

9. JOHN S. RUNGE, Petroleum geologist, Casper, Wyoming

EXPLORATION FOR OIL AND GAS IN WYOMING, 1964-1965

In the past 12 months significant new discoveries of oil and gas have been completed in the Powder River, Wind River, and Washakie basins. The eastern Powder River basin continues to lead the State in the number of new discoveries. However, remote discoveries of Minnelusa oil in the center of the Powder River basin, gas in deeper portions of the Wind River basin, and gas in several areas along the rim of the Washakie basin have provided new exploration frontiers. Thermal stimulation as a completion technique for exploratory wells also has provided a new exploration frontier.

Deeper drilling in the center of the Powder River basin found oil in the Minnelusa in a structural trap and caused the largest land play that the State has had in several years. Multi-pay gas discoveries in the deeper portion of the Wind River basin, combined with new gas outlets, have provided new exploration incentive for this area. Three gas discoveries along the rim of the Washakie basin have stimulated interest in the exploration potential of this sparsely drilled area.

Thermal stimulation as a completion technique in previously unproductive areas has attracted large leasehold investments in several basins. Pilot projects which were underway during the past 12 months have met with mixed results, several appearing to be successful whereas others appear to be in question. The coming year is expected to reveal additional data concerning the parameters for successful thermal-stimulation projects.

A review of exploratory statistics of the past 20 years reveals that Wyoming has been on an exploratory success-ratio plateau for the last 10 years with an average of 12.6 per cent of all exploratory wells completed as producers. The stratigraphic and combination type traps discovered during this period are 60-70 per cent of the total; structural traps are in the minority. This ratio in classification of new discoveries is expected to continue in the near future.

The decline in leaseholds on Federal and Indian lands of 25 per cent during the last 5 years indicates the change from "protection leaseholds" to "drillable leaseholds." The result is the increasing availability of leases at lower prices and the upgrading of exploratory prospects. This is expected to have a favorable effect on the success ratio of exploratory wells.

Wyoming's stable growth in production and reserves of petroleum and the rapid cash flow from unrestricted production combine to make a favorable climate for exploration investment. The increasing diversity in exploration techniques and the numerous areas available for exploration are expected to challenge every geologist working in Wyoming.

10. KYE TROUT, Petroleum engineer and geologist, Bismarck, North Dakota

EXPLORATION AND DEVELOPMENT HIGH-LIGHTS IN NORTH DAKOTA, 1964-1965

The year 1964 was one of renewed activity and interest in North Dakota oil exploration and development with highly significant increases in both wildcatting and development drilling. Indications are that this trend is continuing into 1965, with activity levels the highest since 1958.

At the beginning of 1965, North Dakota official fig-

ures showed 2,065 oil wells and 28 gas wells producing from 103 oil pools and two gas fields.

A new center of drilling interest continues in Billings County with development of dual-completion wells from productive Tyler (Pennsylvanian) and Madison (Mississippian) zones. Deeper exploration for Devonian objectives is underway in McKenzie County, spurred by good wells with attractive economic considerations.

In the shallower north-central North Dakota areas, exploration and development of numerous stratigraphic sequences in Mississippian sections encourage continuing efforts in the vicinity of prolific producing areas. Sherwood field (Madison-Mississippian) has undergone its third significant re-definition and extension development since discovery in 1957. Other discoveries from the same zone have been made, and the hunt for other stratigraphic fields in the Mission Canyon remains a prime factor in North Dakota exploration. Attractive wells in the City of Mohall and Mouse River Park fields have been developed.

Several major lease acquisition programs reminiscent of earlier North Dakota Williston basin days were conducted in Golden Valley, Morton, Grant, Stark, and Sioux Counties, notably by Amerada and Pure, indicating extension of exploratory interest into untested areas. An awakening of renewed exploratory interest in some of North Dakota's "east-side" counties is under way.

A prime factor in North Dakota's oil picture has been, and is, the enlightened and favorable regulatory environment. Adequate markets and transportation facilities, with reasonably good crude oil prices, prevail and make North Dakota competitive with other oil- and gas-producing areas. Dual-completion prospects, moderate lease prices, sensible well spacing, and good well productivities, together with rapid penetration rates and nominal drilling costs, create attractive economic climates for oil operators; North Dakota will remain near the top of the exploration and development ledger in the coming months as a good place to do business and to look for oil and gas.

11. D. D. McLEAN AND H. B. SAWATZKY, Geophysical and Evaluation Division, Saskatchewan Department of Mineral Resources, Regina, Saskatchewan

RECENT MINERAL DISCOVERIES IN SEDIMENTARY BASIN AREA OF SASKATCHEWAN AND POSSIBLE FUTURE DEVELOPMENTS

The demand for Saskatchewan crude oil, the proximity to market, the high success ratio, the large potash reserves, coupled with the newly formed government incentive measures, have created a program of rapid expansion within the mineral industry of Saskatchewan.

During 1964 more than 1,200 wells were drilled in search of petroleum, natural gas, and helium and more than 70 in the search for potash.

Several significant field step-outs and new discoveries were made in Saskatchewan within the known (Lower Cretaceous, Jurassic, and Mississippian) petroleum reservoirs during 1964 and early 1965. The lower Paleozoic formations offer the most exciting possibilities for future developments.

Many of the hydrocarbon traps in Saskatchewan are a combination of stratigraphic and structural features and, therefore, a total approach to exploration employing both geophysical and geological methods is emphasized. Case history studies are important as examples of successful techniques. In potash exploration

the seismograph has proved to be an invaluable tool in describing potential potash reserves by outlining areas of salt removal. Gravity and magnetic control may help to unveil some lower Paleozoic structural anomalies. The Nelson River gravity "high" appears to suggest the position of the boundary between the Churchill and Superior Precambrian provinces in southeastern Saskatchewan and, therefore, outlines a very interesting trend with respect to lower Paleozoic prospects.

12. LLEWELYN JONES, Geological Sciences Branch, Saskatchewan Department of Mineral Resources, Regina, Saskatchewan

SEDIMENTATION AND ECONOMIC PROSPECTS OF MIDDLE DEVONIAN WINNIPEGOSIS FORMATION OF SASKATCHEWAN

The Middle Devonian Winnipegosis Formation of Saskatchewan is divisible into upper and lower members on the basis of a regionally developed argillaceous interval which forms the uppermost part of the lower member.

The lower member consists of a regionally dolomitized marine carbonate of relatively constant thickness and lithology, attaining a maximum observed thickness of 54 ft. The upper member is a varied marine carbonate sequence, with three major facies developments. In the southwest lies a wedge of lithologically relatively consistent carbonates, reaching a maximum thickness of about 130 ft. along a northwest-trending axis extending through Weyburn and Elbow. In the north and east, bioclastic-pelletoidal carbonate banks with true reef intervals (up to 345 ft. thick), and finely laminated, interbank carbonates (up to 68 ft. thick) occur.

The lower member was laid down in a broad epicontinental sea. The relatively shallow, open marine conditions culminated on two occasions in basin-wide, reducing, lagoonal conditions, evidenced by the medial and upper very bituminous argillaceous intervals containing impoverished faunas. The upper member appears to have been deposited in a shallow shelving sea which deepened toward the northeast. Using a regionally developed *Amphipora* zone as a datum, three pre-*Amphipora* tectonic-sedimentation regions are discernible: in the southwest, the Elbow-Weyburn basin, subsiding relatively rapidly to accommodate thick, shallow-water carbonates; in the north and east, the comparatively stable Saskatoon shelf, with thin laminated carbonates and basal carbonates of the bank sediments; and the more rapidly subsiding Meadow Lake-Sayese basin complex, with similar sediments, except that bank sedimentation was further advanced. In post-*Amphipora* time, subsidence continued in the north, accelerated in the shelf area to accommodate thick bank accumulations, whereas, in the southwestern basin, carbonate deposition was almost complete.

Although no commercial quantities of oil or gas have been found in Saskatchewan, production of oil from the Winnipegosis in the Outlook and Redstone fields of northeastern Montana is encouraging. The occurrence of oil and gas "shows" in some drill-stem tests and of oil staining in the Winnipegosis Formation in Saskatchewan offers further encouragement, especially in the Elbow-Weyburn basin, which is a northwestern extension of the oil-producing facies of northeastern Montana. The presence in the southwestern basin of permeability traps resulting from differential dolomitization and recrystallization, and, in the north and east, of important thickening in short distances, associated with variably porous bank carbonates, together with the widespread development of an excellent top seal in the

form of the Prairie Evaporite salt or carbonate-anhydrite sequences, provide excellent conditions for the entrapment of hydrocarbons.

13. FRANK A. RADELLA, Consulting geologist, Billings, Montana

NISKU OF NORTHEASTERN MONTANA WITH SPECIAL REFERENCE TO TULE CREEK AREA, ROOSEVELT COUNTY, MONTANA

Oil accumulations of the Tule Creek area, that are found in the Devonian Nisku Formation, are a result of structural and stratigraphic conditions. Present-day productive structures have about 50 ft. of closure. These structures occur in an area of favorable Nisku patch-reef environment that was subjected to secondary dolomitization.

The Nisku of the Tule Creek field consists of anhydrite, limestone, and dolomite and averages 81 ft. in thickness. The upper one-third of the formation is primarily anhydrite and the lower two-thirds are dolomite. Some limestone always is present in the middle of the anhydrite unit. In the lower two-thirds, where found off structure, the unit is non-productive and (or) out of the favorable facies.

Oil production is from vuggy and intercrystalline porosity and permeability developed by secondary dolomitization. Occasional high-angle fractures contribute only slightly to the over-all reservoir productivity. Abundant relict *Amphipora* and lesser amounts of algae are apparent in the dolomite and appear to be the primary host for the dolomitization process. Only minor amounts of *Amphipora* are found in the non-dolomitized carbonate strata.

On structure, oil-productive dolomite consists of large-sized rhombohedral crystals oriented randomly or in point-to-point contact, improving the primary porosity and creating excellent permeability. The lesser dolomitized, non-productive, off-structure Nisku exhibits good apparent log porosity but very low actual effective permeability. These off-structure dolomites are finer-grained, slightly to moderately calcareous, and have a face-to-face crystal orientation.

The favorable patch-reef facies of the Nisku Formation is controlled by environment and trends locally in a southwest-northeast direction.

Structural closures that occur in the favorable facies area contain reservoir rocks with excellent porosity and permeability.

With a 24-ft.-thick anhydrite bed above the "pay" zone, a 10-ft.-thick dense anhydritic shale (Ireton Member) below, and a lack of extensive fracturing, the Nisku is postulated to be its own source rock.

14. GEORGE H. MURRAY, JR., Consulting geologist, Billings, Montana

QUANTITATIVE FRACTURE STUDY—SANISH POOL, MCKENZIE COUNTY, NORTH DAKOTA

The Sanish pool of the Antelope field has a number of unusual facets which make it almost unique in the Williston basin. Some of these are: (1) high productivity of a number of wells from a nebulous, ill-defined reservoir; (2) association with the steepest dip in the central portion of the basin; (3) very high initial reservoir pressure; and (4) almost complete absence of water production.

Analysis of these factors indicates that Sanish productivity is a function of tension fracturing associated with the relatively sharp Antelope structure. A relationship between fracture permeability and structural