the field are not yet known, it now appears it will exceed the Puckett field in size and equal it in caliber of gas reserves.

Stratigraphic Controls on Pennsylvanian Oil of Paradox Basin, Four Corners Region
SHERMAN A. WENGERD, University of New Mexico, Albuquerque

Whether called an embayment, a re-entrant, a basin, a sag, or a geosyncline, the area underlain by the Paradox prism of sedimentary rocks is today no one of these. This prism reveals a complex history of (1) lithologic variation, (2) diverse tilt, and (3) structural deformation. The Paradox facies of the Four Corners region contains important reserves of Pennsylvanian oil. The *lithologic variation* of any specific sedimentary unit is a function of sedimentational history controlled by provenance and tectonism of the source area, type of transporting agent, chemistry of the marine water, and condition of the sea bottom. The *stratigraphic variations* involve thickness, intersection of bedding surfaces, diastems, and disconformities, and space available for deposition; all of which are closely related to the tilt history as well as the positive or negative shifts of the effective wave and current base. These, then, are the controls which affected the juxtaposition of different rock types to yield linear controls on the early regional migration of gas, oil, and water phases. The *structural deformation* of the Paradox prism, often considered to have occurred at finite points or areas in time such as "Laramide" or "mid-Tertiary," in reality must have occurred almost continuously from the initiation of Paradox basination in early Cherokee time, to the present time. This concept, applicable to most Pennsylvanian basins of rapid subsidence, involves recognition of directions and amounts of regional tilt by mapping finite member thickness, specific lithologic character, probable successive fluid types, and possible directions of fluid movement throughout post-depositional history of that member. These data are equated within the framework of the inferred compactional history for each stratal member during basinal subsidence. Early gentle folding occurred parallel with the facies strike and the general strike of stratal convergence during the areal crowding of the basin. These earlier gentle structures appeared in areas of relatively greater lithologic competence ("reefs") near the break-in-shelf slope, and provided the major traps for Pennsylvanian oil.

There can be little doubt that later tectonic events not only modified but probably destroyed many oil accumulations as well as masking the locations of the several large Aneth-type fields still to be found in the Four Corners region.

Structure of the Frontal Belt of Ouachita Mountains
THOMAS A. HENDRICKS, Pan American Petroleum Corporation, Tulsa, Oklahoma

The structure of the frontal belt of the Ouachitas is dominated by faulting. The faulting in general consists of a complex set of reverse faults roughly parallel with the Ouachita Mountain front and a related set of cross faults. Most of the reverse faults appear to dip at high angle and to have a horizontal component of movement that is of the order of magnitude of the vertical movement. Others, such as the Pine Mountain and Windingstair faults, appear to have had greater horizontal movement than vertical movement, and at least locally appear to dip at moderate angles. The Ti Valley fault and some minor faults appear to have a low angle of dip. The cross faults are of two types. In the northern part of the area they are characterized by strike-slip movement. South of the Windingstair fault the movement was dominantly upward. The minimum amount of movement on the reverse faults in the frontal belt appears to have been in excess of 50 miles, with the greatest part of that movement concentrated on the Ti Valley, Windingstair, and Pine Mountain faults. More or less simultaneous deformation seems to have occurred in an extreme frontal block, the block between the Ti Valley and Windingstair faults, and the block south of the Windingstair fault, with the deformation culminating in movement on the Ti Valley and Windingstair faults. Several lines of evidence suggest that the direction of movement was generally northward and that greater movement occurred in the eastern part of the area than in the western part. Incompetent shale zones constituted gliding planes along which thrust movement took place, with the principal ones being the Womble shale, Springer formation, Caney shale, Stanley shale, and Johns Valley shale. One can postulate from indirect evidence the existence of an early period of faulting along the north margin of a late Mississippian-early-Pennsylvanian geosyncline. However, the structural development of the frontal Ouachitas started in Atoka time and continued until middle Pennsylvanian time and possibly as late as early Permian time.

Rocky Mountain Association of Geologists Symposium on Pennsylvanian Rocks of Colorado

WILLIAM WYMAN MALLORY, Bell Associates, Denver, Colorado

The Rocky Mountain Association of Geologists, Denver, Colorado, published in 1958 a volume with this title in conjunction with its field conference on Pennsylvanian rocks of the Maroon basin.

Pennsylvanian tectonism was dominated by vigorous growth of northwest-trending mountain ranges (Frontrangia and Uncompahgria) and their attendant depositional troughs. These obliterated the amoeboid patterns of gentle epeirogeny in Colorado established during early and middle Paleozoic time. Pennsylvanian depositional history began in Colorado with the accumulation of a red clay regolith, the Molas formation, upon the maturely dissected Mississippian Leadville limestone. Four Pennsylvanian basins (or troughs), the Denver, the Maroon, the Paradox, and the Raton, between and adjacent to Uncompahgria and Frontrangia, contain abundant thicknesses of all lithologic types common to cratonic sediments. Two basins in western Colorado, the Maroon and the Paradox, exhibit extensive evaporites, the Paradox and Eagle sequences. All the basins contain large volumes of red, arkosic conglomerates and finer clastics (the Fountain, Maroon, Cutler, and Sangre de Cristo formations) which grade laterally into marine limestones, shales, and sandstones with or without passing through an evaporite facies.

Western Colorado marine sequences bear the names Hermosa group, Morgan formation, and Weber sandstone. In the Raton basin the Sangre de Cristo and Madera formations, predominantly clastic, comprise the section. In the Denver basin, only the Fountain arkose facies crops out (except for a trace of Glen Eyrie claystone near Colorado Springs); the series terms Morrow, Atoka, Des Moines, Missouri, and Virgil have been borrowed from the Mid-Continent region as subdivisions.

The uplifts attained maximum development in the Des Moines epoch and continued tectonically active into middle Permian time. Pennsylvanian deposition carried over without hiatus into the Wolfcamp epoch of the Permian period. The existing Uncompaghre uplift and the Frontrange uplift (now masked by the Laramidian Front and Park Ranges) are part of the present tectonic pattern of Colorado.

The bulk of Colorado oil has been produced from three reservoir classes: (1) Cretaceous sandstone lenses scattered across the Denver basin, (2) the Weber sandstone of the Rangely pool in the Maroon basin, (3) the Hermosa carbonate reservoirs in the Paradox basin. The latter two, Permo-Pennsylvanian in age, are outstandingly important. The size and youth of Pennsylvanian carbonate pools indicate large reserves in these rocks.

Recent Developments in Alaska

W. B. SHERMAN, Pan American Land and Royalty Co., and J. W. WATSON, DeGolyer and MacNaughton, Dallas, Texas

The discovery of commercially recoverable oil on the Kenai Peninsula by Richfield in 1957, coupled with the prior oil and gas discoveries made by the Navy in and adjacent to Naval Petroleum Reserve No. 4 in Northern Alaska, and the subsequent opening to public leasing of Interior Department lands east of the Reserve have caused the oil companies to renew their interest in Alaska.