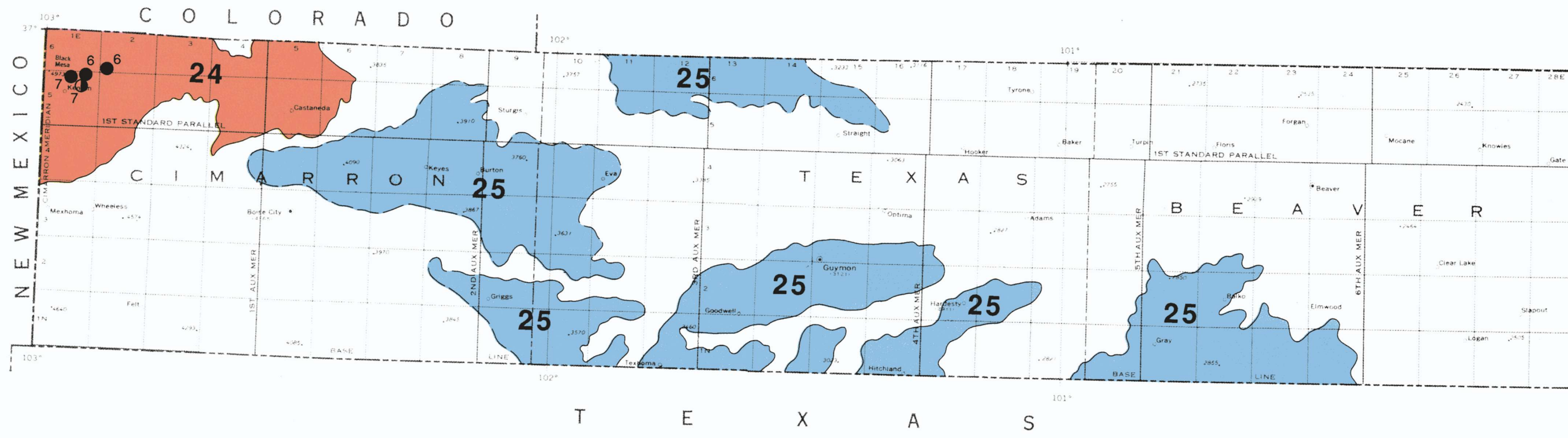

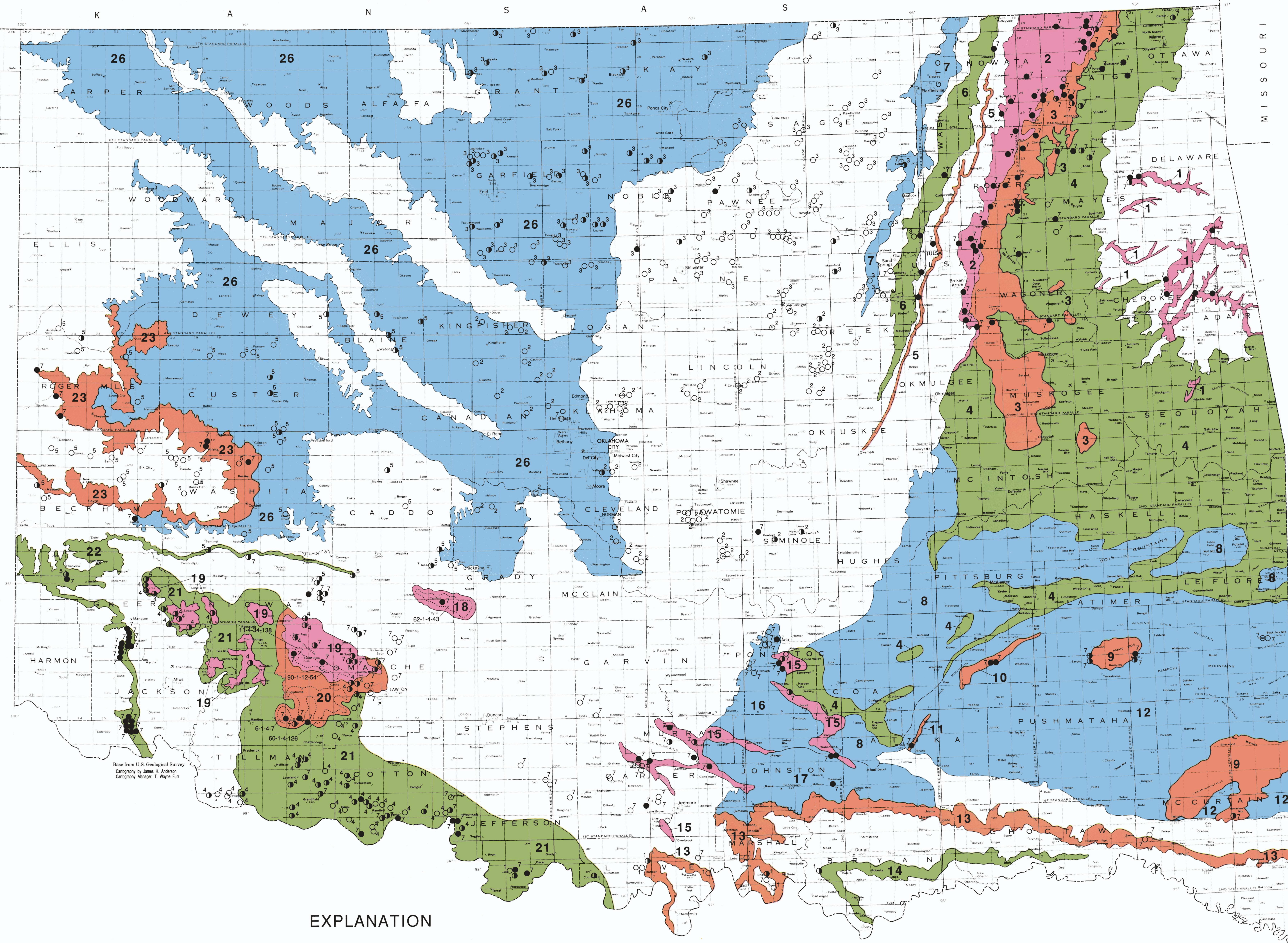

INTRODUCTION

The Oklahoma Geological Survey in cooperation with the Oklahoma State Department of Health evaluated and rated near-surface geologic conditions in Oklahoma for radon potential. Radon-222 is a radioactive gas with a half-life of 3.84 days. It is one of a series of isotopes produced during the radioactive decay of uranium-238 to stable lead-206 . Each successive isotopic transformation is accompanied by the emission of alpha or beta particles and/or gamma radiation. Lung tissue damage, possibly resulting in cancer, occurs as radon's progeny isotopes, which are solid and can lodge in lung tissue, continue to release radiation. Alpha-emitting polonium isotopes are considered to be the most damaging. Health hazards resulting from exposure and inhalation of above-normal levels of indoor radon (4 pico-Curies per liter, 4 pCi/L), radon detection, recommended safety levels, and remedial methods are summarized in publications issued by the U.S. Environmental Protection Agency (1986,1987).

Radium-226 and, ultimately, uranium-238 are the precursors of radon-222. At present, little is known about the concentration and distribution of radon and radium in Oklahoma rocks and soils. More is known about the distribution of uranium in various geologic formations, because uranium is used in the nuclear and defense industries. Thus, uranium is utilized in this assessment as a mappable indicator of radon.

This study is a reconnaissance-level investigation only. The evaluation of bedrock formations for radon potential is intended to serve as a guide for site-specific indoor-radon surveys.

GEOLOGY

Three principal mountain belts, Ouachita, Arbuckle, and Wichita, occur in the southern third of the State (Fig. 1). These mountain belts were formed by folding, faulting, and uplifting during the Pennsylvanian Period, about 300 million years ago. Thick sequences of Paleozoic sedimentary rocks, some igneous rocks (granite, rhyolite, and gabbro), and a variety of structural features (faults and folds) are exposed in these mountain belts. The major sedimentary basins include the Anadarko, Arkoma, Ardmore, Marietta, and Hollis (Fig. 1). These basins subsided more rapidly than adjacent areas and contain 10,000 to 40,000 ft of sedimentary rocks.

Rocks of every geologic system are represented in Oklahoma (Fig. 2). Nearly 99% of the State's surface is underlain by sedimentary rocks; the remainder is underlain mostly by igneous rocks in the Wichita and Arbuckle Mountains, and there is a smaller area of slightly metamorphosed rocks in the Ouachita Mountains. Permian rocks are exposed at the surface over 46% of the State. Other exposures include Pennsylvanian (25%), Tertiary (11%), Cretaceous (7%), and Mississippian (6%). Devonian through Precambrian rock types are exposed over 5% of the State. Quaternary river, terrace, and lake deposits cover the pre-Quaternary rock units over about 25% of the State.

Geologic maps at a scale of 1:250,000 in the Oklahoma Geological Survey's Hydrologic Atlas series and the Texas Bureau of Economic Geology's Texas Atlas series provided the basic outcrop information for the assessment (Fig. 3; Geology References 1–11). Additional geologic information in numerous county reports, published articles, and unpublished student theses aided in the evaluation.

AIRBORNE RADIOMETRIC SURVEYS

Statewide airborne radiometric surveys, which measured ground-surface gamma-ray intensity, were conducted for each 1° × 2° quadrangle (scale 1:250,000) during the U.S. Department of Energy's National Uranium Resource Evaluation (NURE) program, 1975–1983 (Airborne Radiometric Surveys References 1–8). Except for the McAlester Quadrangle, the east–west flightlines were spaced 3–6 mi apart, and the north–south tielines were spaced 12–24 mi apart. In the McAlester Quadrangle, north–south flightlines were spaced 6 mi apart, and the east–west tielines were spaced 24 mi apart. The gamma-ray measurements recorded bismuth-214 concentrations in the top few inches of the ground surface. Bismuth-214 is a daughter product of radon-222 in the uranium-238 decay series. Therefore, the radiation values recorded by the survey are believed to be approximately proportional to near-surface radon concentrations in the soil. The NURE reports provided extensive data on equivalent uranium (eU, uranium calculated from radiometric surveys) concentrations across the State. The U.S. Geological Survey reprocessed the radiometric-survey data and produced a computer-generated National Equivalent Uranium Map (Duval, 1989). Preliminary copies of this map and report were very useful in delineating areas of radon potential in the State.

URANIUM OCCURRENCE AND ANALYTICAL DATA

Oklahoma presently has no known economic uranium deposits. However, generation of indoor-radon concentrations in excess of EPA's standard (>4 pCi/L of air) does not require ore-grade uranium (>500 ppm). Under favorable conditions, rocks and residual soils containing much lower uranium contents are capable of generating above-normal radon levels.

In Oklahoma, uranium is associated with many different rock types and geological environments. Uranium occurrences in the State are divided into seven types based on the mode of uranium enrichment and size, distribution, and geologic continuity of the occurrence:

Type 1.—*Uranium associated with granitic rocks and their late-stage intrusives (dikes and sills).* The best example is in the Wichita Mountains (Area 19), where granites contain 4.6–11 ppm uranium, and certain dikes average 153 ppm uranium.

Type 2.—*Uranium associated with arkosic sediments (weathered granite).* Uranium occurs in sediments derived from erosion of granitic rocks, with or without redistribution by ground water. The best example is found immediately south of the Wichita Mountains (Area 20) in the granite facies of the Post Oak Conglomerate, which ranges from 1 to 126 ppm uranium.

Type 3.—*Uranium associated with dark, organic-rich shales.* Laterally persistent black shales of east-central and northeastern Oklahoma (Area 4) contain 10–20 ppm uranium.

Type 4.—*Uranium associated with phosphatic black shales.* Phosphate nodules, concretions, and thin discontinuous layers in black shales significantly elevate their uranium content. The best examples occur in northeastern Oklahoma (Areas 2, 3, 5, and 6), where phosphate nodules contain 20–600 ppm uranium. These black shales contain as much as 5% nodules, average 20–50 ppm uranium, and represent the State's most uranium-rich and laterally persistent rock units.

Type 5.—*Uranium associated with lignite and bituminous coal beds.* Lignite is particularly effective in concentrating uranium and has worldwide measured uranium values of 10–2,500 ppm. Some thin lignite beds occur in southern Oklahoma (Area 14), but the uranium concentration is unknown. Samples of three northeastern Oklahoma coal beds (Areas 3 and 4) contain 10–40 ppm uranium.

Type 6.—Uranium associated with local point-sources. Uranium enrichment of the point source type is common and widespread across the State, but generally has very limited areal extent. In the Cement area, southwestern Oklahoma (Area 18), the largest known point-source occurrence in the State is associated with an oil field. Uranium ore was mined at Cement and contained as much as 20,460 ppm uranium.

Type 7.—*Uranium associated with stratiform bodies.* Rocks with above-average, but highly variable (60–16,100 ppm) uranium concentrations are confined to certain stratigraphic units in Permian red beds of western and southwestern Oklahoma (Areas 22 and 23). The origin of uranium enrichment is not well understood.

Several private and government reports describe uranium occurrences by chemical and radiometric analyses, rock type, and origin. Totten and Fay's statewide study and the NURE quadrangle folio reports for the Enid, Oklahoma City, Sherman, Clinton, Lawton, and Dalhart Quadrangles were essential to this study (Analytical Data References 1–7). Sample locations and uranium concentration information are shown on the Radon-Potential Map.

RADON-POTENTIAL RATINGS AND MAP UNITS

Several factors were used to evaluate the near-surface radon potential of the State's bedrock units. Uranium analyses and airborne radiometric surveys were the two most important rating factors in the evaluation. Rock type, the number of samples, and the type of uranium occurrence were the next-most-important factors considered. Topography, structure, and the radon potential of similar rocks outside Oklahoma were additional factors. It should be noted that many of the rock-sample analyses plotted on the Radon-Potential Map are in areas with known uranium-enriched bedrock and do not indicate the average uranium content of the entire geologic formation.

Based on these factors and considerations, five radon-potential categories were developed: *generally very low, generally low, locally low to moderate, locally moderate,* and *locally moderate to high.* Twenty-six areas in the State were outlined, numbered, and assigned a radon-potential rating. The modifiers *generally* and *locally* are used because the designated potential rating may not necessarily be equally distributed throughout an area. Local sub-areas within an area may have radon potentials different from that assigned to the entire area.

Areas underlain by formations with uranium contents equal to or less than the crustal average (2.5 ppm uranium) are rated *generally very low* or *generally low*. Approximately 80% of the State is included in these two categories.

DISCUSSION

Four factors determine how much radon in the ground may enter a building (Tanner, 1986): (1) Radium (uranium) must be in the soil and/or bedrock; higher concentrations are potentially more hazardous when other variables are equal. (2) About 90% of a given amount of radon decays in 13 days; radon must be able to rapidly migrate through pore spaces in the rock and/or soil (moderate to high soil permeability). (3) The structure must have openings (such as cracks in the foundation) below ground level for radon to enter a building. (4) Low internal air pressure within a building creates a pressure differential across the ground/structure interface, producing a "pumping" effect that will draw in soil gases. The study considered only factor (1) and did not address other significant variables, such as soil characteristics, ground-water hydrology, precipitation and other atmospheric conditions, and types and conditions of building structures.

The boundary lines of the 26 areas on the Radon-Potential Map are approximate; the map scale is too small to accurately portray individual beds within a formation. Within a given area, higher or lower radon potentials may exist. The map scale, limited analytical data, time constraints, and lateral lithologic variations in rock units precluded a site-by-site analysis.

This map does *not* predict indoor-radon levels. Climate, rock and soil permeability, ground-water saturation and movement, and building construction and usage strongly affect indoor-radon levels. The low–moderate–high radon potential rating scheme only compares the distribution of uranium-bearing rocks from one outlined area to another.

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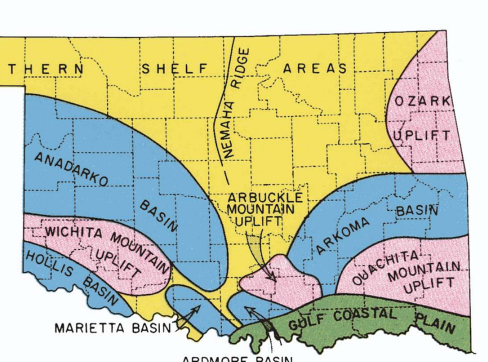

Figure 1. Tectonic-province map of Oklahoma (modified from Johnson and others, 1979).

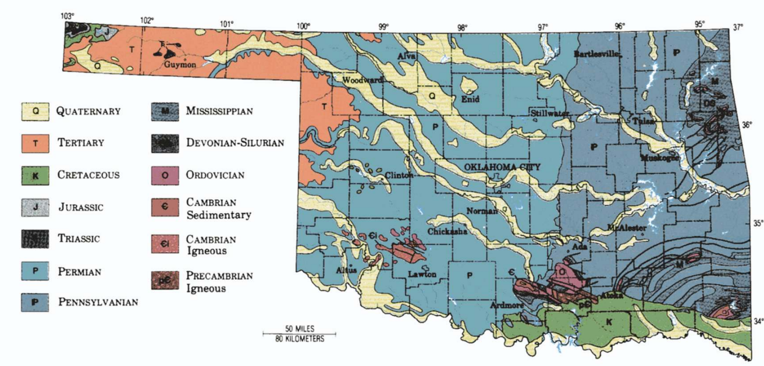

Figure 2. Generalized geologic map of Oklahoma (modified from Johnson and others, 1979).

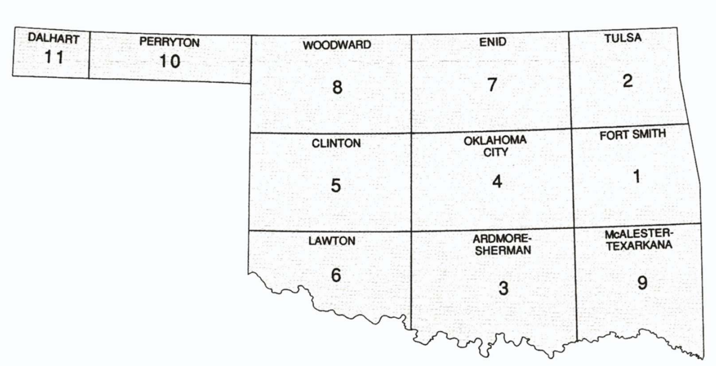

Figure 3. Index to geologic-map references and quadrangle (1:250,000) location map.

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EXPLANATION

RADON POTENTIAL

LOCALLY MODERATE TO HIGH (Areas 1,2,15,18,19)

LOCALLY MODERATE (Areas 3,5,9,10,11,13,20,23,24)

LOCALLY LOW TO MODERATE (Areas 4,6,14,21,22)

GENERALLY LOW (Areas 7,8,12,16,17,25,26)

GENERALLY VERY LOW

Boundary between areas of different radon potential; dashed where inferred

U_3O_8 CONCENTRATION (ppm) IN OUTCROP SAMPLES

○2 <3 ppm
◐5 3–20 ppm
●7 >20 ppm

Number beside uranium-concentration symbol corresponds to map references in Analytical Data section.

AREA WITH NUMEROUS ROCK SAMPLES

62-1-4-43

62	1	4	43
NUMBER OF SAMPLES	MINIMUM	AVERAGE	MAXIMUM

Minimum, average, and maximum values in ppm uranium (see Analytical Data reference 4)

RADON-POTENTIAL MAP OF OKLAHOMA

Compiled By
JAMES R. FLOOD, TOM B. THOMAS,
NEIL H. SUNESON, and KENNETH V. LUZA
1990

Scale 1:750,000