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Symposium on Petroleum Geology of Australia

Petroleum Geology of Western Australia.

by

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Summary: In Western Australia, Marine sedimentary rocks ranging in age from Cambrian to Miocene include formations which have the characteristics of source and reservoir rocks.

The characteristics of source and reservoir rocks are described briefly and criteria for their recognition are enumerated. The assessment of the known possibilities of commercial accumulations of petroleum in Western Australia requires the definite recognition of source and reservoir beds which are likely to be in hydraulic contact, and the recognition in such reservoir beds of structural, stratigraphic, or hydraulic traps where petroleum may have accumulated.

The main sedimentary basins are discussed separately. The Bonaparte Gulf Basin is not well enough known to be assessed. The outcrop area of the Canning Basin (including the Fitzroy Basin) gives little information relevant to the assessment of the basin's oil potential. The most likely prospective stratigraphic targets are discussed and the more likely areas for accumulations mentioned. Only in the northern part of the Carnarvon Basin is there enough geological and geophysical information to give a useful assessment of oil possibilities. The likely reservoir beds in contact with source beds are named and the areas in which traps are likely to be developed in these reservoir beds are suggested. The southern part of the Carnarvon Basin is not known enough to discuss its potential except in relation to the Cretaceous. The Perth Basin is likely to contain a thick sedimentary sequence with anticlinal structures indicated, but nothing is known of the pre-Mesozoic sequence over most of the basin, the possibilities of which can be assessed only after exploratory drilling has been done. The Eucla Basin is insufficiently known for reliable assessment.

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PETROLEUM GEOLOGY OF WESTERN AUSTRALIA.

by

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In Western Australia, marine sedimentary rocks ranging in age from Cambrian to Miocene include formations which are considered to have the characteristics of source, reservoir, and cap rocks in relation to the accumulation of petroleum.

Petroleum is regarded as being derived directly and quickly from dead organisms, of which marine plankton is quantitatively the most important. On this assumption, source beds are those deposited in an environment favouring the abundant growth of plankton at the surface, a non-oxidizing layer at the sediment-water interface, rapid burial without reworking by wave or current action or by scavenging organisms, and a continuation of reducing conditions in the buried material. Such environments exist to-day in areas such as the Gulf of Mexico, eastern Mediterranean Sea, Black Sea, Caspian Sea, China Sea, Bay of Bengal and Gulf of Papua. P.W. Smith (1954) has already established this for the Gulf of Mexico. The following criteria are known to apply to the recognition of source beds : presence of argillaceous (as distinct from merely fine-grained) beds - the clay minerals tend to inhibit the escape of petroleum during burial : presence of fixed carbon with or without hydrocarbons; presence of disseminated or nodular pyrite - indicating reducing environment: presence of graded bedding; absence of clean quartz sandstone and calcarenite; absence of invertebrate trails and burrows; absence of benthonic fossils; presence of pelegic fossils, especially microfossils; absence of evidence of reworking such as intro-formational conglomerate, scour and fill structure, ripple-marking and current bedding of the argillaceous sediment; absence of evidence of subsequent oxidation under terrestrial conditions - overlying basal conglomerate, leaching (pale) and oxidization (red, brown and yellow).

Soon after burial, the petroleum derived from dead organic matter is dispersed as droplets in the connate water. The droplets may escape directly into the overlying sea water, move into an overlying more permeable bed sealed by a succeeding clay bed, or be held, by adsorption on to clay minerals, in the source bed. As the sediments are more deeply buried they are compacted. A volume of fluid equal to the volume compaction of the sediments must pass out of the sediments, and initially most of this expressed fluid moves vertically upward. Because the oil is in disperse phase it can be held in an argillaceous sediment by adsorption on the clay minerals.

At a stage in compaction related to the lithology of the sediments (their mineral composition, grain-size, and bed thickness) the expressed water moves more easily laterally in the more permeable beds than vertically through the less permeable. Probably at about the same stage the compaction of the source bed forces oil droplets together into a continuous film around grains. When this happens, further compaction will force out from the source bed oil as well as water. On entering the bigger voids of the more permeable bed the oil will reform into disperse droplets in the connate water. Under the load of the overlying sediments this water with the contained oil droplets will move laterally towards the area of lower hydraulic pressure potential. Oil droplets will tend to move towards the top of the permeable bed at a rate controlled by the density difference between the oil and the water, the size of the droplet, the size of the voids, and the horizontal velocity of the water. After oil droplets reach the top of the permeable bed they will move with the water along the top of the bed and will accumulate in any of the well-known traps until the trap is full under the existing dynamic hydraulic conditions; then additional oil will pass on beyond the trap.

In order that this process may produce commercial accumulations of petroleum (either gas or oil) the migrating petroleum must move into a formation of sufficient thickness and permeability to enable a large volume of recoverable petroleum to accumulate, and this formation must include large confined areas of relatively low hydraulic pressure potential. Such a formation can be a petroleum reservoir only if it is covered by a formation which is effectively impermeable to petroleum, e.g. shale, dense limestone, greywacke, calcilutite, evaporites, petroleum residues.

In assessing the possibility of petroleum production in an untested area it is necessary to know stratigraphic sequences in some detail, preferably much of the palaeogeography, the location and size of closed structures, and whether they are likely to contain reservoir beds in hydraulic contact with source beds. Of the sedimentary areas of Western Australia only the north part of the Carnarvon Basin is known well enough to allow a reasonably reliable assessment.

The Bonaparte Gulf Basin has been examined in reconnaissance only, and although it is known that there are Cambrian, Ordovician, Carboniferous, and Permian marine sediments there, details of lithology, sedimentary environment, structure, and palaeogeography are not known.

In the Canning Basin the stratigraphy, structure, and palaeogeography of the Permian sediments are reasonably well known. The only likely source formation is the Noonkanbah, and the Noonkanbah Formation is likely to lead into reservoir beds only along the Fenton Fault, and where the formation's contact with the Permian-Mesozoic unconformity is covered by permeable sandstone- in the area south of the Fenton Fault and possibly in the Broome-La Grange area. The Devonian is known only in shelf facies. The abundance of fossils indicates favorable conditions for marine life, so that source beds may be expected in the area overlain by Permian sediments. The only possible reservoir formation known is the sandstone overlying basement at the 67-mile Bore. If the Fenton Fault indicates a feature which, structurally and physically, was relatively high throughout the basin's sedimentation, suitable reservoir formations (sandstone or reef limestone) may have developed there. Although the small outcrop of Ordovician sediments includes source beds, nothing is known about the extensions of this system. If it extends as far west as the 67-Mile Bore area its source beds also could feed into the basal sand there.

In the north part of the Carnarvon Basin, the only possible source beds in the Tertiary are in the Mandu Calcarenite, which contains some calcitutite beds which have most of the characteristics of source beds. It is unlikely that any effective reservoir beds are in contact with this formation. The Cretaceous has two good source beds - the Gearle Siltstone and the Muderong Shale - but only the base of the Muderong, which overlies the Birdrong Formation, is in contact with a reservoir bed. It is unlikely that the Muderong feeds laterally into the Birdrong. The Byro Group of the Permian contains several good source formations, but it has probably been eroded off the area west of the Yandagee Hill Fault, except perhaps in the Giralia area. In the Giralia area these source beds are probably in contact with the Birdrong reservoir formation and may be the source of the oil found in Rough Range No. 1. The richly fossiliferous Callytharra Formation is not a source bed in outcrop as far west as the Yandagee Hill Fault, but farther west it may be a source formation which could feed into the overlying Wooramel Sandstone or, at the unconformity, into the Birdrong Formation. No source beds are known in the outcropping Carboniferous or Devonian, although fossiliferous limestone in the Carboniferous may, and in the Devonian does, develop source-bed facies in the western part of the basin. These source beds may feed into the Birdrong in the

area between Carnarvon and Minilya and into the Harris Sandstone north of Minilya and along the Wandagee Hill Fault-zone. Pre-Devonian sediments are indicated by gravity anomaly in the Carnarvon area and by seismic evidence in the Giralia - Rough Range area. By analogy with the Fitzroy Basin these could be Ordovician. As it is truncated by the Palaeozoic-Mesozoic unconformity this sequence could feed into a basal sand or be sealed by a basal shale; the nature of the formation at the unconformity is not known. West Australian Petroleum Company's Cape Range Well No. 2 may give this information. If this formation is permeable, structural traps may exist under the eastern anticlinal bend of the Cape Range and in the submarine 'Jacob Ramussens' Anticline indicated bathymetrically off the mouth of Yardie Creek. The formation may feed eastward into the Birdrong in the vicinity of the Giralia Anticline. If it is impermeable, as indicated by Rough Range Well No. 1, traps below the unconformity in the pre-Permian Palaeozoic sequence may occur west of a line approximately from the Cape Range anticlinal axis to Cape Farquhar.

The only known source beds in the south part of the Carnarvon Basin are the Cretaceous Shale (equivalent of the Gearle Siltstone) outcropping near the mouth of the Murchison River, and parts of the Byro Group exposed on Byro Plains, Wooramel River. The shale may feed into the overlying Alinga Greensand, especially north of the area of outcrop; the Alinga Greensand may be a reservoir bed with structural closure on Dirk Hartog Island, Peron Peninsula and Tamala Station. The Butte Sandstone (equivalent of the Birdrong) would be a good reservoir bed, but it is not known to be in contact with source beds. The Byro Group is not known to be in contact with a reservoir bed.

The Perth Basin, extending from the Greenough River to the south coast east of Cape Leeuwin, is known to contain Tertiary, Cretaceous, Jurassic and Permian marine sediments, but no source beds are known in outcrop. Gravity anomalies confirmed by seismic survey indicate a thick sedimentary section and anticlinal structures. Exploratory drilling will be necessary before the petroleum possibilities of the Perth Basin can be assessed; such drilling can be carried out in favorable structural locations already indicated by seismic and gravity surveys - southwest of Gingin and on the coast west of Cookernup. By inference from the Fitzroy and Carnarvon Basins it is possible that a marine sequence ranging from Cambrian to Permian is present under the Mesozoic. If source and reservoir beds are found, the contact with the Precambrian at the Darling Scarp and the main south and north plunges of the basin at Mingenew and Wommerup respectively may offer possibilities of stratigraphic traps.

Miocene, Cretaceous and Permian sediments are known from the Eucla Basin, but no source beds have been reported. Source beds and up-dip stratigraphic traps may be developed off-shore, but until exploratory drilling is done the oil possibilities of this basin cannot be reliably assessed.