west. Two smaller, detached thickened parts of the Plattsburg limestone are also present in the area and probably represent small banks. A second cause of thickness variations in the Plattsburg limestone is local structural warping during deposition, which permitted greater thicknesses to accumulate over downwarps and less thicknesses over upwarps. Thickness of the Vilas shale also has been affected by this cause.

Thickness of the Vilas shale has been observed to be inversely related to thickness of the Plattsburg limestone at most localities where the two formations are exposed. Where the Plattsburg limestone is thick, the Vilas shale tends to be thin, and *vice versa*. The Vilas shale has been interpreted to be an off-bank lateral time equivalent of the thickened Spring Hill member.

Deposition of the bank is interpreted to have been strongly influenced by carbonate-secreting organisms, including crinoids, bryozoans, brachiopods, mollusks, and algae, which flourished over the bank. The organisms may have influenced deposition of silt and clay (Hickory Creek shale member) by exerting a sediment-binding effect, and probably helped stabilize slopes at least as great as 7° on the sides of the bank. In addition, the carbonate-secreting organism contributed large quantities of calcareous material to form the upper part (Spring Hill limestone member) of the bank.

Where thick, the Spring Hill limestone member of the Plattsburg may be divided into three tabular lithologic subdivisions which occur in regular vertical sequence. The lower subdivision has been termed the fragment-pellet subdivision because of the abundance of irregular-shaped fragments and pellets. Much of the fragmental and pelletal material appears to be of algal origin. The middle subdivision is termed the crystalline subdivision because of the abundance of sparry calcite which is closely associated with fragments of carbonate encrusted blades of various forms of calcareous algae. Some of the algal forms resemble the alga *Anchicodium*, although positive identifications have not been made because of the lack of preservation of essential details. The upper subdivision is termed the calcarenite subdivision because of the abundance of calcarenite composed of grains with varying degrees of rounding and sorting.

During deposition of the crystalline limestone subdivision of the Spring Hill member, carbonate-secreting algae may have imparted sufficient rigidity to the bank to cause it to be wave-resistant and thus allowing it to be classed as a reef. However, during deposition of most of the other parts of the Plattsburg bank, the deposits probably did not possess sufficient coherence to be wave-resistant.

Porosity in the Spring Hill member in outcrops is closely related to limestone lithology. Highest porosity occurs in the crystalline limestone subdivision, where conspicuous pores and vugs occur in visibly crystalline calcite. Some of the crystalline calcite is interpreted to have formed through precipitation in open spaces which were not filled with calcareous mud during deposition because of the sheltering effect of individual fragments of carbonate-encrusted calcareous algae. Other crystalline calcite appears to have been produced through recrystallization of calcareous algae. It seems possible that favorable oil reservoir conditions in certain Pennsylvanian limestone in central and western Kansas may be provided by porous zones in thickened limestone lenses similar in origin to the thickened Plattsburg in the Neodesha-Fredonia area.

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Pre-Desmoinesian Isopachous and Paleogeologic Studies in Central Mid-Continent Region

Major tectonic features of the central Mid-Continent area are outlined and their relationship to present thickness and distribution of pre-Desmoinesian strata is discussed.

Cambro-Ordovician "Arbuckle Group" thickens southward from zero along the Nemaha and Central Kansas uplifts to nearly 7,000 feet in southern Oklahoma. The Simpson, with maximum thickness of 3,000 feet in southern Oklahoma, thins northward by convergence and overlap of younger units to extinction in northwestern Kansas. Viola-Fernvale thins northward from 1,500 feet in Anadarko basin to 200 feet in southern Kansas, thickens to 400 feet in Salina basin.

The Sylvan-Maquoketa is limited to two areas, one in Oklahoma, the second in northeastern Kansas. Maximum thickness in Oklahoma is 600 feet, in Kansas about 150 feet. Distribution of Hunton resembles that of Sylvan; maximum thickness exceeds 1,500 feet in Oklahoma and 650 feet in Forest City basin. Woodford-Chattanooga lies with regional unconformity on units from Precambrian through Hunton. A 600-foot maximum is postulated for the Anadarko basin; 50–100 feet covers eastern Oklahoma and Kansas. Mississippian limestones are widespread with 4,000 feet in Anadarko basin, 1,600 feet in Hugoton embayment and zero in northern Kansas.

Lower Pennsylvania Springer is limited to a narrow belt in Anadarko and McAlester basins with maximum of 4,000 feet near Ardmore. Overlying Morrow overlaps Springer reaching maximum of 1,500 feet in McAlester basin and more than 4,300 feet in Anadarko basin. Distribution of Atoka resembles that of Morrow with 5,000 feet maximum in the Anadarko basin and approximately 8,000 feet in the McAlester basin. Widespread Desmoinesian sediments rest with marked unconformity on Atokan and older rocks.

Epeirogenic movements were mild throughout early Paleozoic with geosynclinal development in southern Oklahoma. Eustatic changes produced major unconformities and offlap-overlap relations. Strong warping occurred in post-Hunton, pre-Chattanooga time. Major orogenic movements are post-Mississippian, pre-Desmoinesian with maximum movement in late Morrowan. Final structural development took place in late Cretaceous and early Tertiary. Throughout much of Paleozoic time, the axis of maximum deposition in southern Oklahoma paralleled the Wichita-Amarillo trend in the "Wichita embayment."

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Beattie Limestone Facies and Their Bearing on Cyclic Sedimentation Theory

Cyclic upper Paleozoic deposits in the northern Mid-Continent region have long challenged the ingenuity of geologists seeking a rational interpretation of their origin. Most theories have been based principally on the vertical succession of lithologic features in stratigraphic sequences hundreds of feet thick. The present study of the Beattie limestone (Wolfcampian) is based on the conviction that additional clues to an understanding of depositional environments can be gained by studying in detail thin stratigraphic units as they change facies across a depositional basin. The three members of the Beattie (in ascending order, Cottonwood limestone, Florena shale, Morrill limestone) have been examined in outcrop from Nemaha County, Nebraska to Osage County, Oklahoma and followed in the subsurface westward nearly to Colorado. Regional paleotectonic studies indicate that the line of outcrop runs almost from shore to shore diagonally across an elongate seaway extending from northeastern Wyoming southeastward to northeastern Oklahoma. Thirteen distinct facies of the Beattie are recognized, based on mineralogic, paleontologic, petrographic, and field data. Two facies provinces with a boundary in central Greenwood County, Kansas, are clearly indicated. Basin topography is demonstrated to be the prime controlling influence on the distribution and nature of the facies. Simple transgression-regression explanations are not adequate to explain observed facies patterns in the Beattie limestone.

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Mississippian Rocks in Northern Oklahoma

Mississippian rocks divided into series by lithologic criteria and by electric-log character underlie Early or Middle Pennsylvanian rocks in the central part of northern Oklahoma. Osagean rocks, or locally, rocks older than Mississippian, underlie Middle Pennsylvanian strata along the north-trending Central Oklahoma arch which includes the Nemaha ridge on the west, the Oklahoma City uplift at the south, and the Cushing anticline on the east. The arch narrows southward as a result of greater uplift and steeper dip, so that on its west flank, the boundaries of Chesterian and Meramecian units which are beveled by Early and Middle Pennsylvanian erosion trend east and then south toward the Oklahoma City uplift. From the east the boundaries trend southwest and then south on the east side of the uplift.

Chesterian strata thicken toward the Anadarko and McAlester basins. Meramecian rocks rest with angular unconformity on the Osagean unit and both series thicken northward on the east side of the arch.

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Western Limits of Oil Creek Sand in Southern Oklahoma and Northern Texas

The Ordovician Oil Creek sand is found over most of central and southern Oklahoma and parts of Cooke and Grayson counties, Texas. It is one of the best oil- and gas-producing formations in this area.

Subsurface and surface control now available places the western limit of the sand along a line which extends from Stephens County, Oklahoma, to Grayson County, Texas. Generally, in Oklahoma, the limit of the sand is the result of a facies change; in Texas, it is the result of truncation.

Isopachous interpretations in southern Oklahoma show a rapid thickening of the sand away from the strand line. The sand is generally thin in northern Texas.

There have been several recent deep gas-distillate discoveries in Love County, Oklahoma, and Grayson County, Texas, in the Oil Creek sand. Most of these fields seem to be associated with structural traps. There are, however, truncation traps in Grayson County containing oil.

Large accumulations of oil or gas which have used the wedge-out nature of the sand as a trapping agent have not been found so far; however, there are several areas which seem prospective for a trap of this type in the Oil Creek sand.

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Preservation of Early Paleozoic Oil and Gas

One episode in the geologic history of much of the United States and part of Canada consisted of three parts: (1) the formation of several great upfolds or arches at the end of Mississippian time, (2) the erosion of the elevated rocks until Precambrian rocks were exposed along the crests of these uplifts, and (3) the deposition of Pennsylvanian sediments across the eroded and peneplaned surface. A paleogeologic map of this surface of unconformity shows the geology of the eroded surface at the time it was overlapped.

A question that may have significance in exploration is how and where was the oil preserved in the pre-Pennsylvanian rocks during this episode? Obviously all of the "loose" or "free" oil and gas would be expected to have moved into the anticlines and arches and have been eroded or have escaped by seepages along the outcrops of that time. Yet a great amount of petroleum was preserved in the early Paleozoic rocks as evidenced by the oil and gas production in rocks of these ages today. How? and Where?

Some of the possible solutions include such phenomena as oil fields protected because erosion did not extend deep enough, buried wedge belts of permeability, favorable hydrodynamic gradients, late generation of petroleum, late transformation of organic matter to petroleum, late accumulation of petroleum into phase continuity, and post-unconformity (Pennsylvanian) source of the petroleum. Any one, or combinations of several, may explain where and how the oil and gas now found in early Paleozoic rocks were preserved during such an episode. If the regions favorable for the preservation of oil and gas can be located, then these would be areas in which to concentrate detailed structural and stratigraphic work in order to locate specific traps. The same type of reasoning would apply to each surface of unconformity in the geologic section.

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Stratigraphic Frontiers in Petroleum Geology

Like other frontiers that change in location or nature, stratigraphy at beginning of the 1960s appropriately is subjected to reappraisal as an indispensable component of petroleum geology, not to say the most important single subscience applied to oil and gas exploration. Such recognition in no way belittles investigations in the fields of geophysics, geochemistry, sedimentation, petrology, paleontology, structural geology, and the like, because all of these are more or less closely linked with stratigraphical studies. The present paper is introduced by a brief analysis of the stratigraphic content of contributions published during the last two decades in two international journals devoted to petroleum geology and geophysics. This is followed by discussion of the current outlook relating to rock stratigraphy, time-rock stratigraphy, biostratigraphy, Pleistocene stratigraphy, and Precambrian stratigraphy, only the last of which has little importance for the petroleum geologist. Finally, functions of the American Commission on Stratigraphy are stated and purposes of Stratigraphic Codes (a considerably revised North American Code now made ready for publication) are pointed out.

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Relating Seismic Time to Geological Datum

Seismic time must be related to a common datum in