local drilling and by close observation of individual well productivity.

Primary porosity is generally absent. Whole-core analysis reveals a fracture porosity average of 2% or less and an average net effective productive interval thickness range of 50–400 ft.

Reserves are limited and estimates differ in direct proportion to the fracture density, gas/oil ratios, initial potentials, and total number of producing wells in an area. Commercial production can be obtained if the available facts are evaluated properly.

13. L. E. GATEWOOD, Consultant, Oklahoma City, Oklahoma

CRINER-PAYNE AREA, STUDY IN STRUCTURAL GROWTH

Criner-Payne field, located in T. 5 and 6 N., R. 3 W., is the largest oil field in McClain County in terms of reservoir oil in place and areal extent. It is near the southern end of the Nemaha ridge. This highly faulted structure owes its present position to local crustal downbreaking along the flanks of the regional Hunton uplift. Continuous structural growth occurred from Ordovician through Pennsylvanian time as a result of a subsiding Anadarko basin; gentle progressive compressional folding culminated in the sharper folds and faults near the rim of the syncline.

Post-Hunton tilting and truncation, and post-Morrowan—pre-Desmoinesian uplift, can be matched closely with the stages of evolution of the Anadarko basin and the Nemaha ridge. The growth and tilting have resulted in the shifting of the younger fold axis progressively eastward from the Simpson axis.

The field is characterized by two distinctly different producing zones. The Bromide Sand, with structural relief of about 1,700 feet, produces only on up-thrown closures against north-south-trending faults. The Bois d'Arc Member of the Hunton Limestone has structural relief of about 1,650 feet, but the oil occurs generally wherever there is porosity and (or) fracturing, without regard to the structural position. Most Hunton porosity occurs west of the fold axis on the more steeply dipping western flank which was more exposed during intermittent stages of growth and tilting. Approximately 80% of the total acre-feet of Hunton porosity is localized west of the fold axis, but this comprises only about 35% of the total Hunton productive area.

14. L. R. RILEY, Humble Oil & Refining Company, Ardmore, Oklahoma

CHALLENGE OF DEEP EXPLORATION—CHITWOOD POOL, GRADY COUNTY, OKLAHOMA

In February, 1965, the South Alex and Chitwood producing areas were consolidated and designated Chitwood. These two Bromide producing areas are closely related geographically and geologically, and both are included in this discussion. Emphasis of this discussion is placed on the deeper producing Simpson rocks.

Even though there is this close relationship, geological and reservoir data indicate that the two areas are separate. Based on structural data from subsurface and seismograph, the two producing areas are located on separate anticlines. This interpretation is supported by differing condensate ratios in the wells of the two sectors.

Production ranges in depth from 15,908 to 17,202 ft.; Oklahoma's deepest productive well is located in the South Alex part of the field.

Production capabilities of the wells appear to be related directly to porosities and permeabilities which change significantly from well to well. The changes are sufficiently great that wells range from very good producers to dry holes.

Data from petrographic analysis indicate a small amount of pressure solution and a large amount of secondary silica growth. Both factors decrease original porosity of the reservoir.

Predicting the presence or absence of porosity is a most difficult problem. Extremely high drilling costs make it necessary to drill a minimum number of dry holes. Subsurface control from 640-acre spacing leads to unreliable development predictions.

15. R. C. LARSON, Larson Exploration Company, Tulsa, Oklahoma

HEALDTON ARBUCKLE FIELD AND ITS RELATIONSHIP TO OTHER POTENTIAL ARBUCKLE STRUCTURE

The Healdton Arbuckle oil field of Carter County, Oklahoma, is an example of a large reservoir for which ample subsurface information was available to the exploration geologist prior to discovery. In the application of refined and sophisticated exploration techniques elsewhere, the industry ignored basic and fundamental subsurface facts in this area. This pool is located in the middle of a productive zone that pre-dates World War I. Oil in the Arbuckle actually was produced from this reservoir for many years before the Sinclair No. 1 Ratcliff was drilled to find what is now recognized as the Healdton Arbuckle field. This paper deals with the facts leading to the Sinclair discovery and it attempts to reveal how they may be used to find additional pools. It is felt that a basic understanding of the producing pool is requisite to intelligent exploration for additional traps of a similar type.

16. K. H. HOLMES, Mobil Oil Company, Oklahoma City, Oklahoma

STRATIGRAPHIC TRAPS IN NORTHWEST QUINLAN AND CEDARDALE FIELDS, NORTHWESTERN OKLAHOMA

Northwest Quinlan and Cedardale fields in eastern Woodward and western Major Counties, Oklahoma, are located on the northern shelf of the Anadarko basin. Both fields produce gas from stratigraphic traps in the Mississippian Chester Limestone. Production at Cedardale is primarily from the Pennsylvanian Cottage Grove Sandstone.

Traps in the Chester were formed by lateral changes in the original limestone deposition and cementation. Original porosity and permeability were later altered by subaerial leaching which preceded the deposition of the overlying Pennsylvanian sediments.

The trap in the Cottage Grove Sandstone was formed by an updip facies change from sandstone to shale on the gently sloping shelf.

Cedardale was discovered in 1957 and Northwest Quinlan in 1958. Production has been established in 55 sections and development drilling is continuing with the limits of these fields still not defined.

17. J. F. JOHNSON, Sinclair Oil & Gas Company, Tulsa, Oklahoma

RECENT ADVANCES IN GEOLOGY AND GEOPHYSICS

No wholly new exploration techniques have evolved during the past 10 years. However, geologists and geophysicists have learned that there is more to discovering oil fields than the detection of closed structures and the selection of sites where rocks have sufficient porosity to hold oil. They have realized that oil fields are located only in favorable geological settings characterized by certain large-scale geological features. They also have realized that it is possible, using geology and geophysics, to analyze geological information intelligently, including well cuttings, surface samples, surface and subsurface geological maps, seismic records, gravity information, and magnetic information in order to determine whether or not the local geological environment is conducive to oil accumulation. Modern exploration techniques make possible the localization of potential oil reservoirs in such sedimentary features as limestone reef complexes, deltas, beaches, *etc.* The most difficult aspects of this modern exploration concept are the correlation of geological and geophysical data and the reduction of geophysical data into meaningful geology.

The past decade has witnessed a rebirth of sedimentary petrology in oil-finding. This renaissance involves the study of Recent sediments as a key to the past and the application of geochemistry, paleontology, and petrology to the definition of sedimentary depositional patterns. During the past 10 years, geophysicists not only have improved their equipment for better measurements of the properties of sediments but also have made significant progress in developing methods of presenting geophysical data in geological form.

18. A. B. SHAW, Pan American Petroleum Corporation Research Center, Tulsa, Oklahoma

PALEONTOLOGY IN MID-CONTINENT EXPLORATION

Paleontology (including both invertebrate paleontology and palynology) is the natural complement to the use of structure and stratigraphy in oil exploration. The decision to use it or not is fundamentally economic as is the decision to use structure (seismic) or stratigraphy. However, the changing pattern of exploration makes the use of fossils increasingly appropriate. Fossils can be used to supply evidence of time correlation and original environmental conditions that is independent of the data obtained from the rocks themselves. It is also being found that fossils themselves in many instances provide the trapping mechanism.

Fusulines are the only fossil group with a long history of application in the Mid-Continent, but many other microfossils are now becoming more useful as their study matures. There is no universally applicable fossil group because no organism was ever able to survive everywhere, but each System and many environments contain organic remains especially suitable to use therein. Thus, competence in several fossil groups is necessary to cope with normal exploration problems. Multiple competence also assures that for most subsurface problems enough usable fossils will be available to provide answers. The increased sophistication of lithostratigraphy and production techniques has made coring more commonplace. This makes available the whole range of macrofossils, which are especially valuable because in many cases their significance already is understood.

19. L. R. WILSON, University of Oklahoma, Norman, Oklahoma

PALYNOLOGICAL EVIDENCE FOR FOLDING, FAULTING, AND EROSIONAL CONTACTS IN SUBSURFACE

Palynological studies, conducted on exposed rocks illustrating various degrees of folding, faulting, and other expressions, have been used to interpret conditions observed in subsurface samples. Palynological evidence of rock folding or faulting is shown by degrees of spore and pollen preservation and progressive color changes from yellow to black. Folded structures generally can be distinguished from fault structures by more uniform and widespread occurrence of specific palynological physical changes. Regions containing igneous intrusions show similar palynological changes, but differ in proportion to type and distribution of igneous bodies. Unconformities are detected by marked palynological assemblage changes and in many instances by recycled fossils above an erosional surface. Recognition of palynological physical aspects can be useful in the identification of paleogeographic features, direction and approximate location of stratigraphic traps, paleotemperature conditions within an area, and probable oil or gas potentials.

20. K. H. ANDERSON, Missouri Geological Survey, Rolla, Missouri

FOREST CITY BASIN OF MISSOURI, KANSAS, NEBRASKA, AND IOWA

The Forest City basin of Missouri, Kansas, Nebraska, and Iowa is the area of the first oil and gas production west of the Mississippi River. Production was found near Paola, Kansas, within a few years of the birth of the American oil industry at Titusville, Pennsylvania.

Initial movements of the Ozark uplift and the Chautauqua arch began in Late Ordovician time. Attendant subsidence in the northern Kansas area formed an ancestral basin which was later bisected by the Nemaha anticline, forming the Salina basin on the west and an unnamed basin on the east. Post-Mississippian, Pre-Atokan peneplanation of the entire region took place before renewed activity along the Nemaha anticline uplifted the area west of the anticline while downwarping east of the Nemaha scarp formed the Forest City basin. Thus, it is defined as a Pennsylvanian-age basin. Movement along the Nemaha structure may have begun as early as pre-St. Peter time but certainly during Early Mississippian time and continued intermittently until at least the Early Permian.

The Cherokee and Forest City basins were separated by a low arch until middle Cherokee time when the Forest City basin filled with sediments and the two basins joined across the Bourbon arch.

Northeast-trending folds developed after Mississippian deposition, whereas previous structural orientation had been toward the northwest.

21. G. H. WEBER, Oil And Gas Journal, Tulsa, Oklahoma

HEAVY OIL IN MID-CONTINENT

Heavy oil is nothing new, and it has been known since the early days of the oil industry. There has never been a practical method by which these low-gravity crudes could be recovered in commercial amounts.

However, the advent of steam flooding and fire flooding has provided a means by which these oils can now be driven to the bore hole and produced on a practical basis.

There are vast amounts of these deposits through the Mid-Continent area with especially attractive accumulations centering in eastern Oklahoma, eastern Kansas, and western Missouri. They range from barely producible heavy oil to solids. Some of the sandstones in which these hydrocarbons occur contain 700–800 barrels per acre-foot in-place reserves. As a rule, the sandstones are lenticular and almost defy generalization.

Their advent on the United States industrial scene has been termed "The Quiet Revolution." At least 7 steam and fire-recovery projects are known to be active now; 10 have been terminated; and at least 4 are in the planning stage. Success or failure of these projects will determine the future of heavy oil in the Mid-Continent.