FINAL AND INTERPRETATIVE REPORT

MAGELLAN PETROLEUM

OP189

NORTHERN TERRITORY
GEOLOGICAL SURVEY

HISTORY OF PETROLEUM EXPLORATION

PERMIT 189

Prior to 1978, petroleum prospects in the area covered by Permit 189 attracted little attention. Work done in prior years had indicated that most of the sediments underlying the area were Early Cambrian to Late Proterozoic in age. At that time, such sediments were not known to produce oil or gas anywhere in the world. A second reason for lack of interest was the complicated geology seen in surface outcrops. Such complexity makes the search for productive structures both difficult and expensive.

Also, elsewhere in the Amadeus Basin there were more promising areas with known productive sediments and less complex structures. For this reason, the area now covered by Permit 189 was not included when earlier permits were applied for.

Although Early Cambrian and Late Proterozoic rocks were not highly regarded as potential productive reservoirs, one source-rock analysis for shales of the Pertatataka Formation from the Ooraminna No. 1 well did indicate the presence of hydrocarbons. Despite this encouragement, the low economic incentives at that time (i.e. oil price of about U.S. $1.80 per barrel), high exploration costs, and remote location discouraged exploration in the general area of Permit 189.

From 1973 to the present, a number of diverse factors have made the area covered by Permit 189 much more attractive.

Among these are:

1. An escalation in the price of oil to U.S. $34.00 per barrel;

2. The development of more sophisticated seismic techniques, both in data gathering and processing, that now provide means to map highly complicated geological features and successfully locate productive structural closures that previously could not be mapped.

3. Newer and better methods of well stimulation that allow production from reservoirs of very low porosities and permeabilities which previously had been classed as noneconomic.

4. The news that elsewhere in the world (Russia), Early Cambrian and Late Proterozoic rocks are productive and contain giant fields.

5. Studies conducted by Magellan that indicated the loading of Late Proterozoic and Cambrianrocks, by younger sediments, had been sufficiently light throughout geologic time in the areas just west of Permit 189, to allow the retention of oil and gas.

As a result of all these factors, Coastal Caribbean Oil and Minerals Ltd. applied for the present Permit 189. Field geological surveys were commenced in 1979.

In October, 1980, the Australian Bureau of Mineral Resources, Geology and Geophysics (B.M.R.) announced the discovery of live oil in limestones of the Chandler Formation in their shallow stratigraphic test at Ulta Bank Creek in the northwest corner of Permit 189. This suggests that if the structural complexities can be resolved the chances of economic production within Permit 189 should be excellent.

TECHNICAL NOTES ON STRUCTURES IN THE AMADEUS BASIN

GENERAL STATEMENT

The following notes summarise much more detailed information contained in a 1980 report that D.A. McNaughton coauthored with W.A. Huckaba. Although this geological report did not deal with petroleum prospects on lands covered by Permit 189, it included three sheets that present the results of recent surface mapping that R.Q. Oaks completed along the boundary line between Permits 175 and 189.

Subsurface geological information available on Permit 189, comprises one shallow stratigraphic test (B.M.R. shallow well at Ulta Bank Creek) and the seismic and gravity control in the Camel Flat Syncline, area.

STRUCTURAL HISTORY

The northeastern part of the Amadeus Basin has had a long and varied structural history starting with broad surface subsidence some 850 million years ago and ending with a mountain-building episode some 300 million years ago (the Alice Springs orogeny). Since then, the earth's surface in this part of central Australia has been rather stable.

Early surface subsidence initiated marine deposition that started with basal layers of sand (Heavitree Quartzite). With the passage of time the climate became more arid and/or connections between the shallow seas covering central Australia and the open ocean became restricted. These led to a change from sand to evaporite deposition (Bitter Springs

Formation). Thick salt deposits which accumulated at that time were to play a very important role in all subsequent structural movements that occurred both before and during the Alice Springs orogeny.

A similar change from sand to evaporite desposition occurred during Early Cambrian time when desposition of Arumbera sand was followed by Chandler evaporite desposition. For purposes of this report, attention is focussed on these two layers of evaporites in the eastern part of the Amadeus Basin.

Firstly, the older and thicker layer (Bitter Springs) flowed in response to sediment loading, thereby initiating the formation of salt related structures. Secondly, a world-wide association exists between evaporites and petroleum accumulation. Although this association arises in part from factors such as the excellent sealing characteristics of salt over-lying oil and gas accumulations, and the physical association of salt-cored structures forming petroleum traps, recognition is emerging that rates of organic production and preservation may have been very high in some saline basins. Thus these basins were favourable places for the desposition and preservation of petroleum source rocks.

This association between evaporites and petroleum seems to exist in rocks of very different ages. For example, Middle East oil is associated with Mesozoic evaporites, Irkutsk oil and gas accumulations in Siberia are associated with Late Proterozoic and Early Cambrian evaporites, and oil and gas shows in the Amadeus Basin are common in Chandler and Bitter Springs evaporites of Cambrian and Late Proterozoic age respectively.

PETROLEUM POTENTIAL IN PERMIT 189

REGIONAL STRUCTURAL SETTING

Permit 189 covers about 8,100 square kilometres in the eastern part of the Amadeus Basin. It is bordered on the west and on the north-west by Permit 175.

Rocks underlying the northern part of Permit 189, north of Allambi Hills uplifts, form one or more thrust sheets above a detachment or detachments in Bitter Springs salt. These thrust sheets were transported to the south-southeast during the Alice Springs orogeny. The zone of multiple thrust faults that reach the surface along the Allambi Hills uplifts probably forms the leading edge of this thrust complex.

Intensities of structural deformation appear to decrease southward from Allambi Hills uplifts, e.g., the open, low-relief Camel Flat syncline and the anticlines responsible for the Rodinga and Pillar hills. It is postulated that several of these anticlines are surface expressions of small individual thrust faults that climb upward through the geologic section from a sole fault in the Bitter Springs Formation.

R. Oaks is of the opinion, from examinations of outcrops in the Rodinga and Pillar hills, that neither the finding, nor the defining, of any structural traps that may be preserved on these anticlines should pose insurmountable problems for seismologists using newly developed seismic techniques.

Seismic exploration north of the Allambi Hills uplifts may introduce geologists and geophysicists to subsurface structures that have not been mapped elsewhere in the Amadeus

Basin. For example, trends of folds in this area "box-the-compass" and thus differ from the previously mentioned local parallelism of fold trends on Permits 175 and 178.

Crest fault exhibits 1½ to 2 kilometres of horizontal slip. This type of fault previously was recognised only in the extreme western part of the Amadeus Basin. Finally, steeply dipping normal faults appear to be much more common on Permit 189 than elsewhere in the Amadeus Basin.

PETROLEUM SOURCE ROCKS

The presence of commercial quantities of petroleum at Mereenie and Palm Valley fields establishes that both oil and gas have been generated in the Amadeus Basin. Shales of the Horn Valley Formation probably are the source of petroleum in these two fields, and are generally considered the major potential source rocks in the central part of the Amadeus Basin. Although this formation is absent in outcrops in Permit 189, due to erosion prior to deposition of the Mereenie Formation, several older formations present in Permit 189 are considered important hydrocarbon source rocks. This has been demonstrated by the gas accumulation in sandstones of Lower Cambrian and/or Upper Proterozoic age at Dingo which almost certainly are sourced from shales of similar age.

Various geochemical analyses of well samples have indicated high amounts of extractable organic carbon for shales within the Areyonga and Pertatataka formations and for limestones within the lower part of the Bitter Springs Formation. Various gas shows have been recorded within limestones of the Bitter Springs, Areyonga, and Chandler formations in the four wells drilled less than 50 kilometres west and northwest of Permit 189, and an oil show was encountered by the B.M.R. in the Bitter Springs north of the permit boundary. Free oil was recovered by the B.M.R. from the Chandler Formation within the northwest part of Permit 189 at 130 metres below the surface. Throughout Permit 189 outcrops of limestone of both the Bitter Springs and Chandler formations typically have a strong bituminous odor. Within the Cambrian sequence above the Chandler, carbonates in the lower part of the Giles Creek Formation had a "live" oil show in Alice No. 1 well and also have a slight bituminous odor locally in outcrop.

Thus rocks of Late Proterozoic to Cambrian age exhibit promising source-rock characteristics. Sufficient periods of burial have occurred at appropriate depths for generation of hydrocarbons from each of these potential source rocks, particularly those of Late Proterozoic age. The carbonate nature of most of the potential source rocks suggests that generated hydrocarbons may be less gas-prone and more oil-prone than expected for shale source rocks buried to similar depths.

RESERVOIR ROCKS

Sandstones of the Pacoota and Stairway formations are the main reservoir rocks in the Palm Valley and Mereenie fields. Porosity types appear to be predominantly matrix and fracture, respectively at Mereenie and Palm Valley. In Permit 189, outcrops of these sandstones are limited to the extreme southwest corner, in settings unlikely for traps. However, R. Oaks examined outcrops in many parts of Permit 189, and concluded that potential reservoir rocks are present at several levels in the geological sequence.

North of the Camel Flat syncline the most promising sandstones with open pore spaces are in the Arumbera Formation. Some of these sandstones have porosities as high as 26 percent in outcrop, and locally retain fair to good reservoir-rock characteristics in the subsurface (Alice No. 1, Ooraminna No. 1 and Wallaby No. 1 wells). More significantly, lower Arumbera sandstones with fair reservoir characteristics are gas bearing at Dingo. Similarly, high porosities are also present in sandstones of the Mereenie Formation and the basal part of the Hermannsburg Formation, both in surface outcrops and in the subsurface (Orange No. 1 well). Favourable trapping conditions for these two formations in Permit 189 may be present south of the axis of Camel Flat syncline. Sandstones of the Areyonga, Arumbera, Mereenie, and Hermannsburg formations, where cemented by quartz and later folded and faulted, also may contain extensive fracture porosity.

Most of the carbonates exposed throughout Permit 189 are dense rocks with little open pore space. However, such rocks are brittle and subject to fracture. Surface geologic mapping indicates that numerous folds and faults with intersecting trends are present in Permit 189. Thus, secondary porosity created by fracturing of brittle rocks should be a common characteristic in several Cambrian and Late Proterozoic formations. Such fracturing should be most severe across crests of folds and at intersections of faults or of faults and folds.

The lower parts of the Bitter Springs and Chandler formations are especially favourable as potential reservoir rocks. Both contain limestones, which are generally prone to enlargement of of fractures by solution. The limestones in these two units are particularly liable to fracture due to flowage of interlayered salt beds. High bituminous contents of these limestones require little or no migration of generated hydrocarbons into adjacent fractures. In addition, carbonic acid produced during generation of hydrocarbons is a major agent of solution of carbonates.

Modern techniques of hydraulic fracturing can be used during completion of a well to increase the permeability in fractured rocks near the borehole. Where successful, these techniques stimulate increased rates of flow of hydrocarbons to the borehole.

RESERVOIR SEALS

Below the Goyder Formations, shales and two salt-bearing units are both laterally widespread and strategically placed vertically to form good seals for sandstone and carbonate reservoir rocks. The effectiveness of the thick shales of the Pertatataka Formation is suggested by shows of gas in the underlying Areyonga and Bitter Springs formations. Another concentration of shows of gas and live oil was recorded from the Chandler and lower Giles Creek formations, but not from the overlying shale-rich upper Giles Creek and Shannon formations. Salt in the lower Chandler Formation and shales in the Tood River Formation and within the Arumbera seal the permeable sandstones of the Arumbera Formation to vertical migration of hydrocarbons, except perhaps near faults, as is definitely demonstrated at Dingo.

Because salt was intimately involved during folding and faulting, many of the faults in Permit 189 may be well sealed by salt. Thus, in Permit 189, petroleum hydrocarbons may be able to migrate only short distances vertically. If so, large accumulations can result where the hydrocarbons are able to migrate laterally to the highest parts of closed structures such as anticlines or fault-bounded traps.

CONCLUSIONS

Within Permit 189, several prospects and leads have been identified. These include structural traps (anticlines, combinations of folds and faults, and faults alone) and possible stratigraphic traps. Other types of stratigraphic traps may be present elsewhere, especially near older growth anticlines, where pinchouts of reservoir rocks can develop against the flanks of the structure during desposition. Upward intrusion of salt also may form another type of structural trap locally in Permit 189.