GEOLOGIC HISTORY OF OKLAHOMA

Compiled by Kenneth S. Johnson, Oklahoma Geological Survey

Due to forces within the Earth, parts of Oklahoma in the geologic past were alternately below or above sea level. Thick layers of sediments accumulated in shallow seas that covered large areas. The sediments were later buried and lithified (hardened to rock) into marine shales, limestones, and sandstones over geologic time. In areas near the ancient seas, sands and clays accumulated as alluvial and deltaic deposits that subsequently were lithified to sandstones and shales. When the areas were later elevated above the seas, rocks and sediments that had been deposited earlier were exposed and eroded. Uplift was accomplished by the gentle arching of broad areas, or by mountain building where rocks were intensely folded, faulted, and thrust upward.

The principal mountain belts, the Ouachita, Arbuckle, and Wichita Mountains, are in the southern third of Oklahoma (Fig. 2). These were the sites of folding, faulting, and uplifting during the Pennsylvanian Period. The mountain belts exposed a great variety of geologic structures and brought igneous rocks and thick sequences of Paleozoic sedimentary strata to the surface. The uplifts provide sites where one can observe and collect a great number of fossils, rocks, and minerals (see Table 1 and Figure 35).

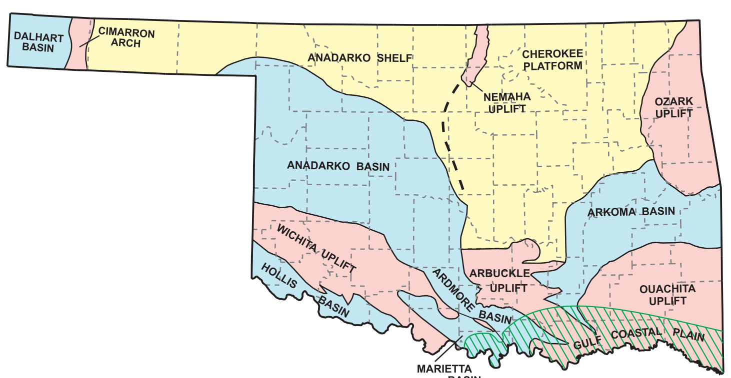


Figure 2. Major geologic provinces of Oklahoma (generalized from page 1, Fig. 1).

The principal sites of sedimentation were elongate basins that subsided more rapidly than adjacent areas, and received 10,000–40,000 ft of sediment. Major sedimentary basins were confined to the southern half of Oklahoma and include Anadarko, Arkoma, Ardmore, Marietta, Hollis, and Ouachita Basins; the Ouachita Basin is the site of today's Ouachita Mountains, and was active from Late Cambrian to Early Pennsylvanian. A smaller basin, the Dalhart Basin, is in the western Panhandle.

The following discussion is modified from Johnson (1971), Johnson and others (1989), and Johnson (1996). (Note that many geologic terms are defined in the Glossary of Selected Terms on pages 20 and 21. The stratigraphic column on page 21 illustrates principal Oklahoma rock formations and their ages).

Precambrian and Cambrian Igneous and Metamorphic Activity

Oklahoma's oldest rocks are Precambrian igneous and metamorphic rocks that formed about 1.4 billion years ago. Then in another episode of igneous activity, during the Early and Middle Cambrian, granites, rhyolites, gabbros, and basalts formed in southwestern and south-central Oklahoma. Heat and fluids of Cambrian magmas changed older sedimentary rocks into metamorphic rocks.

Precambrian and Cambrian igneous and metamorphic rocks underlie all of Oklahoma and are the floor or basement on which younger rocks rest. The top of the basement rocks typically is ~1,000 ft below the Earth's surface in the Ozark Uplift in northeastern Oklahoma, except where granite crops out at Spavinaw, in Mayes County. To the south and southwest, the depth to basement increases to 30,000–40,000 ft beneath deep sedimentary basins (Fig. 3). Adjacent to the basins, basement rocks were uplifted above sea level in two major fault blocks and are exposed in the Wichita and Arbuckle Mountains. Igneous rocks and hydrothermal-mineral veins crop out locally in these mountains.

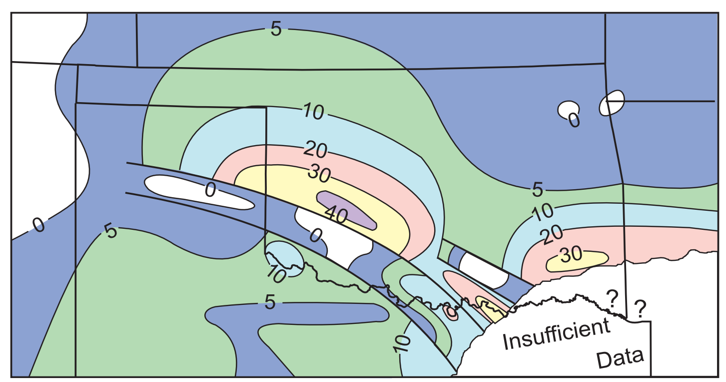


Figure 3. Generalized contours showing elevation (in thousands of feet below sea level) of the eroded top of Precambrian and Cambrian basement rocks in Oklahoma and parts of adjacent states.

Late Cambrian and Ordovician Periods

Following a brief period when newly formed Cambrian igneous rocks and ancient Precambrian rocks were partly eroded, shallow seas covered Oklahoma during the early Paleozoic Era. This began a long period of geologic time (515 million years) when parts of Oklahoma were alternately inundated by shallow seas and then raised above sea level. Many rocks that formed in the various sedimentary environments contain fossils and diverse mineral deposits.

The sea first invaded Oklahoma in the Late Cambrian and moved across the State from the east or southeast. The Reagan Sandstone, consisting of sand and gravel eroded from exposed and weathered basement, was deposited in southern and eastern parts of Oklahoma. Thick limestones and dolomites of the overlying Arbuckle Group (Late Cambrian and Early Ordovician) covered almost the entire State (Fig. 4). The Arbuckle

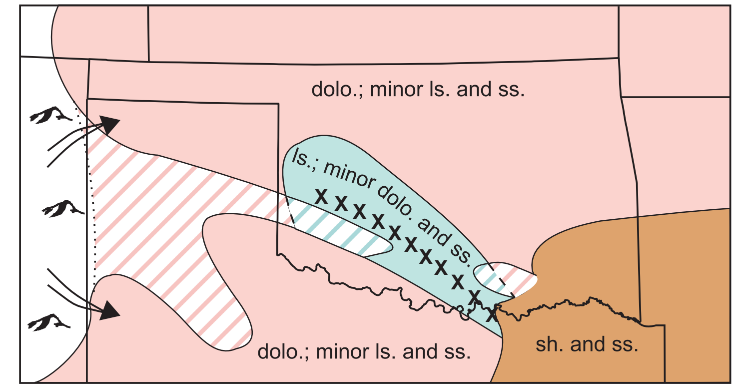


Figure 4. Principal rock types of Late Cambrian and Early Ordovician age in Oklahoma (explanation of map symbols, below, applies to Figures 4-18).

EXPLANATION

Principal Rock Types	Rocks are present	Rocks now eroded
Limestone (ls.)		
Dolomite (dolo.)		
Sandstone (ss.)		
Shale (sh.)		
Salt		

Other Rock Types

Gypsum (gyp.) Chert (cht.)

Symbols

Line separating areas of different principal rock types (dashed where eroded)

Possible original extent of depositional area

XXXXXX Principal axis of sedimentation

Major mountain area

Low mountains and hills

General movement of clastic sediments (sand, gravel, and clay)

Group marine sediments increase in thickness southward from 1,000–2,000 ft in northern shelf areas (Anadarko Shelf and Cherokee Platform) to about 7,000 ft in the Anadarko and Ardmore Basins, and in the Arbuckle Mountains. Thick deposits of black shale, sandstone, and some limestone are present in the Ouachita province in the southeast. Shallow-marine limestones, sandstones, and shales characterize Middle and Late Ordovician rocks throughout most of Oklahoma (Fig. 5). Some of the most widespread rock units include Simpson Group sandstones, Viola Group limestones, and the Sylvan Shale. These strata are up to 2,500 ft thick in the deep Anadarko and Ardmore Basins and in the Arbuckle Mountains. Thick layers of black shale, along with some chert and sandstone beds, occur in the Ouachita Mountains region to the southeast.

Limestone and other Late Cambrian and Ordovician rocks exposed in the Arbuckle Mountains and on the flanks of the Wichita Mountains contain abundant fossils of early marine

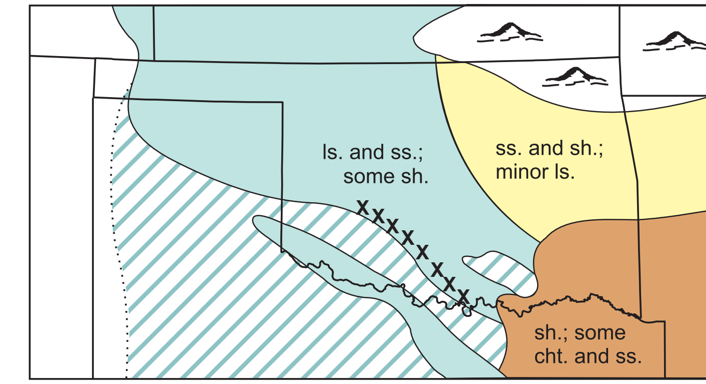


Figure 5. Principal rock types of Middle and Late Ordovician age in Oklahoma (see Fig. 4 for explanation of symbols).

invertebrates such as trilobites, brachiopods, and bryozoans.

Silurian and Devonian Periods

Silurian and Devonian sedimentary rocks in Oklahoma (except for deposits in the Ouachita Basin) are limestone and dolomite overlain by black shale (Fig. 6). The Hunton Group (latest Ordovician, Silurian, and Early Devonian) is commonly 100–500 ft thick (maximum, 1,000 ft) and was eroded from northern shelf areas. Invertebrate marine fossils, such as brachiopods, trilobites, and crinoids, are abundant in the Hunton in the Arbuckle Mountains and in equivalent strata in the Ozark Uplift.

After a period of widespread uplift and erosion, the Late Devonian to earliest Mississippian Woodford Shale was deposited in essentially the same areas as the Hunton, and northward into Kansas.

The pre-Woodford erosional surface is a conspicuous unconformity: 500–1,000 ft of strata were eroded over broad areas, and the Woodford or younger Mississippian units rest on Ordovician and Silurian rocks. The Woodford typically is 50–200 ft thick, but it is as thick as 600 ft in the Arbuckle Mountains. The Devonian–Mississippian boundary is placed at the top of the Woodford because only the uppermost few feet of Woodford is earliest Mississippian.

In the Ouachita Basin, sandstone and shale of the Blaylock and Missouri Mountain Formations are Silurian. The Arkansas Novaculite (chert) is Silurian, Devonian, and Early Mississippian. These three formations are 500–1,500 ft in total thickness.

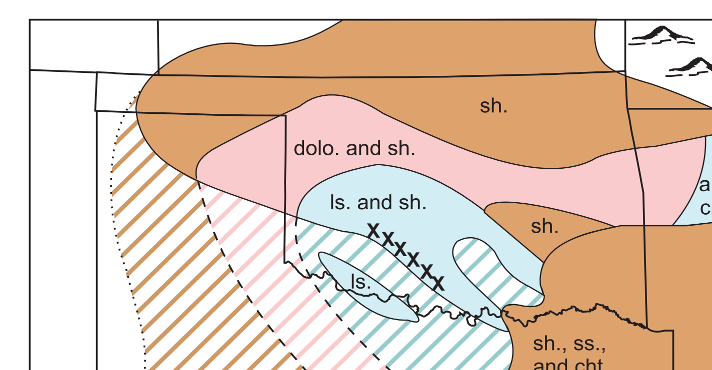


Figure 6. Principal rock types of Silurian and Devonian age in Oklahoma (see Fig. 4 for explanation of symbols).

GEOLOGIC HISTORY OF OKLAHOMA (continued)

Mississippian Period

Shallow seas covered most of Oklahoma during most of the first half of the Mississippian Period (Fig. 7). Limestone and chert are the dominant sedimentary rocks in most areas, and the Arkansas Novaculite occurs in the Ouachita Basin. Important units are Keokuk and Reeds Spring Formations in the Ozarks, Sycamore Limestone in southern Oklahoma, and "Mississippi lime" (a term for thick Mississippian limestones) in the subsurface across most of northern Oklahoma. Early Mississippian limestones, which are the youngest of the thick carbonate sequences in Oklahoma, provide evidence for early and middle Paleozoic crustal stability.

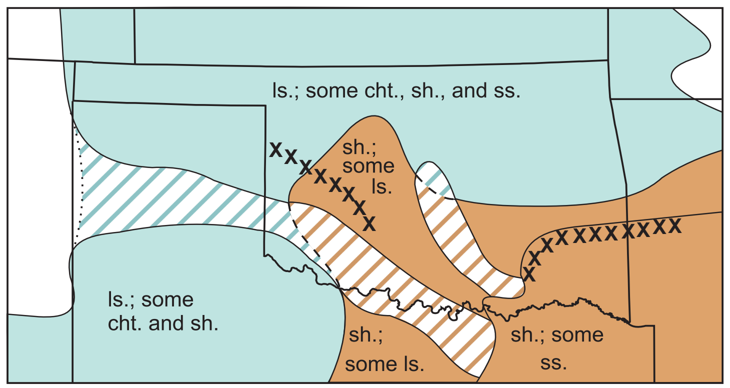


Figure 7. Principal rock types of Mississippian age in Oklahoma (see Fig. 4 for explanation of symbols).

Basins in southern Oklahoma in the last half of the Mississippian rapidly subsided, resulting in thick sedimentary deposits that consist predominantly of shale, with layers of limestone and sandstone (Fig. 7). Principal Mississippian formations in southern Oklahoma (excluding the Ouachitas) are the Caney Shale, Goddard Formation, and Springer Formation (which is partly Early Pennsylvanian): these and the underlying Sycamore Limestone are 1,500–6,000 ft thick in the Ardmore and eastern Anadarko Basins and nearby areas. The greatest thickness of Mississippian strata is 10,000 ft of interbedded sandstone and shale of the Stanley Group in the Ouachita Basin. Most Mississippian strata in central and north-central Oklahoma were eroded during the Early Pennsylvanian. In the western Anadarko Basin, Mississippian strata consist of cherty limestones and shales 3,000 ft thick, thinning to 200–400 ft east of the Nemaha Uplift.

Mississippian rocks host various fossils and minerals. Marine limestones and shales in the Arbuckle Mountains and Ozark Uplift contain abundant invertebrate marine fossils, such as crinoids, bryozoans, blastoids, and brachiopods. The Tri-State mining district in northeastern Oklahoma (Miami-Picher area) yielded beautiful crystals of galena, sphalerite, and calcite.

Pennsylvanian Period

The Pennsylvanian Period was a time of crustal unrest in Oklahoma: both orogeny and basin subsidence in the south; gentle raising and lowering of broad areas in the north. Uplifts in Colorado and New Mexico gave rise to the mountain chain referred to as the Ancestral Rockies. Sediments deposited earlier in the Wichita, Arbuckle, and Ouachita Uplifts were lithified, deformed, and uplifted to form major mountains, while nearby basins subsided rapidly and received sediments eroded from the highlands. Pennsylvanian rocks are dominantly marine shale, but beds of sandstone, limestone, conglomerate, and coal also occur. Pennsylvanian strata, commonly 2,000–5,000 ft thick in shelf areas in the north, are up to 16,000 ft in the Anadarko Basin, 15,000 ft in the Ardmore Basin, 13,000 ft in the Marietta Basin, and 18,000 ft in the Arkoma Basin.

Pennsylvanian rocks contain petroleum reservoirs that yield more oil and gas than any other rocks in Oklahoma, and they also have large coal reserves in eastern Oklahoma. The Pennsylvanian interests collectors for two reasons. (1) Pennsylvanian sediments contain abundant invertebrate and plant fossils in eastern and south-central Oklahoma. Invertebrates include various brachiopods, crinoids, bryozoans, gastropods,

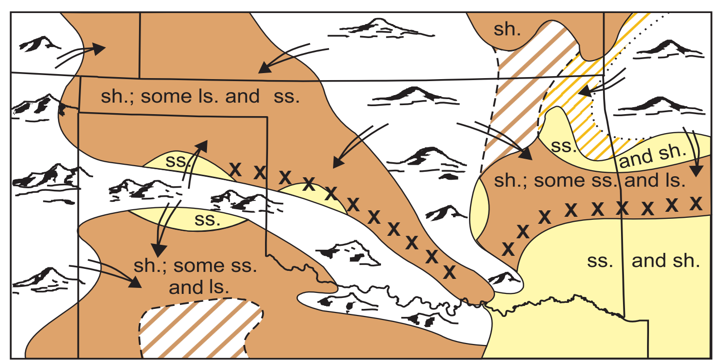


Figure 8. Principal rock types of Early Pennsylvanian (Morrowan and Atokan) age in Oklahoma (see Fig. 4 for explanation of symbols).

and bivalves. Plant remains include petrified wood, fossil leaves, and extensive coal strata. The primary vertebrate fossils are shark teeth. (2) Pennsylvanian mountain-building caused the uplift of deeply buried Precambrian through Mississippian rocks in the Wichita, Arbuckle, Ouachita, and Ozark Uplifts. The older, fossiliferous and mineral-bearing rocks now are exposed after the erosion of younger, overlying strata.

The Pennsylvanian Period, subdivided into five epochs of time, includes (from oldest to youngest): Morrowan (Early), Atokan, Desmoinesian (Middle), Missourian, and Virgilian (Late). Orogenies occurred in all five epochs, but each pulse of mountain building affected different areas by varying degrees.

Folding and uplift of pre-Morrowan rocks characterize a major Pennsylvanian orogeny, the Wichita orogeny (Morrowan and early Atokan), resulting in 10,000–15,000 ft of uplift in the Wichita Mountains and in the Criner Hills south of Ardmore (Fig. 8). Conglomerate and eroded granite fragments (locally called granite wash) commonly are present near major uplifts, and the coarse-grained rocks grade into sandstone and shale toward the basin centers.

A broad, north-trending arch rose above sea level across central Oklahoma during this time; along its axis, a narrow belt of fault-block mountains, the Nemaha Uplift, extended north from Oklahoma City into Kansas. A broad uplift also

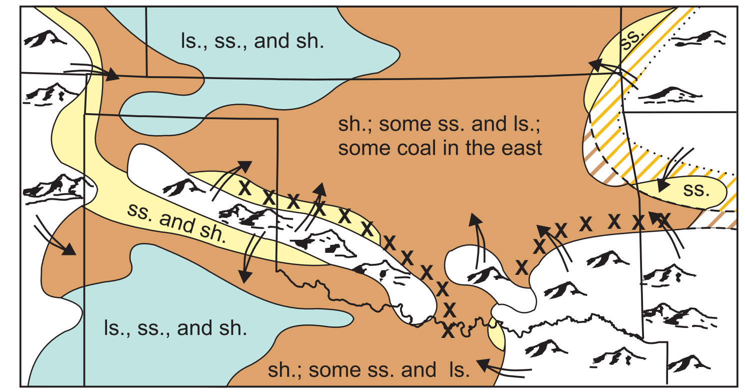


Figure 9. Principal rock types of Middle Pennsylvanian (Desmoinesian) age in Oklahoma (see Fig. 4 for explanation of symbols).

occurred at this time in the Ozark region of northeastern Oklahoma. The Morrowan and Atokan uplift resulted in erosion that removed all or part of the pre-Pennsylvanian rocks from the Wichita Mountains, Criner Hills, and central Oklahoma Arch. Less erosion occurred in other areas. The most profound Paleozoic unconformity in Oklahoma occurs at the base of Pennsylvanian rocks, and is recognized everywhere but in the deeper parts of major basins.

Principal pulses of deformation in the Ouachita Mountains

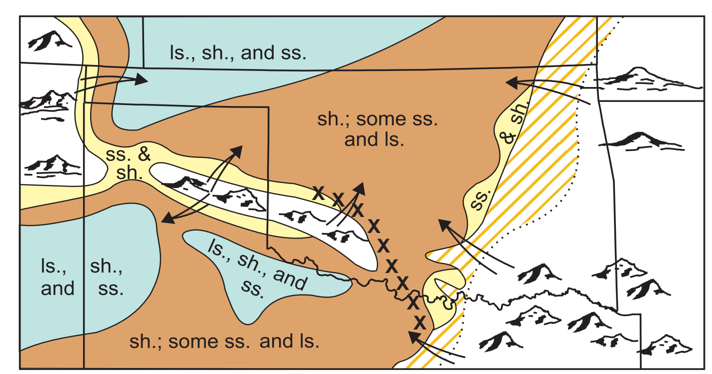


Figure 10. Principal rock types of Late Pennsylvanian (Missourian and Virgilian) age in Oklahoma (see Fig. 4 for explanation of symbols).

area probably started in the Mississippian, and the fold and thrust belt progressed northward. The pulses, known as the Ouachita orogeny, stopped by the end of the Desmoinesian (Fig. 9); the pulses included the northward thrusting of rocks (perhaps up to 50 mi of thrusting). Uplifting the Ouachita Mountains above sea level probably occurred during the Desmoinesian; the Ouachitas remained high into the Permian Period.

Downwarping of the Ouachita Basin shifted northward into the Arkoma Basin during Atokan and Desmoinesian times, and deformation ceased after folding and faulting of the Arkoma Basin. Of special importance in the Arkoma Basin and northeastern Oklahoma are Desmoinesian coal beds formed from plant matter that had accumulated in swamps. At widely scattered locations throughout eastern Oklahoma, Desmoinesian strata are well known for fossil trees, wood, and leaves.

The last major Pennsylvanian orogeny, the Arbuckle orogeny, was a strong compression and uplift during the Virgilian. The orogeny affected many mountain areas in southern Oklahoma and caused prominent folding in the Ardmore, Marietta, and Anadarko Basins (Fig. 10). Much of the folding, faulting, and uplift in the Arbuckle Mountains likely occurred in the late Virgilian. By the end of the Pennsylvanian, Oklahoma's mountain systems were essentially as they are today, although subsequent gentle uplift and associated erosion cut deeper into underlying rocks and greatly reduced the original height of the mountains.

Permian Period

Following Pennsylvanian mountain building, an Early Permian (Wolfcampian) shallow inland sea covered most of

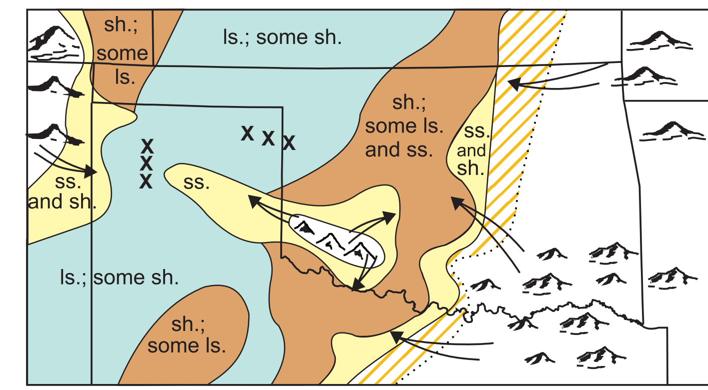


Figure 11. Principal rock types of Early Permian (Wolfcampian) age in Oklahoma (see Fig. 4 for explanation of symbols).

western Oklahoma and the Panhandle, extending north from west Texas to Nebraska and the Dakotas. Shallow-marine limestones and gray shales are found in the center of the ancient seaway (Fig. 11), grading laterally to the east and west

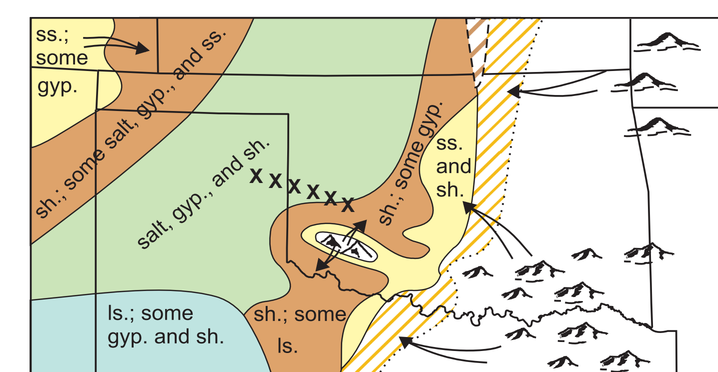


Figure 12. Principal rock types of Early Permian (Leonardian) age in Oklahoma (see Fig. 4 for explanation of symbols).

into limestones, red shales, and red sandstones (Permian red beds). During the later Leonardian (Early Permian; Fig. 12), evaporating sea water deposited thick beds of salt and gypsum (or anhydrite), such as the Wellington and Cimarron evaporites. Throughout the Early Permian, the Wichita, Arbuckle, Ouachita, and Ozark Mountains were still high, supplying eroded sand and mud to central and western Oklahoma. Alluvial, deltaic, and nearshore-marine red sandstone and shale characterize the Early Permian sea margin, interfingering with gray marine shale, anhydrite, limestone, dolomite, and salt that typically were deposited toward the center of the sea. Most Early Permian outcrops are red shales, although thin limestones and dolomites occur in north-central Oklahoma,

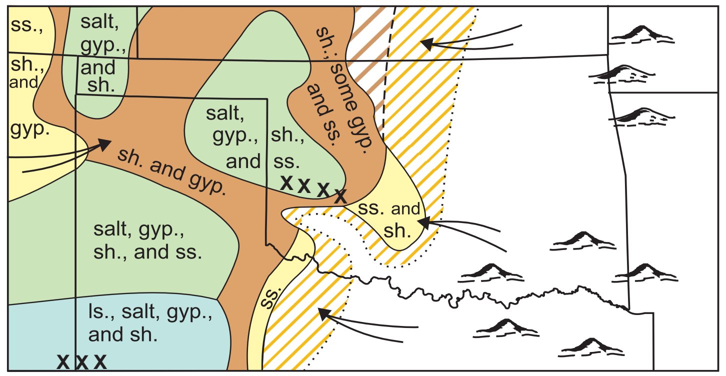


Figure 13. Principal rock types of Late Permian (Guadalupian) age in Oklahoma (see Fig. 4 for explanation of symbols).

and crossbedded sandstones are common in central and south-central areas. The red color, common in Permian rocks, results from iron oxides (chiefly hematite) that coat the grains in the sandstones and shales.

By the Late Permian, the Wichitas were mostly buried by sediment and the mountains to the east were largely eroded (Figs. 13-14). Red shale and sandstone typify Guadalupian rocks, although thick, white gypsum and thin dolomite beds of the Blaine and Cloud Chief Formations also occur. Thick salt units occur in the subsurface (Fig. 13). The Rush Springs Sandstone forms canyons in much of western Oklahoma. Latest Permian (Ochoan) rocks are mostly red-bed sandstones and shales, but they contain some gypsum and

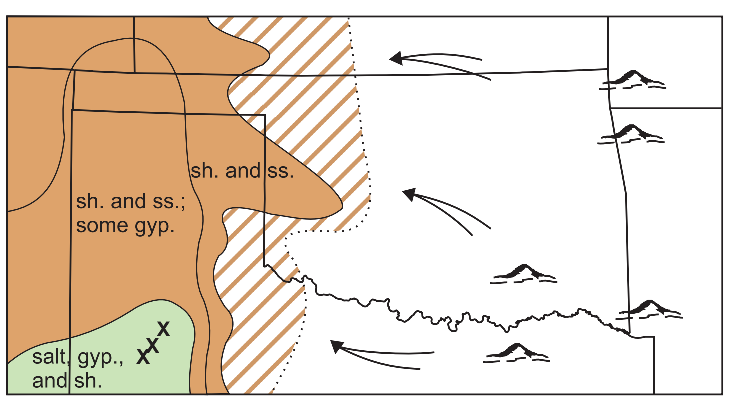


Figure 14. Principal rock types of Late Permian (Ochoan) age in Oklahoma (see Fig. 4 for explanation of symbols).

dolomite in the west (Fig. 14). The entire Permian sequence is commonly 1,000–5,000 ft thick, but can be 6,000–6,500 ft in deeper parts of the Anadarko Basin.

Permian sedimentary rocks in central and western Oklahoma contain various fossils and minerals. Fossils, though rare, include vertebrates (e.g., fish, amphibians, and reptiles), insects, and a few marine invertebrates. Minerals are more common and include gypsum (selenite and satin spar), halite (in subsurface and on salt plains), and rose rocks (barite rose, the official state rock of Oklahoma).

Triassic and Jurassic Periods

Triassic and Jurassic rocks are restricted to the Panhandle (Fig. 15); most of Oklahoma probably was above sea level at this time. Sandstones, shales, and conglomerates formed in central and western Oklahoma from sediments deposited mainly in rivers and lakes that drained hills and lowlands of Permian sedimentary strata. Hills in central Colorado and

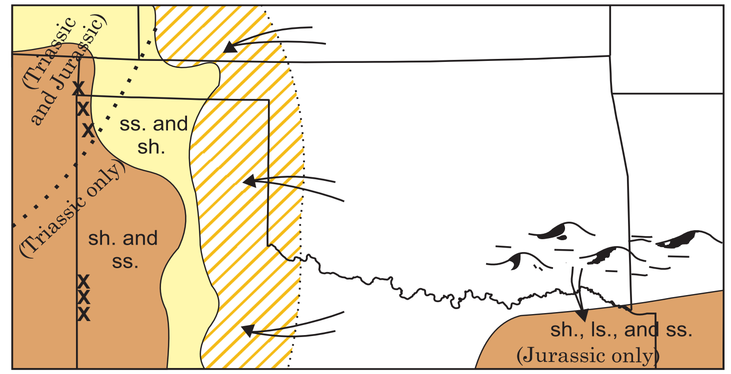


Figure 15. Principal rock types of Triassic and Jurassic age in Oklahoma (see Fig. 4 for explanation of symbols).

northern New Mexico also supplied some sediments. Triassic and Jurassic strata in the Panhandle are mostly red and gray, and are typically 200–700 ft thick.

Southeastern Oklahoma probably was an area of low mountains and hills and was the source of sediment eroded from the Ouachita Mountains. The Gulf of Mexico almost extended into Oklahoma during the Jurassic. Triassic and Jurassic fossils in Oklahoma include some invertebrates, petrified wood, and vertebrates such as dinosaurs, crocodiles, turtles, and fish. In the Panhandle, the Jurassic Morrison Formation is noteworthy because of its abundant dinosaur bones.

Cretaceous Period

Cretaceous seas covered all but northeastern and east-central Oklahoma (Fig. 16). The ancestral Gulf of Mexico extended across southeastern Oklahoma in the Early Cretaceous, and shallow seas extended north in the last great inundation of the western interior of the United States (including Oklahoma) during the Late Cretaceous. Shale, sandstone, and limestone are about 200 ft thick in the Panhandle and as thick as 2,000–3,000 ft in the Gulf Coastal Plain (Fig. 16). A major unconformity is exposed throughout the southeast, where

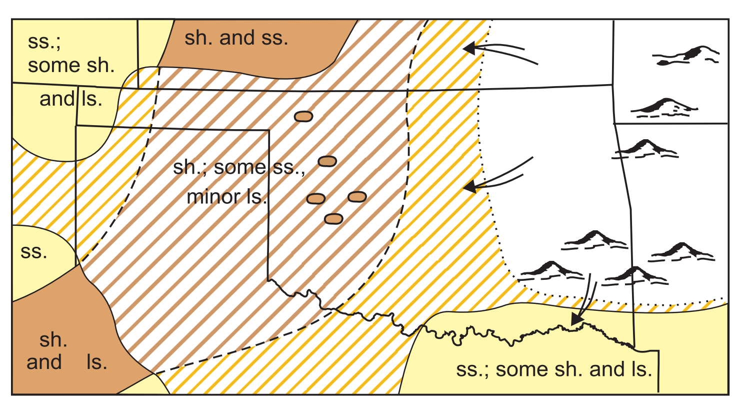


Figure 16. Principal rock types of Cretaceous age in Oklahoma (see Fig. 4 for explanation of symbols).

Cretaceous strata rest on rocks from the Precambrian through the Permian. Uplift of the Rocky Mountains in the Late Cretaceous and Early Tertiary caused a broad uplift of Oklahoma, imparting an eastward tilt that resulted in the final withdrawal of the sea.

Cretaceous marine rocks in southeastern and western Oklahoma contain shark teeth and various invertebrate fossils, such as oysters, echinoids, and giant ammonites. Nonmarine Cretaceous strata contain dinosaur bones.

Cretaceous strata have been eroded from almost all parts of western Oklahoma (Fig. 16), except where blocks of Cretaceous rock (several acres to several square miles wide) have dropped down several hundred feet into sinkholes formed by dissolution of underlying Permian salts.

Tertiary Period

The ancestral Gulf of Mexico extended almost to the southeast corner of Oklahoma in the Early Tertiary, and the shoreline gradually retreated southward through the remainder of the period. Oklahoma supplied some sediments deposited to the southeast, including gravels, sands, and clays (Fig. 17).

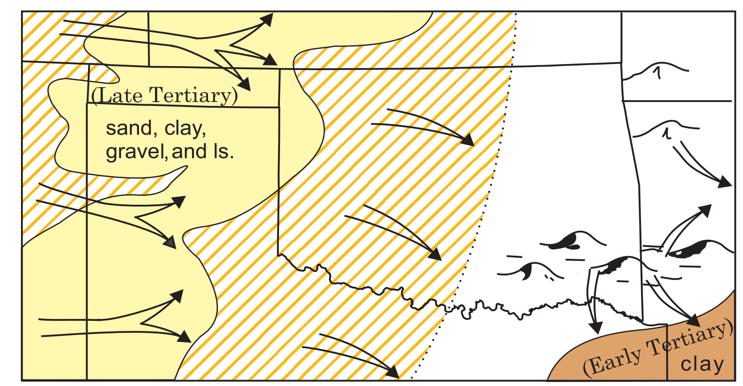


Figure 17. Principal rock types of Tertiary age in Oklahoma (see Fig. 4 for explanation of symbols).

In the Late Tertiary, a thick blanket of sand, silt, clay, and gravel eroded from the Rocky Mountains was deposited across the High Plains and farther east by a system of coalescing rivers and lakes. Some middle and upper parts of the Tertiary deposits consist of eolian sediment, and some fresh-water lakes had limestone deposits. Deposits in western Oklahoma, the Ogallala Formation, are 200–600 ft thick; they may have extended across central Oklahoma, thinning eastward. The nonmarine Ogallala contains fossil wood, snails, clams, and vertebrates such as horses, camels, rhinoceroses, and mastodons.

In the northwest corner of the Panhandle, a prominent layer of Tertiary basaltic lava that flowed from a volcano in southeastern Colorado caps Black Mesa.

Quaternary Period

The Quaternary Period, the last 1.6 million years of Earth history, is divided into the Pleistocene Epoch (the "Great Ice Age") and the Holocene or Recent Epoch that we live in today. The boundary between the epochs is about 11,500 years ago, at the end of the last continental glaciation. During that time the glaciers extended south only as far as northeastern Kansas. Major rivers fed by meltwater from Rocky Mountain glaciers and the increased precipitation associated with glaciation sculpted Oklahoma's land (Fig. 18). Today's major drainage systems originated during the Pleistocene. The rivers' shifting positions are marked by alluvial deposits left as terraces, now tens to hundreds of feet above present-day flood plains.

The Quaternary is characterized as a time when rocks and loose sediment at the surface are being weathered to soil, and the soil particles then are carried away to streams and rivers. In this manner, hills and mountains are eroded, and sediments are transported to the sea, or are temporarily deposited in river beds and banks and in lake bottoms. Clay, silt, sand,

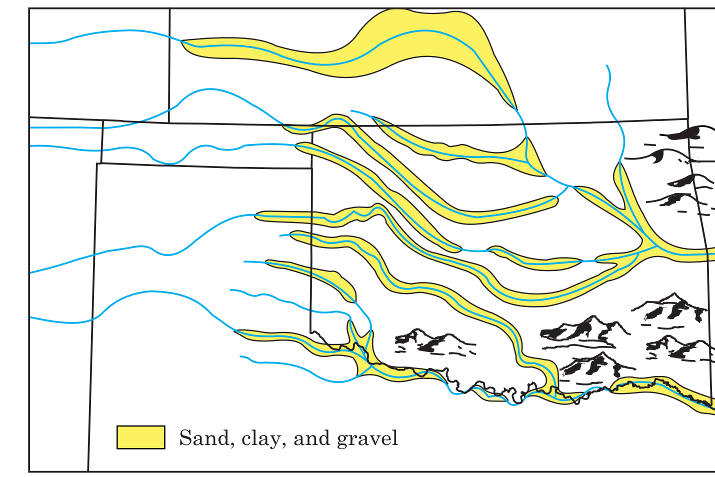
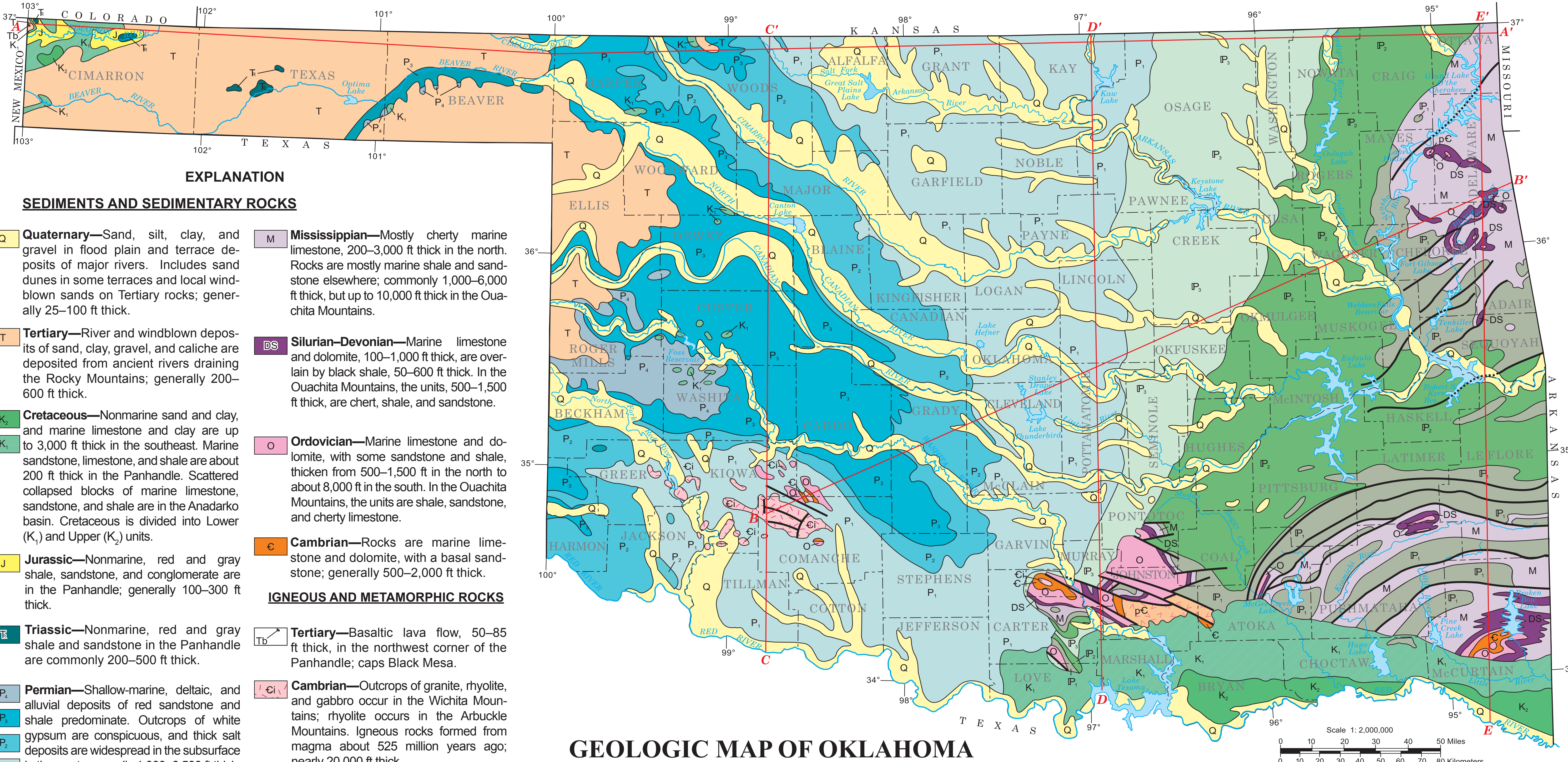


Figure 18. Major rivers of Oklahoma and principal deposits of Quaternary age (see Fig. 4 for explanation of symbols)

and gravel from Pleistocene and Holocene rivers and lakes are typically unconsolidated and 25–100 ft thick. Finding Pleistocene terraces more than 100–300 ft above modern flood plains attests to the great amount of erosion and down cutting performed by major rivers in the last 1.6 million years. Modern flood plains consist mainly of alluvium deposited during the Holocene.

Quaternary river-borne sediments decrease in grain size from west to east across Oklahoma; gravel, commonly mixed with river sands in the west, is abraded so much during transport that it is almost absent in the east. Eolian sediments characterize Quaternary deposits in parts of western Oklahoma: sand dunes, mainly on the north sides of major rivers, and some of the Ogallala (Tertiary) sands and silts, were reworked by Quaternary winds.

Quaternary sediments locally contain fossil wood, snail shells, and bones and teeth of land vertebrates (e.g., horses, camels, bison, mastodons, mammoths). Some fossils were eroded from the Ogallala and redeposited in the Quaternary. Horses, camels, mastodons, mammoths and other large animals lived in Oklahoma during the Pleistocene, but they died out at the end of the Pleistocene and the beginning of the Holocene.



EXPLANATION

SEDIMENTS AND SEDIMENTARY ROCKS

Q **Quaternary—**Sand, silt, clay, and gravel in flood plain and terrace deposits of major rivers. Includes sand dunes in some terraces and local windblown sands on Tertiary rocks; generally 25–100 ft thick.

T **Tertiary—**River and windblown deposits of sand, clay, gravel, and caliche are deposited from ancient rivers draining the Rocky Mountains; generally 200–600 ft thick.

K_2, K_1 **Cretaceous—**Nonmarine sand and clay, and marine limestone and clay are up to 3,000 ft thick in the southeast. Marine sandstone, limestone, and shale are about 200 ft thick in the Panhandle. Scattered collapsed blocks of marine limestone, sandstone, and shale are in the Anadarko basin. Cretaceous is divided into Lower (K_1) and Upper (K_2) units.

J **Jurassic—**Nonmarine, red and gray shale, sandstone, and conglomerate are in the Panhandle; generally 100–300 ft thick.

Ꞇ **Triassic—**Nonmarine, red and gray shale and sandstone in the Panhandle are commonly 200–500 ft thick.

P_4, P_3, P_2, P_1 **Permian—**Shallow-marine, deltaic, and alluvial deposits of red sandstone and shale predominate. Outcrops of white gypsum are conspicuous, and thick salt deposits are widespread in the subsurface in the west; generally 1,000–6,500 ft thick. Permian is divided into Lower (P_1) and Upper (P_2, P_3, and P_4) units; lower part of P_1 is marine red sandstone and shale, with some thin beds of limestone.

$\mathbb{P}_3$, $\mathbb{P}_2$, $\mathbb{P}_1$ **Pennsylvanian—**Mostly marine shale, with interbedded sandstone, limestone, and coal. Thickness is commonly 2,000–5,000 ft, but much greater in the Anadarko Basin (16,000 ft thick), Ardmore Basin (15,000 ft), Marietta Basin (13,000 ft), Ouachita Mountains (15,000 ft), and Arkoma Basin (18,000 ft). Thick conglomerates occur near the Wichita and Arbuckle Mountains. Units are divided into Lower ($\mathbb{P}_1$), Middle ($\mathbb{P}_2$), and Upper ($\mathbb{P}_3$) Pennsylvanian.

M **Mississippian—**Mostly cherty marine limestone, 200–3,000 ft thick in the north. Rocks are mostly marine shale and sandstone elsewhere; commonly 1,000–6,000 ft thick, but up to 10,000 ft thick in the Ouachita Mountains.

DS **Silurian–Devonian—**Marine limestone and dolomite, 100–1,000 ft thick, are overlain by black shale, 50–600 ft thick. In the Ouachita Mountains, the units, 500–1,500 ft thick, are chert, shale, and sandstone.

O **Ordovician—**Marine limestone and dolomite, with some sandstone and shale, thicken from 500–1,500 ft in the north to about 8,000 ft in the south. In the Ouachita Mountains, the units are shale, sandstone, and cherty limestone.

Ꞓ **Cambrian—**Rocks are marine limestone and dolomite, with a basal sandstone; generally 500–2,000 ft thick.

IGNEOUS AND METAMORPHIC ROCKS

Tb **Tertiary—**Basaltic lava flow, 50–85 ft thick, in the northwest corner of the Panhandle; caps Black Mesa.

Ꞓi **Cambrian—**Outcrops of granite, rhyolite, and gabbro occur in the Wichita Mountains; rhyolite occurs in the Arbuckle Mountains. Igneous rocks formed from magma about 525 million years ago; nearly 20,000 ft thick.

pꞒ **Precambrian—**Granite and gneiss (a metamorphosed igneous rock) crop out in the Arbuckle Mountains, and granite crops out in a small area in Mayes County. Formed about 1.4 billion years ago, these are the oldest rock outcrops in Oklahoma.

Symbols

Geologic contact

Fault; dotted where concealed by Quaternary sediments

A–A′ Line of cross section (see p. 7)

GEOLOGIC MAP OF OKLAHOMA

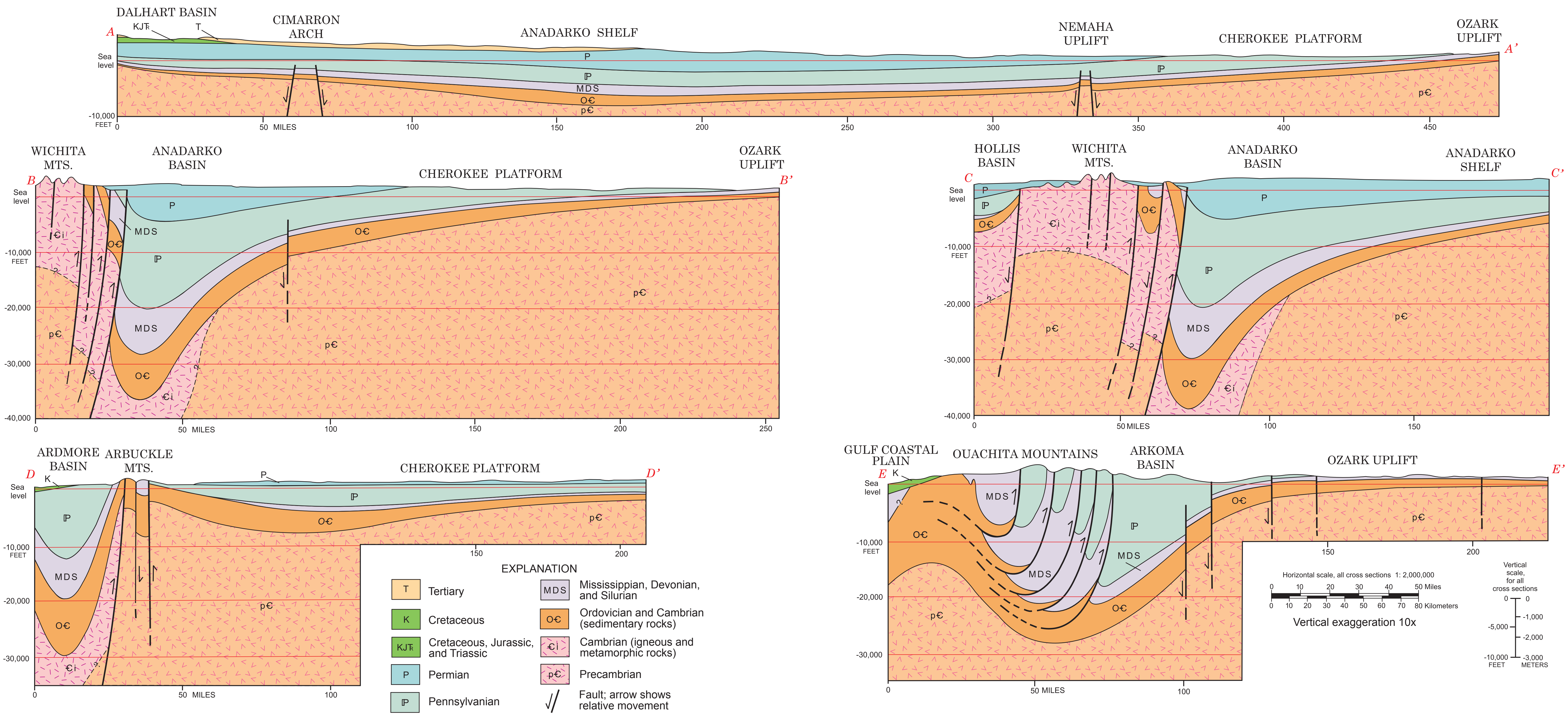
Kenneth S. Johnson, Oklahoma Geological Survey

The geologic map of Oklahoma shows rock units that crop out or are mantled by a thin soil veneer. Quaternary sediments laid down by streams and rivers locally overly Precambrian through Tertiary bedrock. The geologic map helps one understand the age and character of Oklahoma's rocks in assessing petroleum reservoirs, mineral deposits, construction sites, engineering properties, ground-water-aquifer characteristics, and to remedy environmental problems.

About 99% of all outcrops in Oklahoma are sedimentary rocks. Remaining outcrops are (1) igneous rocks, mainly in the Wichita and Arbuckle Mountains, (2) metamorphic rocks in the eastern Arbuckles, and (3) mildly metamorphosed rocks in the core of the Ouachita Mountains.

Rocks formed during every geologic period crop out in Oklahoma. About 46% of Oklahoma has Permian rocks exposed at the surface. Other extensive outcrops are Pennsylvanian (about 25%), Tertiary (11%), Cretaceous (7%), Mississippian (6%), Ordovician (1%), and Cambrian (1%); Precambrian, Silurian, Devonian, Triassic, and Jurassic rocks each are exposed in less than 1% of Oklahoma. These outcrops do not include the Quaternary river, terrace, and lake deposits overlying older rocks in Oklahoma.

Bedrock geology on this map is derived from Miser (1954). Quaternary alluvium and terrace deposits are derived from nine hydrologic atlases of Oklahoma prepared jointly by the Oklahoma Geological Survey and the U.S. Geological Survey (Marcher, 1969; Marcher and Bingham, 1971; Hart, 1974; Bingham and Moore, 1975; Carr and Bergman, 1976; Havens, 1977; Bingham and Bergman, 1980; Morton, 1981; Marcher and Bergman, 1983).



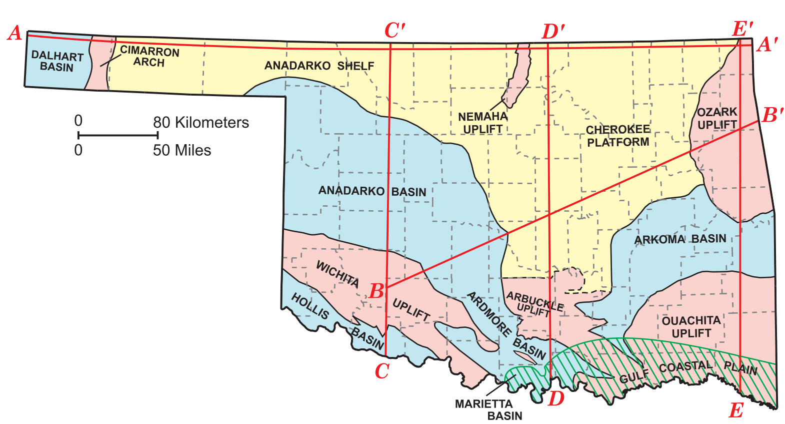


Figure 19. Geologic cross sections across the major geologic province map of Oklahoma (generalized from fig.1) : A-A', B-B', C-C', D-D' and E-E'.

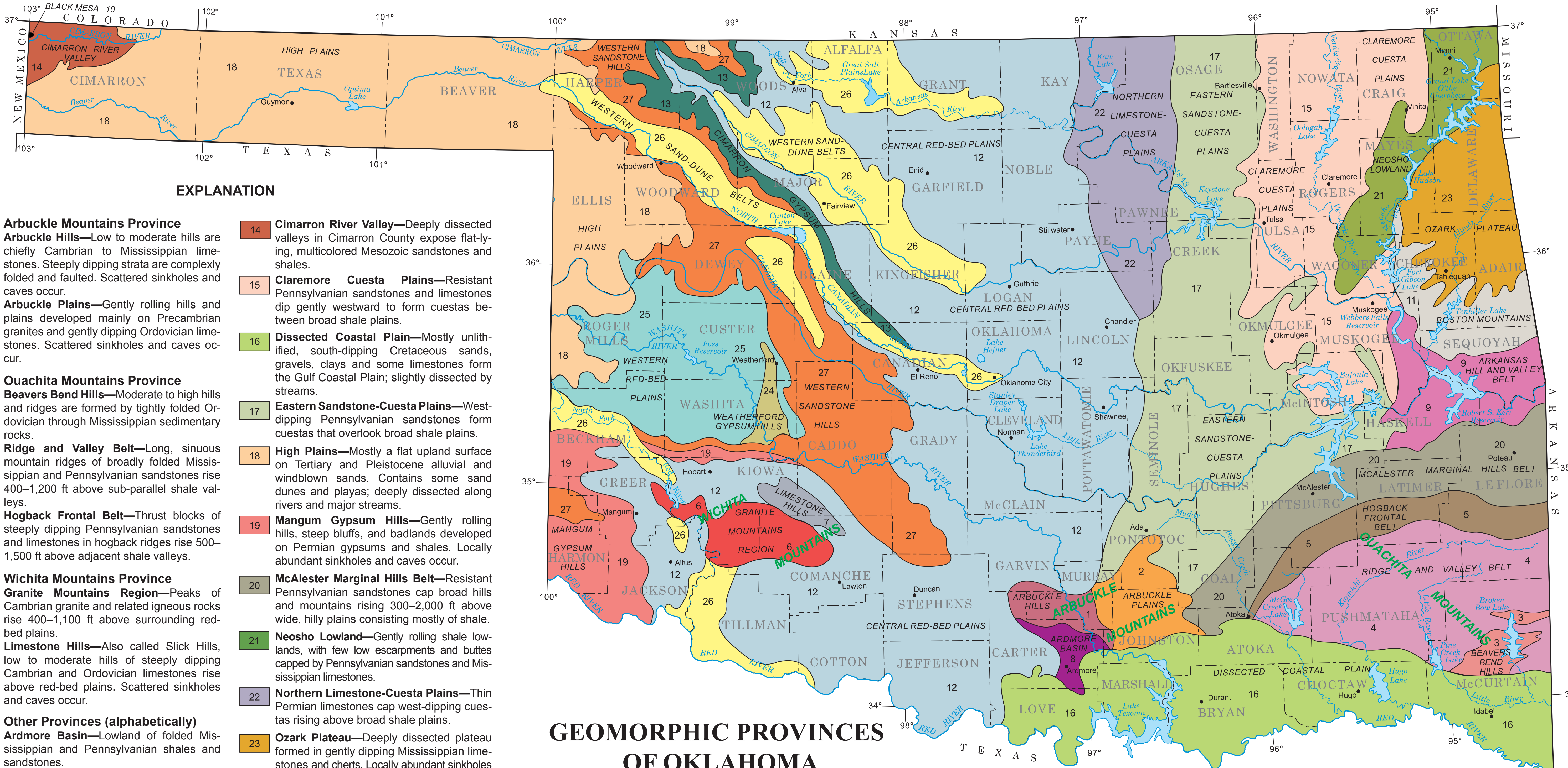
GEOLOGIC CROSS SECTIONS OF OKLAHOMA

Kenneth S. Johnson, Oklahoma Geological Survey

These cross sections show the subsurface configuration of rock units in Oklahoma, depicting the roots of mountain systems and the great depths of major sedimentary basins (Fig. 19). Data from the many petroleum wells drilled deep below the land surface (Oklahoma has more than 460,000 petroleum test holes) helped to create the cross sections.

By collecting and studying the drill cuttings, cores, and logs from petroleum tests, water wells, and mineral-exploration tests, and then integrating all these data with geologic mapping and geophysical studies, geologists can determine thickness, depth, and character of subsurface rock formations in most of Oklahoma. With these data, geologists then can do the following: (1) more precisely unravel the complex and exciting geologic history of Oklahoma; (2) more accurately assess location, quality, and quantity of Oklahoma's petroleum, mineral, and water resources; and (3) more effectively identify and attempt to remedy natural geohazards, such as earthquakes, flood-prone areas, sinkholes, landslides, and expanding soils, and man-induced conditions such as groundwater contamination, waste disposal, and mine-land subsidence.

Figure 19 (to the left) and the Geologic map of Oklahoma on page 6 show the lines of cross section. The horizontal scales of the cross sections are the same as for the Geologic Map on page 6: vertical exaggeration is 10x.



EXPLANATION

Arbuckle Mountains Province

1 **Arbuckle Hills—**Low to moderate hills are chiefly Cambrian to Mississippian limestones. Steeply dipping strata are complexly folded and faulted. Scattered sinkholes and caves occur.

2 **Arbuckle Plains—**Gently rolling hills and plains developed mainly on Precambrian granites and gently dipping Ordovician limestones. Scattered sinkholes and caves occur.

Ouachita Mountains Province

3 **Beavers Bend Hills—**Moderate to high hills and ridges are formed by tightly folded Ordovician through Mississippian sedimentary rocks.

4 **Ridge and Valley Belt—**Long, sinuous mountain ridges of broadly folded Mississippian and Pennsylvanian sandstones rise 400–1,200 ft above sub-parallel shale valleys.

5 **Hogback Frontal Belt—**Thrust blocks of steeply dipping Pennsylvanian sandstones and limestones in hogback ridges rise 500–1,500 ft above adjacent shale valleys.

Wichita Mountains Province

6 **Granite Mountains Region—**Peaks of Cambrian granite and related igneous rocks rise 400–1,100 ft above surrounding red-bed plains.

7 **Limestone Hills—**Also called Slick Hills, low to moderate hills of steeply dipping Cambrian and Ordovician limestones rise above red-bed plains. Scattered sinkholes and caves occur.

Other Provinces (alphabetically)

8 **Ardmore Basin—**Lowland of folded Mississippian and Pennsylvanian shales and sandstones.

9 **Arkansas Hill and Valley Belt—**Broad, gently rolling plains and valleys with scattered hills, 100–300 ft high, are capped by Pennsylvanian sandstones.

10 **Black Mesa—**Flat-topped erosional remnant of Tertiary basaltic lava flow that was extruded from a volcano in Colorado; the highest point in Oklahoma (elevation, 4,973 ft).

11 **Boston Mountains—**Deeply dissected plateau is capped by gently dipping Pennsylvanian sandstones.

12 **Central Red-Bed Plains—**Permian red shales and sandstones form gently rolling hills and broad, flat plains.

13 **Cimarron Gypsum Hills—**Escarpments and badlands developed on Permian gypsums and shales. Locally abundant sinkholes and caves occur.

14 **Cimarron River Valley—**Deeply dissected valleys in Cimarron County expose flat-lying, multicolored Mesozoic sandstones and shales.

15 **Claremore Cuesta Plains—**Resistant Pennsylvanian sandstones and limestones dip gently westward to form cuestas between broad shale plains.

16 **Dissected Coastal Plain—**Mostly unlithified, south-dipping Cretaceous sands, gravels, clays and some limestones form the Gulf Coastal Plain; slightly dissected by streams.

17 **Eastern Sandstone-Cuesta Plains—**West-dipping Pennsylvanian sandstones form cuestas that overlook broad shale plains.

18 **High Plains—**Mostly a flat upland surface on Tertiary and Pleistocene alluvial and windblown sands. Contains some sand dunes and playas; deeply dissected along rivers and major streams.

19 **Mangum Gypsum Hills—**Gently rolling hills, steep bluffs, and badlands developed on Permian gypsums and shales. Locally abundant sinkholes and caves occur.

20 **McAlester Marginal Hills Belt—**Resistant Pennsylvanian sandstones cap broad hills and mountains rising 300–2,000 ft above wide, hilly plains consisting mostly of shale.

21 **Neosho Lowland—**Gently rolling shale lowlands, with few low escarpments and buttes capped by Pennsylvanian sandstones and Mississippian limestones.

22 **Northern Limestone-Cuesta Plains—**Thin Permian limestones cap west-dipping cuestas rising above broad shale plains.

23 **Ozark Plateau—**Deeply dissected plateau formed in gently dipping Mississippian limestones and cherts. Locally abundant sinkholes and caves occur.

24 **Weatherford Gypsum Hills—**Gently rolling hills occur in massive Permian gypsum beds, 100 ft thick. Locally abundant sinkholes and caves occur.

25 **Western Red-Bed Plains—**Gently rolling hills of nearly flat-lying Permian red sandstones and shales.

26 **Western Sand-Dune Belts—**Hummocky fields of grass-covered, stabilized sand dunes and some active dunes, occur mainly on north sides of major rivers. Sand is from Quaternary alluvium and terrace deposits.

27 **Western Sandstone Hills—**Slightly lithified, nearly flat-lying Permian red sandstones form gently rolling hills cut by steep-walled canyons.

GEOMORPHIC PROVINCES OF OKLAHOMA

Neville M. Curtis, Jr., William E. Ham, and Kenneth S. Johnson, Oklahoma Geological Survey

A geomorphic province is part of the Earth's surface where a suite of rocks with similar geologic character and structure underwent a similar geologic history, and where the present-day character and landforms differ significantly from adjacent provinces. The term used here is the same as "physiographic province."

Most outcrops in Oklahoma consist of horizontal or gently dipping sandstones, sands, and shales of Pennsylvanian, Permian, Cretaceous, and Tertiary ages (see Geologic Map of Oklahoma on page 6). Some sandstones (mainly in eastern Oklahoma) are well indurated (cemented), but in most other parts of Oklahoma they are not so well indurated and erode easily; therefore, much of Oklahoma is gently rolling hills and broad, flat plains. Elsewhere, erosion-resistant layers of sandstone, limestone, or gypsum form protective caps on buttes, cuestas, escarpments, and high hills.

Among the more impressive geomorphic provinces are several mountain belts and uplifts in southern and northeastern Oklahoma. In the southern third of Oklahoma, well-indurated rocks were folded, faulted, and uplifted forming the Wichita, Arbuckle, and Ouachita Mountains. The mountains and high hills, the resistant rock units, and the complex geology of these three provinces contrast sharply with Oklahoma's typical rolling hills and broad plains. In hilly, wooded areas of the Ozark Plateau and Boston Mountains in northeastern Oklahoma, streams and rivers created sharp relief locally by cutting down into resistant limestones and sandstones.