

Figure 21. Map of Oklahoma shows felt-earthquake locations (Oklahoma Geological Survey data), seismic areas (numbers and dashed red lines; also see page 9), and landslide potential (modified from Radbruch-Hall and others, 1982).

Natural Geologic Hazards

Natural geologic hazards are events or processes that have caused, or may cause, hazardous conditions. Some examples in Oklahoma are earthquakes, landslides, expansive soils, radon, floods, and karst/salt dissolution.

Earthquakes—Geologists' ability to detect and accurately locate earthquakes in Oklahoma was greatly improved after a statewide network of seismograph stations was installed (see page 9). The frequency of earthquakes and their possible correlation to specific fault zones are being studied. This information hopefully will provide a data base to use in developing numerical estimates of earthquake risk, including earthquake magnitude, for various parts of Oklahoma. Numerical-risk estimates could lead to better-designed, large-scale structures such as dams, high-rise buildings, and power plants, and to provide information necessary to establish insurance rates.

Earthquakes frequently occur in three principal areas in Oklahoma (Fig. 21), including: Canadian County (1); Garvin and nearby counties (2); and Love, Jefferson, and Carter Counties (3). The southeast part of Oklahoma is another area of low-level earthquake activity.

Landslides—Landslides and slumps are a common highway-construction problem in parts of Oklahoma. Most landslides occur in the eastern one-third of Oklahoma (Hayes, 1971), due to wetter climate (39-59 inches of precipitation per year) and steep slopes associated with mountainous terrain (Fig. 21). In eastern Oklahoma, thick shales weather quickly and produce large quantities of clay-rich colluvium. The colluvium occurs on slopes as a veneer about three feet thick, masking underlying bedrock. The landslide threat is higher where natural slopes exceed a 2:1 gradient.

Expansive Soils-Clay-rich shales, or soils from the weathering of shales, may contain smectite clay minerals, such as montmorillonite, that swell up to 1.5 to 2.0 times their original dry volume after adding water. Over 75% of Oklahoma bedrock units are possible sources for expansive soils (Fig. 22). Soil saturation from rainfall, lawn watering, or sewer leakage may cause major damage by soils expanding under sidewalks, highways, utility lines, and foundations. If construction takes place on wet expanded soils, then shrinkage may occur after drying, resulting in severe cracking in structures.

Principal geologic units in Oklahoma having high shrink-swell potential are Cretaceous shales that crop out in southern Oklahoma. Other shales that locally have moderately high shrink-swell potential are several Pennsylvanian units in the east and several Permian units in central Oklahoma.

Radon—Radon is a naturally occurring radioactive gas formed by the radioactive decay of uranium. The generation of indoor-radon concentrations in excess of the U.S. Environmental Protection Agency standard (more than 4 picocuries per liter of air) does not require ore-grade uranium (more than 500 parts per million). Rocks and residual soils with much lower amounts of uranium under favorable conditions can generate above-normal radon levels (Fig. 23).

Uranium is associated with various rock types and geologic environments in Oklahoma. Seven types of uranium occurrences are based on the mode of uranium enrichment and the size, distribution, and geologic continuity of that occurrence: (1) granitic rocks and associated late-stage intrusions (dikes and sills); (2) arkosic sediments (weathered granite detritus); (3) dark, organic-rich shales; (4) phosphatic black shales; (5) lignite and bituminous coal; (6) local point sources; and (7) stratiform deposits (confined to certain Permian stratigraphic units in western and southwestern Oklahoma).

Flood-Prone Areas—Flood plains are areas adjacent to rivers and streams that occasionally



Figure 22. Map shows relative abundance of expansive soils in Oklahoma (modified from Schuster 1981)

GEOLOGIC HAZARDS IN OKLAHOMA

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Figure 24. Map shows general distribution of karst terrains in Oklahoma (modified from Johnson and Quinlan, 1995)



Figure 25. Map shows general locations of principal underground mines and strip mines in Oklahoma (from Johnson, 1974; Friedman, 1979); only coal and copper strip mines are shown.

stream can carry in its channel, waters rise and flood adjacent lowlands. Floods can occur at any time in Oklahoma, but major floods are frequent in spring and fall (Tortorelli and others, 1991). Flood-prone areas are identified and mapped by the U.S. Geological Survey (Water Resources Division), the U.S. Army Corps of Engineers, and private contractors for the National Flood Insurance Program administered by the Federal Emergency Management Agency (FEMA). The FEMA program intends to delineate areas that have about 1 chance in 100 on average of being inundated in any particular year (a 100-year-flood frequency). The program uses available information







Figure 23. Map shows relative abundance of uranium minerals in Oklahoma capable of generating indoor-radon concentrations in excess of the U.S. Environmental Protection Agency standard (more than 4 picocuries per liter of air) (modified from Flood and others, 1990).

development has occurred.

As of June 2002, FEMA identified over 350 Oklahoma communities and/or counties for participation in the national flood-insurance program. A map-panel index is available for every participating community. One may examine flood-insurance-rate maps at county-clerk offices, city halls, county courthouses, city-engineer offices, or city-planning departments.

Areas of Karst and Salt Dissolution—Where water-soluble rocks (e.g., limestone, dolomite, gypsum, anhydrite, salt) are at or near the surface, karst and dissolution features are prone to develop by the dissolving action of circulating ground water. Resulting sinkholes and caverns are potential hazards if the land surface subsides or collapses into the underground voids. The Ozark Mountains in northeastern Oklahoma, the Arbuckle Mountains in south-central Oklahoma, and the Limestone Hills in southwestern Oklahoma (Fig. 24) are the principal areas where karst features develop in limestone and dolomite. Gypsum and shallow salt deposits can cause karst and dissolution problems in many areas in western Oklahoma.

Limestone, dolomite, gypsum, and anhydrite beds that crop out, or are within 20 ft of the surface, represent the greatest potential for karst development and its associated environmental and engineering problems. Where soluble rocks are 20-100 ft deep there exists less (yet real) potential for karst development and associated problems. Man-Made Geologic Hazards

Some human activities that may create present or future geologic hazards in Oklahoma include underground mining, strip mining, and disposal of industrial wastes.

Underground Mines-Since the early 1800s, Oklahomans have intermittently conducted underground mining. Major underground mining occurred from 1872 through the 1940s in eastern Oklahoma coal fields, and from 1904 through 1970 in the Tri-State lead-zinc district in northeastern Oklahoma and parts of Kansas and Missouri (Fig. 25). Underground mines extracting gypsum, limestone, base metals, and asphalt in other districts also created potential hazards such as: (1) roofrock collapse, causing surface subsidence or collapse; (2) acidic or toxic mine waters; and (3) mine

flooding.

Strip Mines and Open-Pit Mines— Oklahomans have operated strip mines and open-pit mines since pioneer days in the early 1800s (Fig. 25). Large-scale quarrying and open-pit mining for stone, sand and gravel, asphalt, and other nonfuel resources began in the late 1800s. Significant strip-mining in eastern Oklahoma coal fields began about 1915 with the development of large earth-moving equipment. Land disturbed by surface mining is a potential problem because: (1) spoil piles and fill material may not be fully compacted, leading to subsiding or settling; (2) ponds and ground water in the area may be acidic or toxic; and (3) highwalls and quarry benches may be unstable.

Industrial-Waste Disposal in Geologic Formations-Solid- and liquid-industrial-waste disposal in Oklahoma includes surface burial in soils or rock units, and subsurface injection for liquid-industrial waste (Johnson and others, 1980). The primary concern in selecting a suitable wastedisposal site is the assurance that waste will remain isolated from ground water aquifers and the biosphere for as long as the waste is hazardous to humans and the environment.

Rock units in Oklahoma favored for surface disposal are impermeable sedimentary rocks, such as shale and clay; porous and permeable sedimentary rocks, such as sandstone, limestone, and dolomite, are most desirable for subsurface waste disposal (Johnson and others, 1980). The porous and flood but are normally dry, sometimes for many years. When storms produce more runoff than a on past floods and, in some places, detailed field surveys and inspections to determine permeable rock units should be surrounded by impermeable strata to assure waste containment.

flood frequency. Many early maps of flood-prone areas are being revised, especially where urban