curvature (the second derivative of structure) can be expressed mathematically and it is found that permeability varies as the third power of curvature. A map of values of structural curvature shows a remarkable coincidence between areas of maximum curvature and areas of best productivity.

Volumetric considerations show that the quantities of oil being produced cannot be coming from the Sanish zone. It is concluded that the immediately overlying, highly petroliferous, Bakken Shale is the immediate as well as the ultimate source of this production. The role of the Sanish fracture system is primarily that of a gathering system for many increments of production in the Bakken.

The extremely high initial reservoir pressure indicates that the Sanish-Bakken accumulation is in an isolated, completely oil-saturated reservoir and, hence, is independent of structure in the normal sense. Similar accumulations should exist anywhere in the Williston basin where a permeable bed, of limited areal extent, is in direct contact with either of the Bakken shales.

15. STEVEN H. HARRIS, Harris, Brown and Klemer, Bismarck, North Dakota; COOPER B. LAND, JR., North American Royalties, Inc.; AND JOHN H. McKEEVER, Pan American Petroleum Corporation, Denver, Colorado

RELATION OF MISSION CANYON STRATIGRAPHY TO OIL PRODUCTION IN NORTH-CENTRAL NORTH DAKOTA

Nineteen oil fields in Renville and western Bottineau Counties, North Dakota, produce or have produced from the Mission Canyon (Mississippian) Formation. The production is primarily stratigraphic and occurs within five distinct and mappable sedimentary cycles herein named, in ascending order: Wayne beds, Glenburn beds, Mohall beds, Sherwood beds, and Bluell beds. Proper recognition and use of this cyclic framework are essential for interpreting the sedimentary history of the Mission Canyon. Structural, isopachous, and lithofacies studies can outline optimum areas to seek production within each unit.

16. ALAN R. HANSEN, Sun Oil Company, Billings, Montana

REEF TRENDS OF MISSISSIPPIAN RATCLIFFE ZONE, NORTHEASTERN MONTANA AND NORTHWESTERN NORTH DAKOTA

Algal pelletoid reef deposits comprise the oil-productive rocks of the Ratcliffe zone in the subject area. These rocks were formed in a moderate- to high-energy environment near the western limits of the Williston basin.

The reef trends were partially controlled by older faults or hinge lines which were re-activated during Ratcliffe time.

17. WILLIAM W. BALLARD, Balcron Oil Company, Billings, Montana

KIBBEY FORMATION OF MONTANA

Laboratory and field studies of the Kibbey Formation indicate that Kibbey rocks were deposited largely in shallow, marine, oxidizing water in the Big Snowy sea which extended across central Montana during Late Mississippian time. The Siouxia (Transcontinental) arch east of the depositional site supplied most of the detritus for the Kibbey rocks. The climate was semiarid. Relatively stable tectonic conditions with moderate to low relief prevailed in the source area throughout Kibbey deposition.

The present northern limit of Kibbey rocks is a result of post-Kibbey erosion; the southern limit, although locally determined by erosion, is essentially the depositional limit.

Sandstone beds of the Kibbey produce oil in Musselshell and McCone Counties, and produced for a short time in Roosevelt County, Montana. Kibbey rocks at *all three* productive localities appear to have been deposited under very similar environmental conditions and in essentially the same position with respect to the axis of the Big Snowy sea.

18. JAMES L. ALBRIGHT, Pubco Petroleum Corporation, Albuquerque, New Mexico

LISBON VALLEY ANTICLINE, PARADOX BASIN, UTAH—EXPLORATION AND DEVELOPMENT

In 1959, Pure Oil Company made sensational simultaneous discoveries of the first major oil and gas accumulations from the Mississippian in the Paradox fold and fault belt at Lisbon and McIntyre Canyon Units. These discoveries indicated that the tectonics of the pre-salt flowage structures in the province could and would be solved. A massive exploration program was launched, but during the intervening years, only three relatively minor discoveries have been made in pre-Pennsylvanian rocks. Two of these are associated with the Lisbon structural complex.

Similarities between the Persian salt anticlines and those of the Paradox basin had long been recognized and the idea of parallel, but offset, pre-salt structures was the basis on which large blocks were leased. Many operators were wary of seismic problems associated with salt flowage and(or) solution; however, Pure persevered and, in 1957, demonstrated at Big Flat field that seismic mapping was feasible and that the Mississippian could contain oil. This led to Pure's successful survey at Lisbon.

Drilling has shown that the thickened salt core of the Lisbon Valley surface anticline occupies the crestal graben of an offset-toward-the-southwest pre-salt anticline. Mississippian fault traps closed against salt have been found on the upthrown blocks on each side of the graben. Largest of these is the Lisbon Unit with 1,800 ft. of effective closure. In addition to the Mississippian, oil production has been obtained from the Devonian Ouray and McCracken but early promise of these formations as important objectives has not materialized.

One well, now abandoned, has produced oil from the Paradox salt.

Post-salt Pennsylvanian producing potential is indicated by two shut-in wells from multiple Hermosa sandstones on the downthrown block of the surface anticline which is closed against salt. Several wells within the Lisbon Unit have also tested "shows" of oil on drill-stem tests of the Ismay.

The Lisbon Valley-Dolores trend is only one of the five major salt flowage structural trends of the Paradox basin. Traps similar to those at Lisbon can be expected to be associated with other salt anticlines. A conservative estimate of the ultimate gross value of recoverable hydrocarbons from the Lisbon anticline is $100,000,000. Search for similar accumulations is indeed warranted!

19. JAMES A. PETERSON, University of Montana, Missoula, Montana.

STRATIGRAPHIC VS. STRUCTURAL CONTROLS ON HYDROCARBON ACCUMULATION IN ANETH AREA, PARADOX BASIN

Pennsylvanian oil and gas accumulations in the southern Paradox basin occur in carbonate mounds of