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SUMMARY

On 4th December, 1953 the discovery of oil in West Australian Petroleum Company's first exploration bore, Rough Range No. 1, was announced. It was stated that the tested flow was 500 barrels a day. This is the first significant flow of oil in Australia, although small flows of oil and some flows of gas have occurred in other parts of the continent.

Despite the fact that this is the first exploration bore for oil in this basin, the stratigraphy and structure of the basin is moderately well established. A party of the Commonwealth Bureau of Mineral Resources has been carrying out a detailed reconnaissance of this large basin for five years. In addition geophysical parties of the same Bureau carried out reconnaissance gravity surveys and seismic traverses. London Seismograph Service carried out a seismic survey of the Rough Range area for West Australian Petroleum Ltd to prove subsurface structure before drilling and also ran several seismic traverses for regional information. As a result of this work, the stratigraphy and structure are known well enough to have made prediction of formations in the bore reasonably accurate as to depths and quite accurate as to identify. The main new fact that has so far come out of this bore is the indubitable presence of oil in a basin where no seepage or other direct sign of petroleum has been found. The following short statement of the stratigraphy, structure and palaeogeography of the Carnarvon Basin as at present known will indicate the geological background on which the West Australian Petroleum Company decided to test.

The Carnarvon (formerly called 'North-West') Basin is an epi-continental basin stretching from Exmouth Gulf (21°45'S., 115°E) in the north to the Murchison River (27°30'S) in the South and inland from the Indian Ocean coast for up to 130 miles. The gravity survey indicates that it is an asymmetrical basin with its axis running north-south from Exmouth Gulf to Carnarvon. In the eastern part of the basin the regional westward dip is mainly very gentle, although at the eastern edge of outcrop dips of 30 to 45 degrees are common. The profiles of London Seismograph Service in the Rough Range area indicate an eastward dip of about 5 degrees in the western part of the basin.

The oldest sedimentary rocks of this basin which appear in outcrop are Middle to Upper Devonian fossiliferous limestone, and greywacke and quartz sandstone, resting with marked angular unconformity on the Pre-Cambrian schists, gneiss and granite of the basin floor. The maximum thickness of the Devonian in outcrop is 4900 feet. The conformable Lower Carboniferous limestone and greywacke is 2900 feet thick in outcrop. Between this and the Permian is an erosional and slight angular unconformity so that the base of the Permian overlaps the whole of the Devonian-Carboniferous sequence onto the Pre-Cambrian basement. At the base of the Permian System is a thin clean quartz sandstone which grades up into the marine glacial sediments of the Lyons Group, which is about 5000 feet in maximum outcrop thickness. The Lyons Group is probably of Sakmarian age. Conformably overlying the top of the Lyons Group is the richly fossiliferous calcarenaceous Callytharra Formation, up to 760 feet thick. An erosional unconformity which has removed varying thicknesses of the Callytharra is overlain by a thin quartz greywacke in the basinward part of the

outcrop and by clean quartz sandstone (Wooramel Sandstone) elsewhere. Conformably above the Wooramel is the Byro Group of black siltstone and shale and fine-grained quartz greywacke with a maximum thickness of 5300 feet. The arenaceous Kennedy Group, at the top of the Permian sequence of the basin, is up to 2500 feet thick. In the coastal region, there is a fairly thick sequence of Cretaceous and Tertiary age. At the base, resting with an angular unconformity on the Permian sediments, is a glauconitic sandstone and siltstone (Birdrong Formation) up to 100 feet thick in outcrop and up to 300 feet thick in bores. The Winning Group of siltstone, shale and radiolarite is up to 830 feet thick in outcrop but thickens rapidly westward to over 1000 feet. In Rough Range No. 1, the Winning Group is 2000 feet thick. The Cardabia Group (Upper Cretaceous to Palaeocene) has up to 600 feet mainly of calcarenite. The Eocene Giralia Calcarenite is up to 300 feet thick. The Lower Miocene Cape Range Group outcropping mainly in the Cape Range, has a maximum thickness of about 1300 feet. There are many disconformities in the Cretaceous-Tertiary sequence.

The major structural unit is of course the basin as a whole. The part east of the axis mainly contains Palaeozoic sediments and is up to 100 miles wide and contains sediments at least 20,000 and perhaps as much as 30,000 feet thick. The western part, up to 60 miles wide (including the continental shelf which almost certainly is part of the basin), has most of the Tertiary and Cretaceous sediments and probably the facies variants of most of the Palaeozoic sediments which are exposed only in the eastern part.

The main structural control is the strong and relatively stable pre-Cambrian basement, which has carried most of the compressional stresses. The faults in the sediments are mainly inherited from active faults in the basement so that, although the major faults have the geometrical and stratigraphic characteristics of high-angle overthrusts, there is very little evidence in the sediments of the minor structures due to compressional stress and shear failure. The major faults are arranged en echelon in a belt about 50 miles wide running south-south-east from Cape Range through Gascoyne Junction. The structures in Tertiary and Cretaceous sediments near the coast are believed to have been produced by vertical uplift of blocks of sediments due to thrust-faulting of the basement. This is borne out by the seismic surveys which indicate faults under the steep flank of all of the anticlines investigated.

The Devonian-Carboniferous sequence was deposited in a basin the margin of which was well to the east of the present eastern edge of outcrop. Cores from a water bore near Carnarvon indicate that this sequence extended at least to that locality but no other information is available on the extent of the area of deposition of that sequence. In the late Carboniferous emergence, the Devonian-Carboniferous sediments were eroded off the eastern and southern part of the area now occupied by Palaeozoic sediments. The Permian marine basin of deposition probably extended a short distance north-east of the present edge of outcrop. In the south-eastern part of the basin, the edge of deposition was probably very close to the present margin. The early part of the Permian deposition was controlled by the glacial environment of the adjoining land mass. With the melting of the ice an abundant marine fauna developed, producing the fossiliferous calcareous Callytharra Formation. Possibly resulting from the removal of ice load, the margin of the basin was for a short time emergent and the surface of the Callytharra was eroded. The new transgression is marked by the Wooramel Sandstone. This was followed by rapid deposition of the Byro Group, in a basin only slightly bigger than the present outcrop area. With the close of Permian sedimentation the Arenaceous Kennedy Group was deposited in a very greatly restricted basin. Between the deposition of the Kennedy Group and the Cretaceous sediments the area of the basin was uplifted and faulted and eroded nearly to a peneplain. Faults of several thousand feet throw are common in the central part of the area but, before the Lower Cretaceous inundation, nearly all topographic expression of these faults had been removed. The Lower Cretaceous transgression

inundated the basin area eastward to the meridian of Onslow. An intermittent regression occurred between Upper Cretaceous and Eocene so that after the Eocene the whole of the area of the basin was exposed. The next transgression, in Lower Miocene, extended eastward to about the east shore of Exmouth Gulf and from there to Carnarvon. This inundation was short-lived as regression occurred within the Miocene. The Miocene regression was followed by tectonic movement which produced folds in the coastal Cretaceous and Tertiary sediments and displaced the Cretaceous sediments in the central part of the area.

In the Palaeozoic sequence below the Kennedy Group, almost all formations become thicker towards the north and west. This divergence is repeated in the Cretaceous and Tertiary sediments which thicken rapidly westward and very rapidly northward. Gravity results in the Cape Range area show a high positive gravity anomaly centred on the west coast of the Cape Range peninsula, but the geometry of the Cape Range Anticline suggests that there is probably a very great thickness of sediments underlying the Tertiary Limestone. The facies variation in the outcropping area of Palaeozoic sediments is so small (over distances of 150 miles) that it is felt that in the coastal area where there is no outcrop of Palaeozoic sediments the Formations will be present with only minor variations in type. This is confirmed by the facies of the Devonian found in the Pelican Hill Bore near Carnarvon. The lithology is somewhat finer-grained than in outcrop 90 miles eastward but is recognizable as a variant of the outcrop lithology. For this reason the oil possibilities of the coastal structures, which offer the most obvious structural traps, have been assessed in terms of the sequence known in outcrop.

Source formations, containing abundant marine fossils and evidence of anaerobic bottom conditions and rapid burial without reworking of bottom sediment, are known in the Devonian, Permian Callytharra and Byro Group and Lower Cretaceous Winning Group.

In the absence of strong compressional effects in the sediments which might produce fracture-reservoirs, the main type of reservoir bed in this basin is likely to be the clean quartz sandstones of the Devonian, basal Permian and Wooramel Sandstone and basal Cretaceous Birdrong Formation. The association of the source and reservoir formation is particularly favourable in the Devonian and in the Permian Callytharra-Wooramel. Less favourable reservoir beds which may locally be permeable enough to hold oil are the cleaner quartz greywackes of the Byro and Lyons Groups and the calcarenites of the Upper Cretaceous and Tertiary.

Cap rock in this basin is mainly shale or siltstone. Adequate thickness of fine-grained clastics is found above the Devonian source-reservoir association, above the Callytharra-Wooramel unit and above the Lower Cretaceous Birdrong Formation. It is doubtful if there is adequate cap rock in the Upper Cretaceous and Tertiary sequence to hold oil in this part of the section although some of the calcilutite beds may be competent to hold oil under low pressure. If this is so the thin persistent greensand between the Cretaceous and the Palaeocene may be a minor reservoir bed.

The oil reported in Rough Range Bore No. 1 is in the top of the Lower Cretaceous Birdrong Formation, which there, as in outcrop, rests unconformably above the truncated Palaeozoic sediments. In the bore the underlying sediments appear to be a facies variant of the Lyons Group.

The oil could have originated in the Muderong Shale at the base of the Winning Group, in the Permian above the Lyons Group or in pre-Lyons Group sediments. The Muderong Shale is a possible source formation for oil but the density of the oil (35° API) indicates that in this case Cretaceous source rocks have contributed but little to this crude, as they have not been exposed to oxidation and evaporation such as would produce this type of oil. The oil may have accumulated in one of the Permian reservoir beds and been held in the erosion-truncated beds by wax seal which was

removed partly by the erosion of the old surface during the Lower Cretaceous transgression and partly by the rise in temperature on burial beneath about 3500 feet of Cretaceous and Tertiary sediments. The third possibility is that the oil originates in older sediments (Carboniferous or older) and has migrated along faults to its present pool. The faults in this area are mainly thrusts which tend to be self sealing and, as shown in the area of outcrop, to have very little fracture permeability in the vicinity. Of these possibilities the second source, from the younger Permian sediments, is believed most likely. From a consideration of the gravity results, it appears reasonably certain that, if this is the case, oil will be found in the Birdrong Formation in the Cape Range, Warroora and Gnarraloo and possibly in the Giralia Anticlines. The Chargoo, Gerardi, Chirrida, Minilya, Homestead, Yankee Tank and Grierson Anticlines are very much less likely producers from this sand.

The Birdrong Formation is the main artesian aquifer of the basin and in it the water is good stock water. This indicates that the water in the aquifer is not stagnant and since the intake beds are known at about 300 feet above sea level the ground water flow in this area is almost certainly westward with a submarine outlet. This flow will have the effect of tilting the oil-water surface towards the west and may be sufficient to form hydraulic traps for oil on west-dipping monoclines.

In the absence of seepages or other signs of oil at the surface of the basin or in water bores, the likelihood of oil accumulation depended on the scientific appraisal of a large number of sedimentary, structural and ecological facts. However convincing this sort of appraisal may be to the experienced geologist, the proved occurrence of oil is of great importance in confirming the geologists ideas and in ensuring that the area will be adequately tested.