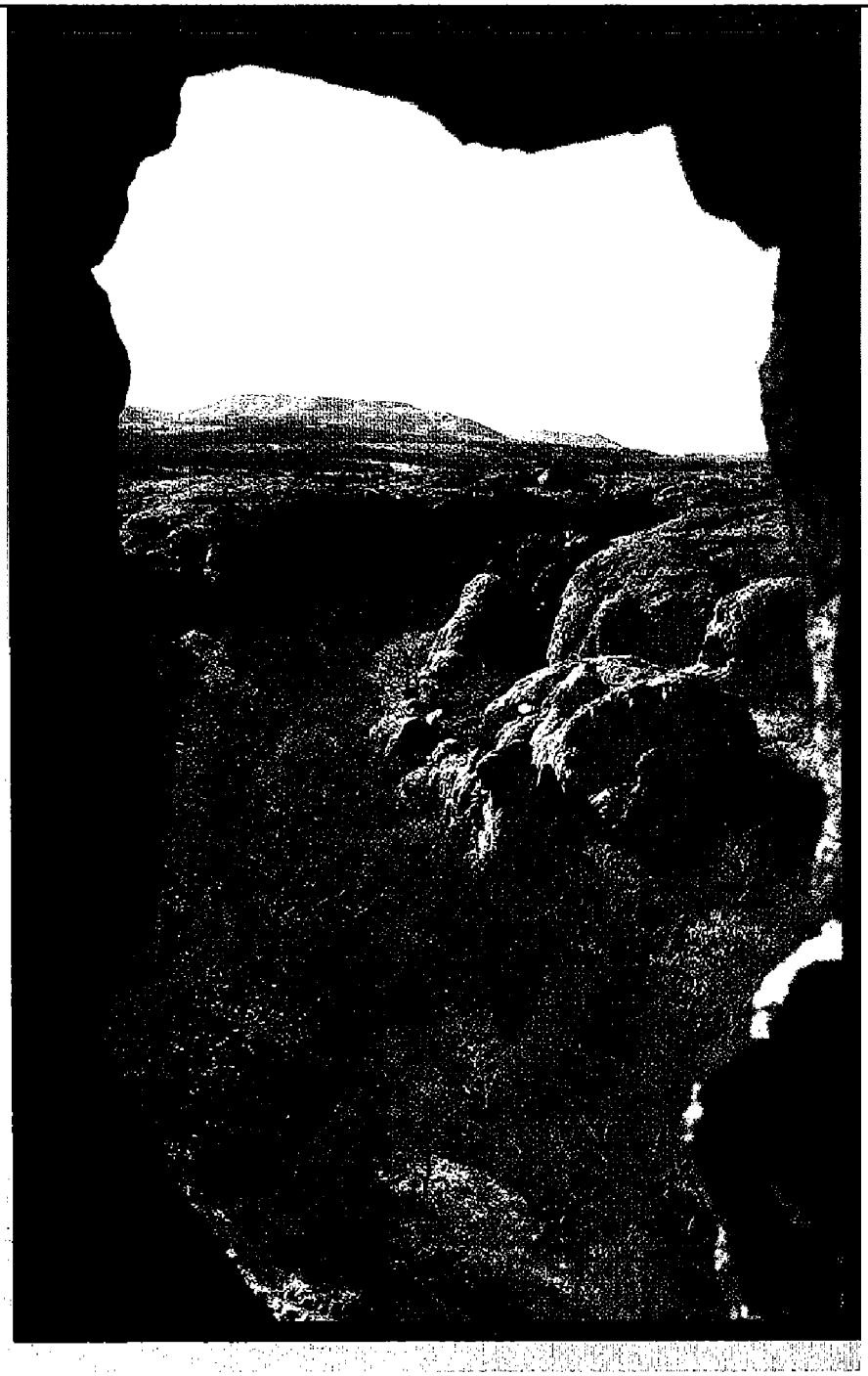
the GEE(*whiz!*)OLOGY *of* Oklahoma

. . . AMAZING

geological facts about our State



on the COVER

WINDOW ON THE WICHITA MOUNTAINS, SOUTHWESTERN OKLAHOMA

M. Charles Gilbert
University of Oklahoma

The picture on the cover was photographed through a small natural bridge of Quanah Granite near the intersection of Quanah Creek and a tributary, Cow Creek—not far south of Lake Quanah Parker, in the Wichita Mountains National Wildlife Refuge. The view is to the west–northwest, across the central lowland of the eastern Wichitas. Elk Mountain, one of the most prominent peaks in the area (2,250 feet elevation; about 650 feet relief) is visible about 4 miles away. It is a favorite of climbers and hikers because of the huge granite blocks and craggy pinnacles that adorn its top and sides, and the rather challenging southwest face with steep topographic drops and views across Charons Gardens and plains to the southwest and west.

The flat surface between the camera location and Elk Mountain is an ancient erosion surface. The Quanah Granite, which forms the surface, originated as magma that intruded and crystallized deep in the Earth's crust about 525 million years ago. Much later, in Pennsylvanian time, the area was uplifted and deeply eroded, exposing the granite and generating this topographic scene during the Permian age.

About 280 million years ago—still during the Permian—delta-plain sediments (known to geologists as the Post Oak Conglomerate) buried this topography. In the last few million years, erosion has again stripped this area of Permian and younger overlying rocks, exposing a topography formed long ago. Thus, the Wichita Mountains have become a geologic museum where features that formed hundreds of millions of years ago are on display.

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the GEE(*whiz!*) OLOGY of Oklahoma

compiled by
Neil H. Suneson
Oklahoma Geological Survey

INTRODUCTION

Did you know that when Oklahoma became the 46th State, in 1907, it was the largest oil-producing entity in the world? That is but one of a myriad facts about the geology and resources of this extraordinary young State. Although today Oklahoma does not have an active volcano, a sandy beach, or a towering mountain range, in the geologic past it had all those. Even now, the geology of our State and the resources derived from that geology rival those of many other places on Earth.

Oklahoma contains the Anadarko basin, which is one of the most prolific oil and gas provinces and also North America's deepest sedimentary basin. Our State has four geologically different uplifts—the ancient mountain ranges we call the Arbuckles, Ouachitas, Ozarks, and Wichitas. Some of the oldest rocks (1.4 billion years) in the southern Midcontinent are exposed here—as well as some of the youngest, for selenite crystals are forming today in river sediments in the northern part of the State. The State Rock—red barite rose—occurs in few other places in the world.

The geology of Oklahoma has made it a major producer of oil and gas; its reserves of gypsum could sustain current production through the next millenium; and it is the only producer of iodine in the United States, now filling about 25% of national demand. Crushed stone, sand and gravel, and coal also contribute to the economy of Oklahoma and the Nation.

Through more than a century of geological studies that began with the Territorial Geological Survey and continue in this 91st year of the Oklahoma Geological Survey, many scientific and economic observations and interpretations have been made about the geology and natural resources of Oklahoma. These studies were conducted by a large number of geoscientists who worked in academia, state and federal surveys, and industry. As a result of their efforts, few other states can match our three-dimensional view of Oklahoma's geology. And new discoveries continue to be made, to the benefit of current and future generations.

In 1998, Governor Frank Keating proclaimed the second week in October as Earth Sciences Week in the State of Oklahoma. October 10–16, 1999, marked the second annual celebration. As a contribution to this event, the Oklahoma Geological Survey has compiled this list of notable—even amazing—facts about the geology of Oklahoma, its resources, and some of its geologists.

We hope you enjoy reading these facts about Oklahoma geology. If you think of others, let us know and we will consider them for a future edition. Write to us at 100 E. Boyd St., Rm. N-131, Norman, OK 73019, or call (405) 325-3031. You also can contact us through our website at http://www.ou.edu/special/ogs-pttc/.

did you know — Geology and Oklahoma's Environment

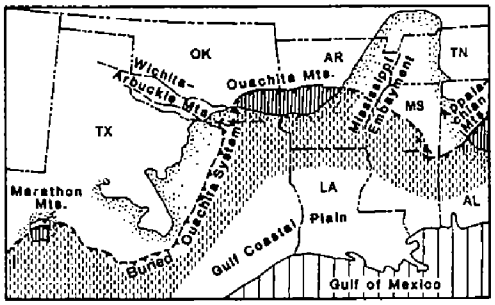

Figure 1. Map of Ouachita Mountains, most of which are buried by younger rocks and sediments.

Figure 2. Entrance to Jester Cave, the longest gypsum cave in the world outside of Russia.

Figure 3. Monument marking the highest point in Oklahoma, in Black Mesa State Park.

➤ Granite exposed in the Arbuckle Mountains in Johnston County is about 1.4 billion years old. It is the oldest rock exposed between the southern Appalachians and the Rocky Mountains.

➤ Oklahoma once had a mountain system very much like the Colorado Rockies. During the Pennsylvanian period, the Wichita and Arbuckle Mountains were connected to the Rockies. Ever since, Oklahoma's mountains have been eroding but the Rockies were uplifted a second time, beginning about 70 million years ago. Today, the Wichitas and the Arbuckles are less striking than the modern-day Rockies, but their roots sink just as deeply into the Earth's crust.

➤ The Ouachita Mountains in southeastern Oklahoma are part of a mountain belt that extends from Alabama to Mexico. In the United States, the only parts of this great belt not buried by younger rocks are the Ouachita Mountains in Arkansas and Oklahoma and the Marathon Mountains in West Texas. *(Fig. 1.)*

➤ Virtually all the lakes and reservoirs in Oklahoma are artificial; their water is impounded by dams. The only natural lakes in the State are oxbow lakes scattered along the flood plains of major rivers and the playa lakes in the High Plains of northwestern Oklahoma and the Panhandle.

➤ The longest gypsum cave in the world, outside Russia, is Jester Cave in Greer County. More than 33,000 feet of passageways have been mapped in the cave. And Alabaster Caverns, in Woodward County, is the largest commercial gypsum cave in North America. *(Fig. 2.)*

➤ The highest point in Oklahoma, at 4,973 feet above sea level, is in Black Mesa State Park in Cimarron County. The mesa is capped by a basalt lava flow less than 5 million years old. The lava flowed from a volcano in southeastern Colorado. *(Fig. 3.)*

- About 2,500 tons of dissolved salt (table salt, or NaCl) is carried down the Cimarron River every day from the Big Salt Plain, near Plainview in Woods County.

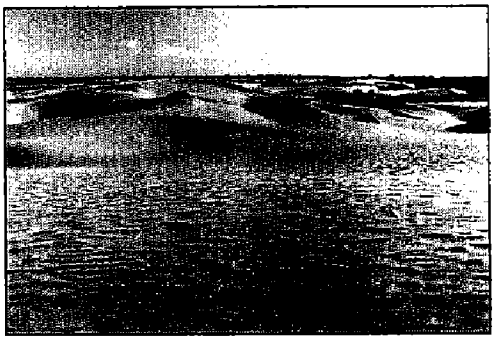

Figure 4. Sand dunes at Little Sahara State Park.

- A 1,400-acre area just north of the Cimarron River, near Waynoka in Woods County, contains so many sand dunes that it is known as Little Sahara. The dunes consist of sand grains blown from the flood plain of the Cimarron by the prevailing southwesterly winds. The area, which attracts numerous dune-buggy drivers and cyclists, has been designated Little Sahara State Park. *(Fig. 4.)*

- The barite rose, found in only a few places worldwide, is the State Rock of Oklahoma. It received its official status in March 1968. Norman and Noble in Cleveland County have become world famous for rose rocks, where they are found in the Garber Sandstone (Permian age). *(Fig. 5.)*

Figure 5. Oklahoma's State Rock, the rose rock.

Ancient Life in Oklahoma

did you know

- The largest trilobite fossils west of the Mississippi River are found in Oklahoma. Trilobites of the genus *Isotelus* occur in the Bromide Formation (Ordovician age) in the Criner Hills in Carter County and in the eastern Arbuckle Mountains near Bromide, in Johnston County. *(Fig. 6.)*

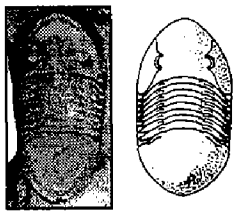

Figure 6. Trilobite *Isotelus*, (actual size 2.4 inches long).

- One of the largest known stumps of the world's oldest tree is on display on the campus of East Central University in Ada, Pontotoc County. *Archaeopteris* (extinct) was moderately abundant in Devonian time, and its petrified remains occur in the Woodford Formation near Ada and in the Arbuckle Mountains. *(Fig. 7.)*

Figure 7. *Archaeopteris* stump on the East Central University campus, Ada.

- White Mound in southeastern Murray County is world famous for its Early Devonian invertebrate fossils. These fossils include ostracodes, trilobites, brachiopods, corals, cephalopods, crinoids, gastropods, and sponges. Well-preserved trilobite specimens from the Haragan Formation at White Mound are found in museums around the world.

Ancient Life in Oklahoma *(continued)*

Figure 8. Prepared slab of numerous specimens of trilobite *Homotelus*. Slab is 6 inches long and 4 inches high.

➤ The trilobite *Homotelus* is found in great abundance in only a few layers of the Bromide Formation (Ordovician) in the Criner Hills of Carter County. Specimens occur by the thousands in seven distinct layers, each only a few inches thick. Museums and other collections from around the world prize these fossils. *(Fig. 8.)*

➤ Asphalt-impregnated limestone in the Deese Group (Pennsylvanian age) near Sulphur in Murray County contains some of the world's oldest fossils that retain their original shell material. Most fossils are imprints or casts of shells, or the original shell material, which consists of aragonite and magnesian calcite, has been replaced by another mineral. The Deese fossils are pristine, retaining their original iridescence.

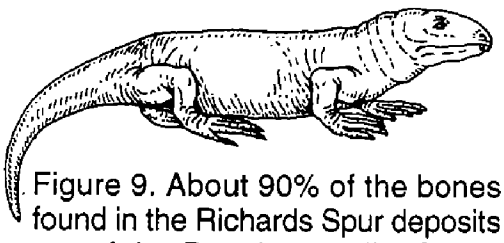

Figure 9. About 90% of the bones found in the Richards Spur deposits are of the Permian reptile *Captorhinus aguti*. This reconstruction is of a specimen about 1 foot long.

➤ The Dolese Brothers limestone quarry at Richards Spur in Comanche County contains the richest deposit of Early Permian reptile and amphibian fossils in Oklahoma, and is one of the richest in the world. The fossils occur in fissures and solution cavities in the Kindblade Limestone (Ordovician age); these openings in the rock were later filled with Early Permian sediment—and bones. *(Fig. 9.)*

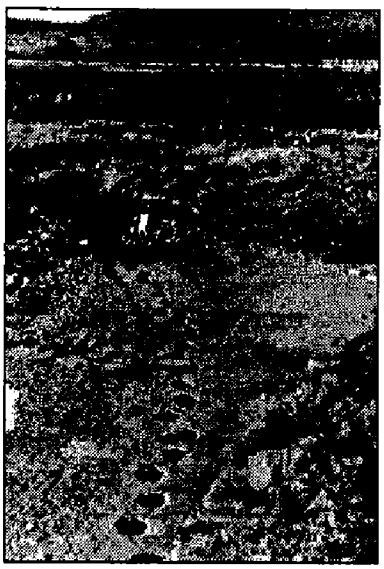

Figure 10. Tracks of a medium-sized ornithopod dinosaur near Kenton in Cimarron County.

➤ During the Mesozoic era (the "Age of Reptiles"), many kinds of dinosaurs roamed what is now Oklahoma. *Apatosaurus, Barosaurus, Camptosaurus, Diplodocus, Saurophaganax,* and *Stegosaurus* bones have been found near Black Mesa in Cimarron County. Other dinosaurs (described below) lived in southeastern Oklahoma.

➤ Just north of Kenton in Cimarron County, 28 fossil footprints of an ornithopod dinosaur can be seen preserved in sandstone of the Morrison Formation (Jurassic age). The dinosaur was probably about 6 feet tall at the hip and about 17 feet long. *(Fig. 10.)*

➤ One of the largest of all the Early Cretaceous carnivorous dinosaurs lived in what is now southeastern Oklahoma. *Acrocanthosaurus atokensis* ("high-spined lizard from Atoka") was first described in 1940 from two specimens found in the Antlers Formation (Early Cretaceous age) in Atoka County. The North Carolina State Museum of Natural Sciences paid $3 million for another, nearly complete, 40-foot-long skeleton of *Acrocanthosaurus* discovered near Eagletown in McCurtain County. A complete cast made from the original skeleton can be seen at the Goddard Children's Museum at Lake of the Arbuckles, in Murray County. *(Fig. 11.)*

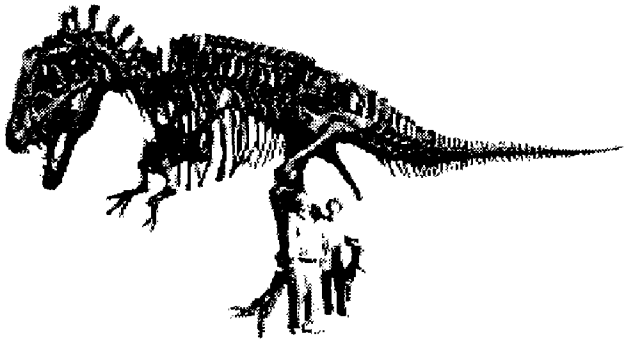

Figure 11. Skeleton of *Acrocanthosaurus*. Note the prominent spines that extend upward from the dinosaur's back.

➤ Bones of the raptor dinosaur *Deinonychus* were discovered with bones of its presumed prey, the ornithopod dinosaur *Tenontosaurus*, in the Antlers Formation in Atoka County. They are being excavated and studied by paleontologists from the Sam Noble Oklahoma Museum of Natural History in Norman. The lightly built, agile *Deinonychus* was a close relative of the velociraptors featured in the movie *Jurassic Park* and may have hunted in packs. *(Fig. 12.)*

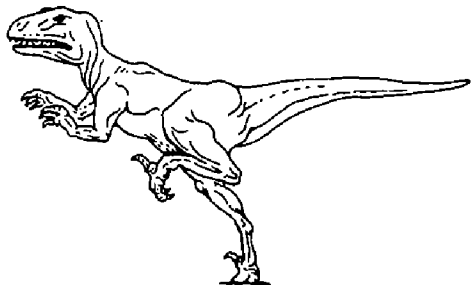

Figure 12. Reconstruction of *Deinonychus* ("terrible claw"). Adults were about 3 feet tall and nearly 10 feet long from head to tail.

➤ A fossil bed consisting almost entirely of Cretaceous-age ammonite fossils can be found around parts of Lake Texoma, in southern Oklahoma. These fossils, some as large as 2 feet in diameter, are popular with local collectors and look like giant snails. In fact, they are extinct cephalopods and are related to the squid, octopus, and chambered nautilus. The fossils are in the lower part of the Duck Creek Member of the Caddo Formation. *(Fig. 13.)*

Figure 13. Large ammonite *Eopachydiscus*, typical of those found along the shores of Lake Texoma.

➤ During Miocene time, Oklahoma was home to rhinoceroses, camels, ancient elephants, ground sloths, three-toed horses, bone-eating dogs (with hyena-like jaws), and saber-toothed cats. About the same time, alligators lived in present-day Beaver County. *(Fig. 14.)*

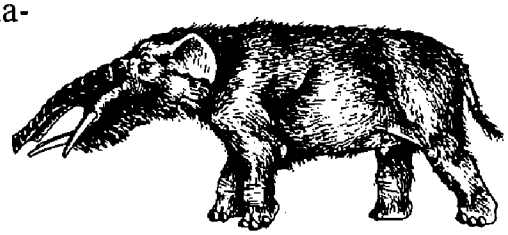

Figure 14. Reconstruction of the extinct gomphothere *Platybelodon*, an ancient elephant whose bones have been found in Beaver County.

did you know

Geological Resources of Oklahoma

ENERGY SOURCES

Coal

➤ Coal has been mined continuously on a commercial scale in eastern Oklahoma ever since the first reported production in 1873. Mining was begun primarily to fire the steam engines of railroad locomotives. At first, most of the coal was mined underground. Most miners were European immigrants, and many of their descendants still live in the coal belt of eastern Oklahoma. Today, almost all Oklahoma coal is strip-mined, with overlying soil and rock being removed by heavy earth-moving equipment. Only one mine, in Le Flore County, is still worked underground. *(Fig. 15.)*

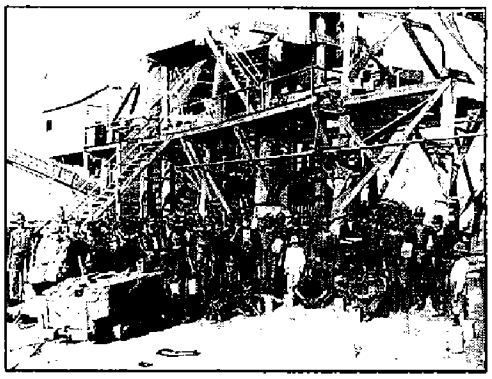

Figure 15. Coal miners pose in front of the head frame of a shaft to a coal mine in Indian Territory, 1902.

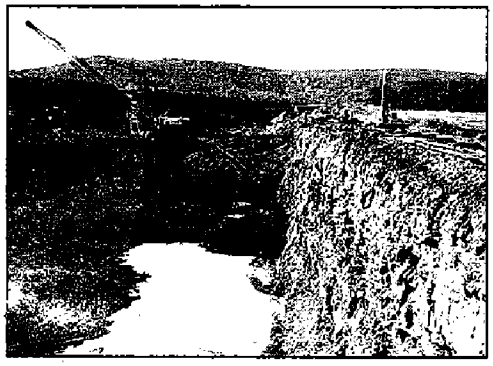

Figure 16. Wister coal mine in Le Flore County, with dragline, headwall, and drill rig used for drilling shotholes. This mine is typical of Oklahoma strip mines.

➤ Since 1873, about 275 million tons of coal has been produced in Oklahoma. For the past few years, about 1.7 million tons of bituminous coal has been mined annually in eastern Oklahoma and burned to generate electricity and to furnish process heat for industrial use. This is enough coal to supply more than 650,000 people with electricity. Oklahoma has about 1.6 billion tons of bituminous-coal reserves (reserves are the economically recoverable part of coal resources), of which about 342 million tons is available for surface mining. *(Fig. 16; also see map of nonpetroleum mineral resources, p. 19.)*

➤ About 70–80% of the electricity generated and used in Oklahoma now comes from six coal-burning power plants in the State. These plants burn a total of 20 million tons of coal per year. Almost 95% of the 20 million tons is shipped by rail from Wyoming because Wyoming coal contains less sulfur than Oklahoma coal and thus burns more cleanly. *(Fig. 17.)*

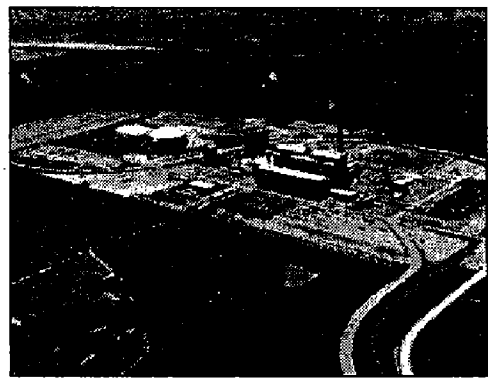

Figure 17. AES Shady Point coal-fired power plant near Poteau.

➤ Bituminous coal in Oklahoma is the source of a kind of natural gas known as coalbed methane. Since 1988, more than 700 wells have been drilled into Oklahoma coal beds to produce methane. (Coalbed methane is burned just like any other natural gas.)

Oil and Gas

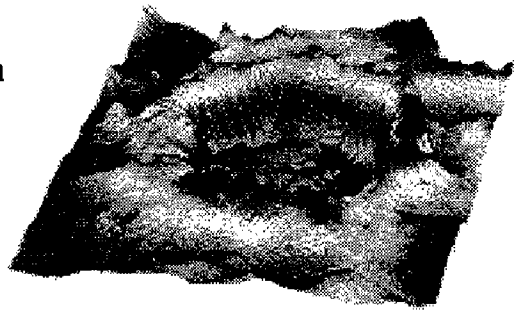

Figure 18. Three-dimensional, computer-generated illustration of the Ames structure, which now is deeply buried by sedimentary rocks.

- The Ames structure, in the Ringwood field, Major County, produces oil and gas from an ancient meteorite crater formed in Early Ordovician time. Much of the production is from rock shattered by the meteorite and later buried by 10,000 feet of sedimentary deposits. *(Fig. 18.)*

- In Oklahoma, a shallow oil or gas well, about 3,000 feet deep, can be drilled in a few days; a deep gas well, about 15,000 feet deep, takes 2 to 4 months to drill. A shallow well might cost about $150,000, and a deep well about $1.3 million. To drill and complete a very deep well (over 25,000 feet deep) would cost more than $10 million.

- Although many of Oklahoma's oil wells had an initial production of hundreds or even thousands of barrels of oil per day, the daily average for all producing wells is now about 2 barrels. That's because the original reservoir pressure that drives the oil in most fields has fallen as the oil and gas were produced; also, most of the mobile oil, the easiest to remove, has already been extracted.

- Since 1891, Oklahoma has produced about 14 billion barrels of oil and 83 trillion cubic feet of natural gas. Gasoline refined from that much oil would enable a car that averages 20 miles per gallon to make almost 22 million round trips to the Moon.

- More than 460,000 wells have been drilled for oil and gas in Oklahoma since 1915, the year the State began keeping records. (That total includes producing wells and dry holes.) If earlier wells are counted, the total probably would be closer to 500,000. At the end of 1998, there were about 88,000 producing oil wells and 30,000 producing gas wells. *(See map of oil and gas production, p. 19.)*

- Oil, coming from deep in the ground, must be discovered through long and costly exploration. Then it must be pumped, transported (sometimes half way around the world), and refined. Even after adding taxes, it still sells for about half of what we pay for bottled water in a grocery store.

Geological Resources of Oklahoma *(continued)*

INDUSTRIAL MINERALS

➤ In 1997, Oklahoma produced a number of industrial, or nonfuel, minerals worth about $411 million. Leading nonfuel commodities in 1997 were crushed stone (worth $134 million), portland and masonry cement ($131 million), sand and gravel ($33 million), glass sand ($27 million), iodine ($24 million), and gypsum ($18 million). *(See map of nonpetroleum mineral resources, p. 19.)*

➤ Oklahoma is the only state in the country producing iodine, an important constituent in animal feed, disinfectants, photography, and pharmaceuticals. In northwestern Oklahoma, three companies have drilled wells 7,000–10,000 feet deep and pumped out brine yielding nearly 3 million pounds of iodine annually, about 25% of all U.S. consumption. And in 1998, 10% of all the iodine produced in the world came from Oklahoma.

Figure 19. Gypsum quarry at Fletcher, Comanche County, operated by Temple-Inland Products Corporation.

➤ Gypsum, a mineral with many uses in agriculture, construction, food processing, and in the manufacture of pharmaceuticals, is an $18-million-per-year industry in Oklahoma. Gypsum resources in western Oklahoma are estimated at 48 billion tons, enough to supply the United States for 1,500 years at the present rate of consumption. *(Fig. 19.)*

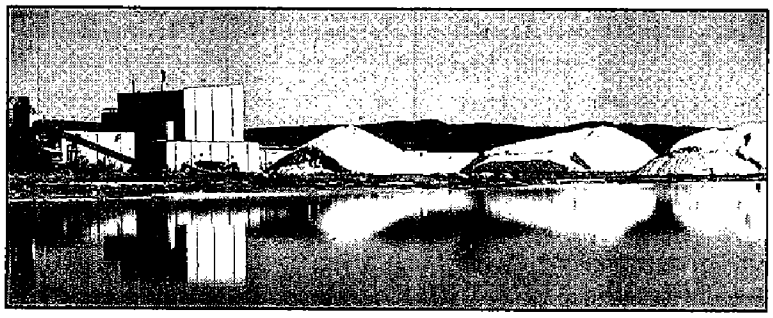

Figure 20. Cargill Salt Company salt-mining operation in northwest Oklahoma.

➤ Resources of common salt (NaCl) in western Oklahoma are estimated at more than 21 trillion tons, enough to meet the current rate of use in the United States for 500,000 years. Most of the salt occurs as buried geologic formations. About 200,000 tons of salt was produced in Oklahoma in 1998, all evaporated from brine in Woods County. *(Fig. 20.)*

➤ Volcanic ash was once mined for abrasives in Beaver, Hughes, and Okfuskee Counties. Some of the ash was blown by the wind from Mount Mazama (in Oregon, where only Crater Lake now remains of the volcano) and from volcanoes in Yellowstone National Park, Wyoming, and northern New Mexico. The volcanoes erupted thousands to hundreds of thousands of years ago.

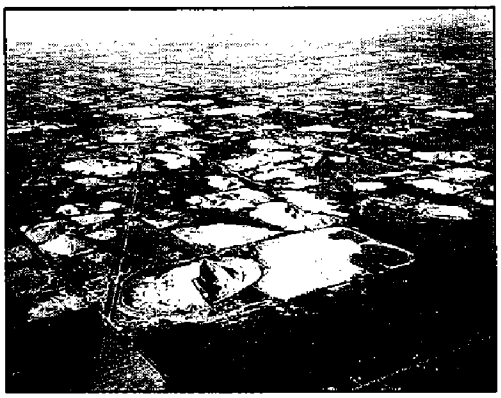

Figure 21. Aerial photograph of Picher mining district. Chat (waste) piles are now quarried for roadbed material.

METALS

➤ Almost every year from 1918 to 1945, Oklahoma led the country in zinc production. More than 5.2 million tons of zinc (and 1.3 million tons of lead) were produced from the Picher Field in Ottawa County from 1891, when mining began, to 1970, when operations ceased. Because about 20 pounds of zinc is used in every car, Oklahoma could have supplied the zinc for more than half a billion cars. *(Fig. 21.)*

Figure 22. Oblique aerial photograph looking northwest of Eagle-Picher copper strip mine at Creta. Highwall on left side of pit is about 40 ft high.

➤ Copper was mined in Oklahoma between 1965 and 1975. In that period Eagle-Picher Industries strip-mined its Creta copper deposit in Jackson County and produced more than 1.5 million tons of ore with an average grade of about 1.90% copper. The ore was chalcocite, a copper sulfide, which occurred in a shale bed 6 to 12 inches thick in the Flowerpot Shale (Permian age). *(Fig. 22.)*

➤ The Southwest Davis zinc field, in the Arbuckle Mountains in Murray County, was discovered by Gertrude Selma Sober. She began prospecting in 1907 and discovered the small field in 1909. Although her involvement in mining did not last long, she pursued other interests in geology and in 1933 received her B.S. degree from the University of Oklahoma at the age of 63. In 1988, Sober was inducted posthumously into the National Mining Hall of Fame in Leadville, Colorado. *(Fig. 23.)*

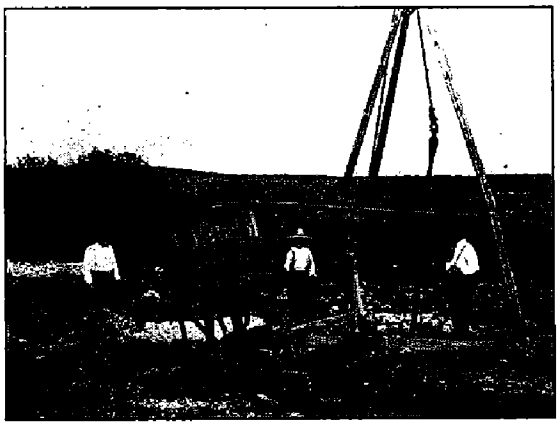

Figure 23. Cable-tool rig used to explore for zinc in the Southwest Davis zinc field. Gertrude Sober in center. Photo taken in 1909.

did you know

- The builders of Spiro Mounds in eastern Oklahoma (1,000–800 years ago) made paint by mixing clay or grease with galena (lead sulfide) for gray, with limonite (hydrated iron oxide) for yellow, malachite (hydrated copper carbonate) for green, hematite (iron oxide) for red, and azurite (another hydrated copper carbonate) for blue.

- As early as 1850, copper ore was mined near present-day Byars in McClain County, by Col. Randolph B. Marcy, the first person on record to trace the Red River to its source.

Figure 24. Rock Mary, landmark for emigrants traveling through Oklahoma during the California gold rush.

- Rock Mary, an isolated sandstone butte near Red Rock Canyon State Park in Caddo County, was a landmark for California-bound emigrants. Rock Mary was named in 1849 for 17-year-old Mary Conway, who was one of the emigrants and the daughter of a governor of Arkansas. The butte consists of Rush Springs Sandstone (Permian age), which also forms Red Rock Canyon. *(Fig. 24.)*

- The first well to produce oil in Oklahoma was drilled in 1859, but not to find oil. It was drilled in a search for salt at a saline spring on the Neosho River, probably near Salina, in Mayes County. It is said to have produced about 10 barrels of oil per day for about a year.

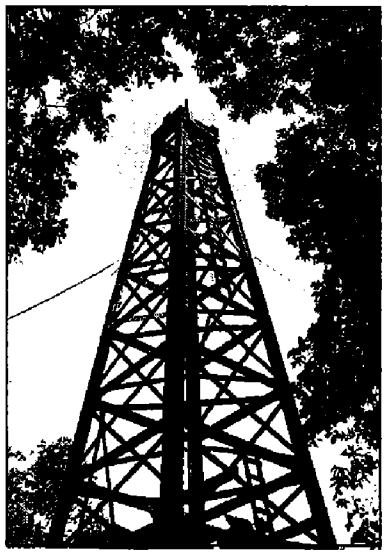

Fig. 25. Reconstruction of the No. 1 Nellie Johnstone well near Bartlesville.

- The first well specifically seeking oil in Oklahoma was drilled in 1872 near an oil seep (an "oil spring") in the Cherokee Nation; its exact location is unknown. Two other exploratory wells were drilled (also near oil seeps) in 1883 on Clear Boggy Creek near Atoka, Atoka County, and in 1886 near Chelsea, Rogers County. These recovered sub-commercial quantities of oil, the Atoka well in 1888 and the Chelsea well in 1889. The small amount of oil they produced commonly was used by local ranchers as tick-dip.

- The first commercial oil well in Oklahoma was the No. 1 Nellie Johnstone, drilled in 1897 on the banks of the Caney River near Bartlesville, Washington County. However, commercial production did not begin until 1904, when transport to markets became feasible. *(Fig. 25.)*

- By 1906, Tulsa was known as the Oil Capital of the World. In 1909, more than 300 oil companies were chartered in Oklahoma.

- Oklahoma produced more oil than any other state in the country from 1907 (the year of statehood) to 1923. In 1927, oil production in Oklahoma reached an all-time annual high of 278 million barrels.

- In 1913, Henry Kendall College (now Tulsa University) offered the first petroleum geology course in the Midcontinent. In 1915, the University of Oklahoma offered its first course in petroleum geology.

- Some of the largest and most widely known oil and gas companies had their beginnings in Oklahoma, including Champlin Petroleum Company, Cities Service Company, Continental Oil Company (Conoco), Kerr-McGee Corporation, Phillips Petroleum Company, Sinclair Oil and Gas Company, and Skelly Oil Company.

- A graduate of the University of Oklahoma developed the seismic-reflection method, which is one of the most valued techniques in petroleum exploration today. John Clarence Karcher formed a small company that first tested his method in 1921 near Belle Isle in Oklahoma City. His first company failed, but through his efforts a second company, Geophysical Services, Inc., continued to refine the method. This second company led to another, called Texas Instruments. *(Fig. 26.)*

Figure 26. Monument near Belle Isle reads "Birthplace of the Reflection Seismograph. Field tests which confirmed the validity of the reflection seismograph method of prospecting for oil were conducted near this spot on June 4, 1921. The shot has virtually echoed around the world. This monument was erected on the golden anniversary, 1921–1971, by the Geophysical Society of Oklahoma City to commemorate the event."

- The largest professional organization for petroleum geologists in the world, the American Association of Petroleum Geologists (AAPG), was founded in Oklahoma. Members first met formally in Norman in 1916; the headquarters office has been in Tulsa since 1926. *(Fig. 27.)*

Figure 27. Headquarters of the American Association of Petroleum Geologists in Tulsa.

- In 1930, during the early years of the Oklahoma City oil field, the drilling of a well later called the "Wild Mary Sudick" encountered very high pressure that resulted in a blow out. Oil was blown into the air and carried by the wind as far as Norman, about 12 miles away.

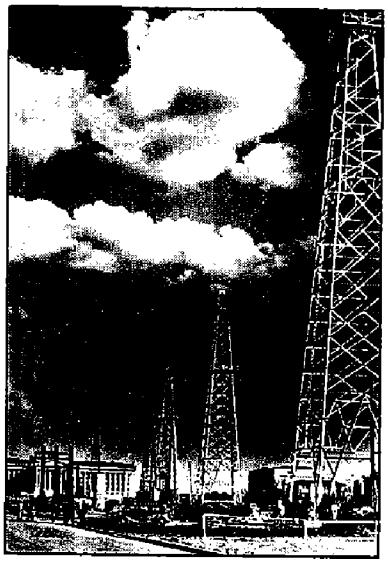

Figure 28. Oil derricks in front of the Capitol Building.

Figure 29. U.S. oil-field crew in England breaking for tea, early 1940s.

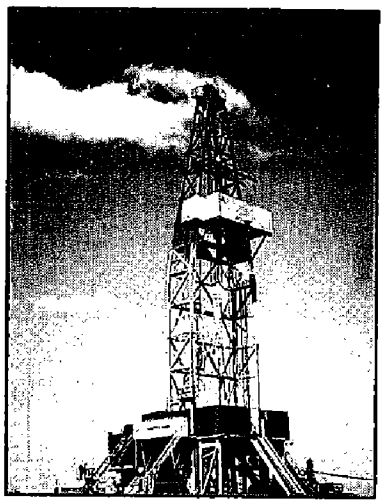

Figure 30. Drilling rig for the Lone Star No. 1 Bertha Rogers well, Washita County.

- Oklahoma's State Capitol is the only one in the country that once had producing oil wells on its grounds. The wells are now inactive. *(Fig. 28.)*
- Noble Drilling Company, of Ardmore, Carter County, was instrumental in developing an oil field in the legendary Sherwood Forest in England in the early 1940s. It was a significant contribution to the defense of Britain during World War II, because aviation fuel was badly needed for fighter planes of the Royal Air Force. Drilling crews worked in near-darkness at night because of the blackout. They also had to live on 1,200 calories a day, because food was scarce. *(Fig. 29.)*
- The deepest well ever drilled anywhere for oil and gas is in Washita County. It is the Lone Star Producing Company No. 1 Bertha Rogers. On April 13, 1974, drillers reached a total depth of 31,441 feet, only 239 feet short of 6 miles. The temperature at that depth was so high that sulfur in liquid form occurred at the bottom of the well. (It solidified as it circulated out of the hole.) The total cost of the well was $5.9 million (in 1974 dollars) and it took almost 2 years to drill and complete. The well discovered gas at 13,000 feet. *(Fig. 30.)*
- The second deepest natural-gas producing well in the world is the Leede Oil and Gas Company No. 1-29 McCall, in Beckham County. It was completed in 1985, producing gas from the Henryhouse Formation (Late Silurian age) at a depth of 24,763 feet to 25,000 feet. (The deepest gas producer in the world is in Pecos County, Texas.)
- The Kinta natural gas field is about 70 miles long and extends across five counties—Haskell, Latimer, Le Flore, Pittsburg, and Sequoyah. *(See map of oil and gas production, p. 19.)*
- The greatest number of well completions in Oklahoma was achieved in 1982, when 12,012 wells began producing oil or gas or both. Large numbers of wells in the State were completed in the "oil boom" years of the 1970s and early 1980s. Before that time, the highest number of well completions was in 1913, at 9,131, during Oklahoma's original "Black Gold Era" (1908–1928).

- Oklahoma has deposits of solid hydrocarbons, which are rare in the geologic record. Most of them are in the Ouachita Mountains. They occur as veins formed when oil filled fractures in the rock and later turned into a solid that looks like coal. One solid hydrocarbon, impsonite, is named for Impson Valley in western Pushmataha County. Near Page, in Le Flore County, impsonite was mined for fuel before 1911, and during World War I it was burned to recover vanadium from the ash. (Vanadium is used in making steel.) *(Fig. 31.)*

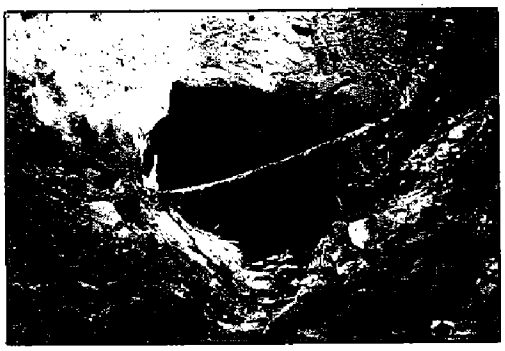

Figure 31. The Page impsonite mine in 1945.

- In 1915, the University of Oklahoma had the largest class in paleontology in the United States, taught in the attic of Old Science Hall.

- Between 1935 and 1942, John W. Stovall, then director of the Oklahoma Museum of Natural History, in Norman, opened 17 dinosaur-bone quarries near Black Mesa in Cimarron County under the Works Progress Administration (later the Works Project Administration). About 6,000 bones were collected from those quarries, all in the Morrison Formation (Jurassic). Many of the bones are only now being properly curated and studied, and among them new species are being discovered. One of the quarries can be visited near Oklahoma Highway 325, about 8 miles east of Kenton. *(Fig. 32.)*

Figure 32. John W. Stovall (1891–1953) examining a fossil *Tenontosaurus* skull.

- The deepest coal mined in Oklahoma came from the Carbon No. 5 mine east of McAlester, in Pittsburg County. The coal, 1,600 feet below the surface, was produced in the early 1960s.

Earthquakes in Oklahoma

did you know

- The earliest well-documented Oklahoma earthquake occurred near present-day Jefferson, Grant County, in 1897.

- Oklahoma counties with the most earthquakes recorded during 1977 through 1998 were Garvin (290), Grady (188), McClain (125), and Canadian (82). Fourteen Oklahoma counties had only one or two earthquakes, and Washington, Nowata, Jackson, Craig, Cimarron, and Adair Counties had none.

Earthquakes in Oklahoma *(continued)*

➤ In the 22 years from 1977 through 1998, the Oklahoma Geological Survey detected and located 1,429 earthquakes in the State. Of those, 67 were felt by Oklahomans. In 1997, an earthquake of magnitude 4.4 was felt from Durant (Bryan County) to Spavinaw (Mayes County). Another, of magnitude 4.2, occurred in 1998 and was felt from Pawnee (Pawnee County) to North Dallas, Texas.

Figure 33. Front-page headline from the *Norman Transcript*, April 9, 1952.

➤ The largest (magnitude 5.5) well-documented earthquake centered in Oklahoma was felt throughout the State and in parts of seven others. It occurred on April 9, 1952, and is known as the El Reno earthquake for its epicenter in Canadian County. It caused a 50-foot-long crack in the State Capitol Office Building in Oklahoma City. An earthquake of similar magnitude occurred in the Indian Territory in 1882. *(Fig. 33).*

Figure 34. Meers fault scarp (escarpment). View looking north.

➤ One of the best examples of a Recent fault (with movement in the last 10,000 years) east of the Rocky Mountains is found in Oklahoma. It is the Meers fault, which is exposed in northern Comanche County for about 18 miles. The maximum relief along the fault is 15 feet. Movement along the fault last occurred about 1,100 to 1,500 years ago. *(Fig. 34).*

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FIGURE CREDITS

1. Modified from Arbenz, J. K., 1989, The Ouachita system, *in* Bally, A. W.; and Palmer, A. R. (eds.), The geology of North America—an overview: Geological Society of America, Boulder, Colorado, The Geology of North America, v. A, p. 372.
2. Kenneth S. Johnson, Oklahoma Geological Survey.
3. Neil H. Suneson, Oklahoma Geological Survey.
4. Fred W. Marvel, Oklahoma Department of Tourism and Recreation.
5. David London, School of Geology and Geophysics, University of Oklahoma.
6. Photograph—From Babcock, L. E., 1996, Chapter 8, Phylum Arthropoda, Class Trilobita, *in* Feldman, R. M. (ed.), Fossils of Ohio: Ohio Department of Natural Resources, Division of Geological Survey, Bulletin 70, fig. 8-3.5, p. 107. Line drawing—From Easton, W. H., 1960, Invertebrate paleontology: Harper and Row, New York, fig. 12.12.3, p. 512. With permission.
7. Keith A. Catto, Jr., Oklahoma Geological Survey.
8. A. Allen Graffham, Geological Enterprises, Inc.
9. Coral McCallister, Department of Zoology, University of Oklahoma.
10. From Conard, Kelly; Lockley, M. G.; and Prince, N. K., 1987, Triassic and Jurassic vertebrate-dominated trace fossil assemblages of the Cimarron Valley region: implications for paleoecology and biostratigraphy, *in* Lucas, S. G.; and Hunt, A. P. (eds.), Northeastern New Mexico: New Mexico Geological Society Guidebook, 38th field conference, fig. 12, p. 135. With permission.
11. A. Allen Graffham, Geological Enterprises, Inc.
12. Coral McCallister, Department of Zoology, University of Oklahoma.
13. From Kennedy, W. J.; Wright, C. W.; and Chancellor, G. R., 1983, The Cretaceous ammonite *Eopachydiscus* and the origin of Pachydiscidae: Paleontology, v. 26, pt. 3, pl. 68, figs. 10 and 11, p. 659. With permission.
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19–22. Kenneth S. Johnson, Oklahoma Geological Survey.

23. Courtesy Western History Collections, University of Oklahoma Libraries.

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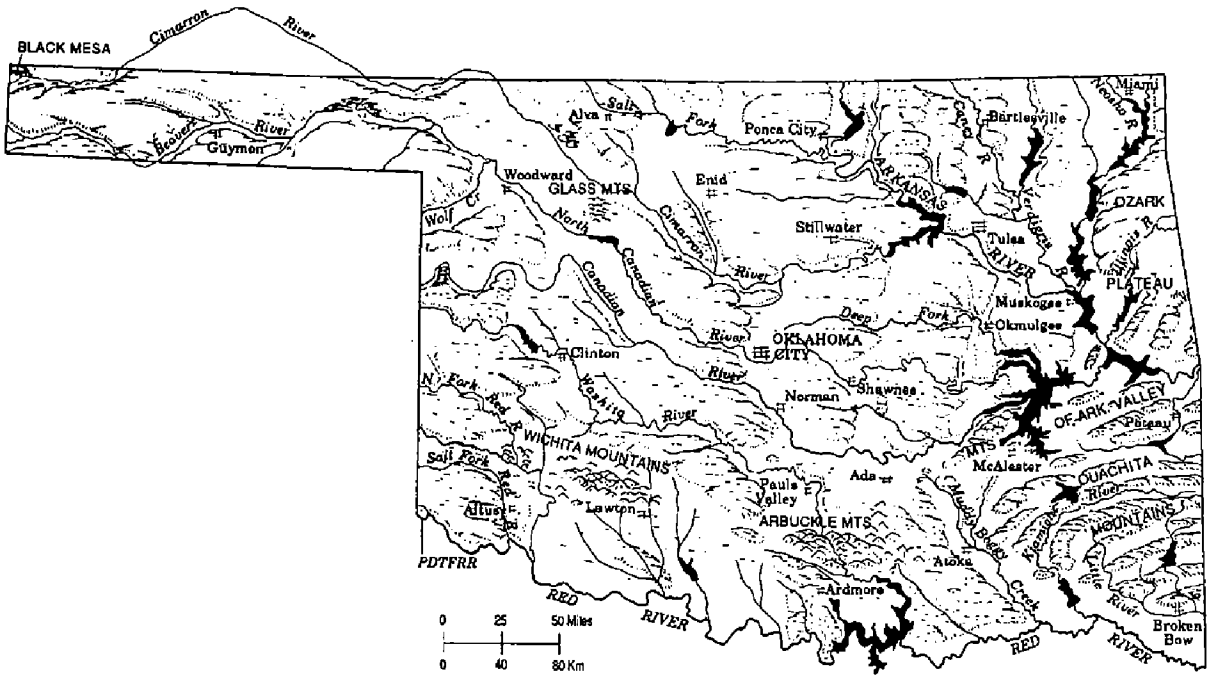
26. Kenneth S. Johnson, Oklahoma Geological Survey.
27. Courtesy American Association of Petroleum Geologists.
28. Courtesy Western History Collections, University of Oklahoma Libraries.
29. From Woodward, G. H.; and Woodward, G. S., The Secret of Sherwood Forest: University of Oklahoma Press, Norman, p. 156. Photo courtesy BP-Amoco, Inc.
30. Kenneth S. Johnson, Oklahoma Geological Survey.
31. M. C. Oakes and J. O. Beach, courtesy Western History Collections, University of Oklahoma Libraries.
32. Courtesy Sam Noble Oklahoma Museum of Natural History, University of Oklahoma.
33. Norman Transcript, April 9, 1952, p. 1, top headline.
34. Kenneth V. Luza, Oklahoma Geological Survey.

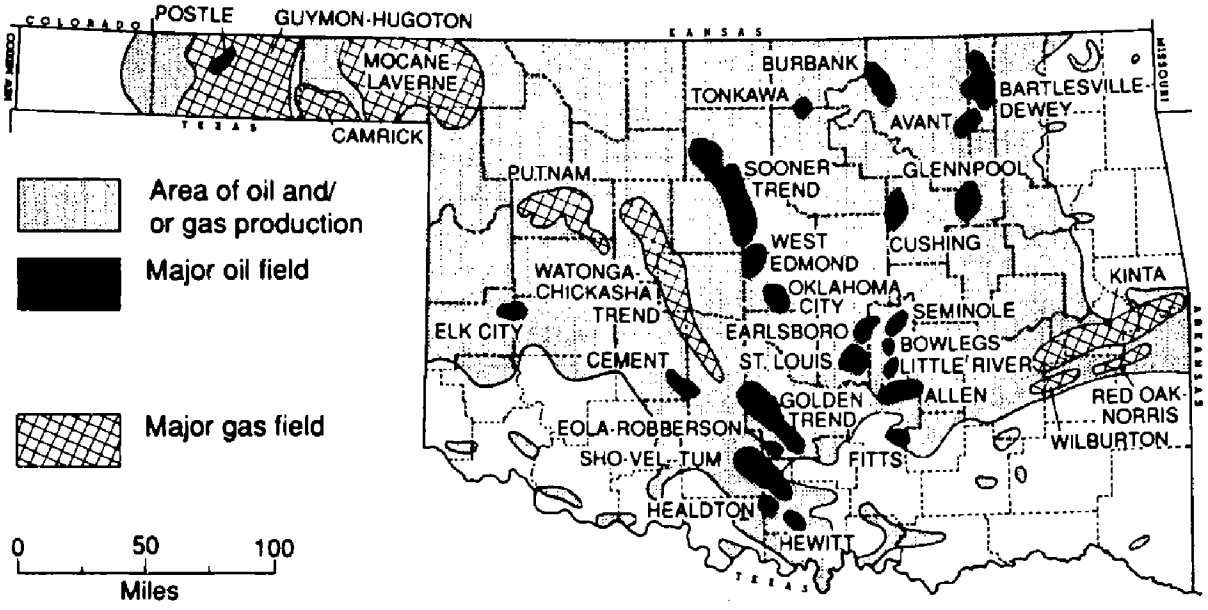
Helpful Maps

Counties of Oklahoma

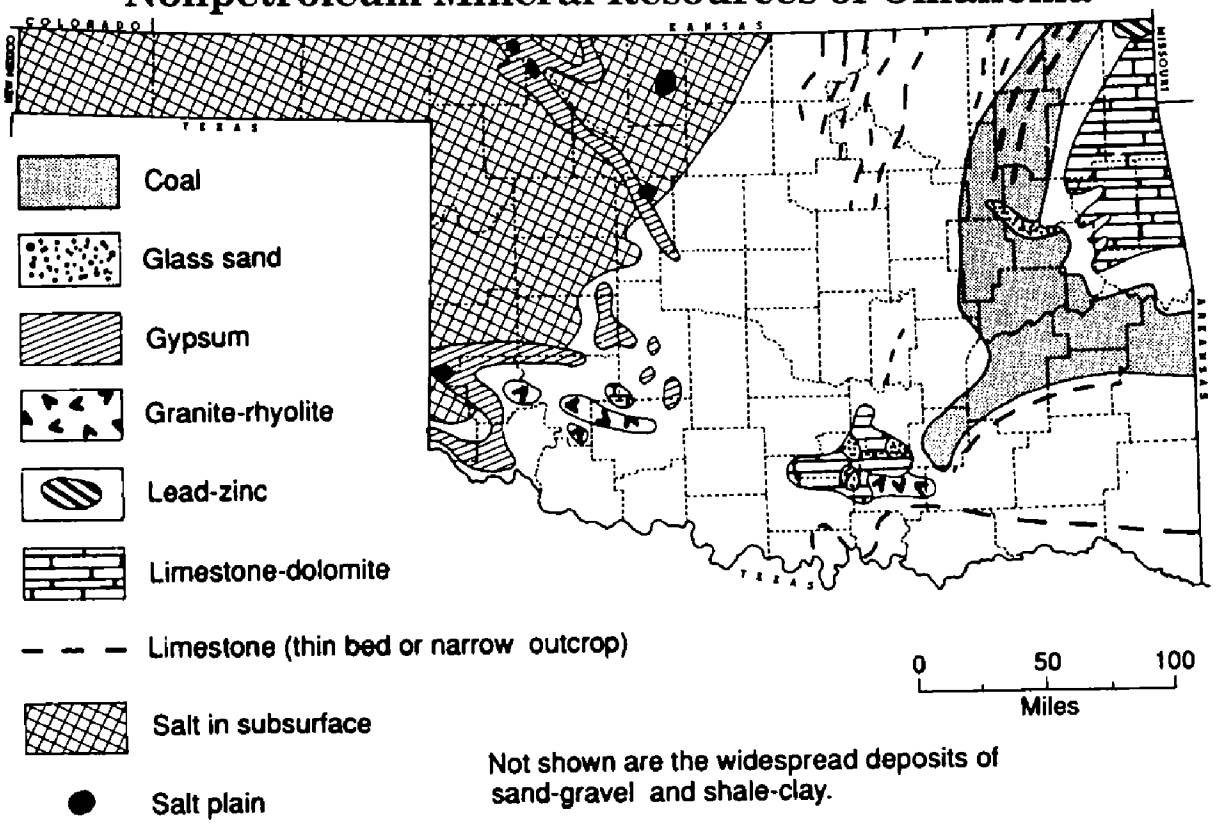
Landforms of Oklahoma



Major Oil and Gas Fields of Oklahoma and Areas of Lesser Petroleum Production



Nonpetroleum Mineral Resources of Oklahoma



Not shown are the widespread deposits of sand-gravel and shale-clay.

Generalized Geological Time Scale

did you know

DIVISIONS OF GEOLOGIC TIME				Age (approx.) in millions of years
Eon	Era	Period	Epoch	
Phanerozoic	Cenozoic	Quaternary	Holocene	0.010
			Pleistocene	1.6
		Tertiary	Pliocene	5
			Miocene	23
			Oligocene	35
			Eocene	57
			Paleocene	65
	Mesozoic	Cretaceous	Late	97
			Early	146
		Jurassic	Late	157
			Middle	178
			Early	208
		Triassic	Late	235
			Middle	241
			Early	245
	Paleozoic	Permian	Late	256
			Early	290
		Carboniferous: Pennsylvanian	Late	303
			Middle	311
			Early	323
		Carboniferous: Mississippian	Late	345
			Early	363
		Devonian	Late	377
			Middle	386
			Early	409
		Silurian	Late	424
			Early	439
		Ordovician	Late	464
			Middle	476
			Early	510
		Cambrian	Late	517
			Middle	536
			Early	570