Tertiary, and Quaternary sedimentary units are present in the Colorado part of the Anadarko basin. All rocks below the Atokan-Desmoinesian series of the Pennsylvanian system appear to have been deposited in broad, shallow epicontinental seas. Strong epeirogenic unwarp of the Sierra Grande-Apishapa uplift beginning in Atokan-Desmoinesian time and persisting with decreasing intensity through Virgil time resulted in the removal from most of this uplifted area of all sediments down to the granite basement. Concurrently, a band of coarse, arkosic, clastic material was contributed to the Atokan-Desmoinesian, Missourian, and Virgilian sediments fringing the uplift areas. Beyond the perimeter of this coarse clastic material Pennsylvanian and lower Permian deposition was normal shallow marine. Definition of the Las Animas arch throughout Permian and Pennsylvanian time was slight, and this feature did not achieve regional prominence until Cretaceous time.

By middle Permian time the Sierra Grande-Apishapa uplift had been completely inundated by Permian seas. Deposition from middle Permian to the close of Permian time was evidently in a restricted basin environment as upper Permian sediments are increasingly evaporitic.

Recent discoveries in the Morrowan series and the Atokan Desmoinesian series on the southern end of the Las Animas arch and in an area from the Freezeout Creek fault zone to the Kansas and Oklahoma state lines give southeastern Colorado increasing stature as an oil and gas province. Lenticular bodies of the Morrowan "McClave" sand and fingers of arkosic sandstone in the Atokan-Desmoinesian on the southern end of the Las Animas arch offer attractive stratigraphic trap prospects of sizeable proportions. Thick lower Morrowan "Keyes" sand intervals and numerous Atokan-Desmoinesian arkosic sands present interesting structural trap possibilities in the area between the Freezeout Creek fault zone and the Oklahoma and Kansas state lines. North and east of the perimeter of arkosic material derived from the Apishapa-Sierra Grande uplift structural and possibly stratigraphic entrapment of hydrocarbons in carbonate rocks of Missourian, Virgilian, and lower Leonardian age offer a relatively unexplored potential.

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Prospecting for Stratigraphic Traps

Stratigraphic traps are directly related to their respective environments of deposition. An understanding of the depositional environment is essential to successful prospecting for oil or gas from this type of reservoir. Isopach studies of shale units directly above, or both above and below a lenticular reservoir sandstone, are of considerable value in reconstructing depositional environments. Such shale intervals, either directly above a reservoir sandstone, or embracing it, are genetic units, and variations in thickness are completely independent of present-day structural configuration. Isopach maps of such genetic units serve as realistic indicators of where certain lenticular sands were deposited. Depositional trends of beach sands, offshore bars, and strike valley sands are readily determined from such studies. Structural maps, constructed on a reliable time marker within the genetic interval, serve as a means of localizing oil or gas accumulation within any of these reservoir types. In all such studies electrical log data are essential, since arbitrarily selected genetic units are seldom named formational units. The thinner the genetic interval, the greater the necessity for accurate "picks" from electrical log data.

Deltaic reservoirs are poorly understood and only rarely recognized by the geologist. This type of reservoir is, nevertheless, abundantly preserved in the sedimentary section. Regional isopach studies of depositional environment are prerequisite for the construction of meaningful exploration maps of this type of reservoir. An understanding of the trends of distributary fingers and the influence of differential compaction in producing drape structures, likewise, is important.

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Geology of Natural Gas in Arkansas Valley, Arkansas

The Arkansas Valley is an east-west trending synclinorium bounded on the north by the Ozark uplift and on the south by the Ouachita Mountain anticlinorium. The Valley is an eastward extension of the McAlester basin of southeastern Oklahoma.

Pennsylvanian Atoka sediments form the principal outcrops in the Arkansas Valley. The Atoka measures 20,000 feet or more near the Ouachita front. Post-Atoka Pennsylvanian sediments (Hartshorne through Boggy) aggregate 3,000 feet in the western part of the Valley. Cambrian through Pennsylvanian Morrow sediments thicken southward from 5,000 feet or less in the Ozarks to an estimated 25,000 feet of correlatives in the Ouachitas. Little is known of the pre-Pennsylvanian section in the Arkansas Valley because of inadequate drilling densities.

Morrow shales, sandstones, and subordinate limestones were deposited mainly under shallow-water marine conditions. Morrow facies changes occur southeastward in the subsurface and eastward on the outcrop. Meagerly fossiliferous dark shales and lenticular sandstones constitute the Atoka in the Valley. Regional Atoka facies changes have not been observed.

Numerous east-west trending anticlines and synclines have surface expression in the Arkansas Valley. Many are faulted parallel with their axes. Steeply dipping flanks of the folds are indicated on the surface mostly by sharp ridges, and open synclines are expressed by flat-topped mountains. Folds in the southern part of the Arkansas Valley are tight and asymmetrical, with steeper north flanks. Dips of 50° or more are common. Progressively northward, the structures are less tightly folded and more nearly symmetrical. The folding was initiated during the Ouachita orogeny as early as Middle Pennsylvanian time and terminated after Boggy time.

A major fault system marks the structural boundary between the Valley and the Ozarks. These faults are normal and predominantly downthrown toward the south with displacements up to 3,000 feet. The structural boundary between the Arkansas Valley and the Ouachitas is more difficult to define. Faults near the Ouachita front are predominantly downthrown toward the north. High-angle reverse faults and low-angle thrusts are the common types in that region. Major faulting in the Arkansas Valley was not initiated until Atoka time or later.

Only dry gas is produced in the Arkansas Valley, chiefly from the Atoka but increasingly from the Morrow. The gas is sweet, generally high in methane and low in nitrogen. Currently there are 41 designated gas fields in the Arkansas Valley. Daily production averages 50 million cubic feet. Cumulative production since the first commercial well in 1902 totals 300 billion cubic feet. Reserves are in excess of 800 billion cubic feet.

Pennsylvanian production is expected to be expanded both eastward and southward in the Arkansas Valley. Pre-Pennsylvanian sediments, especially the Mississippian 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 microscale.

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-