band of deposition between the area of continuous beach sands and the seaward pinch-out of the Gallup tongue. In addition, fractured reservoirs with poorly developed sands could be expected throughout this band and for a short distance seaward.

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Rocky Mountain Association of Geologists Symposium on Pennsylvanian Rocks of Colorado

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

The principal results of these collected studies show that 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 depositional basins (or troughs), the Denver, Maroon, Paradox, and Raton, between and adjacent to Uncompahgria and Frontrangia, contain abundant thicknesses of all lithologic types common to cratonic sediments. Two of the basins in western Colorado, the Maroon and 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 the Magdalena group, predominantly clastic, comprise the section. In the Denver basin, only the Fountain arkose facies outcrops (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 faunal subdivisions.

The uplifts attained maximum development in the Des Moines epoch and continued tectonically active into middle Permian or Leonard time. Pennsylvanian deposition carried over without hiatus into the Wolfcamp epoch of the Permian period. The rejuvenated Uncompahgre and the Front range uplifts (now masked by the Laramide Front and Park Ranges) are part of the present tectonic pattern of Colorado.

The bulk of Colorado oil may be classified as follows: (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 last two, Permo-Pennsylvanian in age, contain outstandingly important additional reserves. The size and relative youth of Pennsylvanian carbonate pools indicate that additional large reserves can be anticipated in these rocks.

R. G. MCCROSSAN, Imperial Oil Limited, Calgary, Alberta

Application of Resistivity Mapping to Upper Devonian Interreef Ireton Formation of Alberta

The Woodbend group of Upper Devonian age in central Alberta is a reef complex characterized by large-scale facies changes. The reefs, which grew in a subsiding basin and were initiated in restricted areas of suitable depth, are surrounded by the calcareous shales and argillaceous limestones of the Duvernay and Ireton formations. Isopach maps indicate relative movements of the basin during deposition. Very fine carbonate clastics derived from the reefs were spread throughout the basin during Duvernay and lower Ireton time. The distribution of these carbonates was detected by mapping the average apparent resistivity of a stratigraphic interval from borehole measurements.

The pore volume of these rocks decreases with increasing depth and carbonate content, and resistivity increases correspondingly. The straight-line relation of carbonate content and porosity suggests that reduction of porosity is directly proportional to the volume of calcite grains present. Other factors affecting porosity aside from carbonate content and depth of burial are small by comparison. Internal redeposition of calcium carbonate has been unimportant.

Resistivity mapping in the subsurface shows promise of being a useful exploration tool for determining the relative amount of coarser grains in shale.

RICHARD M. MODEL and JOHN J. SCHULTE, Northern Pacific Railway Company, Oil Development Department, Billings, Montana

Oil and Gas Possibilities of Porcupine Dome, Rosebud County, Montana

"What is the matter with Porcupine dome?" This question is often asked by explorationists working in central Montana. Although it does not have as much closure as some central Montana structures, in areal extent it is the largest feature in the Big Snowy anticlinorium. Twenty wells drilled

in the Judith River formation rimrock bounding the higher structural part of the dome have failed to establish production.

To determine the relation of these wells to surface structure, a reconnaissance with the aid of air photos was undertaken during the 1958 field season. An attempt was made to find mappable units in the apparently monotonous Upper Cretaceous sequence cropping out on the central part of the dome. Although lithologic changes in these formations are subtle, it is believed that substantial progress has been made in recognizing the distribution of these rocks. As a result a better understanding of the structural configuration of Porcupine dome has been reached.

From this preliminary work several important exploratory possibilities are suggested.

1. The highest structural point on the dome has not been tested.
2. The most prominent anticlinal axial trend, approximately 36 miles in length, has not been drilled for a distance of 30 miles. Several untested closures are indicated along the trend.
3. The present structure of the dome is essentially the result of Laramide orogeny. Application of hydrodynamic factors, as modified by stratigraphic controls and ensuing time, points to possible areas for oil and/or gas entrapment.

It is concluded that Porcupine dome has not been adequately explored and that its possibilities for hydrocarbon production can be determined only by the drilling of favorably positioned wells.

GEORGE H. MURRY, JR., Consultant, Billings, Montana

Examples of Hydrodynamics in Williston Basin at Poplar and North Tioga Fields

One of the generally accepted inferences with regard to the Williston basin has been that it should be relatively free from hydrodynamic influences. However, a large proportion of the pools in this basin have inclined oil-water contacts and, in some, tilting is an essential feature of the trap. Two excellent examples of such fields are the Poplar pool in northeastern Montana and the North Tioga pool on the north end of the Nesson trend. The reservoir in the Charles formation at Poplar has a readily demonstrable tilt in the oil-water contact of approximately 40 feet per mile north-northeast. At North Tioga a dip of the same order of magnitude, but toward the southeast, is apparent in the water table in the Mission Canyon formation. In both places, log and sample studies show that the tilting can not be ascribed to an "apparent condition" arising from stratigraphic changes. The tilt at Poplar is merely an interesting aberration in an essentially structural accumulation. On the other hand, hydrodynamics is a necessary component of the trap at North Tioga.

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Core Examination

The Oxbow-Carnduff field of southeastern Saskatchewan emphasizes the need of detailed lithological studies in evaluating a reservoir. A critical comparison of routine core analysis and detailed core studies in the field shows that a substantial percentage of the reservoir unit, which has porosity and permeability above a reasonable lower cut-off, is ineffective and unstained. The effective pay within the unit is determined not only by its porosity and permeability but also by the grain size of the carbonate. This example points out the need of full use of core examination in conjunction with core analysis in the evaluation of a reservoir.

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Structural Control Related to Stratigraphic Traps, Piceance Creek Basin, Colorado

Few if any accumulations of petroleum classified as being of stratigraphic origin are totally independent of structural control. In a consideration of the stratigraphic potential of a basin, therefore, it is prerequisite that due consideration be given to at least the principal structural deformations that have occurred within the basin during and since the deposition of the most prospective formations.

Scrutiny of thickness variations in the sediments the Piceance Creek basin reveals that the basic tectonic framework controlling the present configuration of the basin was in evidence at least as early as the oldest Cretaceous sediments represented in the basin. Stronger border components, such as the Uncompahgre arch, the White River uplift, and possibly the Douglas Creek arch are identifiable as positive structural elements during earlier periods, and were periodically active in influencing the nature of deposition within the Piceance Creek basin from Cretaceous through Eocene time.

With the exception of a few features deep within the basin, where data is not available or is inconclusive, thickness variations within the Mancos shale section indicate either early or continued phases in the structural development of all of the principal components forming the tectonic framework of the present basin. The Danforth Hills anticline on the northeastern side of the basin is revealed as an active positive area during Mancos time. The Douglas Creek arch is clearly defined by a relatively thin Mancos shale section.

Thickness variations of the later Cretaceous sediments (Mesaverde) indicate continued structural development of the basin similar to Mancos time, though of a greater magnitude.