pian and Arbuckle correlative sections, are prospective targets for oil or gas.

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History of Petroleum Development of Mississippian Oil and Gas

The purpose of the paper is to present a short summary of development programs in which the Mississippian was the primary objective and to give a few facts concerning how the reserves from the Mississippian were found. This treacherous part of the geological column presents a variety of difficult problems; some of these are pointed out in this paper.

The history of development of Kansas and Oklahoma is emphasized, but also mentioned is the development history of Utah, Wyoming, Montana, Illinois, and Canada. Maps include the fields producing from the Mississippian in Kansas and Oklahoma.

The recent play in Osage County shows how the land attitude can highly influence a play. Methods of prospecting are discussed and several prospective areas are pointed out. The final part of the paper includes recommendations for necessary changes in the economics of drilling wells where the Mississippian is an objective. The conversion of dry-hole money to bottom-hole money is highly recommended.

The foreign influence on our domestic picture, and general oil depreciation are discussed.

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Southwestern Nebraska (Cambridge Arch Area)

The task of science in general is the breaking-down of the unknown into basic simplicities and the rebuilding of its findings into understandable complexities. In the case of geology and of the petroleum geologists' tasks, this also holds true, with the addition that the rebuilding must be into economically profitable understandable complexities (oil fields). The Cambridge arch represents an area in the stage of development where these theories can be applied.

The Cambridge arch is a medium-size structurally positive area on a major structural belt of crustal weakness, pre-Cambrian in age. That is, it is a feature of intrastate size on a trend of interstate length, which is described by the alignment of: the Black Hills, South Dakota; Chadron and Cambridge arches, Nebraska; Central Kansas uplift, and perhaps additional extensions on both ends. Just as these intermediate features have a relationship to something bigger, there is a control and an interrelationship to something smaller. That is, smaller trends emanate from the intermediates that are pre-Cambrian in age and lineament- or fracture-pattern-controlled. It is through the studies of these lineaments and intersection of lineaments that we find the exploratory tool to resolve the findings into the economically profitable complexities.

Studies of the Warner, Cahoj, and Reiher fields are presented to bring out the salient points and offer evidence of lineaments that have had minor positive movement throughout long periods of geologic time and have in turn affected the stratigraphic deposition on a micro-scale.

Maps with regional scope, covering the entire geologic column, are presented to help locate lineaments, show the inter-relationship of the intermediates to their micro-counterparts, and illustrate the general stratigraphic conditions over the arch area.

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Government's Helium Conservation Program

Helium, one of the completely inert gases and a short time ago considered a rare gas, has become important in many ways. Large quantities are being used in metallurgical processes, in the development of nuclear power and in national defense. First discovered as a constituent of the sun in 1868, and on the earth in 1895, it was only in 1903 that it was found in natural gas. With first commercial production from natural gas on a very limited scale in 1918, the annual production and demand for helium today is approximately 330 million cubic feet—70 times the production in 1937. Increased demands are seen for the future.

Helium is being lost at the rate of more than 3 billion cubic feet per year through the marketing of fuel gas containing it, and there have been few significant discoveries of new helium sources in the last 15 years. The Department of the Interior proposes a helium conservation program that would extract helium from fuel gas going to market and store it for future use. By such a program it is anticipated that an adequate supply of helium will be reasonably assured up to the year 2000. Legislation to provide for such a program has been presented to the Congress for consideration. Private industry would be invited to participate in the program but if it should not indicate a willingness and capability to perform in a reasonable time, the Government would undertake the program as a Government operation.

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Application of Palynology to Geology

Palynology is the study of pollen and spores. Throughout much of geologic time, these microscopic plant particles have been accumulating in sediments. Their recovery from sediments enables the palynologist to establish correlation based on time equivalence. A brief sketch of the development of palynology is followed by an examination of the basic principles of the field. During the examination of these principles, their potential value to the field of geology is illustrated as well as some of the recent correlations established on the basis of palynological work.

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Marine Bank Development in Plattsburg Limestone (Upper Pennsylvanian) in Neodesha-Fredonia Area, Southeastern Kansas

The Plattsburg limestone is anomalously thick in the Neodesha-Fredonia area, swelling from less than 10 feet to maximum thickness of 115 feet. Thickening is due to large increases in thickness of two of the three members into which the Plattsburg has been divided. The Merriam limestone (lower member) varies only slightly in thickness, ranging from 1 to 3 feet, but the Hickory Creek shale (middle member) ranges from 1 to 45 feet, and the Spring Hill limestone (upper member) ranges from 3 to 88 feet in thickness.

The principal cause of thickening of the Plattsburg limestone is interpreted to be due to deposition of an extensive, lens-shaped shallow marine bank which rose above the general level of the surrounding sea floor. The shape of the bank is thought to be partly reflected by present thickness variations in the Plattsburg limestone. The bank was at least 14 miles long northwest and southeast, and about 12 miles wide northeast and south-

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