An Assessment of the Petroleum Potential of the Gulf of Carpentaria With Particular Reference to Oil Permits 98 and 99, Northern Territory

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INTRODUCTION

The Gulf of Carpentaria is the major indentation in the North Australian coastline, occupying an area of more than100,000 square miles. British Admiralty charts, based mainly on soundings taken 160 years ago, indicate a maximum depth of water of 250 feet in a narrow central north-east trending depression. Nearer the shoreline recorded depths do not exceed 200 feet and the ocean floor slopes gently from the shore.

A few wells have been drilled along the east coast of the Gulf and on Mornington Island and a regional aeromagnetic survey covers the area. The ages and types of surface outcrops fringing the gulf have been adequately determined, but detailed geological work has been undertaken only in a few isolated areas.

Oil Permit 98 has been granted to Messrs. Hare and Mapleback and Oil Permit 99 to Farmout Drillers N. L. The location of these Permits is shown in Fig. 1.

The regional geology will be discussed, followed by an interpretation of aeromagnetic surveys and seafloor contours. Possible areas of thick sediments will be indicated and the petroleum potentialities of Permits 98 and 99 considered.

GEOGRAPHICAL AND ECONOMIC FACTORS

The area under consideration lies between 11^{o}S lat. and 16^{o}S lat. The climate is tropical with the major rainfall occurring during the Monsoon Season, from December to March. Summer temperatures and humidity are high and the Monsoon Season is generally accompanied by cyclonic disturbances. Consequently, the best period for field operations is from April to early November.

The north-west corner of O.P.99(1) is about 500 miles by sea from the city of Darwin, capital of the Northern Territory (Fig. 1). Darwin has a population of 12,500 and has good harbour facilities and an international airport. Landing strips for light aircraft are available at Roper River Mission, Groote Eylandt Mission and Yirkala Mission.(Fig. 2).

The locations of Mt. Isa and Weipa should be noted (Fig. 2). The former is a major lead, zinc, copper producer; the latter has huge deposits of bauxite. Both centres constitute potential markets for cheap fuel. Mt. Isa hauls coal 800 miles by rail for smelting and generation of electricity. It is understood that present plans for the development of Weipa are based on shipping bauxite some 1,300 miles to coalfields near Gladstone for conversion to alumina. These long hauls could be avoided if a cheap fuel such as natural gas were discovered in the Gulf. Further discoveries of large deposits of bauxite have been made in the Northern Territory near the western boundary of O.P.99(1). These facts alone should lend incentive to the development of a natural gas industry in the area.

REGIONAL GEOLOGY

The Gulf of Carpentaria is a major embayment due to subsidence along old lines of faulting. The reader's attention is drawn to the fact that the major fault trends in the old rocks roughly parallel the present edges of the Gulf embayment (Fig. 1). The Gulf is seen as a graben type area of subsidence in the basement rocks and as such it received sediments of Mesozoic, Tertiary and Quaternary age. The area of Mesozoic deposition within and around the Gulf is known as the Carpentaria Basin; it is a sub-basin of the Great Artesian Basin. The nature of the mainland rocks will be considered.

The Rocks Fringing the Gulf:

Precambrian Rocks: The oldest rocks fringing the Gulf are grouped into the Cloncurry Complex and range in age from ? Archaen to Lower Proterozoic. The rocks assigned a ? Archaen age consist of gneiss, schist and acid and basic crystalline rocks probably with extensive granite.

Overlying these beds are Lower Proterozoic rocks laid down in two meridional basins separated by an Archaen tectonic land (Carter and Brooks, B.M.R.). The older strata are mainly acid and basic lavas which were succeeded by sediments laid down in the two troughs. Sedimentation continued in the western trough while orogenic forces caused folding and extensive faulting along meridional axes in the eastern trough. Granite intrusion, metamorphism and metasomatism were associated with this orogeny. A second orogenic phase, accompanied by granite intrusion and uplift, deformed the whole region and brought to a close Lower Proterozoic sedimentation. Intrusion of basic igneous rocks accompanied this latter orogeny.

It is not proposed to deal with the Lower Proterozoic in detail here. It is important to note, however, that the Lower Proterozoic basins (or geosynclines?) are directed meridionally at the southern end of the Gulf (Fig. 1) and that they are infilled with metasediments. An Archaen stable block is postulated on the eastern side of the eastern trough and on the western side of the western trough. A tectonic land separates the troughs.

The implications of this disposition of Lower Proterozoic troughs within the Archaen basement should be considered in conjunction with the results of the aeromagnetic survey over this mainland area.

Upper Proterozoic lavas and shallow water sediments are developed to the north-west of Mt. Isa and fringe the Gulf along its western and south-western shores. These rocks were laid down in the McArthur Basin (Fig. 1), a large depositional element which was affected throughout its development by strong but spasmodic vertical movements. The total thickness of sediments laid down exceeds 30,000 feet, according to the Bureau of Mineral Resources. Total thicknesses vary considerably within the Basin. The first rocks deposited were a mixed arenite-rudite-volcanic sequence with local boulder beds and coarse conglomerates and the rocks of Groote Eylandt probably belong to this sequence. These beds are followed by a carbonate assemblage including dolomites, calcilutites, cherts and marls; minor volcanics and arenites occur and algal biostromes and bioherms were formed. A widespread vertical movement followed and new basins formed to the south and west. One such area is the South Nicholson Basin. The sediments laid down in these basins unconformably overlie the older rocks and consist of arenites with some volcanics and dolomites. Sedimentary iron ores occur in the sequence.

The Upper Proterozoic, then, consists of unmetamorphosed sediments interbedded with volcanics. Deposition was controlled by faulting and the thickness of the sedimentary section within the McArthur Basin varies between wide limits.

Upper Palaeozoic beds outcrop south-east of Normanton where they overlie Precambrian rocks of the Georgetown massif. The section consists of sediments and volcanics of Permocarboniferous age, intruded by felsite and granite of Upper Permian age.

Mesozoic sediments outcrop extensively along the eastern and south-eastern margins of the Gulf and restricted outcrops occur along the north coast of the Northern Territory.

The sediments fringing the Queensland portion of the Gulf are co-extensive in outcrop with the Great Artesian Basin blanket, but the Euroka Ridge forms a subsurface divide east of Mt. Isa. Mesozoic sediments north of this ridge are allocated to the Carpentaria Basin.

Except in the northern part of Cape York Peninsula and in parts of the eastern margin where thin Jurassic sediments intervene, the Mesozoic section is made up of Cretaceous beds directly overlying Proterozoic or Palaeozoic rocks. The section thickens regionally seawards; local variations in this overall condition result from irregularities in the Pre-Mesozoic topography. The area presently occupied by Mesozoic outcrop is seen as a shelf bounding a deep basin within the Gulf itself, the basin configuration being largely fault controlled. A maximum thickness of 3,000 feet is assigned to the mainland Cretaceous. This thickness is made up of sediments of Aptian and Albian age, the former consisting of shales and sandstones, in part glauconitic and pyritic, and the latter consisting of fossiliferous limestone with sandstones and fossiliferous shales.

Across Torres Strait in Western Papua (Fig. 1), the Morehead No. 1 Well passed through 3,800 feet of Cretaceous mudstones and sandstones overlying 800+ feet of Jurassic sediments. Sufficient fossils were found to allocate an Albian age to the upper part of the section.

On the northern coast of the Northern Territory thin lateritised sediments have been assigned to the Lower Cretaceous on fossil evidence.

On the mainland, Tertiary sands, gravels and clays some 400 feet thick unconformably overlie the Cretaceous sediments. No marine fossils have been found. In the Morehead Well, however, 2,300 feet of fossiliferous Lower Miocene sediments were intersected immediately above the Cretaceous. The beds include limestones, mudstones and sandstones, and the section was overlain by 860 feet of fossiliferous Upper to Middle Miocene limestone. The well spudded in Pliocene mudstones with intercalations of shelly marl and these beds persisted for 240 feet to the top of the Miocene. At Morehead, then, a Tertiary section about 3,400 feet thick and mainly marine has been established.

DISTRIBUTION OF SEDIMENTS IN THE GULF

The critical factor in assessing the petroleum potentialities of Oil Permits 98 and 99 is the off-shore distribution of Mesozoic and Tertiary sediments. Fig. 2 shows the stratigraphic columns established in the various wells

drilled around the coast of the Gulf together with aeromagnetic contours showing possible basement configuration.

In Mesozoic times the Gulf was a negative element formed by downwarping along old fault lines in the basement rocks. Step faulting provided a deep trough in the central part of the Gulf and sediments encroached over older rocks on the present mainland and in Papua west of the Cape York-Oriomo Ridge. The basin was confined by fault scarps seaward from existing pre-Mesozoic outcrops.

In the Morehead region over 4,000 feet of Mesozoic sediments were laid down. Much of this section is marine and marine Cretaceous beds overlap old rocks on the eastern side of the Gulf. Marine Tertiary sedimentation followed west of the Cape York-Oriomo Ridge and presumably within the central part of the Gulf. At Morehead, over 3,000 feet of Tertiary sediments were laid down and a veneer of Tertiary beds still exists over the Mesozoic on the mainland east of the Gulf. The greatest established thickness of Mesozoic and Tertiary sediments is the 8,000 feet at Morehead, a thickness compatible with the 10,000 feet estimated from aeromagnetics for the central part of the Gulf.

Consequently, it is reasonable to assume on geological grounds that the central part of the Gulf is occupied by a trough containing at least 10,000 feet of Mesozoic and Tertiary sediments which are predominantly marine. These sediments wedge progressively shorewards across a series of step faults which parallel the coastline.

AN INTERPRETATION OF THE AEROMAGNETICS

Fig. 2 shows depth to basement contours compiled by Aero Service Ltd. from a reconnaissance survey. The contours compare well with depths to basement established by drilling and, provided the reconnaissance nature of the survey is borne in mind, they give a fair picture of the basin configuration.

An earlier survey consists of reconnaissance lines around the shoreline with a few lines crossing the Gulf; a report on this by N.B. Sauve has proved helpful.

A difficulty in indicating thickness of sediments over the area is that the Upper Proterozoic, though basement for our purposes, is predominantly sedimentary and will not have the magnetic characteristics of basement rocks. Thus the thick sedimentary section shown in O.P. 99(2) is almost certainly Upper Proterozoic. Upper Proterozoic

beds should also make up the thick sections shown west of Mornington Island. Both these localities were designated 'areas of interest' in the final report by Aero Service on the later survey although, clearly, the possibility that the sections would be Upper Proterozoic was well recognised.

In his report on the earlier survey, Sauve said "The basement rocks in the southern and eastern part of the area appear to be represented reasonably as would be expected, but in the western part of the area, although basement rocks are known to exist, they are apparently represented only as small 'pips' on otherwise smooth profiles."

Faulting: In the earlier report Sauve suggested a number of faults which were supported by the later survey. These faults form part of the framework of the Mesozoic-Tertiary basin and their inferred locations are shown in Fig. 2. The faults with which we are mainly concerned are designated F1 and F2. As remarked earlier, basement rocks show better character on the east coast than on the west coast. Consequently F2 is more accurately located than F1 since it represents the junction of sediments having a flat magnetic profile with basement rocks exhibiting a characteristic irregular profile. F1, on the other hand, is located in an area of uniformly flat profiles and its existence has been inferred from the rather rapid thickening of section seawards from the coast. Its position in Fig. 2 is not compatible with the geology and I have shown an alternative position F1(a) which I think fits the geology better. This position approximates to an anomaly in each of the two central transverse profiles of the earlier aeromagnetic survey. It also approximates to a line of shallower bathymetric contours which parallels the coast east of Groote Eylandt and trends northwards (Fig. 3).

The eastern half of O.P.98, O.P.99(1) is expected to contain a pile of Mesozoic and Tertiary sediments, largely marine and some 10,000 feet thick, forming part of the sequence infilling the central graben of the Gulf. The graben is defined by faults F1(a) and F2 which are paralleled by step faults giving progressive basement uplift landwards.

BATHYMETRIC CONTOURS

Fig. 3 shows bathymetric contours based on soundings shown on the British Admiralty chart. Two lines of shallower water depths may have structural significance - the line east of Groote Eylandt which has been discussed and an east-west line along $10^{o}30'$S lat., developed

mainly between 138°E and 141°E. The significance of the latter feature is difficult to assess: it may be a continuation of the line of Upper Proterozoic outcrops forming the Wessell Islands. An aeromagnetic profile along 11°S in the earlier survey shows a good deal of character as far west as 138°E; consequently, the high in the bathymetric contours may be due to a buried ridge of metamorphic/igneous basement.

PETROLEUM POTENTIALITIES

On our present knowledge, the petroleum potentialities of O.P.98 and O.P.99 will be confined to Mesozoic and Tertiary sediments. The evidence we have favours a thick development of these beds in the central graben of the Gulf, extending into the eastern part of O.P.98, O.P.99(1). A summary of the type of sediments expected and their petroleum potential follows:-

Mesozoic: Only the Cretaceous will be considered.

Lithology: Dark grey and black shales and mudstones, with limestones; fossiliferous. Sandstones and siltstones, occasionally with gypsum.

Oil and Gas Shows: Traces of oil and small gas flows were found in stratigraphic wells on the eastern side of the Gulf on Cape York Peninsula. The Cretaceous here is not adequately capped. In Western Papua, the Morehead No. 1 Well had only slight shows of gas near total depth but a number of gas and oil seepages in the Cretaceous are known from outcrops. Farther east, Barikewa No. 1 produced gas flows from the Cretaceous ranging from 18 million c.f.d. to 90 million c.f.d.

Tertiary: The Morehead No. 1 Well intersected 3,400 feet of Tertiary sediments of which 3,162 feet were Miocene. These sediments should extend southward into the central graben of the Gulf.

Lithology: Shelly limestones, detrital limestones, mudstones, sandy limestones and calcareous sandstones. Fossiliferous.

Oil and Gas Shows: Numerous oil and gas seepages are reported from Miocene outcrops in Papua. Most Miocene tests were drilled in the Oriomo trough region, east of the Cape York-Oriomo Ridge. Kuru No. 1 encountered a gas flow in the Lower-Middle Miocene limestone estimated at 50 - 100 million c.f.d. Puri No. 1 produced 1,600 b.p.d. of oil from Lower Miocene limestone before going to water.

The Cretaceous and Tertiary sediments expected in the central graben of the Gulf thus have been established to be petroliferous elsewhere .

Because of the absence of Mesozoic-Tertiary tectonism in the Gulf region, traps for oil and gas will be limited to drape structures over basement highs, fault traps and stratigraphic traps. The location of the postulated fault F1(a) and its subsidiary step faults is critical. The search for oil and gas should be directed at Mesozoic and Tertiary sediments wedging out along these fault lines, at traps due to faults within the Mesozoic and Tertiary and at drape structures. O.P.98 and O.P.99(1) are well situated to receive hydrocarbons from the deeper trough to the east.

Because of the density contrast between the Upper Proterozoic and the Mesozoic-Tertiary sediments, detailed gravity may locate these fault lines. More detailed aeromagnetic coverage may show sufficient contrast between the two groups to broadly define the area of interest. Seismic traverses would be most effective in showing faulting and drape structures; the detailing of stratigraphic traps would follow. A valuable preliminary would be the mapping of the ocean floor and younger sediments using shallow marine seismic techniques.

CONCLUSION

Oil Permits 98 and 99 are both worthy of further exploration. In O.P.98 and O.P.99(1) work should be aimed primarily at locating faults since these structures control the deposition of sediments and the accumulation of oil and gas. It is difficult to escape the conclusion that the sedimentary section of O.P.99(2) will consist largely of Upper Proterozoic beds. Although these latter sediments are not metamorphosed their capacity to generate oil has yet to be established.

The usual difficulties attendant on off-shore operations will apply to the Permits. Water depths are within the range presently being worked in the Gulf of Mexico and no special difficulties are foreseen for operations here.

The anticipated sedimentary section of the central graben is attractive and we may note in passing that in the Gulf of Mexico the Miocene is a prolific producer.

Were natural gas discovered in O.P.98 or O.P.99(1) the establishment of an alumina refinery on the adjacent bauxite deposits would surely follow.