenses of sandstone are present.

The Doe Creek Limestone is one of the hardest rocks in this part of Oklahoma, and it was quarried for riprap in building several dams and bridges. In some areas, particularly in bluffs just behind the ranch house, differential weathering does accent the bedding. In parts of the deposit the rock weathers to rounded boulders, much like the spheroidal weathering pattern seen in many granite outcrops. This weathering initiates from a series of irregular, widely spaced joints or fractures, which isolate a block several feet across. As weathering progresses from these joints, the block is rounded off. Locally, the Doe Creek has a boxwork weathering pattern where intersecting veins of hard calcite stand in bold relief as the intervening softer limestone is more rapidly weathered to form the hollows. Some of the boxwork pattern is very coarse, with veins up to 0.5 inch thick, and some of it is very finely textured. Calcite crystals 1 to 3 mm long are present along some of the veins.

The fossils found at this site are poorly preserved and consist mostly of small pelecypod (clam) shells that almost cover some bedding surfaces (fig. 41). Other fossils include gastropods (snails), brachiopods, and bryozoans. The shell material has been removed; one finds only shell impressions that look something like small fingernails (about half an inch long). These fossils are fairly abundant in the layers near the top of the hill between the old quarry north of the gate and the windmill north of the house. Examination of fossils in this deposit indicates that the sandstone is of marine origin. Cabbage-head algae are reported in outcrops of the Doe Creek Limestone adjacent to the highway just to the southwest. These algal masses are as large as a foot in diameter and weigh 50 pounds or more.

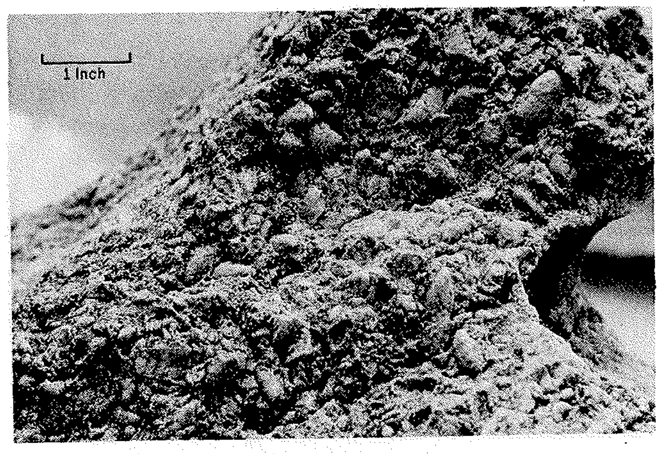


Figure 41. Poorly preserved clam shells cover some bedding surfaces of the Doe Creek Limestone Lentil of the Marlow Formation.

The Doe Creek Limestone rests unconformably upon the reddish-brown Dog Creek Shale at this site. Several thousand feet to the northeast, however, it is separated from the Dog Creek by 20 to 30 feet of orange-brown sandstone of the Marlow Formation.

Six miles to the southwest three prominent buttes are also capped by the Doe Creek Limestone, and a mile to the west are benches of white gypsum of the Blaine Formation.

Woods County Site 4: Big Salt Plain

Access: Contact Mr. Ezra Blackmon, Route 1, Freedom (telephone: 621-3498), who lives at the salt plant on the north side of the salt plain.

Site location: E½ sec. 20, T. 27 N., R. 19 W.

Topographic map: Selman SE (7½'), in preparation.

References: Fay (1965), Johnson (1970), Ward (1961a, 1961b).

Big Salt Plain consists of about 4,000 acres of flat, salty bottom land adjacent to the channel of the Cimarron River 8 miles west of Freedom (fig. 42). The river is flanked on both sides by the Cimarron Gypsum Hills where high escarpments of red Flowerpot Shale are capped by gypsum beds of the Blaine Formation. The sandy alluvium is nearly saturated with brine and is totally barren of vegetation. Common salt, the mineral halite (NaCl), forms crusts 6 to 12 inches thick around brine springs during dry spells, and these natural encrustations were scraped up and hauled away by Indians and early-day explorers and settlers.

Geologic studies show that Big Salt Plain is immediately underlain by salt of the Flowerpot Shale. The salt unit is locally only 30 feet below the surface (see fig. 2), and it comprises layers of rock salt interbedded with lesser amounts of reddish-brown shale. Natural brine, formed when ground water dissolves rock salt here and farther west, carries 2,500 tons of NaCl upward into the alluvium and to the surface each day, making this the major site for salt-water pollution of the Cimarron River. Federal

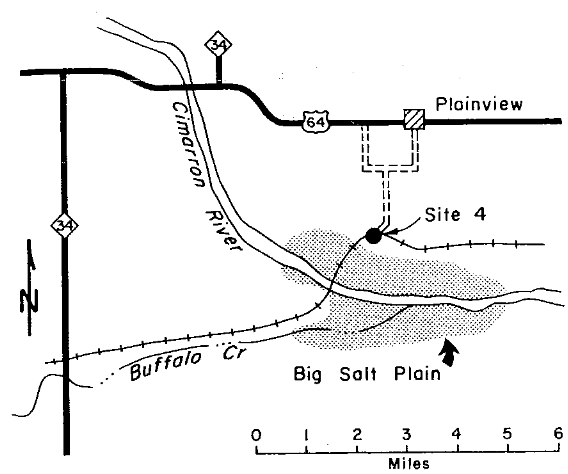


Figure 42. Location map for Woods County site 4, Big Salt Plain.

and State agencies are now investigating this area, looking for the best means of controlling brine emission and improving the quality of water downstream.

Saturated brine not only permeates the alluvium but also flows underground through natural-solution caverns in the Flowerpot salt. Blackmon Salt Company pumps 1,000 gallons of brine per minute from wells drilled into these salt cavities 40 to 100 feet below the surface and channels the brine into 2-foot-deep, flat-bottomed earthen pans built on the surface of the salt plain (fig. 43). As water is evaporated by the sun's heat, the brine becomes supersaturated and salt crystals settle to the bottom of the pan. Salt produced in this manner is called "solar salt." Brine is added intermittently to maintain a water depth of about 12 inches. Although salt is produced throughout the year, most of it forms during the hot, dry summer months. About 60 acres of evaporating pans are in use or under construction.

Harvesting is done when the salt crust on the floor of the pan is about 6 inches thick, and then only the top half is removed. The bottom several inches of salt is left in place permanently to provide a fairly firm base and to prevent intermixing of salt with underlying sand. Workers harvest about 2 tons of salt per minute and truck the salt to a nearby outdoor stockpile for drying. A warehouse was constructed recently for storage of bulk and bagged salt.

Brine used by the company is saturated with salt. It has a specific gravity of 1.208 and the concentration of sodium chloride ($NaCl$) is about 337 grams per liter. Na and Cl constitute 98 percent of all dissolved solids in the brine, and also make up 98 percent of the solar salt produced from the brine, according to recent analyses made by the Oklahoma Geological Survey (Johnson, 1970). Mr. Blackmon reports that a number of chemical analyses of his salt show a purity of 99.2 to 99.8 percent sodium chloride. Chief impurities in both brine and salt are calcium (Ca) and sulfate (SO_4). Solar salt produced here contains about 1.8 percent gypsum ($CaSO_4 \cdot 2H_2O$) that is precipitated from brine along with the halite, plus smaller amounts of quartz sand grains blown into the evaporating pans by the wind. Gypsum and quartz remain as a residue when samples of this salt are dissolved in fresh water.

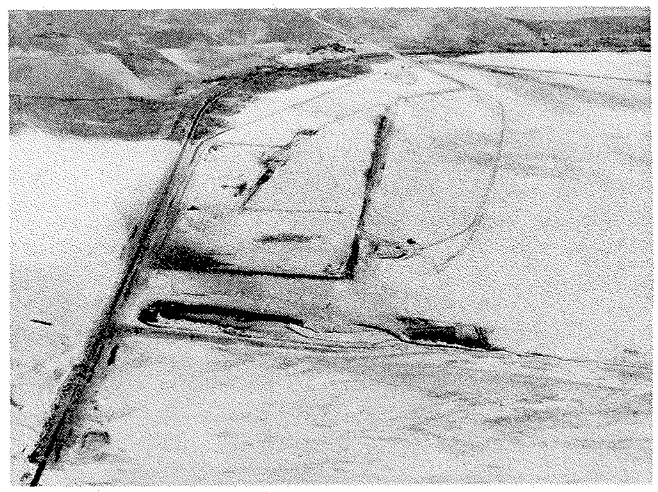


Figure 43. Low dikes outline earthen pans where salt is produced on Big Salt Plain. View looking northeast.

Climatic conditions in northwest Oklahoma are favorable for solar evaporation of brine. Mean annual precipitation is about 23 inches, and annual evaporation of fresh water from lakes in the area averages about 63 inches: therefore, net annual evaporation of fresh water is about 40 inches. But dissolved salts retard the evaporation of water. It has been estimated that only 28 inches of saturated brine will evaporate from Big Salt Plain in an average year. Evaporation is greatest during the summer; nearly 40 percent of the annual evaporation occurs in June, July, and August, and 70 percent occurs from May through October.

Blackmon Salt Company sold 7,268 short tons of salt during 1969 in the form of solar salt and brine. The salt is used for stock feed, as a recharger for water softeners, and to remove ice from streets and roads. Brine, sold by the truckload, is being used as drilling fluid in oil and gas test wells. Expanded use of these high-purity brine resources at Big Salt Plain would serve the dual purpose of increasing Oklahoma's mineral production and of decreasing the pollution of a major river.

Woods County Site 5: Little Sahara sand dunes

Access: Little Sahara Recreation Area is a State-owned (1,060-acre) park free to the public at all times. Facilities include picnic tables, drinking water, and toilets. Several camels and other animals are kept in a small zoo.

Site location: secs. 23 and 26, T. 24 N., R. 16 W.

Topographic map: Waynoka W (7½').

References: Fay (1965).

Sand dunes, which are mounds or ridges of windblown sand, are common on the north side of most major rivers in northwest Oklahoma. They form mainly through the reworking of Pleistocene terrace deposits by the wind. Little Sahara Recreation Area, located in Woods County 3 miles south of Waynoka on U.S. Highway 281 (fig. 44), is a popular place to inspect well-developed dunes. The total thickness of the sand in the park ranges from 25 to 75 feet. Dune buggies have disturbed the form of dunes close to the highway, so you may wish to walk to the well-formed dunes about 0.5 to 1.0 mile northwest of the observation tower (beware of the buggies!).

Sand dunes are asymmetrical, with a steep slope on the lee (downwind) side and a gentler slope on the

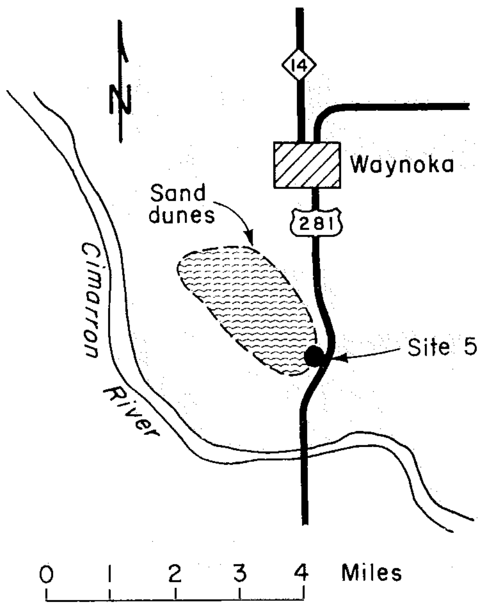


Figure 44. Location map for Woods County site 5, Little Sahara sand dunes.

windward (upwind) side. The wind blows, rolls, or pushes grains of sand up the gentle windward slope, but its velocity is reduced on the lee side of the dune crest and the sand grains drop onto the lee slope (fig. 45). Removing sand from the windward slope and redepositing it in tilted layers on the lee slope cause the entire dune to migrate slowly in the downwind direction. In this way a single dune or a field of dunes can encroach on fertile fields (fig. 46), roads, or even homes. Sand dunes largely devoid of vegetation and undergoing some migration are said to be "active."

Layers of sand deposited on the lee slope are inclined at the same angle as the lee slope itself—usually an angle of 30° to 35°. If sand is added so as to make the slope steeper than 35° the slope becomes unstable, causing sand to slide down until the angle is once again attained. This angle, called the "angle of repose," represents the steepest slope at which loose sand remains stable.

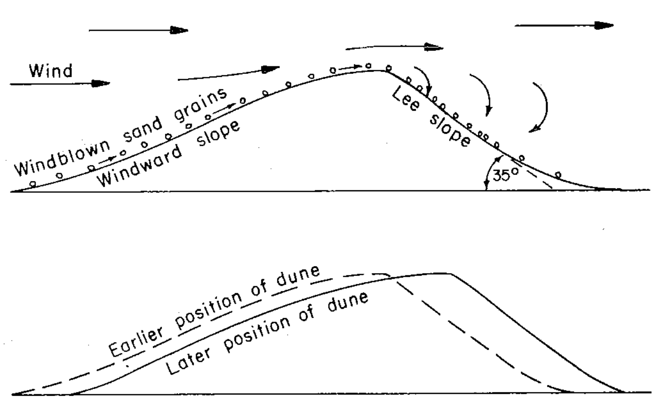


Figure 45. Cross sections showing development (above) and migration (below) of sand dunes.

A cover of grasses or other vegetation on dunes slows or stops their migration, because the wind cannot move sand grains effectively through the plants. Such stabilized dunes are gradually rounded by erosion and become part of a rolling or hummocky surface. Removal of vegetation can easily lead to a new cycle of dune development and migration.

Sand in the dunes at Little Sahara is largely reworked from terrace deposits left by the Cimarron River when it flowed across this area earlier in Pleistocene time but is partly blown from flood-plain deposits of the present-day river. It is mostly well-sorted quartz sand that is very fine to medium grained (0.06 to 0.5 mm in diameter). Silt- and clay-sized particles are almost completely missing because they are easily blown away, leaving only the coarser sand grains.

Prevailing winds are from the south and southwest; thus the steeper lee slopes at Little Sahara are generally on the north or northeast. Small ripples (1 to 3 inches from crest to crest) on the surface of active dunes indicate wind direction during the last few hours or days. Northeastward migration of dunes has caused relocation of the highway 3 times during the last 40 years; the first road, a dirt road,

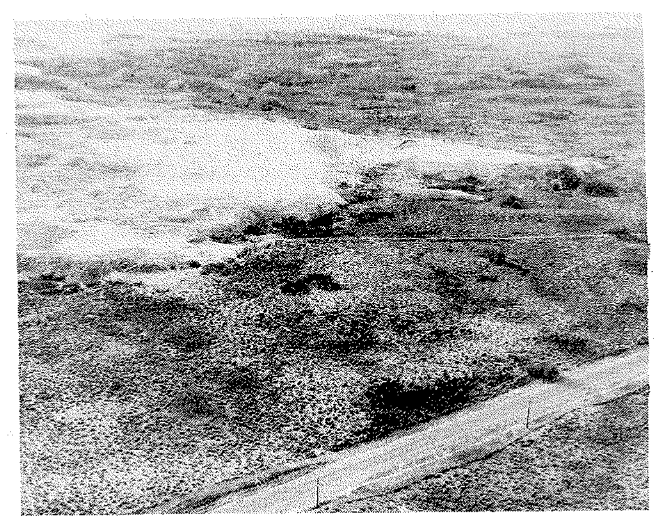


Figure 46. Aerial view (looking west) of sand dunes migrating toward right (north).

was covered by sand about 1930, and each of the 3 subsequent roads was built 25 to 50 yards east of the previous location.

Because layers of sand deposited on lee slopes can be preserved as crossbeds, we can sometimes reconstruct ancient wind patterns from them even if the shape of the dunes has been modified. Some of the stabilized dunes in northwest Oklahoma were formed thousands of years ago and may indicate wind directions quite different from today's. Evidence of dune migration can even be found in Permian rock units by examining crossbeds (see Blaine County site 4).

Other major active dune fields in the region are similarly located on the north side of the Cimarron River 8 miles southeast of Waynoka, and 5, 9, and 13 miles northwest of Waynoka. Stabilized dune fields on the north side of the Cimarron River are along its entire length in the northwest Oklahoma region and in a large area north and northeast of Great Salt Plains Reservoir. Large areas of stabilized dunes north of the North Canadian River are located in the following areas: from west of U.S. Highway 183 to Beaver County, in the Woodward-Mooreland area, north of Seiling, and from Canton Reservoir to Watonga.

Woodward County

Woodward County Site 1: Alabaster Caverns State Park

Access: Entry to Alabaster Caverns State Park is free, but a fee is charged for guided tours of the cave from 8 a.m. to 5 p.m. every day. Contact Superintendent, Alabaster Caverns State Park, Freedom, Oklahoma, for further information.

Site location: secs. 28 and 33, T. 26 N., R. 18 W.

Topographic map: Alabaster Caverns (7½'), in preparation.

References: Myers and others (1969).

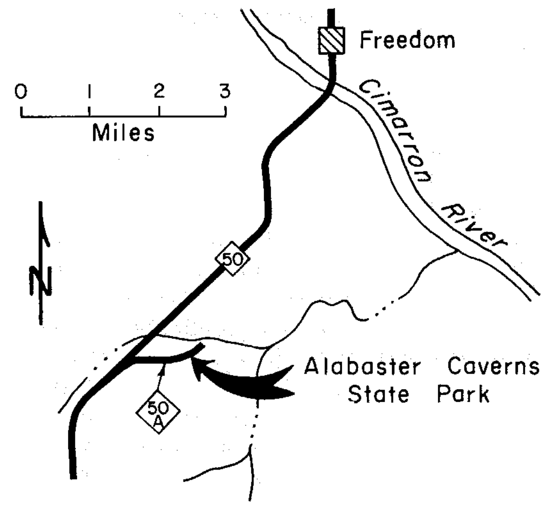


Figure 47. Location map for Woodward County site 1, Alabaster Caverns State Park.

Alabaster Caverns State Park, 6 miles south of Freedom (fig. 47), embraces 200 acres of fairly rugged land containing solution features such as caves, sinkholes, and a natural bridge. In fact, Alabaster Cavern itself is the largest known gypsum cave in the world. (The term "alabaster" is applied to compact fine-grained gypsum.) Not all of the gypsum in the caverns is the alabaster variety; some of it is massive rock gypsum made up largely of coarse selenite crystals. The following description is based upon a comprehensive study by Myers and others (1969) on the geology, history, and bats of Alabaster Cavern and Woodward County.

Rocks of the area include interbedded gypsum, shale, and dolomite of the Blaine Formation of Permian age underlain by the thick red-brown Flowerpot Shale (fig. 48). Resistant beds of gypsum and dolomite cap benches and buttes, whereas the shales are more easily eroded and are exposed mainly in gypsum-capped cliffs or canyons (fig. 49). Principal rock units in the Blaine Formation are named (ascending order): the Medicine Lodge Gypsum (25 feet thick), unnamed shale (13 feet), Nescatunga Gypsum (13 feet), unnamed shale (7 feet), and Shimer Gypsum (13 feet). Gypsum beds are mostly white and light gray, whereas shales are reddish brown or greenish gray. At the base of each gypsum is a light-gray dolomite bed 1 to 2 feet thick.

Water action is evident in the deep canyons carved by down-cutting streams and in the many karst features of the area. Slow dissolution of soluble gypsum has produced sinkholes, caves, natural bridges, and collapsed blocks. Streams are intermittent; many are short and drain into sinkholes. Drainage is mainly underground; water moves through solution caverns and discharges as springs into major streams. Ground water, flowing in fractures and minute openings along bedding planes and nearly vertical joints, dissolves and carries gypsum away in solution. In this way fractures are widened, caverns are enlarged, and large blocks of rock are loosened until they settle or fall. Dissolved gypsum goes into solution in the ground water and gives the water a "gyppy" taste.

Cave development seen today at Alabaster Cavern probably began in the latter part of the Pleistocene Epoch (Myers and others, 1969), at which time the Cimarron River and its tributaries cut below the gypsums of the Blaine Formation to permit draining of ground water that flowed through them. By the same token, water trickling through these same gypsum beds, deep underground and several miles to the southwest, is now enlarging cavities that will be surface caves and sinkholes thousands of years from now when those deeply buried rocks are exposed.

Alabaster Cavern is almost wholly developed within the Medicine Lodge Gypsum Bed. The accessible part is 2,300 feet long and has a maximum width of 60 feet and a maximum height of 50 feet. Although there are many branches from the main chamber, most lateral openings are small and have not been explored. A second, smaller cave, called the Upper Room, has developed in the Nescatunga Gypsum and an underlying shale. The Upper Room has a single known opening through a sinkhole, but this cave is not presently open to the public. Although no large opening has been found connecting the Upper Room to

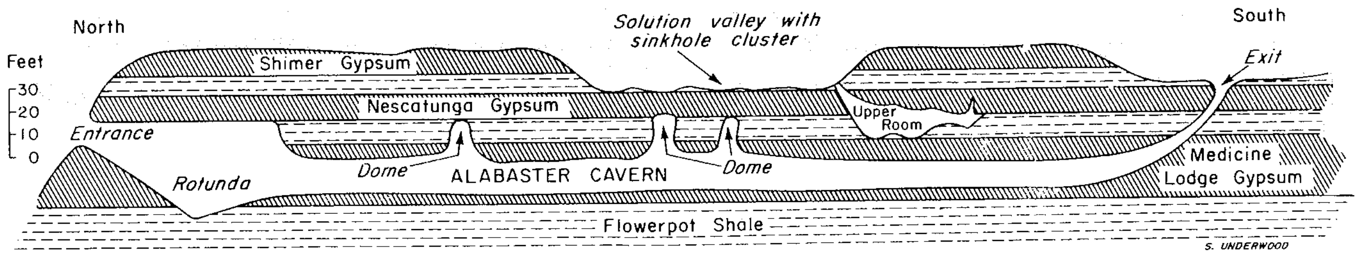


Figure 48. Cross section showing vertical and stratigraphic relationships of gypsum beds in the Blaine Formation at Alabaster Cavern (Woodward County site 1). Length of cross section is approximately 2,000 feet. Modified from Myers and others (1969).

Alabaster Cavern, there are probably small open crevices or tubular connections.

Alabaster Cavern consists of three main sections, each of nearly equal length: a collapse section near the entrance, a middle section with domes in the roof, and a channel section at the end. In the collapse section, the cavern floor is a mass of gypsum, shale, and selenite boulders that have fallen from the roof. In the Rotunda, the first and largest room, the roof is the base of the Nescatunga Gypsum and the floor is part of the Flowerpot Shale: thus, the entire Medicine Lodge Gypsum has been dissolved, and parts of the underlying and overlying shales are also eroded.

The ceiling of the middle section is characterized by many domes. The land surface above the dome section contains a cluster of sinkholes through which rain water has been channeled downward into gypsum and shale beds. The abrasive action of the underground stream that helped form the cavern is best seen in the channel section, where the gypsum roof, walls, and floor are smooth and polished.

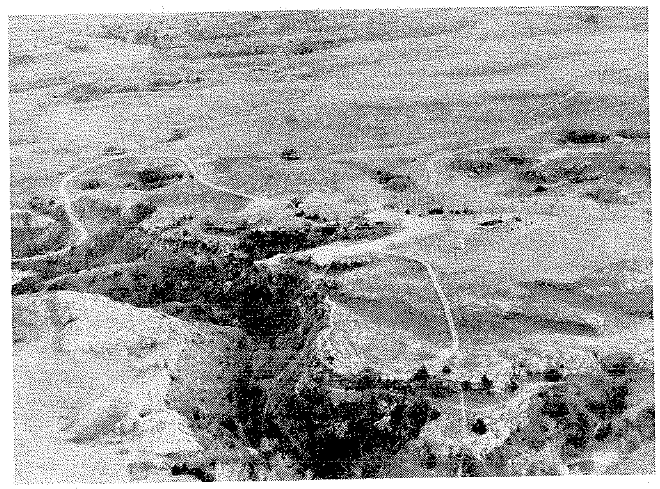


Figure 49. View of Alabaster Caverns State Park looking southeast. Entrance to Alabaster Cavern and administration building are in center of photograph; cavern exit is near trees above center of right side of photograph.

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).

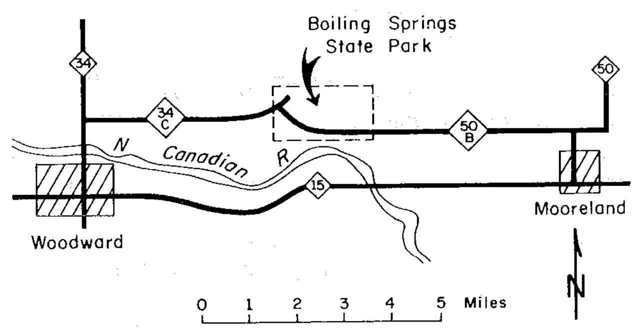


Figure 50. Location map for Woodward County site 2, Boiling Springs State Park.

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 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).

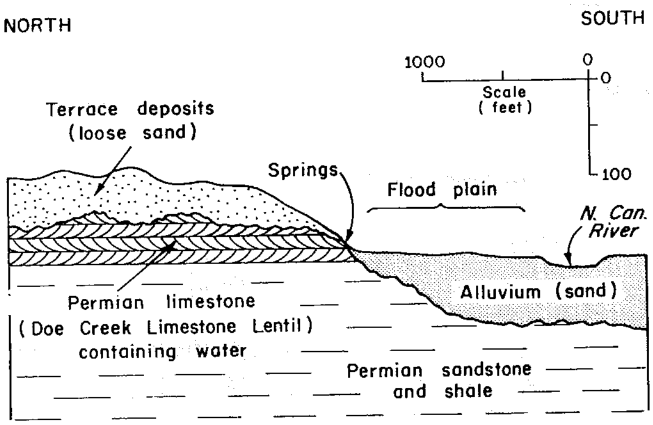


Figure 51. Schematic cross section through Boiling Springs State Park.

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.

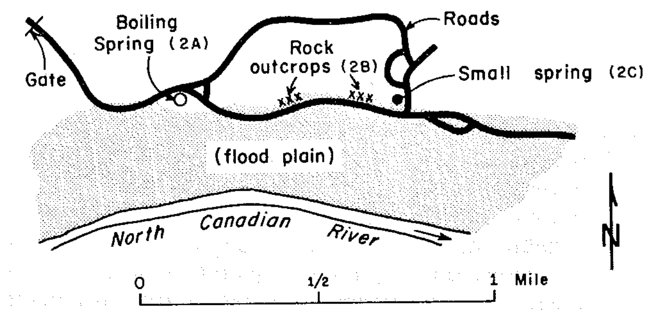


Figure 52. Map of principal features and locations in Boiling Springs State Park.

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.

Woodward County Site 3: Caliche deposits

Access: Roadcuts are open to public examination, but watch carefully for traffic at the intersection.

Site location: common corner of secs. 5, 6, 7, and 8, T. 22 N., R. 21 W.

Topographic map: Woodward (7½').

References: None.

Caliche, an impure limestone or highly calcareous sandstone, is one of the few hard rock materials in northwest Oklahoma. It caps the east- and northeast-facing bluffs at the edge of the High Plains and the high hills about 5 miles southwest of Woodward. Caliche is well exposed in section-line roadcuts at the intersection next to the radio towers 2 miles south of State Highway 15 (fig. 53).

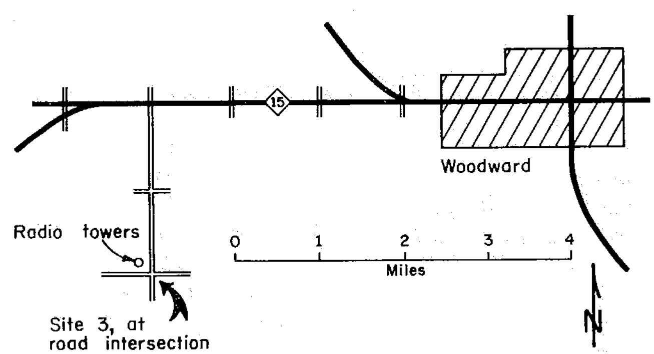


Figure 53. Location map for Woodward County site 3.

Caliche is believed to result from soil-forming processes. Water moving upward in semiarid or arid regions evaporates, leaving a precipitate of calcite, which can strongly cement a near-surface loose sand deposit. Most of the caliche at this site is probably 30 to 50 percent calcite, with the remainder sand, silt, and clay; but some thin layers (6 to 18 inches thick) are nearly pure calcite or limestone. Calcite in caliche is soluble, and therefore solution features and cavities are seen locally. Soil development on hard caliche beds is usually limited to 6 to 12 inches of brown topsoil.

Open pits north and south of the road just west of the towers are the result of mining the caliche for road material. The hardest caliche – now almost all mined out – was used in highway construction, whereas other, less pure material (some mixed with clay) is used to surface dirt roads in the area. Caliche roads stand up quite well in dry weather and even in moderately wet weather, but they tend to break down during long wet spells. Apparently, the calcite and clays bond together and help produce the hard surface.

Some of the older Ogallala sands underlying the caliche are exposed in roadcuts 0.3 mile north of the intersection. Most of the sand is buff colored, fine to coarse grained, and friable; some of it is calcareous. Early stages of caliche development can be seen where white calcite has been precipitated around sand grains in large irregular masses and layers. Small white tubules, slightly more resistant than the sand, result from calcite precipitation around plant rootlets.

About 500 feet east of the intersection fine- to coarse-grained sand unconformably overlies and is younger than the caliche bed. Layers of this loose sand dip eastward. The material probably is windblown sand deposited on the leeward east slope of the hill.

Oil and Gas Wells

Access: Arrangements can be made to have a group visit a drilling well by stopping and asking permission. The geologist or engineer at the well site is usually glad to explain various aspects of petroleum exploration, drilling, and production. Engineers can assist in explaining the operation of pumps, separators, and other surface installations in one of the many fields now producing petroleum in the region.

References: Fay and others (1962), Myers and others (1959).

Petroleum (oil and gas) produced in northwest Oklahoma originated hundreds of millions of years ago. Most scientists believe that petroleum formed from decaying remains of countless small marine animals and plants that were buried in the muds of ancient sea floors. The petroleum then moved slowly through small interconnected pores in rocks and collected where it encountered nonporous rock. Oil and gas therefore occupy the small spaces between grains or crystals that constitute a porous rock (fig. 54); they do not exist in large open cavities or pools, as is sometimes believed.

Most of the world's large oil and gas fields are in or near great sedimentary basins where thick sequences of marine sediments were deposited: the Anadarko basin of western Oklahoma is such a basin (see fig. 8). Oil and/or gas has been produced in every county of northwest Oklahoma from porous sandstones and limestones ranging in age from Ordovician through Pennsylvanian (see list of formations) and from depths of 5,000 to 12,000 feet below the surface (see the material on subsurface rocks in the first section of this guidebook).

Principal stratigraphic units producing oil and gas in northwest Oklahoma

Permian (none)
Pennsylvanian:
- Laverty-Hoover sand
- Tonkawa sand
- Cottage Grove Sandstone
- Layton sand
- Oswego lime
- Cherokee Group (including Red Fork sand)
- Morrowan Series

Mississippian:
- Chesterian Series (including Mississippi "chat," Mississippi lime, and Manning zone)
- Meramecian Series

Devonian and Silurian:
- Hunton lime (or Hunton Group)

Ordovician:
- Viola Limestone
- Simpson Group (including "Wilcox" sand)
- Arbuckle Limestone (or Arbuckle Group)

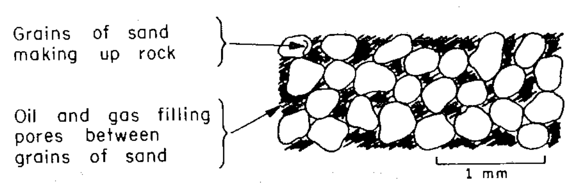


Figure 54. Schematic diagram showing how oil and gas fill pore spaces within a rock.

Standard methods of rotary drilling in the region involve boring a vertical hole deeper and deeper into the earth by rotating a length of drill pipe that has a bit attached at the lower end. The drill pipe passes through a rotary turntable on the derrick floor. As the hole is deepened, additional lengths of drill pipe are added at the upper end. Drilling "mud" (a mixture of water, clay, and chemicals) is pumped down the inside of the drill pipe to the bit: it cools the bit and circulates the rock cuttings to ground level through the opening between the drill pipe and the rock wall of the hole. Casing is normally set to prevent cave-ins, to seal off Permian salt strata and other salt-water zones, and to protect fresh-water aquifers.

Wells drilled within or adjacent to proved oil or gas fields have a high probability of being successful, but only 1 out of about 10 "wildcats" (wells drilled in unknown territory) in the region finds enough oil or gas to warrant the added expense of completing it as a producing well. Oil deep underground may be under sufficient natural pressure to force it through the rock pores into the well bore and all the way to the surface (a flowing well), or the pressure may not be enough to force the oil to the surface, in which case a pump is installed to draw the oil up. Gas deep underground is under sufficient pressure to move it easily through porous rock, so it requires no pumping.

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