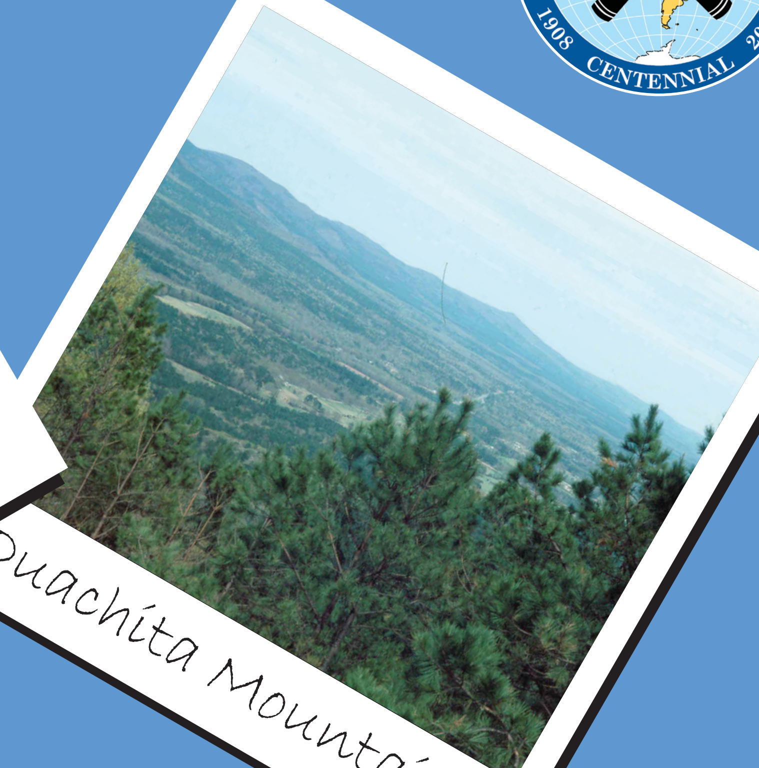
Educational Publication 9
Oklahoma Geological Survey
G. Randy Keller, *Interim Director*

EARTH SCIENCES AND MINERAL RESOURCES OF OKLAHOMA


Alabaster Caverns


Chimney Rock


Gypsum sinkhole


Ouachita Mountains


Gypsum mine


Pumpjack


Copper mill at Creta


Lady Cave

EARTH SCIENCES AND MINERAL RESOURCES OF OKLAHOMA

Kenneth S. Johnson and Kenneth V. Luza, *Editors*

2008

Front Cover:

Photo	County location
Alabaster Caverns	Woodward
Chimney Rock	Woodward
Gypsum sinkhole	Harper
Ouachita Mountains	Le Flore
Gypsum mine	Comanche
Pumpjack	Oklahoma
Copper mill at Creta	Jackson
Lady Cave	Washita

Back Cover:

Glass Mountains	Major
Sprinkler irrigation	Caddo
Granite in Witchitas	Comanche
Limestone in Arbuckles	Murray
Tombstone topography	Carter
Lake Altus	Greer
Solar-salt pans	Woods
Turner Falls	Murray
Glass sands	Johnston
Hennessey Shale	Cleveland

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and sediments) and by lack of a subsoil. Typically these soils are on recently flooded river bottoms or eroded areas that are shallow over rock.

Eolian—Pertaining to the wind; especially said of sediments modified or deposited by the wind.

Epicenter—The point on the earth's surface directly above the focus (hypocenter) of an earthquake.

Era—A large division of geologic time consisting of two or more geologic periods.

Erosion—The natural processes of weathering, disintegration, dissolving, and removal of rock and earth material, mainly by water and wind.

Focus—The point within the earth at which the first motion of an earthquake originates (same as hypocenter).

Fossil—Remains or traces of a prehistoric animal or plant.

Gabbro—A dark-colored, coarse-grained igneous rock formed from magma that cooled beneath the earth's surface. Oklahoma gabbros are dark gray or black.

Geology—The study of the earth, including its structure, history, landforms, and resources.

Geomorphic province—A large region of similar landforms, resulting from erosion of rocks and/or deposition of sediments that are somewhat uniform in nature and structure.

Glass sand—High-purity quartz sand suitable as a raw material in manufacturing glass.

Granite—A light-colored, coarse-grained igneous rock formed from magma that cooled beneath the earth's surface. Oklahoma granites are mostly light gray, pink, red, and brown.

Gypsum—A sedimentary rock consisting of the mineral gypsum, $CaSO_4 \cdot 2H_2O$, formed by chemical precipitation from evaporating sea water.

Hogback—A sharp ridge formed by layers of hard rock that dip steeply downward.

Hydrocarbon—Any gaseous, liquid, or solid organic compound consisting solely of carbon and hydrogen. See crude oil, natural gas, and petroleum.

Hypocenter—Same as "focus."

Igneous rock—Rock formed by cooling and solidification of hot molten material called magma. Magma that flows onto the earth's surface (lava) cools rapidly to form fine-grained rocks, whereas magma that solidifies several miles beneath the surface cools slowly to form coarse-grained rocks.

Inceptisols—Soil order identified by subsoil texture, color, and structure that are very similar to surface layers. Surface and subsoil properties are similar to physical and chemical properties of the parent rock and sediments from which the soil formed.

Karst—A type of topography that is formed when limestone, gypsum, and other water-soluble rocks are dissolved to produce sinkholes, caves, and underground drainage.

Lignite—A brownish-black, low-grade coal.

Limestone—A sedimentary rock consisting mostly of the mineral calcite, $CaCO_3$, formed mainly from lime muds and fossil fragments.

Loam—Soil material that is 7–27% clay particles, 28–50% silt particles, and less than 52% sand particles.

Magma—Molten rock material generated within the earth.

Marine—Refers to sediments deposited in sea water.

Metamorphic rock—Rock that has been changed through intense heat, high pressures, or contact with chemically active fluids from magma.

Mineral spirits—Alcohol-based petrochemical commonly used as a solvent.

Mollisols—Soil order identified by a surface (A) layer with 1% or more organic matter content 10 or more inches thick formed beneath a prairie. Soils usually have a neutral to basic pH (greater than or equal to 7).

Motte—A cluster of trees in a prairie.

Natural gas—Hydrocarbons that exist as a gas at surface temperature and pressure.

Nonmarine—Refers to sediments deposited on land or in lakes, streams, swamps, or deltas.

Organic compounds—Material derived from living, or once living, organisms. In discussions about oil and gas, the term usually refers to such material buried in sedimentary rocks.

Period—One of the fundamental units of geologic time into which earth history is divided. A period is a subdivision of an era.

Permeable—Capable of transmitting a fluid.

Petroleum—Hydrocarbons that exist as a liquid at surface temperature and pressure.

Precipitation—Any form of water particles, such as rain, snow, hail, and/or sleet, that falls from the atmosphere and reaches the ground.

Rhyolite—Light-colored, fine-grained igneous rock (magma) formed from lava that flowed onto the surface of the earth. Oklahoma rhyolites are pink, red, or brown.

Salt—A sedimentary rock consisting of the mineral halite, NaCl, formed by chemical precipitation from evaporating sea water.

Sandstone—A sedimentary rock consisting of sand grains (mostly quartz) cemented together.

Sedimentary rock—Rock formed by the compaction and cementing of sediments deposited in water or from air. Sediments may consist of rock or mineral fragments of various sizes (mud, sand, gravel), the remains of animals or plants, the products of chemical action or evaporation, or mixtures of these materials. Sedimentary rocks typically have a layered structure known as bedding or stratification.

Shale—A sedimentary rock formed from mud and clays.

Shrink-swell potential—The shrinking of soil when dry and swelling when wet.

Soil—A natural, three-dimensional body at the earth's surface. It is capable of supporting plants and has properties resulting from the integrated effect of climate and living matter acting on the earthy parent material, as conditioned by relief over periods of time.

Soil horizon—A layer of soil, approximately parallel to the surface, having distinct characteristics produced by soil-forming processes.

Soil order—The highest (most general) level in the current soil-classification system. Orders identify groups of soils with similar major properties.

Soil profile—A vertical section of the soil extending through all its horizons and into the parent material.

Soil series—A group of soils that have profiles that are almost alike, except for differences in the texture of the surface layer or of the underlying material. All the soils of a series have horizons that are similar in composition, thickness, and arrangement.

Temperature—The degree of hotness or coldness as measured on some definite temperature scale.

Terrace deposit—An old alluvial deposit near, but above, the present-day flood plain of a river.

Tornado—A violently rotating column of air protruding from a cumulonimbus cloud and in contact with the ground; a condensation funnel does not need to reach to the ground for a tornado to be present.

Tripoli—A lightweight form of silica rock used for its abrasive and absorbent properties.

Ultisols—Soil order identified by increasing clay content with increasing soil depth. Subsoil is acidic and contains enough iron (Fe) oxides to impart a red color. Soil is formed beneath a forest.

Unconformity—A substantial break or gap in the geologic record, usually formed by nondeposition or by uplift and erosion of previously deposited rocks and sediments.

Vertisols—Soil order identified by a very high content of shrink-swell clays. These clayey soils, which expand and contract under varying water content, pose many problems for such land use as tillage and roadway and building construction.

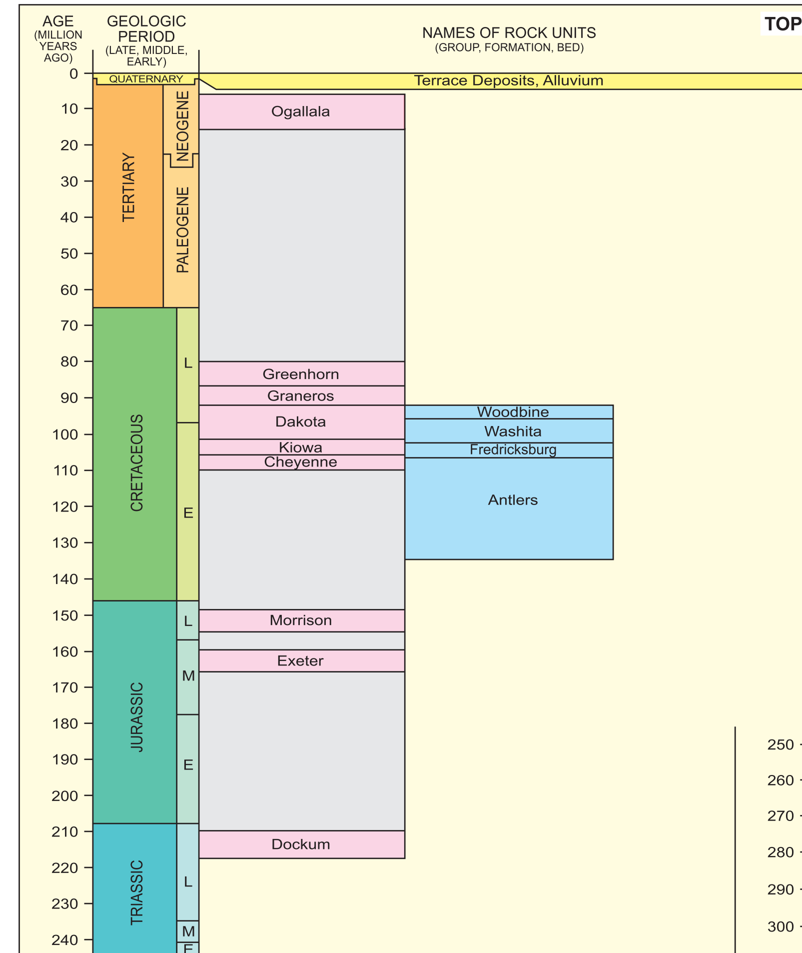
Volcanic ash—Accumulations of glasslike dust ejected from volcanoes. The principal sources of Oklahoma volcanic ash were once-active volcanoes in New Mexico, California, and Wyoming.

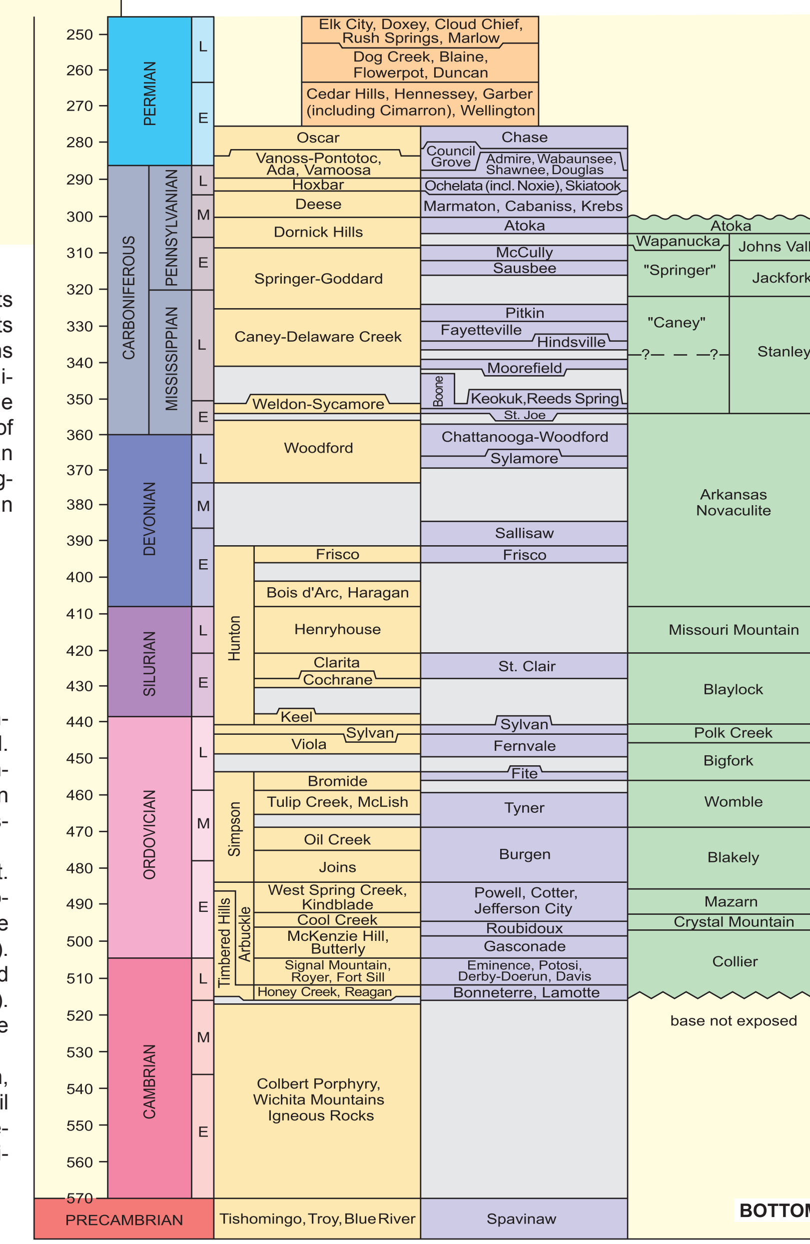
GENERALIZED STRATIGRAPHIC COLUMN OF PRINCIPAL OUTCROP UNITS IN OKLAHOMA

EXPLANATION

(Color Shows Province Where Rocks Crop Out)

- Panhandle and northwestern Oklahoma
- Gulf Coastal Plain
- Anadarko Basin, Anadarko Shelf, southwestern Oklahoma
- Wichita Uplift, Ardmore Basin, Arbuckle Uplift, southern Cherokee Platform
- Ozark Uplift, northern Cherokee Platform, Arkoma Basin
- Ouachita Uplift





Prepared by Neil H. Suneson

Figure 35. The generalized stratigraphic column shows selected rock units of Oklahoma. Ages of geologic-time periods are approximate. Rock units separated by commas show the youngest first; rock units with hyphens are indefinite or interchangeable. Shaded areas represent unconformities. Row or column height does not indicate thickness of rock units. The reader may refer to Figure 1 that illustrates the major geologic provinces of Oklahoma. Sources used to compile the stratigraphic column are Huffman (1958), Zeller (1968), Sutherland and Manger (1979), Bingham and Bergman (1980), Hills and Kottlowski (1983), Lucas and others (1987), Mankin (1987), and Arbenz (1989).

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Over a 20-year period of planning and preparing the publication, we depended on many individuals and their contributions. If we fail to mention them specifically, their omission from these acknowledgements was not our intention. Their contributions were no less significant than those mentioned above.

OKLAHOMA GEOLOGICAL SURVEY
1908 CENTENNIAL 2008

EARTH SCIENCES AND MINERAL RESOURCES OF OKLAHOMA

INTRODUCTION

Kenneth S. Johnson, Oklahoma Geological Survey

Oklahoma is a region of complex and fascinating geology with a multitude of natural resources that originated from geologic processes acting over millions of years of Earth history (see Table 1). Several major sedimentary basins, set among mountain ranges and uplifts, lie beneath the State's surface (Fig. 1). Historically, classic studies of many areas in Oklahoma helped to develop fundamental scientific and engineering principles, including those involved in geology, petroleum exploration, and mineral production. The State has advanced-research programs in hydrology, soil science, and climatology, as well as a comprehensive network for monitoring earthquakes.

The topographic map of Oklahoma on page 2 shows mountains, plains, streams, and lakes, as well as spot elevations above sea level of different parts of the State.

Hundreds of millions of years ago, geologic forces within the Earth's crust caused parts of Oklahoma to subside forming major sedimentary basins, while adjacent areas were folded and thrust upward forming major mountain uplifts. Most outcrops in Oklahoma are sedimentary rocks, consisting mainly of shale, sandstone, and limestone; outcrops of igneous and metamorphic rocks, such as granite, rhyolite, gabbro, and gneiss, occur mostly in the Wichita and Arbuckle Mountains. The geologic history of Oklahoma is discussed on pages 3–5, and its present-day geologic map and cross sections are on pages 6 and 7.

Oklahoma's land surface has 27 geomorphic provinces. Each has a similar geologic character, with rocks that underwent a similar geologic history. Weathering and erosion have shaped rocks in these geomorphic provinces into landforms that are described on page 8.

Oklahoma is not known for its earthquake activity, as are California and other western states. However, about 50 earthquakes were detected in Oklahoma every year since 1977, when seismograph stations were installed to monitor low-intensity tremors. Commonly, only one or two earthquakes are strong enough to be felt locally by citizens; the others are detected by Oklahoma's network of 10 seismograph stations. The earthquake history of Oklahoma is told on page 9.

Oklahoma has abundant mineral resources that include petroleum (crude oil and natural gas), coal, and nonfuel minerals (such as limestone, crushed stone, sand and gravel, iodine, glass sand, gypsum, and shale). The value of petroleum, coal, and nonfuel minerals production reached $11.99 billion in 2004 (latest available data), making the mineral industry the State's largest source of revenue in recent years. Oklahoma's nonfuel resources and coal are discussed on page 10, and its petroleum resources are discussed on page 11.

Water resources in Oklahoma consist of surface water and ground water. Surface waters, shown on page 12, are streams and lakes supplied mainly by precipitation, and locally by springs and seeps. In most parts of Oklahoma, surface water and precipitation percolate down into the ground recharging major aquifers, and saturating other sediments and rock units. Page 13 describes the ground-water resources of Oklahoma. Outlines of stream systems or drainage basins, used for improving the management of Oklahoma surface-water resources, are shown on page 14.

Natural and man-made geologic hazards in Oklahoma are discussed on page 15. In Oklahoma, natural geological processes or conditions that can cause hazardous conditions or environmental problems include earthquakes, landslides, radon, expansive soils, floods, karst features, and salt dissolution/salt springs; some human activities that may create geological hazards include underground mining, strip mining, and disposal of industrial wastes.

The soils and vegetation of Oklahoma depend on local geology and climate; soils develop as parent material (that is, underlying rocks or sediments) is altered by climate, plants and animals, topographic relief, and time. Weathering of parent material helps develop soils shown on page 16. Soil characteristics and climate largely control the types of native vegetation that grow in various parts of Oklahoma (page 17).

Climate conditions in Oklahoma—including temperature and precipitation—and some other Oklahoma weather facts are shown on pages 18 and 19. Violent storms and tornadoes are common in Oklahoma, especially in the spring. Information about Oklahoma tornadoes is presented on page 19.

Finally, a glossary of selected terms and a list of references are given on pages 20 and 21, and a generalized stratigraphic column (Fig. 35) of outcropping rocks is represented on page 21.

Table 1. Geologic Time Scale Compared to a Calendar Year

GEOLOGIC ERA	GEOLOGIC PERIOD	BEGINNING (m.y.a.[1])	COMPARATIVE DATE* DAY	HR	MIN
Cenozoic ("Recent Life")	Quaternary	1.6	December 31	20	53
	Tertiary	65	December 26	17	28
Mesozoic ("Middle Life")	Cretaceous	146	December 20	3	47
	Jurassic	208	December 15	3	6
	Triassic	245	December 12	3	4
Paleozoic ("Ancient Life")	Permian	286	December 8	11	28
	Pennsylvanian	320	December 5	19	14
	Mississippian	360	December 2	13	22
	Devonian	409	November 28	19	49
	Silurian	439	November 26	9	25
	Ordovician	504	November 20	15	12
	Cambrian	570	November 15	18	24
Precambrian		4,500	January 1	0	0

m.y.a.[1] = million years ago. Dates are approximate.
*Prepared by Neil H. Suneson.

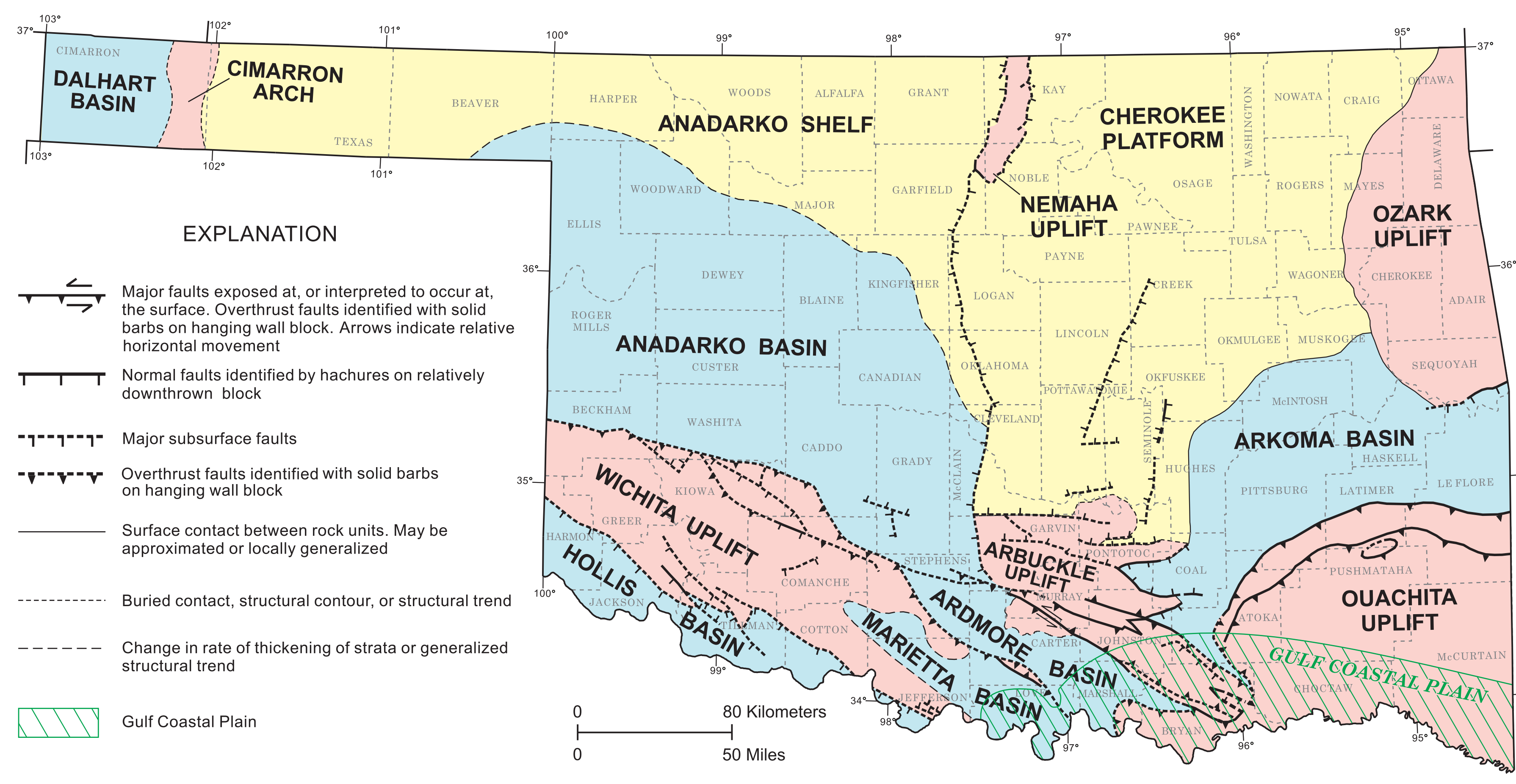

Figure 1. Major geologic provinces of Oklahoma (modified from Northcutt and Campbell, 1995) resulted from tectonic uplift and downwarping of the Earth's crust, mainly during the Pennsylvanian Period. Most province boundaries are structural features. Oklahoma is separated into six major uplifts (Ozark, Nemaha, Ouachita Mountain, Arbuckle, Wichita, and Cimarron) and six major basins (Arkoma, Anadarko, Ardmore, Marietta, Hollis, and Dalhart), and contains three areas of gently dipping strata (Anadarko Shelf, Cherokee Platform, and Gulf Coastal Plain).

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GLOSSARY OF SELECTED TERMS (MOSTLY FROM JACKSON, 1997)

Acre-foot—The volume of liquid and/or solid required to cover 1 acre to a depth of 1 foot.

Alluvium—Flat-surfaced deposits of sand, silt, clay, and gravel in stream beds and on flood plains of present-day rivers and streams.

Alfisols—Soil order identified by increasing clay content with increasing soil depth. Subsoil contains significant amounts of calcium (Ca+2), magnesium (Mg+2), and potassium (K+1) in soil-water solution. Surface is acidic (pH less than 7).

Anhydrite—A mineral or sedimentary rock composed of calcium sulfate, $CaSO_4$; it alters readily to gypsum.

Aridisols—Soil order identified by lack of plant-available water for many months. Soils support only desert plants. Soils can also be very shallow or salty.

Aquifer—A permeable rock or deposit that is water bearing.

Asphalt—A solid or semisolid oil residue remaining in rocks after escape of the gaseous and more liquid components.

Barrel—42 U.S. gallons.

Basalt—A dark-colored fine-grained igneous rock (magma) formed from lava that flowed onto the surface of the earth. Oklahoma basalts are dark gray or black.

Basin—A large area that sank faster than surrounding areas during much of geologic time and in which a great thickness of sediments was deposited.

Bentonite—An absorbent clay formed by decomposition of volcanic ash.

Calcite—A mineral, calcium carbonate, $CaCO_3$; the principal component of limestone and a common cement of sandstones.

Caliche—A porous sedimentary rock consisting of sand or gravel cemented by calcium carbonate.

Chat—The crushed chert, limestone, and dolomite that is left as a by-product of mining and milling lead-zinc ores.

Chert—A dense sedimentary rock or mineral consisting of microscopic particles of silica (quartz). Occurs in layers and as isolated masses. Flint and novaculite are varieties of chert.

Climatology—The science that deals with climates and their phenomena.

Coal—A combustible black sedimentary rock consisting mostly of partly decomposed and carbonized plant matter.

Colluvium—Loose and incoherent mass of soil material and/or rock fragments usually deposited at the base of a slope.

Conglomerate—A sedimentary rock consisting largely of rounded gravel or pebbles cemented together in a finer matrix.

Crude oil—Unrefined hydrocarbons that exist as a liquid in a subsurface reservoir.

Cubic foot (gas)—Amount of gas that will occupy a cubic foot at atmospheric pressure (14.73 pounds per square inch at sea level) and 60° Fahrenheit.

Cuesta—A ridge with a long, gentle slope capped by a hard layer of rock and terminated by a steep slope.

Cumulonimbus—Exceptionally dense and vertically developed cloud type, occurring both as isolated clouds and as a line or wall of clouds; generally accompanied by heavy rain, lightning, and thunder.

Dimension stone—Any stone suitable for cutting and shaping into blocks and slabs for building or ornamental purposes.

Dolomite—A sedimentary rock consisting mostly of the mineral dolomite, $CaMg(CO_3)_2$, formed from dolomite muds and fossil fragments or, more commonly, by alteration of limestone.

Earthquake—A sudden motion or trembling in the earth caused by the abrupt release of slowly accumulated strain.

Earthquake intensity—A measure of the effects of an earthquake at a particular place. Intensity depends not only on the earthquake magnitude, but also on the distance from the origin of the earthquake and on local geology.

Earthquake magnitude—A measure of the strength of an earthquake determined by seismographic observations; determined by taking the common logarithm (base 10) of the largest ground motion recorded during the arrival of a seismic wave type and applying a standard correction for distance to the epicenter. Three magnitude scales, mbLg, m3Hz, MDUR, are used to report magnitude for Oklahoma earthquakes. Each magnitude scale was established to accommodate specific criteria, such as the distance from the epicenter as well as the availability of certain seismic data (see Lawson and Luza, 1995, for detailed explanation).

Entisols—Soil order identified by the properties of the parent material (rock