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THE SEDIMENTARY BASINS OF AUSTRALIA AND THE STRATIGRAPHIC OCCURRENCE OF HYDROCARBONS

COMPILED BY

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THE SEDIMENTARY BASINS OF AUSTRALIA AND THE STRATIGRAPHIC OCCURRENCE OF HYDROCARBONS.

Compiled by M. A. Reynolds.

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SUMMARY

Twenty-five sedimentary basins, two of which can be subdivided (the Great Artesian Basin into six other basins, and the Canning into two), are recognized in Australia. Brief descriptions of their stratigraphy, structure, and occurrences of hydrocarbons are given in alphabetical order. Producing fields, or potential producing horizons have been discovered in eight of these basins, and significant occurrences of hydrocarbons have been found in others.

Other less important basins and off-shore areas are discussed. Mention is made of occurrences of hydrocarbons in the Precambrian, and also of oil shale distribution.

In a general discussion, the basins are grouped according to their geographical distribution; the basins in each region have some stratigraphic and structural similarities.

THE STRATIGRAPHIC OCCURRENCE OF HYDROCARBONS IN THE SEDIMENTARY BASINS OF AUSTRALIA.

INTRODUCTION

This report describes known Australian occurrences of hydrocarbons. Nearly all of the sedimentary basins are described, but most emphasis has been given to those basins with established oil and/or gas fields and known hydrocarbon occurrences.

Before discussion of the hydrocarbon occurrences, the location, area and limits of each basin are briefly described, and their main stratigraphic and structural features are summarized. Current exploration trends in most of the basins are indicated, and some of the more important and most recent references are listed at the end of each description.

The basic reference for this report is an account of "The Sedimentary Basins of Australia and New Guinea" which was issued by the Australian Bureau of Mineral Resources, Geology and Geophysics, in its Record 1963/159 (unpublished); it will be published later in a summary of the oil-search activities in Australia and New Guinea. The original text has been generalized and modified for this report, but the format is similar. The descriptions of the basins in Record 1963/159 were compiled, wherever possible, by geologists with experience in the

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particular basins, and their contributions are acknowledged hereunder:

J. M. Dickins - Bowen, Carnarvon, Drummond, Maryborough, Perth, Sydney and Yarrol Basins;
P. J. Jones - Bonaparte Gulf and Ord Basins;
M. A. Randal - Daly River Basin;
K. G. Smith - Georgina Basin;
J. E. Thompson - Basins in Papua-New Guinea;
J. J. Veevers and A. T. Wells - Canning and Fitzroy Basins;
A. T. Wells, D. J. Forman and L. C. Ranford - Amadeus Basin.

The description of the other basins and compilation of the Record were by M. A. Reynolds.

Apart from the references given for individual basins described in the text, the following are regarded as the most important general references to the sedimentary basins of Australia:

Australia	- David, (1950); Irving, Smith and Walker, (1958); Playford and Johnstone, (1959); Bureau of Mineral Resources, (1960); Trumpy, Guillemot and Tissot, (1960); Geological Society of Australia, (1962); Trumpy and Tissot, (1963).
Queensland	- Hill and Denmead, (1960); Geological Survey of Queensland, (1960).
Tasmania	- Spry and Banks, (1962).
South Australia	- Glaessner and Parkin, (1958).
Western Australia	- McWhae, Playford, Lindner, Glenister and Balme, (1958); Playford, (1965).

Twenty-five basins (including basins under other basins) and eight basins which are subdivisions of two of the main basins are recognized in Australia. The term "basin" is used in this report almost exclusively for areas containing deposits of unaltered sedimentary rocks which are recognized as possible sources and/or reservoirs for hydrocarbon accumulation. Most of these basins are also hydrological basins (or contain hydrological basins) and many were originally described as such. (The prefix "sub-" has generally been avoided because of possible confusion of "sub-" referring to <u>sub</u>surface, <u>sub</u>sidiary or <u>sub</u>division.)

ADAVALE BASIN

The Adavale Basin in south-central Queensland is buried below the eastern part of the Eromanga Basin. The main portion of the Adavale Basin is bounded by a basement arch on the north-western edge, and by faulted or truncated margins on the western, southern and eastern sides; the northern limits are not known. The basin outline, as shown on the map, is very irregular on the southern and south-eastern sides because it incorporates four troughs which may or may not be connected to the main part of the Basin. The area is about 11,000 square miles.

The rocks of the Adavale Basin are unconformably covered by an Upper Permian-Mesozoic sedimentary succession, up to 6000 feet thick, within the Eromanga Basin (a subdivision of the Great Artesian Basin.) On the evidence available from drilling and seismic surveys, the following section occurs in the Adavale Basin:

Lower Permian - dark mudstone, with sandstone, shale, and conglomerate; up to 600 feet.

Unconformity

Upper Devonian to Lower Carboniferous? - mainly red sandstone, shale, and conglomerate of continental and shallow marine facies; up to 10,000 feet.

Lower to Middle Devonian? - basal arkose, volcanics, and marine shale and sandstone; overlain by a carbonate unit (mainly dolomite and an excellent seismic reflector); and interbedded shale, claystone, and sandstone, partly calcareous; at least 5000 feet.

Unconformity

Basement - includes Silurian metamorphics in the south-west, Ordovician basalt in the south-central part, and Silurian granite in the north-east.

The structure of the Basin has no surface expression and has been investigated by geophysical means. It is characterized by elongated and sinuous anticlinal, synclinal, and graben-like structures. Both compressional and tensional forces have contributed to the formation of these structures; some evidence also suggests regional shearing. Late Silurian-Devonian orogenies may have determined the original basin framework, but main deformation of the sediments occurred in late Palaeozoic (Carboniferous?) time.

Towards the end of 1964, gas was encountered in the sandstone unit of Lower Devonian age (below the Middle Devonian dolomite unit); the best rate of flow on drill stem test was about 5 million cubic beet per day, but formation damage probably occurred, so that full potential of the well has not yet been established. Although this unit was porous in other wells drilled on neighbouring structures, it yielded only salt water. It is interesting that Devonian salt was found at about the same stratigraphic level in Boree No. 1 Well to the north of the Basin, (Gerrard, 1964).

The Adavale Basin has been explored by Phillips Petroleum Company and Sunray DX Oil Company for 5½ years by reflection seismic and aeromagnetic surveys, and by the drilling of seven wells. Further seismic work and drilling are being undertaken.

The name "Adavale Basin" was first used by Hier and Fjelstul (1961, p.5) and is again referred to in Kitsman, Lewis and Rowe (1962, p. 7, and Fig. 2). General descriptions of the Basin have been given by Tanner (1962), and recently by Heikkila (1965), whose report is the main reference for this summary.

GERRARD, M.J., 1964 - Boree No. 1 Well Completion Report. Authority to Prospect 101P, Qld. For American Overseas Petroleum Limited (unpubl.).

HEIKKILA, H. H., 1965 - Palaeozoic of the Adavale Basin, Queensland. 8th Comm. Min. Metall. Cong., 30th Sess., Queensland, 1965, (preprint).

HIER, C.D., and FJELSTUL, C.R., 1961 - Geophysical report reconnaissance seismograph survey of Jundah-Yaraka Blackwater-Langlo area Queensland, for Phillips Petroleum Company and Sunray Mid-Continent Oil Co. (unpubl.).

KITSMAN, W.L., LEWIS, J.H., and ROWE, S.M., 1962 - Buckabie No. 1 Well completion report. Bur. Min. Resour. Aust. Petrol. Search Subs. Acts Publ. 41.

TANNER, J.J., 1962 - New geologic concepts resulting from oil exploration in south central Queensland. In "Oil in Australia" Symposium - Paper No. 7 Aust. Inst. Min. Metall. Ann. Conference, 1962, (unpubl.).

AMADEUS BASIN

The Amadeus Basin occupies about 80,000 square miles in the southern part of the Northern Territory and part of Western Australia. It contains a thick sequence of Upper Proterozoic and Palaeozoic sediments preserved in a folded and faulted belt between Precambrian igneous and metamorphic rock complexes to the north and to the south, (an intracratonic geosyncline). The Palaeozoic sediments are confined mainly to the Northern Territory and occupy an area of about 55,000 square miles. To the east and west the Amadeus Basin sediments are transgressed by Permian and Mesozoic rocks. Much of the Basin area is blanketed by Quaternary aeolian sand.

Great diversity of sedimentation has occurred within the Basin, and many formations show marked facies changes. However, the oldest of the Upper Proterozoic units - the Heavitree Quartzite up to 1500 feet thick, and a dolomite unit with dark foetid limestone, and an evaporite facies 2500 feet thick - show little lateral change. Overlying these beds, conformably or disconformably, is a thick sequence of shale and siltstone with lenses and beds of sandstone and carbonate. The lower part of this sequence has tillitic fabric. The sandstone lenses occur throughout but are more common in the upper beds; sandstone tends to replace mudstone in the southern part of the Basin and the thickness of the sediments increases. In the southern central part, near Lake Amadeus, the overall thickness is estimated to be 9000 feet. Environments represented are at least partly marine, mainly neritic to paralic, and partly aqueoglacial.

A major orogeny in the late Upper Proterozoic or early Cambrian times led to folding, uplift and exposure of the southern part of the Basin.

However, sedimentation probably continued without interruption in the north-eastern part. During the Cambrian and Ordovician, the uplifted areas were eroded and gradually subsided, and were again transgressed by the sea. Lateral variations and interfingering of the lithologies are common and some units are diachronic. In the north-eastern part of the Basin, the Cambrian rocks are predominantly carbonates; in western areas sandy facies predominate, and in the central part limestone, dolomite, siltstone and sandstone interfinger. The Ordovician sediments comprise arenites, lutites and carbonates and the lithologies are repeated in two broad cycles of sedimentation. They were deposited in a shallow marine environment and all the major units contain fossils; some beds are rich in pelletal phosphate and glauconite. The total thickness is in excess of 15,000 feet.

A gradual regression of the sea and a change from marine to transitional and continental environments began in the Upper Ordovician as a result of epeirogenic movements in the north-eastern part of the Basin. Up to 3000 feet of sediments, mainly sandstone, were laid down during this time; no diagnostic fossils have been found. The last major unit of the Amadeus Basin was formed during a second major orogenic episode in the Upper Devonian to possibly Carboniferous. At least 10,000 feet of continental siltstone, sandstone and conglomerate were deposited in broad depressions in front of the uplifted zone.

Although small-scale folding occurred locally at various times during the geological history of the Amadeus Basin, the two most important tectonic periods were in the late Upper Proterozoic (or early Cambrian), and in the Upper Devonian (possibly into Lower Carboniferous). During the last period the folding and faulting were along west-north-west axes and gave the Basin its present form; the trends, however, may have been pre-existing Precambrian trends. Whereas the Upper Proterozoic (early Cambrian) faulting indicates thrusting from the south, the Devonian (or Carboniferous) thrusting apparently was from the north. Large nappe complexes involving the Precambrian rocks were produced along the northern margin of the Basin. Planes of decollement formed in evaporitic horizons in the Upper Proterozoic and Cambrian, and the rocks above were pushed ahead of the nappes into Jura-type folds. The evaporites were squeezed into many of the anticlines formed during the Devonian (or Carboniferous) orogeny, but some salt domes have probably also developed as a result of density differences.

Geological mapping in the Amadeus Basin showed that the sediments included potential source, reservoir and cap rocks. Many closed structures are known. Stratigraphic and salt dome traps were also expected to occur. But it was not until 1963, when three wells found hydrocarbons, that the Basin was considered as a possible producer. The reasons for early indifference were because:

(i) outcrops are mainly Upper Proterozoic (initially thought to have no potential) in the south, or Ordovician-Devonian continental facies in the north;

(ii) the Basin has been exposed more or less in its present form since the Palaeozoic, and many of its structures are centrally breached, some down to the Precambrian;

(iii) the Basin is so remote from possible markets.

Hydrocarbons are now known in a small flow of methane gas in marine shale and limestone in the Upper Proterozoic, small oil shows in Cambrian dolomite and sandstone rocks, and gas in substantial quantities and some oil in Ordovician sandstone. The search to date has been mainly in obvious structures.

The most comprehensive accounts of the Amadeus Basin are given in reports by the Bureau of Mineral Resources (B.M.R.), resulting from reconnaissance mapping in 1956-57 and from 1960 to 1964. Recent publications by company personnel who have worked in the area are by Stelck and Hopkins (1962), Ranneft (1963), Williams, Hopkins and McNaughton (1965). Certain other information on drilling and geophysical surveys is available under the Petroleum Search Subsidy Acts. Selected references are as follows:

FORMAN, D. J., 1965 - The geology of the south-western margin of the Amadeus Basin, Central Australia. Bur. Min. Resour. Aust. Rep. 87.

FORMAN, D. J., and MILLIGAN, E. N., - Regional geology and structure of the north-eastern margin of the Amadeus Basin, Northern Territory. Ibid., (in prep.).

PRICHARD, C. E., and QUINLAN, T., 1962 - The geology of the southern half of the Hermannsburg 1:250,000 sheet. Ibid., 61.

QUINLAN, T., in PERRY, R. A., and others, 1962 - Lands of the Alice Springs Area, Northern Territory, 1956-57. C.S.I.R.O. Aust. Land Res. Ser., No. 6.

RANFORD, L. C., COOK, P. J., and WELLS, A. T., (in press) - The geology of the central part of the Amadeus Basin, Northern Territory. Bur. Min. Resour. Aust. Rep. 86.

RANNEFT, T. S. M., 1963 - Amadeus Basin petroleum prospects. J. Aust. Petrol. Expl. Ass., 42-52.

STELCK, C. R., and HOPKINS, R. M., 1962 - Early sequence of interesting shelf deposits, Central Australia. J. Alberta Soc. Petrol. Geol., 10 (1), 1-12.

WELLS, A. T., FORMAN, D. J., and RANFORD, L. C., 1965 - Geological reconnaissance of the Rawlinson and Macdonald 1:250,000 Sheet areas, Western Australia. Bur. Min. Resour. Aust. Rep. 65.

WELLS, A. T., FORMAN, D. J., and RANFORD, L. C., 1965 - Geological reconnaissance of the north-western part of the Amadeus Basin, Northern Territory. Ibid., 85.

WELLS, A. T., RANFORD, L. C., and others - The geology of the north-eastern part of the Amadeus Basin, Northern Territory. Ibid., (in prep.).

WELLS, A. T., STEWART, A. J., and SKWARKO, S. K., (in press) - The geology of the south-eastern part of the Amadeus Basin, Northern Territory. Ibid., 88.

WILLIAMS, G. K., HOPKINS, R. M., and McNAUGHTON, D., 1965 - Distribution of Pacoota reservoir - Amadeus Basin, N.T. J. Aust. Petrol. Expl. Ass., (in pre.).

BONAPARTE GULF BASIN

Outcrops of Palaeozoic rocks cover a land area of about 8000 square miles around the Joseph Bonaparte Gulf; the Basin may extend to the edge of the continental shelf to the north-west, (another 40,000 square miles approximately). A faulted zone trending north-east separates the Basin from Precambrian rocks on the east, and the south-western edge overlaps Precambrian rocks of the Kimberley Block. The Basin lies partly in the Northern Territory and partly in Western Australia.

Unaltered Upper Proterozoic sediments (quartz sandstone, some shale and siltstone, minor volcanics and carbonates) with minor deformation, and highly deformed Lower Proterozoic metasediments and some igneous rocks, flank the Basin. These are unconformably overlain around the southern part of the Basin by basalt, agglomerate and tuff (Antrim Plateau Volcanics) of probable Lower Cambrian age.

The estuary of the Victoria River separates the Palaeozoic and younger outcrops of the Basin - the south-western area with Cambrian, Ordovician, and Devonian to Permian rocks, and the northern part with only Permian, Lower Triassic and undifferentiated younger sediments.

In the south-west, the Upper Proterozoic sediments and Antrim Plateau Volcanics are overlain by 3500 feet of Middle and Upper Cambrian marine sandstones, with minor shale and limestone, followed conformably by Lower Ordovician glauconitic sandstone, up to 600 feet thick. The red colour in parts, glauconitic sandstones, oolitic limestone, and other features such as sun-cracks and ripple marks, suggest a shallow water environment. The beds contain abundant fossils in places. Rhythmically deposited sandstone, sandy dolomite, and stromatolitic dolomite in one particular formation represent strand, lagoonal and algae reef environments in successive transgressions of a shallow sea, (Kaulback & Veevers, 1965).

A hiatus, during which the Basin area may have been a land surface, occurred after the Lower Ordovician. Deposition began again in Upper Devonian, or perhaps Middle Devonian times, with about 4000 feet of cross-stratified conglomeratic sandstone. Minor carbonate horizons occur in the middle of the section, and the beds are generally fossiliferous - pelecypods, brachiopods, fish, plants. Facies and thickness changes, which are most marked in the carbonate part of the section, are attributed to the existence of a submarine ridge (Guillaume, 1965). The sandstone is conformably succeeded by a marine sequence of about 4000 feet of alternating sandstone and carbonate rocks with faunas ranging in age from Upper Devonian to Lower Carboniferous; biogenic deposits are common in this sequence. Marine conditions persisted in the Lower Carboniferous, and sandstone, limestone and dark grey pyritic mudstone beds were laid down. About 1000 feet are known from outcrop. The upper 5000 feet of the above succession change laterally towards the centre of the Basin to a more lutitic facies with thickening to over 6000 feet.

Later Carboniferous sedimentation followed an erosional break and more than 1000 feet of sandstone were formed; lower beds are calcareous and reflect shallow marine conditions whereas upper beds are conglomeratic and probably more paralic in character. The Palaeozoic closed in the south-western part of the Basin with (?) Lower Permian marine and possibly aqueoglacial sedimentation - argillaceous sandstone with boulders (erratic).

In the area north of the Victoria River estuary, at least 1500 feet of sandstone, and shale with coal, crop out in the coastal belt. The sequence is mainly Upper Permian but probably ranges from Lower Permian to Lower Triassic. Some younger Mesozoic or Cainozoic rocks also occur as small outliers north of the estuary; they consist of clay and sandstone with basal conglomerate, some limonite beds, and a thin veneer of laterite.

The structure of the Basin is controlled mainly by faulting which began in the Proterozoic and continued intermittently throughout the Palaeozoic. The movements have divided the Basin into areas of different sedimentary histories with marked variations in the facies and thickness of sediments. In the southern portion, for example, a Proterozoic uplift with a north-east trend separates two such areas.

The dominant fault system trends north-north-east, and forms the eastern border of the Basin; normal step - faulting and some transverse movement is thought to have occurred along this trend, (Drummond, 1963). A subsidiary north-west trending system is shown by normal strike faults (step and block-faults) in the south-western part, and is also reflected outside the margin by faulting in Upper Proterozoic rocks. The most extensive faulting apparently occurred during the Lower Carboniferous, together with some tilting. These movements and consequent erosion have left the Basin more or less in its present form.

Regional dips are north-east in the south-western part of the Basin - up to 40^{o} in the Cambrian-Ordovician sediments but much lower in Upper Devonian and later Palaeozoic rocks, and low to the west in the northern part. The only folds seen in outcrop are broad anticlines along and within the north-north-east fault system. South-west and south dips in islands off the southern shore of the Bonaparte Gulf may reflect a basement high or folding north-west of the Victoria River estuary.

Geophysical exploration has yielded little information on structures within the Basin. A strong north-west trending gravity ridge, parallel to the early Palaeozoic outcrops in the south-western part, probably represents a subsurface divide. A structural "high" may occur at depth towards the coast in the Northern part, parallel to but away from the marginal fault system. A gravity "high" is also indicated north-west of the Victoria River estuary, but only from widely scattered stations; subsequent seismic work has suggested thick sedimentary section, (Bigg-Wither, in prep.).

Probable source, reservoir, and cap rocks occur in the Bonaparte Gulf Basin, but the difficulty will lie in finding suitable traps for hydrocarbons. Sedimentation has been apparently affected mainly by faulting and some associated tilting, hence fault traps, pinch-outs, and unconformity traps may prove to be the best targets. Drilling has found "wet gas" (8% or more of ethane and higher hydrocarbons in Bonaparte No. 2 Well) which was tested at 1.15 million cubic feet per day, with other shows of hydrocarbons, in sandstone lenses within a thick mudstone, shale sequence of the Lower Carboniferous. Formations older than the top of the Upper Devonian have not yet been drilled, but only three deep wells have been drilled to date.

The most comprehensive reference to the Bonaparte Gulf Basin is by Traves, (1955); new information is being provided by recent and current field mapping by the Bureau of Mineral Resources (Veevers et al, 1964; Kaulback & Veevers, 1965), and by Australian Aquitaine Petroleum Pty. Ltd. (Guillaume, 1965).

Reference should be made to Drummond (1963) for a comprehensive bibliography of the Basin and a review of the geology. A compilation of geophysical surveys is also being prepared by the B.M.R., (Bigg-Wither, in prep.)

BIGG-WITHER, A.L., - Compilation and review of the geophysics of Bonaparte Gulf Basin, 1962. Bur. Min. Resour. Aust. Rec. 1963/165 (in prep.).

DRUMMOND, J.M., 1963 - Compilation and review of the geology of Bonaparte Gulf Basin, 1962. Bur. Min. Resour. Aust. Rec. 1963/133 (unpubl.).

KAULBACK, J.A., and VEEVERS, J.J., 1965 - The Cambrian and Ordovician geology of the southern part of the Bonaparte Gulf Basin and the Cambrian and Devonian geology of the outliers, Western Australia. Bur. Min. Resour. Aust. Rec. 1965/49, (unpubl.).

TRAVES, D.M., 1955 - The geology of the Ord-Victoria region, Northern Australia. Bur. Min. Resour. Aust. Bull. 27.

VEEVERS, J.J., ROBERTS, J., KAULBACK, J.A. and JONES, P.J., 1964 - New observations on the Palaeozoic geology of the Ord River area, Western Australia and Northern Territory. Aust. J. Sci., 26(11), 352-353.

BOWEN BASIN

The Bowen Basin is a structurally complex depositional area containing a number of subsidiary troughs of various ages. Its northern limits are exposed; to the south it is overlapped by Lower Jurassic and younger rocks of the Surat Basin, a part of the Great Artesian Basin. The outcropping part of the Bowen Basin, is about 33,000 square miles in size. The Basin narrows to the south below the Surat Basin where the eastern side is fault controlled, but the sediments apparently lens out over a basement shelf along the western edge. To the south, the Bowen Basin was possibly connected with the Sydney Basin from time to time.

Sedimentation possibly began in the Upper Carboniferous but occurred mainly in the Permian and Triassic. Pre-Permian rocks of several ages constitute the basement; they include steeply to gently dipping sediments and volcanics, locally intruded by granite and volcanics and altered to metamorphics (Trumpy and Tissot, op. cit.).

The earliest deposition occurred in two areas; an elongate trough where the eastern margin now exists, and a smaller deep depression in the western part. The eastern trough was filled mainly with andesitic and acid volcanics and pyroclastic deposits, the upper sediments being marine fossiliferous tuffs; a thickness of 12,000 feet in the central part is considered as probably conservative (Malone, 1964). The sediments of the western depression are composed of siltstone, sandstone and conglomerate, with some coal, and are up to 8000 feet thick.

Later marine sedimentation took place in both these troughs, and after a general subsidence of most of the Basin, extended progressively over the whole area, but with only thin development in the southern half of the eastern trough. Subsidence ceased in the western depression at about the end of the Lower Permian; it continued into the Upper Permian in the north-eastern part along an axis parallel to but just west of the axis of the early Permian trough, and was also renewed to the south-east in the Upper Permian. The earliest marine beds were dark grey to black pyritic mudstones, with subgreywackes and some calcareous beds. Later, deposition in shallower conditions produced extensive sandstone beds, and with coal measures formed aroung the north-western margin. Finally deeper water conditions returned, producing mudstone, some sandy beds, and fossiliferous limestone. The overall thickness is up to 8000 feet.

After a rapid regression of the sea, swampy lowlands developed in the Bowen Basin, and thick coal measures of Upper Permian age were formed. The change was possibly associated with uplift along the axis of the early Permian eastern trough (Malone, op. cit.). Sediments were lithic sandstone, siltstone, carbonaceous shale and coal, conglomerate in places, and tuff and agglomerate to the east; maximum thickness of 8000 feet is at the northern end.

Tectonic activity in the late Permian led to uplift and folding of the eastern part of the Basin, and to a downwarp in the southern central part which gave the Basin its present shape and became the locus for Triassic sedimentation. The intense erosion of uplifted Permian and older rocks and contemporaneous vulcanism to the east, together with the subsidence, resulted in 10,000 feet of non-marine conglomerates, lithic sandstones, chocolate, red, green, and grey shales and siltstone of uppermost Permian to Lower Triassic age. Similar sedimentation occurred in Middle-Upper Triassic time as a result of continued tectonic activity, except that the composition of detrital material altered with deeper erosion of the Permian so that more quartz and weathered feldspar are found in the sandstone. Sandstone, and olive-green and brown shales occur, and the succession is up to 8000 feet thick in the southern part of the Basin. Limited marine incursion may have taken place in the Upper Triassic, (hystrichospheres in Sunnybank No. 1 Well and at Hungry Creek - M.A.P.L., 1963; Evans, 1962). General folding ended the Triassic history, and Lower Jurassic beds are unconformable over the older rocks. The Jurassic-Cretaceous sediments of the Surat Basin are discussed later.

The Tertiary which covers part of the Basin consists of volcanics, associated intrusives, and continental sediments; locally these may be thick but generally they are thin.

Structural evolution and sedimentation of the Bowen Basin have been discussed. The western part can be regarded as a platform or intracratonic area with both shelf and deeper water sedimentation. Gentle folds and possibly drape structures, probably with some compressional faulting are found in the western platform area. Tectonism becomes increasingly complex to the north-east apparently towards the mobile, geosynclinal area where the thickest Permian is found. Extensive intrusions of late to post-Permian age, strong folding and faulting have taken place in this north-eastern zone and low grade regional metamorphism is found. In the southern part folding was more gentle and accompanied faulting along the eastern margin - a mobile hinge line that was apparently active until post-Middle Jurassic time, (Mack and Kellar, 1965).

Important discovery wells (oil and gas), and successful development and extension wells in the Bowen-Surat Basins * now number 80. More than 75% produce from Lower Jurassic sandstone formation, and the rest are from the Triassic and Permian (modified after Denton, 1965). Less than 10% of the wells are in the outcropping part of the Bowen Basin, the rest were spudded into the Surat Basin.

* The Bowen and Surat Basins are linked for the discussion of the occurrences of hydrocarbons because some wells drilled in the Surat Basin have made discoveries in the buried part of the Bowen Basin, with or without occurrences in the sequence of the Surat Basin.

Although small amounts of oil have been found in the Bowen Basin sequence, the main discoveries have been gas. The main source of hydrocarbons is thought to be the marine Permian (Traves, 1965; and others), but the earliest source rocks could be in the Upper Carboniferous. Both oil and gas have been obtained from the Lower Jurassic of the Surat Basin sequence. Their source may have been in the Permian (as above), but another likely source is the Lower Jurassic, (Evans, op. cit.; Moran and Gussow, 1963) and possibly the Middle - Upper Triassic.

Lower Jurassic sandstones in the Surat Basin are the best reservoirs to date, but are not consistent producers from all structures. This may be due to:

- flushing by water near outcrop
- impermeable shaly layers
- erratic source beds, and
- migration of the hydrocarbons before development of the structures.

Several sandstone units occur in the Permian and Triassic, but are commonly lenticular or have low porosity and permeability because of poor sorting and clay matrix. Hydrocarbons are not uncommon in these beds, but only a few give economic supplies. Weathered basement has shown oil and gas bleeding in one well, and the ?Upper Carboniferous to Lower Permian basal sand in the western part also produced a large gas flow, but with water.

Stratigraphic entrapment was at least as important as structural, and most are combination traps (Traves, op. cit.). The late Permian - Jurassic tectonic events affected hydrocarbon accumulation in two ways -

(i) activity in the northern and eastern areas reduced prospects because of its intensity and related igneous activity;

(ii) more gentle folding in southern and western parts, with associated local unconformities, enhanced the prospects, and provided traps.

But many other traps are connected with draping over basement highs, permeability barriers, lensing, and pinchouts. One important reservoir is thought to be a buried sand bar.

The outcropping part of the Bowen Basin has been mapped from north to south by Bureau of Mineral Resources (B.M.R.) and Geological Survey of Queensland (G.S.Q.) field parties from 1960 to the present, and several reports will be published in the next twelve months. Extensive studies have been made also by Company geologists both in the outcropping and particularly the subsurface part of the Basin, (Mack, 1963). This present description has used Dickins (in Reynolds, and others, op. cit.) as a basis, and been expanded to include a report by the Institut Francais du Petrole - I. F. P., (Trumpy and Tissot, op. cit.), and recent publications by Malone (1964), and Traves (1965).

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CANNING BASIN

(FITZROY and SOUTH CANNING BASINS)

The largest sedimentary basin in Western Australia (and the second largest in Australia) is the Canning Basin. Excluding the seaward extension, its area is 150,000 square miles. A deep elongated graben-like trough (taphrogeosyncline) called the Fitzroy Basin forms the northern part. The remainder is referred to as the South Canning Basin but geophysical surveys have shown other depressions of importance within this area. One of these, in the south-eastern part, is known as the 'Kidson Basin'.

The basement is similar to that of the Bonaparte Gulf Basin - Lower Proterozoic igneous and metamorphic rocks, unconformably overlain by Upper Proterozoic sediments and intrusives, gently folded but more contorted in some places; basement outcrops are also covered in parts by ?Lower Cambrian basalt flows.

The oldest Palaeozoic sediments, about 3000 feet of ?uppermost Cambrian to Ordovician marine limestone, dolomite, shale, and sandstone, are apparently widespread.

Marine Devonian rocks occur unconformably over Precambrian and Ordovician rocks in the Fitzroy Basin. Biostromes and calcarenite formed initially under fairly uniform deposition. Later deposition was affected by contemporaneous block faulting and differential uplift of various parts of the inundated area. A complex of reef sediments (calcarenite, calcilutite, limestone breccia) with associated off-reef deposits (conglomerate, sandstone, and mudstone) gave rise to much interfingering of the various formations; thin beds of evaporites formed locally in inter-reef lagoons. The overall thickness of Devonian rocks in the Fitzroy Basin is about 5000 feet. East of the main Fitzroy trough, probable Upper Devonian sandstone was deposited in lakes. Although Devonian rocks ~~are apparently absent from platform areas elsewhere in the Canning Basin,~~ they may occur in structural "lows".

9152' in Yulleroo 1500 feet of Lower Carboniferous calcarenite, calcareous mudstone, siltstone, and sandstone to sandy dolomite occur in the northern part of the Fitzroy Basin but their extent is not known. Three and a half rhythmic alternations of shallow marine and shallow freshwater or estuarine deposition took place in the Canning Basin from the Upper Carboniferous to Lower Triassic, the lower cycle showing evidence of glaciation. The Upper Carboniferous sediments of the Fitzroy Basin include more than 5000 feet of interbedded sandstone and mudstone with thin beds of limestone, dolomite and anhydrite. Widespread Permian marine lithic sandstone, conglomerate, sandy limestone, and shale, with tillite and varves in the lower part, and freshwater sandstone, are 14,000 feet thick in the Fitzroy Basin and much thinner elsewhere. Possibly about 1000 feet of Triassic estuarine mudstone and freshwater sandstone occur in the Fitzroy Basin.

In the later Mesozoic, about 2500 feet of Jurassic and Cretaceous marine sandstone, conglomerate, glauconitic siltstone and shale, or freshwater sandstone, according to the environment, were laid down in the Canning Basin. Cainozoic sediments are superficial coastal aeolianite and other coastal sediments, desert sand, travertine, black soil, alluvium, freshwater limestone, and evaporites.

As far as is known, structure in the Canning Basin is mainly a result of graben subsidence of certain parts, in particular the Fitzroy Basin, and less important block uplifts and tilting. The main faulting occurs along mobile zones on the northern and southern sides of the Fitzroy Basin; step faulting associated with the movements left shelves on either side of the main graben zone. The greatest thickness of sediments, some 30,000 feet, occurs in the graben zone. A thinner but full section of Ordovician and Devonian to Permian rocks with Devonian reef complexes occurs along the northern shelf area. On the southern shelf thicknesses to basement are intermediate between those of the graben and those of the South Canning platform area; drilling on the terrace showed the presence of a salt dome which intrudes Devonian and Permian rocks.

The main structural trend appears to have been consistently north-west to south-east from the Precambrian through the Palaeozoic. Broad folding took place in the Fitzroy Basin during the early Mesozoic; the trend of the axes, however, is more east-west to west-north-westerly, and the folds are cut by numerous small north-south normal faults. Veevers and Wells (1961) associate the folding more with differential uplift of the basement than with lateral compression; however, these structures could also have been formed by shear movements along the main mobile zones or along similar north-west, south-eas fault lines in the basement.

The greater part of the South Canning Basin was a platform during Palaeozoic sedimentation, with a ridge (or 'swell') along the northern edge; sediments over the platform are 5000 to 7000 feet thick. Thicker sediments, about 10,000 feet, however, are known in a structural depression in the south-western corner, and geophysical evidence suggests over 20,000 feet of sediments in the Kidson Basin to the south-east. The structure in the remote eastern parts of the Canning Basin is still virtually unknown.

Although minor showings of hydrocarbons have been reported from Ordovician limestone and Devonian reef rocks, the only oil recovered is a very small quantity (5 gallons) from Lower Carboniferous sandstone. This is rather surprising in view of the thick possible source rocks and potential reservoirs within the Canning Basin. To date, only about 20 wells have been drilled to 4000 feet or more, and many of these were apparently based on scanty or incorrect knowledge of the structure. Even now, the geological history of the Canning Basin is not fully known, and the emphasis for exploration is on geophysical surveys. Reef plays, and structures associated with faulting and differential uplift, appear to be the best objectives. Stratigraphic traps could also be important, particularly in the Carboniferous and Permian rocks. However hydrodynamic movements and the time of migration of the oil could also be important factors for accumulation.

The most comprehensive of recent studies on the Canning and Fitzroy Basins is by Veevers and Wells (1961, with contributions from J. H. Rattigan), and this work is the basic reference for the above geological summary. A short paper by Playford (1962) was also referred to. All other important references to the Canning Basin may be found in these publications.

PLAYFORD, P. E., 1962 - A geological appreciation of recent oil exploration in the Canning, Carnarvon, and Perth Basins, Western Australia. Aust. Inst. Min. Metall. Tech. Papers: Oil in Australasia, Ann. Conference, Queensland, 1962.

VEEVERS, J. J. and WELLS, A.T., 1961 - The geology of the Canning Basin, Western Australia. Bur. Min. Resour. Aust. Bull. 60.

CARNARVON BASIN

The Carnarvon Basin occurs along the westernmost side of Western Australia. Geophysical evidence and drilling show a strong meridional ridge through the central part of most of the Basin, and other minor ridges which divide the Carnarvon Basin into subsidiary basins: the Gascoyne Basin west of the meridional ridge, and the Onslow, Merlinleigh, Bidgemia and Byro Basins from north to south along the eastern side.

Recent sands and alluvium obscure the north-eastern margin, but in the east the boundary is the junction of Palaeozoic sediments with Precambrian igneous and metamorphic rocks. The south-eastern margin is partly a subsurface ridge, shown by gravity surveys to extend north from Precambrian outcrops north of Geraldton, and partly the southern edge of the Byro Basin. Both the north-eastern and south-eastern margins extend on to the continental shelf. The land area is about 45,000 square miles.

Sandstone and siltstone units, more than 11,000 feet thick, in which no organic remains have been found, occur at the south-eastern end of the Basin unconformably over Preocambrian basement; they are thought to be Upper Proterozoic or Lower Palaeozoic in age. Early Palaeozoic rocks also include 4000 feet of mainly red sandstone in which well-preserved invertebrate tracks are found, and Silurian fossiliferous dolomite and limestone, with anhydrite, 2500 feet thick, which are not known in outcrop. (The sandstone unit contains red siltstone beds, and Condon, 1964, gives a maximum thickness of 20,600 feet). The two units extend from the south-western part of the Basin across the meridional ridge at least to the central eastern part (see Pearson, 1964).

Devonian (maximum thickness 4700 feet) and Carboniferous (2300 feet) marine sediments are known from the northern part of the Carnarvon Basin, and the Devonian extends as far south as Carnarvon. The Devonian includes greywacke and sandstone near the base, followed by siltstone, limestone, and quartz sandstone, sub-greywacke and conglomerate. The Carboniferous comprises thick fossiliferous limestone with sub-greywacke, siltstone, and conglomerate, overlain by thin oolitic limestone, dark siltstone and sandstone.

An overall thickness of 12000 feet of Permian rocks has been measured. They are thickest east of the meridional ridge but are widespread throughout the Basin. Although mainly developed in rather shallow water, they show a complex of environments with glacial sediments near the base followed by fossiliferous marine limestone, and clastic sediments varying from porous sandstone to dark marine siltstone and shale of deeper water facies. A major break in deposition occurred above the Permian.

Mesozoic sediments are best developed between the Cape Range - Rough Range area and Barrow Island in the northern part of the Carnarvon Basin. The oldest known Mesozoic sediments are Middle-Upper Triassic sandstone and siltstone, at least 400 feet thick, in Learmonth No. 2 Well (Pudovskis, 1964). Dark Jurassic mudstone, up to 11,500 feet thick, with sandstone interbeds, occur in Cape Range No. 2 Well. However, the Jurassic occurs only as thin pockets to the east and south of Rough Range. Up to 5000 feet of Cretaceous sediments, mainly marine, occur in Barrow No. 1 Well (McTavish, 1965), but are thinner to the south-west. Paralic and shelf-type sediments are represented and include basal porous sandstone, shale, radiolarite, siltstone and glauconitic sandy beds, calcilutite and calcarenite. Tertiary limestone and clastic deposits are best developed (up to 2000 feet thick) the northern coastal part of the Carnarvon Basin.

The subsidiary basins of the Carnarvon Basin have been apparently formed in graben or half-graben structures; the meridional ridge is a subsurface horst, possibly formed in the Permian. Faulting is considered to be more common east of the ridge, and reversal of movement has occurred along some of the old fault lines. Evidence for some compressional folding is found in the Devonian-Carboniferous in the eastern part of the Basin. The most important structures, however, seem to be the large north-north-east trending anticlines of the north-western coastal and island region; these have provided two hydrocarbon discoveries.

The first discovery was made in 1954 in the Rough Range Anticline, a structure more than 40 miles long with a structural relief of at least 300 feet (Playford, op. cit.) 39.6^{o} A.P.I. gravity oil was obtained from the basal

Cretaceous sandstone at a rate of 500 barrels per day through a ½-inch choke. After drilling an evaluation well alongside the discovery, ten other wells were drilled on the structure. These ten wells gave no significant shows, and the field was classed as non-commercial. Gas shows were obtained from the Upper Jurassic mudstone sequence in the parallel Cape Range structure, but sands in this sequence were only proved productive in 1964 when the Barrow Island Anticline was drilled. Barrow No. 1 Well gave numerous hydrocarbon showings in the Cretaceous sediments, and in the underlying Upper Jurassic beds, and produced more than 11 million cubic feet per day of wet gas, and oil up o 985 barrels per day (38.1° A.P.I.) through a ½-inch choke. Testing on Barrow Island is continuing; other wells have been subsequently completed as prod cers, and the Barrow field will probably be developed commercially in the near future.

Most of the older, Palaeozoic sequences provide possible source rocks, and some have give shows of hydrocarbons. Porous beds are also present, but the locating of go d permeability in suitable structures will probably provide the main difficulty in finding commercial hydrocarbon accumulations.

A number of references to the Carnarvon Basin resulted from B.M R. mapping in the region between 1948 and 1956, and these, plus the stratigraphy given in McWhae, et. al. (op. cit.) were used by Dickins (in Reynolds and others, op. cit.) to give a current assessment of the Basin. Exploration since then has yielded some new information, but apart from geophysical work by the B.M.R. in the southern half, other information which has become available through subsidized operations has been confined almost entirely to the northern half. Some recent information is given by Playford (op. cit.), and Condon (1964) is preparing a B.M.R. Bulletin on the Geology of the Carnarvon Basin.

CONDON, M. A., 1964 - The geology of the Carnarvon Basin, Western Australia. Part 1: Pre-Cambrian stratigraphy. Bur. Min. Resour. Aust. Rec. 1964/145 (unpubl.)

McTAVISH, R. A., 1965 - Barrow No. 1 Well Completion Report. For West Australian Petroleum Pty. Limited (unpubl.)

PEARSON, G. R., 1964 - Quail No. 1 Well Completion Report. For West Australian Petroleum Pty. Limited (unpubl.)

PUDOVSKIS, V., 1964 - Learmonth No. 2 Well Completion Report. For West Australian Petroleum Pty. Limited (unpubl.).

DALY RIVER BASIN

The Daly River Basin in the northern part of the Northern Territory with about 1000 feet of Cambrian marine limestone and sandstone, and virtually undeformed, shows little prospects for hydrocarbon accumulation; but its extension to the south, referred to as the "Wiso Basin", is virtually unknown and may contain possible source rocks. A recent aeromagnetic survey (Zarzavatjian and Hartman, 1964) in the Wiso Basin area suggests that the magnetic basement is in places at a depth of 12,000 feet, and shows some structural trends. Current field mapping and scout drilling by the B.M.R. will yield more information on this region.

NOAKES, L. C., 1949 - A geological reconnaissance of the Katherine-Darwin Region, Northern Territory. Bur. Min. Resour. Aust. Bull. 16.

ZARZAVATJIAN, P. A. and HARTMAN, R. R., 1964 - Interpretation report of airborne magnetometer survey over Tanami area, Northern Territory. For Exoil Co. Pty. Ltd. (unpubl.).

The report by Traves (op. cit., Bonaparte Gulf Basin) also covers the western side of the region.

DRUMMOND BASIN

The Drummond Basin is a small basin (15,000 square miles) separated from the Bowen Basin on the east by a narrow belt of metamorphic rocks with granite and minor serpentinite intrusions. On the west it is overlapped by Upper Permian to Mesozoic rocks of the Great Artesian Basin, and on the south by Permian rocks of a shelf area which is part of the Bowen Basin. It may extend south-west below the surface towards the Adavale Basin.

The oldest rocks of definite age are Middle Devonian with perhaps some Lower Devonian which occur in the northern part of the Basin and comprise at least 4000 feet of undisturbed marine siltstone. Except for a small thickness with marine horizons in the Upper Devonian, also in the northern part of the Basin, no definite marine horizons are known above the Middle Devonian. The Devonian sediments are siltstone and sandstone with some limestone, conglomerate, thin algal limestone, tuffaceous sandstone, tuff and intermediate to acid lavas, with a total thickness of 10,500 feet. The Carboniferous sequence above is very similar and hard to separate lithologically. Siltstone, conglomerate, sandstone, tuff and algal limestone form the lower 20,000 feet; the upper 15,000 feet are acid lavas, tuff, agglomerate and tuffaceous siltstone and sandstone. Lake Galilee No. 1 Well, on the western side of the Basin, found Carboniferous-Lower Permian interbedded sandstone, shale and siltstone, with calcareous horizons, some pebbly beds and coal seams in the lower part, and some greywacke and breccia beds in the upper part. The Carboniferous-Lower Permian succession is 5800 feet thick.

The overall structure of the Drummond Basin is not well known. Sediments dip westerly off the metamorphics along the eastern side, and are folded into moderately complex anticlines, some quite large, affected by faulting, some of which is thrusting. The main orogeny is thought to have occurred after the Carboniferous sedimentation, but there is evidence for later Permian movements.

The known occurrences of hydrocarbons are in probable Carboniferous sediments. Indications of hydrocarbons, attributed to localised baking of shales (in an area of Carboniferous outcrops) were reported from 438 to 477 feet in P.O.P.L. Twin Hills No. 1, (G.S.Q., op. cit.); Lake Galilee No. 1 obtained ten feet of 43° A.P.I. gravity oil and a small flow of gas from thin poorly permeable sandstone in the ?Carboniferous section. The Middle and Upper Devonian marine rocks appear at present to be the most likely source of hydrocarbons, but lateral changes into marine sediments may occur in the younger sediments deeper in the Basin. Sandstones are apparently the most likely reservoirs, but poor permeability may create problems. Another complication in some places will be the local metamorphism by intrusions.

In the description of the Drummond Basin (in Reynolds and others, op. cit.), J. M. Dickins used the following recent publications as his main references: Hill, (1957, based mainly on the work of Shell Queensland Development Pty. Ltd.); Hill and Denmead, (op. cit.); Malone et al., (1964); Veevers et al., (1964). Geophysical information is available from the subsidized surveys of companies, and work done by the B.M.R.

HILL, D., 1957 - Explanatory notes on the Springsure 4-mile Geological Sheet, 4-mile Geological Series. Note Ser. Bur. Min. Resour. Aust., 5, 1-19.

MALONE, E. J., CORBETT, D. W. P., and JENSEN, A. R., 1964 - Geology of the Mt. Coolon 1:250,000 Area. Bur. Min. Resour. Aust. Rep. 64.

PEMBERTON, R. L., 1965 - Lake Galilee No. 1 Well Completion Report For Exoil No Liability (unpubl.).

VEEVERS, J. J., RANDAL, M. A., MOLLAN, R. G., and PATEN, R. J., 1964 - The Geology of the Clermont 1:250,000 Sheet Area. Bur. Min. Resour. Aust. Rep. 66.

EUCLA BASIN

The Eucla Basin is an hydrological basin along the coast between Western Australia and South Australia. The margins roughly represent the known limits of marine Tertiary deposition north of the Great Australian Bight, and enclose an area of 74,000 square miles. It is broad and shallow with up to 930 feet of Tertiary sediments and 1200 feet of Cretaceous over Precambrian-?Cambrian rocks, (Ludbrook, in Glaessner and Parkin, op. cit.; McWhae, et al., op. cit.) The Eucla Basin extends southerly on to the continental shelf.

The prospects of finding significant accumulations of hydrocarbons do not appear to be good.

GEORGINA BASIN

Although one of the largest basins in Australia, the Georgina Basin of 110,000 square miles has yielded only very minor shows of hydrocarbons. Surface mapping by the B.M.R. (and joint B.M.R.-G.S.Q. parties), and by company personnel, has outlined the stratigraphy, and the broad structural picture has been shown by geophysical surveys. Some areas have been unsuccessfully tested by drilling, but the subsurface geology is still unknown in other parts which geophysical methods indicate should have prospective sections.

The Georgina Basin is defined as that area of lower to middle Palaeozoic sediments extending in a belt from western Queensland to the central northern part of the Northern Territory where it joins the Daly River Basin. It is bounded on the east, north-east and west by Precambrian rocks; in the north-west it is covered in part by Mesozoic sediments. The Georgina Basin sediments extend below the Mesozoic of the Great Artesian Basin in the Toko Syncline which plunges south-east; and they are partly buried by the Mesozoic to the east around the southern edge of a Precambrian shield complex where they were laid down in a shelf area and now protrude as inliers through the Mesozoic sediments in some places. The buried southern and eastern edges of the shelf area are reflected as an extensive belt of steep gravity gradients and are shown on the basins map.

In this report, the Middle Cambrian are regarded as the basal beds of the Georgina Basin, but these are underlain in some marginal areas by thousands of feet of Upper Proterozoic and Lower Cambrian sediments, including sandstone, siltstone, arkose, greywacke and algal, or otherwise fossiliferous carbonate rocks. The thickest known sequences, mainly of Cambrian and Ordovician rocks, crop out in the south and south-east, and numerous breaks in deposition are indicated by palaeontological evidence. The successions vary from west to east as follows:

South-western corner - 4300 feet of dark marine limestone and dolomite with subordinate sandstone, siltstone and shale of Middle-Upper Cambrian age; overlain conformably by 1000 feet of Upper Cambrian to Middle Ordovician glauconitic sandstone, siltstone, limestone and dolomite with coquinite bands, and some oolitic ironstone. The sequence is overlain unconformably by 1200 feet of freshwater sandstone of Upper Devonian age.

Central southern part, including the Toko Syncline - a similar, dominantly carbonate section of Middle-Upper Cambrian, 4200 feet thick (M.A.P.L., 1965); with a thicker Upper Cambrian-Middle Ordovician sequence of limestone and dolomite (including algal beds, breccia, and oolites), sandstone and cherty dolomite, calcilutite, marl, calcarenite, and interbedded sandstone and siltstone with pellet beds, (some phosphatic), up to 2400 feet thick. Possible Devonian sandstone, at least 400 feet thick, overlies the youngest Middle Ordovician unit. South-eastern side - the Middle to Upper Cambrian carbonate sequence, with minor siltstone and shale, is here 3800 feet thick in the subsurface (Green et al., 1963) and about 1000 feet in outcrop; Upper Cambrian to Lower Ordovician carbonate rocks are 2000 feet thick but the more clastic Lower-Middle Ordovician section is missing.

Most of the northern half of the Georgina Basin contains a thin blanket of marine Middle Cambrian sediments consisting of shale, limestone, dolomite, and sandstone. Many of the carbonate rocks are vuggy and cavernous and yield large quantities of water. Thickness is estimated at about 1000 feet in most of the area, but local variations related to basement topography may be expected. Along the northern margin the Middle Cambrian sequence has been faulted, but elsewhere structural deformation is not evident.

The southern areas of thickest sediments are separated from each other, and from the northern area by a blanket of mainly Lower Ordovician carbonate rocks.

The sediments of the southern and south-eastern parts of the Georgina Basin have been faulted and folded during an orogeny which occurred possibly in Carboniferous time. Deformation is locally intense and faults trending north-west have been traced for more than 100 miles, downthrowing consistently on the east. These are thought to be old Precambrian trends against which thrusting from the south-west occurred in the ?Carboniferous (Reynolds, 1965). The thrusting also caused asymmetrical folding and, in the area of the Toko Syncline, minor transverse faulting occurs along north-east trends. Anticlines, domes, and monoclines are known in the southern part of the Georgina Basin, but the most prominent fold is the Toko Syncline; this is an asymmetrical structure, possibly a half-graben with steeply dipping sediments partly overturned along the south-western side, and a low-dipping north-eastern limb. The syncline has been traced by geophysical surveys, and these indicate that the thickness of sediments in the concealed south-eastern end is much greater than in outcrop. Apart from minor warping associated with the development of the Great Artesian Basin in the Mesozoic and small local folding movements in the Tertiary, the region has remained fairly stable since the Palaeozoic.

The Cambrian and Ordovician rocks of the Georgina Basin have yielded small amounts of asphaltic material by drilling, and small gas shows. These were particularly numerous in a well drilled on a small closed structure along the axis in the central part of the Toko Syncline (M.A.P.L., 1965). Prospects of finding a good accumulation were probably spoiled by the transverse faulting in this area, and by the fact that some of the best reservoirs occur at or near the surface. These are sandstones in the Ordovician sequence, interbedded with siltstone, and could be more prospective in the deeper part of the syncline to the south-east.

The other two areas of thickest sediments in the southern part of the Georgina Basin contain a greater proportion of carbonate rocks. Source rocks are present, but drilling to date has failed to find good reservoirs.

This description is based primarily on the work of K. G. Smith who is currently preparing a report on the geology of the Georgina Basin, and is drafting a map at 1:500,000 scale; see also Smith (in prep.). The report will contain a bibliography of the numerous reports which have been written in recent years on the various parts of the Georgina Basin.

GREEN, D. C., HAMLING, D.D., and KYRANIS, N., 1963 - Phillips-Sunray stratigraphic drilling Boulia Area, A.T.P. 54P, Queensland (unpubl.).

M.A.P.L., 1965 - P.A.P.C. Netting Fence No. 1 Well, Queensland. Well Completion Report, Q/54P/214 (unpubl.).

REYNOLDS, M. A., 1965 - Glenormiston 1:250,000 Geological Series. Bur. Min. Resour. Aust. explan. Notes SF/54-9.

SMITH, K. G., - Geology of the Georgina Basin. J. Aust. Petrol. Expl. Ass., 1965 (in prep.).

GIPPSLAND BASIN

The Gippsland Basin occurs along the south-eastern side of Victoria, and includes the off-shore gas field on the Gippsland Shelf, discovered in early 1965 and the most southerly field in Australia. The Basin used to be regarded as Tertiary, but the limits have been extended on the map accompanying this report to include the Cretaceous. The Cretaceous rocks crop out in the Western part and extend south-west towards the Bass Basin, (a submarine basin between Victoria and Tasmania). The land area of the Gippsland Basin is 3500 square miles. Submarine continuations of the Basin margin towards the east have been drawn from aeromagnetic work (B.M.R. geophysical surveys, and Reford, 1962).

The rocks on the north side of the Basin are mainly metamorphosed Ordovician and Silurian sediments intruded in places by granite. Lower - Middle Devonian marine rocks - clastics and carbonates including reef facies - occur in synclines or graben-like troughs with meridional trends within the older rocks. During the major orogeny at the end of the Middle Devonian, the beds were folded and faulted with some thrusting. The main Palaeozoic orogenies at this time were along axes trending north-east and north-west (Boutakoff, 1955). The Middle Devonian sediments are overlain unconformably by Upper Devonian-Lower Carboniferous non-marine clastics and volcanics which are only gently deformed.

South of the south-western, Cretaceous extension of the Basin is a basement inlier, mainly of granite but with a belt of Middle Devonian fossiliferous limestone over Cambrian greenstone near the western edge. Webb (1961, after Talent, 1959) notes that this Middle Devonian limestone can be correlated with the Middle Devonian rocks to the north-east, and suggests extension of these rocks below the Basin. There is no evidence for this from drilling and Hocking and Taylor (1964) believe that the Devonian belts are truncated along the northern edge. (If, in fact, the northern edge is fault-controlled as some evidence suggests, and the Middle Devonian outcrops occur on either side of the Basin but not opposite one another, the possibility that the basement has been offset should not be overlooked.)

Permian argillaceous sandstone and minor mudstone, 600 feet thick, occur below 300 feet of ?Permian volcanics in Duck Bay No. 1 Well in the northern part of the Basin (Ingram, 1964; Evans and Hodgson, 1964). Drilling has also shown a thickness of more than 8000 feet of Lower Cretaceous greywacke, subgreywacke with mudstone, sandstone and coal, which are overlain by 400 feet of ?Lower Cretaceous sandstone and mudstone. The upper sandstone is generally a more porous interval which has yielded small flows of wet gas (50 to 100 thousand cubic feet per day in North Seaspray No. 1), and is similar to the upper part of the Lower Cretaceous of the Otway Basin. The overlying Cainozoic may be summarized as follows:

Quaternary	- multicoloured sand and clay (100 feet).
Pliocene to Upper Miocene	- marl and sand, mostly fossiliferous (600 feet).
Miocene	- grey fossiliferous glauconitic marl and limestone (1400 feet).
	- Disconformity (overlap).
Oligocene	- upper dark micaceous and sandy marl to foraminiferal marl and limestone (250 to more than 700 feet); green glauconitic sand and sandy marl (average 30 feet); basal gravel, sand and marl with marked lithofacies changes (up to 150 feet).
	- Disconformity (overlap)
Lower Oligocene to Upper Eocene	- Coal measures - sand, brown coal, siltstone clay and dolomite (up to 1800 feet).
	- Unconformity at base.

Carter (1964) has made the observation that definite fragments of coal derived from the coal measures occur in the overlying basal Oligocene bed, and a significant time break must have occurred between deposition of these two formation; the coal measures may have formed in the earliest Tertiary.

Mesozoic structures (faults and monoclinal folding associated with major block movements) trend approximately east-west. Two troughs were formed with a major uplifted zone in the centre, and a narrow basement platform along the northern edge. Tertiary structures reflect those of the Mesozoic, and movement continued along the central uplift into the Oligocene; Tertiary strata are only gently deformed. Geophysical surveys have shown that structures may swing towards the north-east off-shore; excellent reflection quality has been obtained in the off-shore seismic surveys, and have found closed structures as well as good wedge-out between the coal measures and the overlying Oligocene section, (and also a buried submarine canyon, Stanford et al., 1965)

The first discovery in the Gippsland Basin was made in 1924; a small amount of oil mixed with water and a flow of gas were obtained from 1070 feet in Oligocene glauconitic sand in Lakes Entrance No. 1 Well. 100,000 gallons of oil were produced from various bores in the Lakes Entrance area between 1930 and 1941. The oil is an asphaltic base crude. 15.7° A.P.I., and specific gravity 0.961; light fractions, including gasoline and kerosene, are missing, (Boutakoff, 1964). The gas is mainly methane and nitrogen, but the proportion of each varies considerably. It is possible that the oil is from marine beds which transgress the "Upper Eocene-Lower Oligocene" coal measures, and that the gas is from brown coal beds. Similar sources probably yield the commercial gas accumulation found in the Gippsland Shelf No. 1 Well. This off-shore occurrence is apparently in a structural trap, but Boutakoff (op. cit.) has also pointed out the possible hydrodynamic influence in the small accumulations on-shore.

Other minor occurrences of hydrocarbons have been reported from the sandy beds at the top of the Lower Cretaceous sediments, and from the Miocene.

The references used to describe the Gippsland Basin are from recent company exploration and other reports as listed hereunder:

BOUTAKOFF, N., 1955 - A new approach to petroleum geology and oil possibilities in Gippsland. Min. geol. J. Dept. Mines Vic., 5(4-5), 39-57.

BOUTAKOFF, N., 1964 - Lakes Entrance Oil and the continental shelf, J. Aust. Petrol. Expl. Ass., 1964, 99-110.

CARTER, A. N., 1964 - Tertiary foraminifera from Gippsland and their stratigraphic significance. Mem. geol. Surv. Vic., 23.

EVANS, P. R., and HODGSON, E. A., 1964 - A palynological report on Arco-Woodside Duck Bay No. 1 Well. Bur. Min. Resour. Aust. Rec. 1964/50 (unpubl.)

HOCKING, J. B., and TAYLOR, D. J., 1964 - The initial marine transgression in the Gippsland Basin, Victoria. J. Aust. Petrol. Expl. Ass., 1964, 125-132.

INGRAM, F. T., 1964 - Duck Bay No. 1 Well Completion Report. For Arco Ltd./ Woodside (Lakes Entrance) Oil Co. N.L. (unpubl.).

REFORD, M. S., 1962 - Airborne magnetometer survey, Bass Strait and Encounter Bay areas Australia, for Haematite Explorations Pty. Ltd. (unpubl.).

STANFORD, E. B., RICHARDS, K. A. and PRESLEY, W. C., 1965 - Gippsland Shelf marine seismic survey final report. For Esso Exploration Aust. Inc. (unpubl.).

TALENT, J. A., 1959 - Contributions to the stratigraphy and palaeontology of the Silurian and Devonian of Gippsland. Ph.D. Thesis, Univ. Melb., Sept., 1959. (see also TALENT, J. A., 1963 - The Devonian of the Mitchell and Wentworth Rivers. Mem. geol. Surv. Vic., 24.)

WEBB, E. A., 1961 - The geology and petroleum potentialities of the Gippsland area of Victoria. Aust. Oil Gas J., 8(2), 14-28.

GREAT ARTESIAN BASIN

The largest sedimentary basin in Australia is the Great Artesian Basin of 680,000 square miles. It has three main subdivisions - the Surat, Eromanga and Carpentaria Basins, and some smaller subdivisions. The boundaries of the subdivisions are largely indefinite, and the division "Great Artesian Basin" cannot yet be abandoned in favour of the smaller units. The subdivisions are as follows:

Carpentaria Basin (93,000 square miles - land area)

The Carpentaria Basin includes most of the Gulf of Carpentaria, and land areas fringing the southern and eastern sides of the Gulf. It extends from northern Queensland towards the island of Papua-New Guinea and West Irian. The western and eastern sides are mainly Precambrian igneous, metamorphic, and sedimentary rocks but some Palaeozoic rocks are also known to occur along the eastern, Cape York Peninsula, side. On the southern side it adjoins the Eromanga Basin across a poorly defined subsurface basement shelf.

Eromanga Basin (470,000 square miles).

The name applies to the whole of the central and south-western parts of the Great Artesian Basin extending from Queensland into the Northern Territory, South Australia and New South Wales. The margins are generally the limits of continuous outcrops of Mesozoic sediments, although some outcrops of Permian sediments which dip into the basin along the north-eastern edge are included. The south-western margin where the Eromanga Basin adjoins the Officer Basin over a shallow basement area is obscured by Quaternary sediments.

Drilling for water and geophysical surveys have shown that much of the Eromanga Basin is underlain by shallow igneous and metamorphic rock basement, particularly in the south-eastern part. However, an area of deeper sedimentation along the central southern edge has been separated from the main basin and called the Lake Frome Embayment.

A prominent, roughly meridional belt known as the Nebine Ridge forms the subsurface margin between the Eromanga and Surat Basins. It is overlapped by thin Mesozoic sediments but a deeper passage between the basins exists towards the northern end of the ridge where a saddle occurs. The igneous and metamorphic complex dividing the Bowen and Drummond Basins is thought to be a continuation of the Nebine Ridge.

Surat Basin (90,000 square miles).

The Surat Basin is an eastern lobe of the Great Artesian Basin, east of the Nebine Ridge, and overlies the southern part of the Bowen Basin. The central part of the eastern margin has been determined by geophysical surveys and recent drilling as a shallow basement arch (see Tallis and Fjelstul, 1965). The southern margin joins the Coonamble Basin along a topographic divide.

Coonamble Basin (20,000 square miles).

The Coonamble Basin is an artesian basin in New South Wales, and forms a smaller subdivision of the Great Artesian Basin. To the north, it joins the Surat Basin. The western and southern margins are the limits of Mesozoic sedimentation, and the eastern side joins the Oxley Basin along a topographic divide.

Oxley Basin (7000 square miles).

The south-eastern tongue of the Great Artesian Basin is a small Mesozoic depression called the Oxley Basin which adjoins the Sydney Basin. The eastern side is an extensive thrust-faulted zone which also limits the north-eastern side of the Sydney Basin, and is probably linked with the faulting along the eastern side of the Bowen Basin.

Lake Frome Embayment

The embayment is probably over a Lower Palaeozoic basin of unknown extent. Aeromagnetic surveys indicate a basement ridge extending north-east from the Flinders Ranges (Milsom, 1965), which possibly forms a northern limit, and Precambrian rocks trending northerly from Broken Hill may mark the eastern edge.

The Great Artesian Basin is a vast depression filled with Permian to Mesozoic sediments. They have been draped over basement "highs", and also cover graben-like structures and depressions within the basement which are filled with older Palaeozoic sediments. Sprigg (1964) referred to the depressions as "sub- (or infra-) basins". The Adavale Basin is of this type; at least five others have been recognized by Sprigg but they are not as well delineated as the Adavale Basin. He also placed the Bowen Basin, where below the Surat Basin, in this category. They are proving to be the most important areas for oil search within the Great Artesian Basin.

The Permian and Triassic section below the Surat Basin is regarded as part of the Bowen Basin; it is overlain with marked unconformity by Lower Jurassic sandstone, and Jurassic - Lower Cretaceous sediments which constitute the Surat Basin section. Thin Permian volcanics, marine sediments and coal measures continue to the south below the Mesozoic rocks of the Coonamble and Oxley Basins. There, the Permian rocks are up to 2300 feet thick (Gerrard, 1963) and are overlain by 350 feet of Triassic clastics and up to 1600 feet of Jurassic to Lower Cretaceous sandstone and shale with some volcanics, red beds, and conglomerate.

Lower Permian sediments below the Eromanga Basin are different to those of the Bowen Basin in that volcanics are not as prominent. They are restricted to a depression between Longreach in central Queensland and the western flank of the Drummond Basin, and to the infra-basins to the south-west. Glacigene sediments and non-marine clastics are most common, but a marine mudstone (300 feet) is known in the south-western corner where Lower Permian sediments are thickest (3000 feet). They are strongly unconformable over older Palaeozoic rocks - mainly Cambrian and Ordovician in the western part, Devonian to the east. However, the Lower Permian sections also show evidence of deformation before the later Permian time when regional warping initiated the Great Artesian Basin. Except for a thin incursion into the south-eastern opening of the depression east of Longreach, no sedimentation is known in the Eromanga Basin contemporaneous with the marine invasion of the Bowen Basin.

Sedimentation probably began in the Eromanga Basin, as such, in the Upper Permian. The sediments - carbonaceous shale, sandstone, conglomerate and coal - were spread north-west from the Bowen Basin into the depression east of Longreach and as blanket deposits over the central and some of the western parts of the Eromanga Basin. Triassic deposition, with red and green mudstones, sandstone and some dolomite beds, followed conformably but was not as widespread. The total Upper Permian-Triassic thickness is up to 2700 feet.

From the beginning of the Jurassic, regional warping which already controlled deposition in the Eromanga Basin, extended over the southern part of the Bowen Basin, forming the Surat, Coonamble and Oxley Basins. The Carpentaria Basin apparently developed also at this time. Although Jurassic and Cretaceous sediments were deposited over most of the Great Artesian Basin, each individual basin had its own separate history of sedimentation. The Coonamble and Oxley Basins have Jurassic sediments but no Cretaceous. In the Surat Basin, the Lower Cretaceous consists of 1250 feet of marine mudstone, above more than 4000 feet of Jurassic sandstone and shale (mainly freshwater). In the Eromanga Basin, the Jurassic varies in thickness and distribution but the basal mudstone section of the Lower Cretaceous is up to 1150 feet thick and overlain by younger Cretaceous mudstone (with a thin but persistent fossiliferous calcareous and radioactive fish-scale zone near its base), and siltstone and sandstone, up to 3000 feet thick; the environment changes from marine to freshwater. In the Carpentaria Basin sedimentation is very similar to that in the Eromanga Basin except that there is no change to freshwater conditions in the Upper Cretaceous sediments, and that thick Tertiary sediments may be developed in the submarine part (3000 feet in Morehead No. 1 Well in south-western Papua.)

The main divisions of the Great Artesian Basin are separated by basement "highs". The Surat and Eromanga Basins are divided by the Nebine Ridge, and the Carpentaria and Eromanga Basins by the Euroka Shelf. The Euroka Shelf has not been specifically defined and the division between the Carpentaria and Eromanga Basins shown on the map is taken from Whitehouse (1954). Geological mapping and reconnaissance gravity surveys since 1960 have shown, however, that an extensive region of shallow basement with some local depressions probably exists south of the Carpentaria Basin, and that this region became an effective barrier to the sea before the Upper Cretaceous. It is an extension of the Precambrian shelf that bounds the southern end of the Georgina Basin, and appears to be terminated on the east by a faulted zone, well-shown on gravity as a belt of negative anomalies with high gradient. Drilling has shown that metamorphic basement occurs below the Mesozoic sediments in parts of this belt; to the north-east, it may be linked structurally with a rift containing thick Devonian - Carboniferous sediments, freshwater and marine, well-folded and intruded by granite and acid volcanics.

The main structure in the Great Artesian Basin has been caused by regional warping and gentle Cainozoic folding in the central regions where sediments are thickest; where sediments are thinner, at the edges or near basement "highs", minor uplifts and faulting have occurred. The axes of folding and faulting commonly follow the trends of structures in the Precambrian or Palaeozoic basement, although in some cases the Cainozoic movements have been in the opposite direction. The structural history may be summarised as follows:

(i) continuous warping, from at least the Jurassic, and uplift in the marginal areas, particularly in the north-east;

(ii) minor folding and faulting of Tertiary age;

(iii) further south-west tilting, which together with the effect of uplift in the Mount Lofty - Flinders Ranges in South Australia during Pliocene orogenies, has caused depression of the Lake Eyre region below sea-level.

A detailed account of the structural evolution of the Great Artesian Basin is given by Sprigg (1961).

The prospects for oil and gas in the Great Artesian Basin seem to depend mainly on sources in the infra-basins. This is so in the Gidgealpa gas field in the Eromanga Basin, and partly so in the Bowen-Surat Basin. Greer (1965) stated that gas in the Gidgealpa field is believed to be indigenous to the Permian sediments; but because the accumulations are near the basal Permian unconformity and because of the variation of the accumulation from well to well, Sprigg (1965) suggests an additional Cambrian or Ordovician source, (Cambrian dolomites in Gidgealpa No. 1 were oil-stained and gave gassy salt water in drill stem tests). Hydrocarbons from the Bowen-Surat Basin are also from an infra-basin, but the marine Lower Jurassic sediments of the Surat Basin are also a probable source of oil and gas.

The types of traps which have been located and which may be expected in the Bowen-Surat Basins have been discussed earlier - mostly combinations of structural and stratigraphic traps. The Gidgealpa entrapment is due to structure, but the drilling was done on buried structure as distinct from the outcropping anticlines drilled earlier; the exposed anticlines contained basement "highs" under thin sedimentary section and were either bald-headed or highly disturbed structurally under the Permian (Sprigg, op. cit.).

Other oil shows and possible oil shale occur in Lower Permian mudstone interbedded with volcanics (1300 feet thick) in Bohena No. 1 in the Coonamble Basin, (Gerrard, op. cit.).

The best source rocks in the Mesozoic sequence of the Great Artesian Basin, (apart from the limited Jurassic marine sediments described in the Bowen-Surat Basin), are the Lower Cretaceous marine mudstones, and many small shows have been reported as a result of the widespread drilling for artesian water. The Jurassic sandstones are excellent reservoirs but these form the main aquifers of the Basin. Any accumulations of hydrocarbons may therefore have been flushed out during tilting, or may have accumulated in traps or under suitable hydrodynamic conditions in regions not yet drilled. Reservoir sands within and above the marine mudstone beds are generally lenticular and mostly filled with salty water.

Besides the work of oil exploration companies, the Great Artesian Basin has been studied for its artesian water (Whitehouse, 1954; Ogilvie, 1954; Ward, 1946). Most of the earlier work is summarized in Glaessner and Parkin (op. cit.), and Hill and Denmead (op. cit.). References used in defining the basin limits for the map are in Reynolds et al., (op. cit.), but some modifications have been made after B. M. R. mapping in the Amadeus and Bowen Basins, and after the Geological Survey of New South Wales - G. S. N. S. W, (1962 - Lake Frome Embayment) and Tallis and Fjelstul (1965 - eastern Surat). Regional mapping has been done in the Queensland part of the Basin by combined B. M. R. - G. S. Q. parties since 1959, and most of the northern part of the Eromanga Basin has been covered. The Mines Departments of South Australia and of New South Wales, and some company personnel have mapped other parts of the Great Artesian Basin. A large area has been covered by geophysical surveys, by companies, the South Australian Mines Department, and the B. M. R.

GERRARD, M. J., 1963 - Bohena No. 1. Well Completion Report, Petroleum Exploration Licence 37, New South Wales. For American Overseas Petroleum Ltd., and Mid-Eastern Oil N.L., (unpubl.).

GREER, W. J., 1965 - Gidgealpa Gas Field, South Australia. Aust. Petrol. Expl. Ass. Ltd. Conference, Adelaide, 1965 (abstract).

G. S. N. S. W., 1962 - Geological map of New South Wales, by the Geological Survey of New South Wales and others. Dep. Mines, Sydney.

MILSOM, J. S., 1965 - Interpretation of the contract aeromagnetic survey, Kopperamanna - Frome area, South Australia, 1963. Bur. Min. Resour. Aust. Rec. 1965/1 (unpubl.).

OGILVIE, C., 1954 - The hydrology of the Queensland portion of the Great Australian Artesian Basin. Appendix H of Artesian Water Supplies in Queensland. Dep. Co-ord. Gen. Public Works Qld., 1955.

SPRIGG, R. C., 1961 - On the structural evolution of the Great Artesian Basin. Aust. Petrol. Expl. Ass. Ltd. Conference Pap., Melbourne, 1961, 37-56.

SPRIGG, R. C., 1964 - Inaugural address 1963: A milestone in Australian oil exploration. J. Aust. Petrol. Expl. Ass., 1964, 6-10.

SPRIGG, R. C., 1965 - Progress of exploration for petroleum in the central and western Great Artesian Basin. 8th Comm. Min. metall. Cong., 30th Sess., Queensland, 1965, (preprint).

TALLIS, N. C. and FJELSTUL, C. R., 1965 - Geophysical report, detail seismograph survey of Tipton area A.T.P. 71 P, Queensland, Australia. For Phillips Petroleum Co., (unpubl.).

WARD, L. K., 1946 - The occurrence, composition, testing and utilization of underground water in South Australia, and the search for further supplies. Bull. geol. Surv. S. Aust., 23, 281.

WHITEHOUSE, F. W., 1954 - The geology of the Queensland portion of the Great Australian Artesian Basin. Appendix G of Artesian Water Supplies in Queensland. Dep. Co-ord. Gen. Public Works Qld., 1955.

IPSWICH - CLARENCE (or CLARENCE - MORETON) BASIN

Although the "Ipswich-Clarence" or "Clarence-Moreton Basin" appears to be a single unit, its sediments have generally been described as occupying separate basins - the Ipswich or Moreton Basin in Queensland, and the Clarence Basin in New South Wales. Reeves (1951) first referred to the "Ipswich-Clarence Basin", but McElroy (1962), who has recently published a comprehensive account of the Basin (with emphasis on the New South Wales part), uses the name "Clarence-Moreton", as has also the Geological Society of Australia, (G.S.A., op. cit.) The boundary of the Basin shown on the map is after McElroy, modified in the northern part after geophysical work by Tallis and Fjelstul (1965). The name Ipswich-Clarence is used on priority.

Highly folded and mildly metamorphosed Palaeozoic strata which have been intruded by granite and ultra-basic to basic rocks occur around the margin of the Basin and form the basement. The rocks include greywacke, slate, phyllite and quartzite, with limestone lenses, and are partly Silurian in age. Marine Carboniferous sediments near the north-western margin in New South Wales (over 1000 feet thick), and just north of the border in Queensland (6500 feet thick) comprise subgreywacke, feldspathic sandstone, dark mudstone, tuffs and minor lava. More than 5000 feet of Permian volcanics, and fossiliferous mudstone, limestone, slate, chert, sandstone and quartzite occur in the same area. The northern and eastern margins of the Basin have been interpreted as mainly controlled by faults, the western margin as depositional on the Palaeozoic structural "high". A subsurface arch apparently separated the Surat Basin to the north-west.

The basal formations of the Ipswich-Clarence Basin are Triassic coal measures - shale, sandstone, coal, and conglomerate - and volcanics. The main sedimentary sequences are about 3500 feet thick in New South Wales and 4300 feet in Queensland; the volcanics are up to 5000 feet thick in New South Wales. Unconformably or disconformably over the Triassic rocks, sequences of non-marine clastic sediments, including coal measures and a thin basalt extrusion, range in age from Upper Triassic to Lower Cretaceous. The basal unit of these sequences may be up to 5000 feet thick in outcrop (McElroy, op. cit.), but the thickness varies considerably and the total sequence is generally not more than 7000 feet - the maximum penetrated in drilling (Relph, 1963). McElroy has postulated that depositional conditions oscillated between paludal and fluvial in a piedmont plain environment, with periods of volcanic activity, and some interruption due to tectonic activity.

Tertiary volcanics, in places over 3000 feet thick, obscure the central-eastern side of the Basin, and also the north-western area where they form part of the Great Dividing Range. Some thin sections of fossiliferous mudstone and sandstone, and lacustrine sediments with oil-shale occur in the Queensland part.

The Ipswich-Clarence Basin has formed in an inter-montaine depression, partly controlled by faults, and has probably altered very little in outline since the Mesozoic. Faulting and folding have occurred during the Mesozoic and Tertiary along axes which are mainly meridional in the south but trending north-west in the north, i.e. following the direction of the central axis of the Basin. Major faulting is normal, and horst structure has been described by McElroy. Minor faulting is common in the Ipswich area, Queensland, in directions varying between north-westerly and east-north-easterly, and transverse east-west faulting is recorded in the south. Some uplifted areas, including local doming, are associated with igneous intrusions.

Shows of hydrocarbons have been known from the Ipswich-Clarence Basin for many years, and some small gas flows have been obtained. These are attributed to the Mesozoic coal measures.

Marine source rocks are unknown in the Mesozoic succession but could possibly be present in earlier sediments preserved in troughs in the basement. However, igneous intrusions and local metamorphism may have adversely affected the prospects in parts of the Basin. The decrease in the rank of the Triassic and Jurassic coals is correlated by McElroy with changes in the degree of tectonism 'rather than with progressive variations associated with depth of burial'. P. R. Evans (in Relph, op. cit.) has also noted the carbonization of spores in Kyogle No. 1 Well, and pointed out the common association of this feature with devolatilization of coal. In another paper, Evans (1963) concluded that a relation existed between spore alteration and carbonization in terms of the carbon ratio in coal in the Bowen Basin, and discussed the possible importance of this relation in terms of oil occurrence.

Sandstone and conglomerates which could form reservoirs occur throughout the Basin, but are generally poorly sorted and kaolinitic with low porosity and permeability.

All of the important references to information on various parts of the Ipswich-Clarence Basin, up to 1959, are given in the bibliography of McElroy (op. cit.) Further references to the Queensland part of the

Basin are made in Hill and Denmead (1960), and subsequent contributions are from company exploration.

EVANS, P. R., 1963 - Spore preservation in the Bowen Basin. Bur. Min. Resour. Aust. Rec. 1963/100 (unpubl.).

HILL, D., and DENMEAD, A. K., (Ed.), 1960 - The geology of Queensland. J. geol. Soc. Aust., 7, 474.

McELROY, C. T., 1962 - The geology of the Clarence-Moreton Basin. Mem. geol. Surv. N.S.W., Geol. 9.

REEVES, F., 1951 - Australian oil possibilities. Bull. Amer. Ass. Petrol. Geol., 35(12), 2479-2525.

RELPH, R. E., 1963 - Kyogle No. 1 Well, New South Wales, Well Completion Report. For Mid-Eastern Oil N.L., (unpubl.).

TALLIS, N. C., and FJELSTUL, C. R., 1965 - Geophysical report, detail seismograph survey of Tipton area, A.T.P. 71P, Queensland, Australia. For Phillips Petroleum Co., (unpubl.).

LAURA BASIN

About half-way along the eastern side of Cape York Peninsula, Queensland, a synclinal depression known as the Laura Basin, has shown minor indications of hydrocarbons. The depression is partly controlled by structure and is set within an older Palaeozoic basin - the Hodgkinson Basin.

The sediments of the Laura Basin are mainly Mesozoic, and rest on Precambrian granite and metamorphics in the west, and slightly metamorphosed Silurian to (?) Lower Carboniferous rocks in the south and east. Stratigraphic information is from surface mapping by the B.M.R., and the drilling of the Cabot-Blueberry Marina No. 1 Well, (M.A.P.L., 1962).

The section is as follows:

Recent to Upper Tertiary	-	Marine and terrigenous sediments (220 feet).
Lower Cretaceous to Jurassic	-	Sandstone and mudstone with coal beds (2400 feet) - marine sediments occur in the Cretaceous and Jurassic.
Permian	-	Steeply dipping (30°) dark mudstone (230 feet) - these beds apparently occur in narrow rift blocks within the Palaeozoic basement.

The Basin is a north-west to south-east depression with thickest deposition in the western central part. Faulting along Palaeozoic trends has occurred on the western side, and uplift with tilting along the eastern side. The western side was an active mobile zone until after the Cretaceous.

The Marina No. 1 Well showed that good reservoir conditions exist in the Laura Basin and rare traces of fluorescence were noted during drilling. Source beds occur in the Lower Cretaceous and Jurassic, and Permian marine rocks may provide sources from within the basement. Better prospects may exist where the Basin passes northwards below Princess Charlotte Bay.

Most of the mapping in the Laura Basin has been done by K. G. Lucas, and a summary of the results will appear in:

DE KEYSER, F., and LUCAS, K. G., - Geology and mineral resources of the Hodgkinson Basin area, North Queensland. Bur. Min. Resour. Aust. Bull. (in prep.).

Other references are:

BURKE, R. R., HARWOOD, C. R., and VIND, E. W., 1963 - Marina Plains reflection seismograph survey. Authority to Prospect 61P (Area B) Queensland, Australia. For Marathon Petrol. Aust. Ltd., (unpubl.).

LUCAS, K. G., 1962 - The geology of the Cooktown 1:250,000 Sheet area. Bur. Min. Resour. Aust. Rec. 1962/149 (unpubl.).

LUCAS, K. G., 1964 - The geology of the Cape Melville 1:250,000 Sheet area. SD 55/9, North Queensland. Bur. Min. Resour. Aust. Rec. 1964/93 (unpubl.).

M. A. P. L., 1962 - Cabot-Blueberry Marina No. 1, Queensland. Well Completion Report, Q/61P/112 (unpubl.).

Some seismic exploration is currently being conducted off-shore in Princess Charlotte Bay.

MARYBOROUGH BASIN

Only minor traces of hydrocarbons are known from the Maryborough Basin along the southern coast of Queensland. A description of the Basin has been given by Dickins (Reynolds et al., op. cit), and his main references were Siller (1961), and Hill and Denmead (op. cit.).

The Basin is small, narrow and elongate, and about 8000 square miles in area; the western side follows a line of granite intrusion and the eastern margin is submarine. Mildly metamorphosed Permian sediments are regarded as basement; they comprise more than 4800 feet of shale, sandstone, conglomerate, limestone, tuff and breccia with marine beds. They are strongly folded, intruded by granite and contain quartz veins, some auriferous.

Sediments which occur in the Maryborough Basin, on-shore, are as follows:

Tertiary - Basalt, sand and clay (400 feet).

Cretaceous - Coal measures (estimated 5000) feet); Dark pyritic shale, sandstone - some glauconitic, and limestone, (mainly marine sediments, up to 6000 feet in Cherwell bore); Intermediate and acidic volcanics and some apparently non-marine clastics (estimated 4500 feet).

Jurassic to Triassic - Shale, sandstone, conglomerate and coal seams (6500 feet).

The Triassic to Jurassic rocks are predominantly or wholly non-marine and are also intruded by granite. The most prospective sediments are Cretaceous, and these were deposited to a maximum of 16,000 feet in a rapidly subsiding trough. Marine Tertiaries more than 1000 feet thick are developed over the Cretaceous off-shore.

The sediments are folded parallel to the main north-westerly trending axis of the Basin. Two groups of faults have been reported - reverse faults parallel to the folding, and normal faults at right angles to the fold axes. Recent geophysical work (Bruce and Thomas, 1964; Bruce, 1964) has shown an eastern hinge line and shallow platform with a basement ridge developed further off-shore and parallel to the main axis of the Basin; because of the probable transgression of Mesozoic sediments over the platform, the basement ridge, rather than the hinge line, is regarded as the north-eastern margin of the Basin. Seismic evidence also suggests that basement reflections are important features in the structures within the Maryborough Basin, and that some of the structures result from draping over older horsts.

Shallow bores (600 feet) in the northern part of the Basin, and at the southern end (up to 835 feet deep) in 1923 and 1924 recorded gas and oil shows from both Cainozoic and Mesozoic sediments (G.S.Q., op. cit.) The origin of these sources is unknown, but some gas would be derived probably from the coaly or carbonaceous deposits penetrated. In the main part of the Basin, Cretaceous sediments could provide possible source rocks, and some of the anticlines could provide good structural traps. Drilling to date has been on structure, however, and unsuccessful. If the anticlinal features which have been drilled are, as geophysical results suggest, drape structures over basement blocks, additional drilling may be warranted on the flanks. The marine Permian where unaltered could offer good prospects if accessible to drilling, but the location of targets would be difficult.

Geological surveys have been undertaken by the Queensland Geological Survey in the Maryborough Basin, and several geophysical surveys (seismic and aeromagnetic) have been made by companies, both on-shore and off-shore. The results of early work are incorporated in Hill and Denmead (op. cit.), and later references as follows:

BRUCE, I. D., 1964 - Final report Bunker Group marine seismic survey Maryborough Basin, Queensland. Authority to Prospect 70P. Shell Development (Aust.) Pty. Ltd. Rep. SDA37 (unpubl.).

BRUCE, I. D., and THOMAS, J. S., 1964 - Final report Pialba-Fraser Island seismic survey, Maryborough Basin, Queensland. Authority to Prospect 70P. Shell Development (Aust.) Pty. Ltd. Rep. SDA24 (unpubl.).

SILLER, C. W., 1961 - The geology and petroleum prospects of the Maryborough Basin, Queensland. <u>Aust. Oil Gas. J.</u> 8(3), 30-36.

TRUMPY, D., and TISSOT, B., 1963 - Recent developments of petroleum prospects in Australia. <u>Inst. Franc. Petrole Rep.</u> Aus. 87 (unpubl.).

MURRAY BASIN

The Murray Basin is a large artesian basin of 100,000 square miles covered by Cainozoic deposits which extend from south-eastern South Australia into south-western New South Wales and north-western Victoria. It is bounded on the south-western side by a granite belt, on the west and north-west by Precambrian and Lower Palaeozoic rocks, and on the east and south by Silurian and Ordovician metamorphics. An east-west belt of Devonian to Lower Carboniferous sediments lies along the northern side; isolated outcrops of marine Cretaceous deposits on the northern and southern sides of this belt suggest a possible connection with the Great Artesian Basin during Mesozoic times. A Tertiary connection with the Otway Basin also exists in the south-western corner.

Permian sediments are known from water bores and wells drilled for oil. Small thicknesses of fluvioglacial sediments have been met in the western part, as in Renmark North No. 1, i.e. 1000 feet of siltstone, shale, and sandstone with a band of tillite. In the east, 3800 feet of Permian coal measures and marine siltstones occur between the Tertiary, and Ordovician phyllite basement in Jerilderie No. 1 Well. Lower Cretaceous marine beds extend from the northern side of the Basin into the north-western part, and are up to 1450 feet thick in North Renmark No. 1; they are mainly sandstone, siltstone, and shale. Tertiary paralic and marine sediments up to 1600 feet thick cover the Basin; the basal sands are overlain by carbonaceous clays and lignites, and followed by fossiliferous limestone.

The sinking of the Murray Basin probably began in the Lower Cretaceous and continued intermittently into the Tertiary; the regional downwarping was accompanied by minor faulting and tilting. The main fault lines and some prominent monoclines follow older Palaeozoic trends varying from north-west to just east of north. Permian sediments which crop out south of the Basin, and probably also those under the Basin, are preserved in graben structures along the main lineaments; (this type of preservation is similar to that observed in other sedimentary basins - the Great Artesian Basin, Laura Basin, and possibly others.)

Two very minor gas shows are known from Lower Permian sediments in the Jerilderie No. 1 Well, and it would seem that the best prospects lie in buried Palaeozoic structures. No surface anticlines, as such, are known.

Most of the published general references to the Murray Basin deal with the south Australian part:

GLAESSNER, M. F., and PARKIN, L. W., (Ed.), 1958 - The geology of South Australia. J. geol. Soc. Aust., 5(2), 163.

LUDBROOK, N. H., 1961 - Stratigraphy of the Murray Basin in South Australia. Bull. geol. Surv. S. Aust., 36.

O'DRISCOLL, E. P. D., 1960 - The hydrology of the Murray Basin Province in South Australia. Ibid., 35.

SEEDSMAN, K. R., 1964 - Geophysical exploration in the South Australian portion of the Murray Basin. J. Aust. Petrol. Expl. Ass., 1964, 90-98.

Another recent report summarizes the results of the first five subsidized wells drilled in the Basin:

B. M. R., (Ed.), 1964 - Summary of data and results. Drilling operations in the Murray Basin New South Wales and South Australia 1961-1962 of Australian Oil and Gas Corporation Limited, Woodside (Lakes Entrance) Oil Company N.L. and Australian Oil Corporation. Bur. Min. Resour. Aust. Petrol. Search Subs. Acts. Publ. 52.

A useful, unpublished reference is by Spence (1958):

SPENCE, J., 1958 - The geology of the Murray Basin. For Frome-Broken Hill Co. Pty. Ltd., Rep. 7500-G-27 (unpubl.).

OFFICER BASIN

Very little is known of the stratigraphy or structure of the Officer Basin, but current extensive geophysical reconnaissance surveys by companies, to be followed by some drilling, are expected to give some indications. The margins shown on the map are also largely speculative. The northern and western margins abut mainly against Archaean outcrops; a north-western lobe has been added on the basis of B.M.R. field mapping and geophysical surveys. The southern edge is the northern margin of the Eucla Basin; the eastern limit is over a shallow, roughly meridional, basement platform determined by geophysical methods; a connection with the Great Artesian Basin is possible over this belt. An area of 133,000 square miles has been calculated for the Basin as shown on the map.

The deepest section determined by geophysical work to date is in the opening into the north-western lobe where up to 15,000 feet of sediments may be present. At least 8000 feet are thought to be Upper Proterozoic and the rest Palaeozoic, with Permian at, or near, the surface. Permian sediments are estimated by Leslie (1961) to be at least 750 feet thick in the diapiric structure at Woolnough Hills in the north-western lobe; they occur around an intrusive core of dolomite and gypsum of probable Upper Proterozoic age. Elsewhere in the lobe, the Permian sediments are flat and crop out in exposures up to 100 feet thick in mesas. They are composed mainly of fluvioglacial sediments. Marine and marginal marine (?Jurassic and Cretaceous) sediments, up to 350 feet thick, also occur in this area in mesas.

The only other evidence of the sediments in the Basin comes from outcrops which dip into the Basin on its northern edge, and the sediments penetrated in Emu No. 1 Well near the eastern margin. The outcrops include Precambrian (Marinoan) to Lower Palaeozoic rocks (sandstone, shale and oolitic limestone) and 5000 feet of well-bedded and cross-bedded sandstone of Ordovician age which rest unconformably on the Proterozoic (Sprigg et. al., in Glaessner and Parkin, op. cit.). The section in Emu No. 1 is 1370 feet of unfossiliferous brown and grey clastics with some carbonate beds; no age was determined, and Grasso (1964) compares the sediments with the Upper Proterozoic and possibly the Ordovician.

The main part of the Basin is thought to be an asymmetric structure, deep along the northern side and becoming shallower to the south, (Quilty and Goodeve, 1958). Subsequent company estimates of over 10,000 feet to basement were made (Shiels, 1961), and Bowman and Harkey (1962) showed increase in section from 5000 to 10,000 feet in a north-westerly direction from the eastern side of the Basin, with possible dip reversal near the eastern end of their traverse.

No occurrences of hydrocarbons are known, and the prospects can only be guessed on available knowledge.

BOWMAN, H. E., and HARKEY, W. J., 1962 - Seismic survey report on the Mabel Creek area, South Australia, Western Australia. For Exoil Pty. Ltd., (unpubl.).

GRASSO, R., 1964 - Exoil Pty. Ltd. Emu No. 1 Well Completion Report. For Exoil Pty. Ltd., (unpubl.).

LESLIE, R. B., 1961 - Geology of the Gibson Desert area, Western Australia. Frome-Broken Hill Company Pty. Ltd., Rep. 3000-G-38 (unpubl.).

QUILTY, J. H., and GOODEVE, P. E., 1958 - Reconnaissance airborne survey of the Eucla Basin, southern Australia. Bur. Min. Resour. Aust. Rec. 1958/87 (unpubl.).

SHIELS, O. J., 1961 - Report on the petroleum prospects of the Officer Basin, South Australia and Western Australia. To Exoil Pty. Ltd., (unpubl.).

ORD BASIN

The Ord Basin occupies an area of 12,000 square miles, south of the Bonaparte Gulf Basin, and on the boundary between Western Australia and the Northern Territory. Lower Cambrian basalts, about 3000 feet thick, were deposited here on a deeply eroded surface of Upper Proterozoic rocks. A disconformable sequence of Middle to probable Upper Cambrian rocks - gypsiferous shale and fossiliferous limestone (2000 feet thick) and sandstone (1500 feet thick) - occur in depressions within the volcanics. The upper sandstone unit may have been continuous with Cambrian sandstones of the Bonaparte Gulf Basin, but the lower rocks are more related to the carbonate province of the Daly River area.

The only important occurrence of hydrocarbons is the report of asphaltite in the volcanics. Its origin is uncertain, but Traves (1955) suggests Upper Proterozoic rocks with more than 2000 feet of sediments, including algal limestone, as a likely source.

A useful summary of this Basin has been given by Jones (in Reynolds, and others, op. cit.). Field mapping in the Western Australian part of the region by the B.M.R. was completed in 1964, (Dow et al., 1964). The report by the field party, and Traves (op. cit.), are the most useful references:

DOW, D. B., GEMUTS, I., PLUMB, K. A. and DUNNET, D., 1964 - The geology of the Ord River region, Western Australia. Bur. Min. Resour. Aust. Rec. 1964/104 (unpubl.).

TRAVES, D. M., 1955 - The geology of the Ord-Victoria region, Northern Australia. Bur. Min. Resour. Aust. Bull. 27.

OTWAY BASIN

Another basin which is partly on-shore, partly off-shore, occurs in western Victoria and south-eastern South Australia. It is the Otway Basin of about 13,000 square miles land area, and probably at least another 10,000 square miles submarine. The northern margin is partly controlled by faulting and partly depositional, and extends westerly to north-westerly from Melbourne to the coast north of Mount Gambier. The off-shore margins are drawn ~~mainly~~ on aeromagnetic survey trends. The landward limits in Victoria are partly obscured by Cainozoic basalt plains.

The rocks north of the Basin are mostly Palaeozoic - basic igneous rocks, mildly metamorphosed sediments, and some unaltered sandstone and conglomerate beds, partly fossiliferous, with intrusions locally of granite and porphyry. Towards the west, the Otway Basin is linked with the Murray Basin for a short distance, but is again separated at the South Australian coast by a wide belt of outcropping granite.

Sedimentation has occurred in the Otway Basin in three main intervals - Lower Cretaceous, Upper Cretaceous, and Tertiary - each separated by a basin-wide unconformity. (Permian spores found in the sediments are thought to be reworked; the Permian, however, is known in outcrop north of the Basin and may be present in places within the Basin.) The sediments, with thicknesses taken from drilling, are as follows:

Quarternary - Fossiliferous limestone, dune sand and calcareous aeolianite, alluvial deposits (up to 300 feet).

Tertiary - Limestone (calcarenite) and marl with sandy basal beds, (up to 2700 feet in eastern part where marly beds are more common);
Glauconitic marls and marine clastics (50 to 450 feet);
Disconformity

Tertiary (C'td.)	-	Argillaceous quartz sandstone with coal lenses in upper part (500 to 2700 feet); Conglomerate and sandstone with chamosite oolites, siderite and sandy limestone, fossiliferous (50 to 400 feet).
		Unconformity
Upper Cretaceous	-	Quartz sandstone with coal measures in part, angular and frosted quartz grains (up to 1500 feet); Quartz sandstone with chlorite pellets, dark grey to grey pyritic siltstone, carbonate cement in sandstone (up to at least 2800 feet); Marine glauconitic dark mudstone (up to 2100 feet); Lithic sandstone with chamosite oolites, shallow marine sediments (300 feet, possibly more in Mount Salt No. 1 Well).
		Unconformity
Lower Cretaceous to Jurassic (?)	-	Orthoquartzite and siltstone with minor coal, partly marine (0-550 feet); Subgreywacke, volcanic sandstone, siltstone, mudstone, and carbonaceous to coaly beds, with various cements - chlorite and diagenetic clays, zeolite, siderite; sediments and cement suggest marine conditions, at least in part (9000 feet maximum); Orthoquartzite sandstone, with minor siltstone, and coal lenses; garnets common (up to ?3300 feet).

Basic intrusions varying in age from Upper Jurassic-Lower Cretaceous to Quaternary have been recorded in drilling, and basalt plains cover 4000 square miles of the surface.

A characteristic feature of sedimentation in the Basin is the cycle of initial marine transgression above the regional unconformities followed by transitional and regressive lithofacies.

Sedimentation began in the Jurassic (?) in a depression that was quite different in its orientation to the older north-west to north-north-east trends of the Palaeozoic rocks to the north. The Otway Basin swings from east-west at the eastern end to west-north-westerly. In cutting across the regional "grain" of the older rocks, it is similar to the Gippsland Basin, it is of about the same age, and may have been connected at this time. (The age of the extensive north-north-east fault between King Island and Melbourne and which controls the eastern end of the Otway Basin is probably younger; the fault has a Palaeozoic trend, but geophysical evidence suggests that it did not influence sedimentation until late in Cretaceous or early Tertiary time). The Otway Basin depression was controlled by faulting, probably a deep rift with marginal displacements up to 5000 feet and possibly more. Faulting was probably normal, but whether it occurred at the intersections of Palaeozoic trends, or was a single fault or series of step faults, or was a transcurrent movement similar to that postulated for the Gippsland Basin, (H.E.P.L. in Reford, 1962), is unknown. Another problem associated with the formation of the Otway Basin is the source of the pyroclastic material in the thick lithic sediments initially deposited; the basic intrusions of Middle Jurassic age (Spry and Banks, op. cit., p.266) in the region to the south-east (Bass Basin and Tasmania) could have contributed, and Upper Jurassic - Lower Cretaceous dolerite intrusions are known from the western Victoria region (Casterton No. 1 Well). Basic intrusions are also suggested just south of Cape Otway from aeromagnetic surveys (H.E.P.L., op. cit.) but their age is not known.

Further faulting took place in the Upper Cretaceous as horst and graben features were formed. However, whereas those in the western part more or less followed the west-north-westerly trend of the Basin's main axis, movements in the eastern part were more complex with major north-easterly and minor meridional trends. The irregular distribution and diachronism (Taylor, 1964) of Upper Cretaceous sediments suggest that the adjustments were taking place during deposition.

The marine transgression in the early Tertiary was part of the widespread marine invasion of parts of coastal and inland southern Australia - Eucla, Saint Vincent, Murray, Otway, Bass (?) and Gippsland Basins. Tertiary deposition was more uniform than in the Upper Cretaceous and although movements occurred during sedimentation, they were strongest in the late Tertiary and Quaternary. Normal faulting was again dominant, but flexuring and warping were associated with the deformations. Sprigg (1962) attributes some faulting and associated minor folding in the west to transcurrent faulting at depth. Some periods of tectonism were accompanied by volcanic activity.

Minor shows of gas and oil have been found at various levels in the Cretaceous succession, with small or decreasing flows of gas in the Port Campbell area; an initial flow of four million cubic feet of petroliferous gas was obtained in Port Campbell No. 1 Well. The occurrences have been mainly from porous sandstone intervals, but small gas flows in Flaxmans No. 1 were associated with fracture porosity.

Possible source rocks and reservoir conditions appear to be best in the late Lower Cretaceous, Upper Cretaceous, and Tertiary sections. Sandstones with coaly beds, similar to the producing intervals of the Gippsland Basin, are present in the Tertiary and late Cretaceous, but the coal measures are not as well-developed. Minor coal horizons occur with porous and permeable orthoquartzites at the top and base of the Jurassic (?) - Lower Cretaceous sequence but in different parts of the Basin - the upper development towards the eastern end, the lower in the west particularly in a graben bordering the northern edge. The thick section of subgreywacke and volcanic clastic sediments in between are apparently not as good prospects because of restricted marine influence (probable paralic environment), and decreased porosity and permeability resulting from the effects of diagenesis. The intense vulcanism in parts of the Basin has not enhanced the prospects.

However, most wells drilled to date have been in a belt more or less parallel to the margin of the Basin, and within a zone where flushing is possible. Also, many have been drilled on structural culminations, whereas stratigraphic or fault traps may be better targets. Possible hydrodynamic conditions, similar to those pointed out by Boutakoff (op. cit.) in the Gippsland Basin, may apply - particularly off-shore. Coastal bitumen occurrences, although widespread and beyond the limits of the Basin, may reflect seeps from submarine parts of the Otway Basin.

As well as the references already given, papers by Sprigg (1952), Boutakoff and Sprigg (1953), and McQueen (1961), and recent contributions by Leslie (1965), and Brown (1965) have been consulted for this report. A bibliography will be included in a current review being undertaken by the B.M.R. - I.F.P. Basins Study Group. Extensive exploration has been undertaken by companies (on-shore drilling, marine and land geophysical surveys) and off-shore drilling is planned. State Geological Surveys are incorporating the results of recent field surveys into a long-term study of the Otway Basin, and the B.M.R. has contributed some geophysical work to this study.

BOUTAKOFF, N., and SPRIGG, R. C., 1953 - Summary report on the petroleum possibilities of the Mount Gambier sunklands. Min. geol. J. Dept. Mines Vic., 5(2), 28-42.

BROWN, G. A., 1965 - New geological concepts Casterton area Otway Basin - Victoria. J. Aust. Petrol. Expl. Ass., Adelaide, 1965.

LESLIE, R. B., 1965 - Petroleum exploration in the Otway Basin. 8th Comm. Min. metall. Congr., 34th Sess., Queensland, 1965 (preprint).

McQUEEN, A. F., 1961 - The geology of the Otway Basin. Aust. Oil Gas. J., 8(2), 8-12.

REFORD, M. S., 1962 - Airborne magnetometer survey, Bass Strait and Encounter Bay areas Australia. For Haematite Explorations Pty. Ltd., (H.E.P.L.), (unpubl.).

REYNOLDS...

SPRIGG, R. C., 1952 - The geology of the South-East Province, South Australia, with special reference to Quaternary coastline migrations and modern beach developments. Geol. Surv. S. Aust. Bull., 24.

SPRIGG, R. C., 1962 - Petroleum prospects of the Gambier Sub-basin in relation to the evolution of the continental terrace. Aust. Inst. Min. Metall., Tech. Papers: Oil in Australasia, Ann. Conference, Queensland, 1962.

TAYLOR, D. J., 1964 - Foraminifera and the stratigraphy of the western Victorian Cretaceous sediments. Proc. Roy. Soc. Vic., 77 (2), 535-602.

PERTH BASIN

Another basin which has produced hydrocarbons ~~in the last three~~ years is the Perth Basin in south-western Western Australia. On-shore, it is a long narrow trough extending some 600 miles along the western coastal edge of the continent, and is up to 50 miles wide - the area is 21,000 square miles. The eastern margin is a prominent fault (the Darling Fault) which bifurcates at the northern end and which separates the Precambrian tableland to the east from the deep basin to the west. At the southern end, the Basin is bounded along the western, coastal side by a narrow Precambrian strip.

An overall thickness of more than 65,000 feet has been determined for the sediments of the Perth Basin. The thickness of sediments in various parts of the Basin is much less than the overall thickness but sections of more than 20,000 feet occur in places from geophysical evidence. Only the upper 25,000 feet are considered as prospective for hydrocarbons.

Eocene	- Shale and siltstone (2000 feet).
Upper Cretaceous	- Greensand and chalk (200 feet); Sandstone (100 feet).
Lower Cretaceous to Jurassic*	- Predominantly non-marine sandstone and mudstone with coal; minor marine limestone, shale and sandstone (possibly more than 14,000 feet in Gingin No. 1).
Triassic	- Dark to grey pyritic shale and siltstone, with sandstone and minor limestone interbeds - marine (4200 feet in Woolmulla No. 1).
Permian	- Tillite, sandstone and shale at base, overlain by marine to continental mudstone with minor limestone, sandstone and coal (an overall thickness of about 6000 feet known in outcrop; more than 4000 feet in Wicherina No. 1 Well).
Silurian to Ordovician	- Red sandstone, with minor siltstone and conglomerate (10,000 feet).

* These beds may extend into the Triassic.

Lower Palaeozoic or Proterozoic - Siltstone with minor sandstone and chert; a few lava flows; sediments mainly from volcanic source (more than 30,000 feet).

(The above table is after Playford and Johnstone, op. cit., modified by Dickins, op. cit., and as a result of more recent drilling by the West Australian Petroleum Pty. Ltd.)

The main structure in the Perth Basin is a long narrow graben or half-graben; easterly dips predominate within the trough, with some west dips along the eastern edge (aeromagnetic and gravity surveys show the deepest part of the Basin to be along the eastern faulted zone). Subsidiary troughs are formed by extensive faulting and the main objectives in these may be very deep. Anticlines appear to be closely associated with faulting, either primarily as drags, or secondarily as drapes.

A well drilled by the B. M. R., (10A, Beagle Ridge) in 1960 to test a pronounced rise in basement (as suggested by aeromagnetic traverses), confirmed the structure, and also found fossils in the Triassic and a show of oil in the Permian. The marine Permian and Triassic siltstones have proved to be probable source rocks. Associated sandstones were found to be tight in the central northern part of the Basin, but subsequent drilling near the north-western margin, and to the south near the eastern margin, have found good reservoir conditions. Prospects near the margins appear to be the best because of the accessibility of Permian and Triassic sediments in suitable structures, and because sorting in sandy intervals is apparently better. Wells in the Yardarino field in the north-western part have yielded gas (97% methane) and condensate (44° A.P.I.) at a maximum rate of 15 million cubic feet per day, and oil (35°-36° A.P.I.) through a $\frac{5}{8}$-inch choke at up to 2000 barrels per day with varying amounts of gas and water (Playford, 1965, op. cit.) However, the oil flow declined with prolonged testing, and other drilling has shown that the field may be small. Production is from Upper Permian sandstone, although oil and gas shows were found in the Lower Triassic. Twenty miles south of Yardarino, Arrowsmith No. 1 has also produced gas (4 million cubic feet per day through a $\frac{1}{8}$-inch choke) from the Permian. Gingin No. 1 has recently obtained gas in five main zones (which gave drill stem tests of between 2 and 4 million cubic feet per day) from Triassic (?) - Lower Jurassic sandstone between depths of 12,000 and 14,000 feet in the central, eastern side of the Basin.

This description follows that of Dickins (op. cit.) with amendments from more recent exploration. Early subsidized operations - geophysical and particularly drilling - have been concentrated in the northern half of the Basin. Gravity surveys have been done over the whole Basin and some anomalies have been outlined in more detail by seismic work, first in the north leading to the Yardarino, Arrowsmith and Gingin discoveries and more recently in the south; many of the southern gravity features are not closed structures, but the section should be as promising as that encountered to the north.

PIRIE - TORRENS BASIN

The Pirie-Torrens Basin (of South Australia) is an elongated, meridional, structural basin of 9000 square miles between Port Pirie in the south and Lake Torrens in the north where it links with the Great Artesian Basin. The western margin is drawn from a pronounced fault line shown by B.M.R. aeromagnetic work in 1962. The eastern side follows the lower limits of Lower Cambrian sediments along the western scarp of the Flinders Ranges and their branch to the north-west. This side is also regarded as structurally controlled (Campana, in Glaessner and Parkin, op. cit.). The southern end opens into Spencer Gulf.

The oldest rocks known from the Basin are Cambrian dolomite and limestone up to 5000 feet thick, and these are overlain by at least 530 feet of Tertiary sediments which appear to be largely continental. Both the Cambrian and Tertiary beds contain oil shows.

The Pirie-Torrens Basin is a graben structure bounded by faults on the east and on the west. The eastern movements occurred during the overthrusting of the western Flinders Ranges rocks in Tertiary time. The fault on the west is shown as a magnetic anomaly with a steep gradient. The graben has preserved Cambrian sediments at depth, and has been filled with Tertiary and Quaternary deposits.

The presence of source rocks has been shown by drilling, and porous zones including reef facies occur in the Cambrian dolomite and limestone; no reservoirs of economic importance have been found, however, and exploration has lapsed.

Drilling was done by Santos Ltd., and the region has been covered by aeromagnetic, gravity and seismic surveys (Santos Ltd., South Australian Mines Department, and B.M.R.). Reference has been made to Playford and Johnstone (op. cit.), and a recent report by Dalgarno (1964) gives more details on the Cambrian stratigraphy of the region:

DALGARNO, C. R., 1964 - Report on the Lower Cambrian stratigraphy of the Flinders Ranges, South Australia. Trans. Roy. Soc. S. Aust., 88, 129-144.

SAINT VINCENT BASIN

The Basin as defined by Glaessner and Wade (in Glaessner and Parkin, op. cit.) is a Cainozoic basin, and the only evidence of hydrocarbons is an insignificant show of gas from the basal Tertiary in Grange No. 1 Well drilled in 1962. Extensive geophysical surveys have been conducted since then, and the Basin has been covered by aeromagnetic and gravity runs; seismic work is also being undertaken in selected areas. Exploration is now being directed to finding submarine targets in the Permian and Cambrian rocks which occur around and under parts of the Basin, and gave small oil and gas shows on Yorke Peninsula.

Cambrian rocks crop out along the north-western edge of Fleurieu Peninsula (south of Adelaide), the northern edge of Kangaroo Island, and on Yorke Peninsula; they comprise sandstone, dark grey limestone (locally very fossiliferous), dolomite, shale, some red beds and evaporites, limestone conglomerate, and 2500 feet of unfossiliferous cross-bedded sandstone and conglomerate. The overall thickness is not known, but is at least 5000 feet (see Daily, 1956, 1963; Sprigg, 1961). Permian sediments (up to 750 feet in a bore on Troubridge Island) are mainly glacial tills and aqueoglacial sediments, with some marine sandy mudstones.

Cainozoic sediments of the Saint Vincent Basin are mainly paralic with alternating marine and non-marine deposits up to 2000 feet thick (Croydon Bore). They occur below Adelaide, and crop out in fault blocks to the south.

On land, the eastern edge is marked by en echelon faults with differential uplift and tilting of the blocks. The faulting follows the axial trends of early Palaeozoic folding. The Gulf of Saint Vincent is regarded as a graben or half-graben structure with the deepest part along the eastern side. Submarine gravity surveys which were completed in early 1965 (Stackler and Sprigg, 1965) demonstrated the extension of a gravity low from beneath Adelaide, along the eastern side of the Gulf, towards Kangaroo Island. A submarine shelf area below the western side of the Gulf corresponds to a series of positive Bouguer gravity anomalies with a longitudinal trend. The aeromagnetic surveys show a similar structural pattern, with depths of 3000 to 6000 feet below the shelf to magnetic basement, and up to 10,000 feet along the eastern depression (Hartman, 1965).

The Tertiary section (2000 feet) is not thought to increase markedly in the submarine part of the Basin, but the sediments are apparently widespread. Below them are Permian sediments in the southern half of the shelf area, Cambrian in the shelf area and southern part of the Basin, and probably thick Upper Proterozoic sediments of the Adelaidean System.

The prospects of this Basin seem to depend mainly on finding a suitable source and reservoir combination below the Tertiary sediments.

DAILY, B., 1956 - The Cambrian in South Australia. El Sistema Cambrico, su paleogeografia y el problema de su base. Int. geol. Cong., 20th Sess., Mexico, Pt 2, 91-147.
Reproduced also in Opik, A.A., and others, 1957 - The Cambrian Geology of Australia. Bur. Min. Resour. Aust. Bull. 49.

DAILY, B., 1963 - The fossiliferous Cambrian succession on Fleurieu Peninsula, South Australia. Rec. S. Aust. Mus., 14(3), 579-601.

HARTMAN, R. R., 1965 - Interpretation report of airborne magnetometer survey over St. Vincent's Gulf and Investigator Strait South Australia. For Beach Petroleum N.L., (unpubl.).

SPRIGG, R. C., 1961 - The oil and gas prospects of the St. Vincents Gulf Graben. Aust. Petrol. Expl. Ass. Ltd. Conference Pap., Melbourne, 1961, 71-88.
(This paper contains an extensive bibliography of work done in the region.).

STACKLER, W. F., and SPRIGG, R. C., 1965 - St. Vincent Gulf Gravity Survey O.E.L. 24 South Australia. For Beach Petroleum N.L., (unpubl.).
(A similar paper was presented for the J. Aust. Petrol. Expl. Ass., Adelaide, 1965, - in prep.).

SYDNEY BASIN

The stratigraphy of the Sydney Basin is similar to that of the Bowen Basin, and Dickins (in Reynolds, and others, op. cit., and 1964) has referred to possible connections between the Basins in both Lower and Upper Permian times.

The Sydney Basin extends north-westwards and inland from Sydney, and is faulted against Carboniferous volcanics and sediments along the north-eastern side, and has a depositional boundary over earlier Palaeozoic rocks to the west. The north-western edge adjoins the Oxley Basin, a subdivision of the Great Artesian Basin, overlying the southern extension of the Bowen Basin. To the south-east, the Sydney Basin is submarine, and this part might be almost as large as the on-shore area of 12,000 square miles.

The sediments include almost 4000 feet of Triassic, mostly non-marine clastics, and an overall thickness of 16,000 feet of Permian deposits which show two main cycles of marine transgression and regression. The greatest thickness is in the northern part.

Triassic - Carbonaceous shale and calcareous flaggy sandstone (800 feet);
Massive cross-bedded white orthoquartzite and minor shale (800 feet);
Lithic to argillaceous sandstone; red, chocolate and green shale; some conglomerate (up to 2300 feet).

Disconformity

Permian - Sandstone, shale, conglomerate and coal measures (possibly more than 3500 feet);
Upper marine mudstone, sandy mudstone, sandstone, with calcareous beds, and a thick conglomeratic section in the middle (6000 feet);
Conglomerate, sandstone, shale and coal (300 feet);
Lower marine beds: mainly mudstone and shale with sandstone, limestone, and some basalt flows in the trough north-west from Newcastle - elsewhere mostly volcanics (6000 feet).

The extensive volcanic deposits which wholly replace the lower marine sequence in the southern part of the Sydney Basin, and elsewhere replace and interdigitate with the lowest beds are thought to be Lower Permian; it has been suggested (Perry and Stuntz, 1963), however, that these deposits closely followed the Upper Carboniferous deposits which crop out to the north of the Basin, and may pre-date the actual formation of the Sydney Basin.

The lowest Permian cycle of marine transgression and regression appears to be confined to the northern part; the sediments of the upper cycle occur over the whole of the Basin although the coal measures are thickest in the Newcastle area. The lowest Triassic sediments are also widespread, but the upper, more eroded section is confined to the central part west of Sydney. Facies changes in the Permian sediments are common throughout the Basin, and also in the Triassic (Loughnan et al., 1964).

Tertiary volcanics intrude the north-western and southern parts of the Basin.

The overall structure appears to be a half-graben with the deepest depression against the mobile fault zone along the north-eastern side, and with a shelf and hingeline developed along the western side. Anticlines and domes occur mainly along the northern edge of the Basin although one of these, the Lochinvar Dome, may extend as a folded structure, parallel to the coast, to the west of Sydney. These structures are only partly known; some, at least, are partly uplifted blocks with sediments draped over them and are partly folded. They are generally elongated in a north-south direction and affect both Permian and Triassic sediments. Perry and Stuntz (op. cit.) refer to strike faults parallel to the structures, and also to transverse faults which usually parallel the north-eastern marginal fault zone; the latter faults, together with the doming effects and the general twisting of structural axes at their northern ends are attributed to south-west thrusting against the north-eastern margin.

The hingeline along the western part of the Basin is partly a fault and partly a monocline; it may also be important in providing traps where changes in sedimentation take place.

Occurrences of hydrocarbons have been mainly methane shows and some small flows, associated with Permian coal measures and in the Lower Triassic; but some oil shows have been found in marine sediments, and favourable source beds appear to be present in the Permian. The sandstones, however, are mostly poorly sorted, argillaceous, tuffaceous or cemented and are not good reservoirs in most cases. Elsewhere the sands have been water saturated.

Exploration in this Basin has been inadequate in some ways to assess properly its prospects (Trumpy and Tissot, op. cit.); not enough wells have reached basement, many wells have been drilled with percussion rigs so that no electric logs and insufficient core material have been available from them, and seismic surveys have been difficult because of the rugged topography of the Triassic sandstones. Also, many of the wells drilled have been on inferred folds, whereas stratigraphic tests of the flanks may have given better prospects. However, the main problem is to find permeable reservoirs.

In addition to the references given by Dickins (op. cit.) much useful information on the Sydney Basin is currently being provided by the exploration companies, the New South Wales Mines Department, and the universities; experimental seismic work is being conducted on behalf of and by the B. M. R. Additional recent references used in the above report are:

DICKINS, J. M., 1964 - Correlation of the Permian of the Hunter Valley, New South Wales and the Bowen Basin, Queensland, with an Appendix on the foraminifera from the Hunter Valley by A. R. Lloyd. Bur. Min. Resour. Aust. Rec. 1964/96 (unpubl.)

LOUGHNAN, F. C., KOKO, M., and BAYLISS, P., 1964 - The red-beds of the Triassic Narrabeen Group. J. geol. Soc. Aust., 11 (1), 65-78.

PERRY, R. G., and STUNTZ, J., 1963 - A.O.G. Loder No. 1 Well Completion Report, Sydney Basin, New South Wales. For Australian Oil and Gas Corp. Ltd., (unpubl.).

A paper presented by J. Stuntz - "Exploration in the Sydney Basin, N.S.W." at the Australian Petroleum Exploration Association meetings in Adelaide, 1965, is not yet available for reference.

TASMANIA BASIN

No hydrocarbon occurrences are known from the Tasmania Basin. Several thousand feet of marine and continental sediments of Permian and Triassic age occur in the Basin, but these have been extensively intruded by dolerite dikes and sills. Twenty four shallow bores (up to 1165 feet) have been drilled in the northern part, and a hole to 430 feet on Bruny Island south of Hobart.

Until more is known of the succession at depth within the Tasmania Basin, and of the possible existence of structures which are not influenced by the dolerite intrusions, the prospects of finding oil or gas accumulations can only be regarded as poor. Current exploration in the submarine Bass Basin to the north may give encouragement in off-shore areas.

The most recent reference to the geology of Tasmania is Spry and Banks (1962), and useful papers have been given on the Permian and Mesozoic rocks by Banks (1952, 1958.)

BANKS, M. R., 1952 - Permian, Triassic and Jurassic rocks in Tasmania. Symposium sur les series de Gondwana. Int. geol. Cong., 19th Sess., Algiers, 63-90.

BANKS, M. R., 1958 - Recent additions to the knowledge of the Permian System in Tasmania. Sobretiro de la Comision de Gondwana. Int. geol. Cong., 20th Sess., Mexico, 151-177.

SPRY, A., and BANKS, M. R., (Ed.) 1962 - The geology of Tasmania. J. geol. Soc. Aust., 9, (2).

YARROL BASIN

The Yarrol Basin is long and narrow, and extends from slightly north of Rockhampton in the central coastal part of Queensland to the south-south-east for some 220 miles, to where it disappears beneath sediments of the Surat Basin. The eastern side is separated by the Yarrol Thrust from a belt of strongly folded and slightly metamorphosed rocks; on the south-western side is an igneous rock complex. To the north of the complex the boundary is taken as the westernmost occurrence of the Carboniferous rocks of Yarrol Basin facies. The overlying Permian rocks in the narrow areas to the north of the Basin, extending past Mackay, are more or less conformable with the Carboniferous sequence, and possibly the Yarrol Basin should be extended to include these Permian rocks. The area of the Yarrol Basin as shown on the map is 7000 square miles.

The lithologic succession, mainly after Maxwell (in Hill and Denmead, op. cit., and 1964) and with addition from drilling (Hoyling and Stewart, 1964), is summarized below:

Tertiary - Terrestrial sediments and volcanics, scattered outcrops.

Jurassic - Sandstone, siltstone, shale and coal (up to 1200 feet);
Shale, some sandstone, minor coal (700 feet);
Sandstone, porous, minor shale and siltstone (400 feet).

?Unconformity

Triassic - Conglomerate, greywacke, shale and siltstone, volcanics - terrestrial (5000 feet, Abercorn No. 1).

Unconformity

Lower Permian- Fossiliferous subgreywacke, sandy shale, conglomerate, shelly limestone, basalt, andesite, agglomerate, tuff (7000 feet sediments, at least 2000 feet volcanics);

Unconformity in parts

Carboniferous - Siltstone, shale, chert, greywacke and subgreywacke, conglomerate, calcarenite and oolitic limestone - marine; much volcanic detritus; (more than 12,000 feet).

Devonian - Volcanics, limestone, sandstone (4600 feet).

The Yarrol Basin apparently formed in the Middle Devonian, and from Upper Devonian until Lower Permian time sedimentation was almost continuously marine. The lithological succession varies throughout the Basin both in facies and thickness, and 'has been influenced strongly by contemporaneous vulcanicity of varying intensity, as well as by the prolific source of detritus from nearby volcanic terrains'. (Maxwell, 1964).

Maxwell (op. cit.) points out that throughout the main period of sedimentation, the Yarrol Basin appears to have been deepest along the eastern side; deeper water conditions existed from Upper Devonian to Middle Carboniferous, with shallower conditions as the sea regressed during Upper Carboniferous to Lower Permian time; along the western side, conditions changed from shallow marine shelf to terrestrial over the same interval. He also refers to the effects of eustatic fluctuation and climatic variation, associated with glacial advances and retreats.

After the Lower Permian and pre-Triassic, the Basin was compressed from the east and raised above sea-level. Many north-south trending anticlines were formed and also the Yarrol Syncline. The Basin was affected by thrust faulting which may have overturned its beds, and by transcurrent faulting, accompanied by extrusion of basic to intermediate volcanics, with serpentinite intruded along the 'Yarrol Thrust' zone. Normal faulting followed the relaxation of the compression, and granite and diorite were intruded into parts of the Basin.

Fairly stable continental conditions prevailed after the Permian, and thick Mesozoic sediments have been deposited along the south-western side.

Possible source rocks are to be found in the Palaeozoic and minor gas (probably associated with coaly intervals) and a weak fluorescence in carbonaceous shale were reported from ?Permian and Triassic strata in Abercorn No. 1 Well. An abnormally high pressure zone, probably a fault plane, containing brackish to salty water with a high content of carbon dioxide was penetrated in the ?Permian. Good reservoir properties occur in the basal Jurassic sandstone (the same as that which produces in the Surat Basin), and may occur in the Palaeozoic strata not yet drilled. The intense tectonic and igneous activity accompanying and after deposition of these beds, however, has not enhanced the prospects of finding oil and gas, and has made exploration for targets difficult.

Amalgamated Petroleum Exploration Pty. Ltd. have done most of the recent exploration in the Yarrol Basin. Their geophysical work includes both aeromagnetic and seismic surveys, and two deep wells, Abercorn No. 1 and Mulgildie No. 1, have been drilled in the south-western part (under Subsidy). Some aeromagnetic lines have also been flown across the area by the B. M. R.

The original summary given by Dickins (op. cit.) has been amended using the later reports by:

HOYLING, N. H. V., and STEWART, H. W. J., 1964 - A. P. Abercorn No. 1, Queensland, Well Completion Report. For Amalgamated Petroleum Exploration Pty. Ltd., (unpubl.).

MAXWELL, W. G. H., 1964 - The geology of the Yarrol Region, Part 1. Biostratigraphy. Pap. Univ. Qld Dep. Geol., 5 (9).

OTHER BASINS AND PROVINCES

Australia has other basins and provinces with sedimentary section, but because of such factors as the small thickness of possible source beds, lack of reservoir potential, or intense folding and igneous intrusion, they are not considered as prospective as the basins already described.

1. Ngalia Basin is an elongated ?trough north of the Amadeus Basin, with much of the geology and structure obscured by recent sand. Cook (1963) describes 3700 feet of Upper Proterozoic clastics and carbonate rocks, 350 feet of lower Palaeozoic sandstone and greywacke, and 7000 feet of upper Palaeozoic conglomeratic sandstone, which dip southwards into the northern central part of the Basin.
2. Bundock, Clarke River and Star Basins, (White, 1961) - these are Upper Devonian - Carboniferous basins in Queensland, of the same age as the Hodgkinson Basin which envelops the Laura Basin to the north. The sediments are mainly terrestrial and have been folded and intruded by granite and acid volcanics; but they are underlain by thick marine Devonian rocks, including reefs, possibly in a rift structure, (referred to earlier under the Great Artesian Basin.)
3. Some 20,000 feet of Devonian sediments, partly marine, are also known from west of Cobar in New South Wales, between the Great Artesian and Murray Basins, (Spence, op. cit. - Murray Basin). Other marine Devonian sediments are known from east of the Murray Basin, between the Murray Basin and the Gippsland Basin, along the northern side of the Gippsland Basin, and along the northern side of the Otway Basin.

4. Unnamed upper Palaeozoic areas of deposition have already been referred to north of the Yarrol Basin; two main areas are known, and the marine Permian rocks, up to 5000 feet thick in the southern part of the westernmost area, are continuous across a divide with Bowen Basin sediments, (Hill and Denmead, op. cit., p.221). Both areas have been intensely folded and intruded by granite and acid volcanics. The Styx Basin contains 1270 feet of Lower Cretaceous coal measures in a narrow meridional structural belt between the two areas of upper Palaeozoic sediments.

5. The Esk Rift is another narrow trough, originating in the Permian, with Mesozoic terrestrial and volcanic rocks of unknown thickness, (but possibly several thousand feet); it passes beneath sediments of the Ipswich-Clarence Basin, and is enclosed between Permian rocks, including marine sediments.

6. The Lorne Basin, (Voisey, 1939, 1959) is a small basin on the New South Wales coast. It contains a few hundred feet of Triassic sediments, mainly arenites, shale with plant remains, and an overlying massive conglomerate. The basal Triassic conglomerate possibly overlies Permian marine mudstone and limestone, similar to those which crop out just north of the Basin, and it is elsewhere unconformable on older Palaeozoic rocks. Faulting and intrusion of alkaline igneous rocks followed sedimentation.

7. A basin of Cretaceous sediments is known to extend off-shore near Darwin and includes both Melville and Bathurst Islands. It may contain at least 3000 feet of Cretaceous marine sediments and has a thin cover of Tertiary rocks, (see Fife and Tinline, 1962).

Precambrian provinces.

Extensive areas of Upper Proterozoic rocks are known from various parts of Australia e.g. the Mount Lofty and Flinders Ranges, Central Australia, the Kimberley Block, and elsewhere in the Northern Territory; and have been of interest as "sedimentary basins" because of the following occurrences, or reported occurrences, of hydrocarbons:

Methane gas from marine shale and limestone in the Upper Proterozoic of the Amadeus Basin;
Asphaltite in Lower Cambrian volcanics from a possible Upper Proterozoic source in the Ord Basin;
Laing and Allen (1956) also give details of a report by W. A. Campbell about oil seeps found in 1904 in the Victoria River region from sandstone which is now regarded as Upper Proterozoic; this is east of the Bonaparte Gulf Basin;
Residual oil in shale, and impsonite (a solid hydrocarbon) in a clastic - carbonate sequence of Upper Proterozoic age in the South Nicholson Basin, a small Precambrian basin of 6000 square miles which protrudes into the central part of the north-eastern margin of the Georgina Basin, (Roberts, et al., 1963).

Off-shore areas.

Off-shore areas are currently being explored, and gas has been found in the off-shore Gippsland Basin. Recent geophysical surveys have shown that other areas of thick sedimentation occur around Australia, and may also be important in the search for oil. Reford (op. cit., Gippsland Basin) has pointed to the existence of the Bass Basin between the Otway and Gippsland Basins and Tasmania, and to the possibility of 12,000 feet of section; this area is being tested by drilling (see also Hopkins, 1965).

Over 1700 feet of Cainozoic sediments were found in the Wreck Island bore at the south end of the Great Barrier Reef, off north-eastern Australia, and thicker section may occur elsewhere in this region. However, because of shallow volcanics in many parts, geophysical interpretation and the selection of drilling targets may prove difficult.

The north-western and northern off-shore areas have been referred to by Fairbridge (1953); he shows a depression on the Sahul Shelf opposite the Bonaparte Gulf Basin and forming an extension of it. The Rowley Depression is also shown opposite the Canning Basin, and the Arafura Depression north of what has recently been called the Arafura Basin (Rix, 1963), and Fairbridge considers that the structural histories of these shelf depressions are analogous to those of the basins opposite on the mainland. This opinion requires confirmation as the stratigraphy of the off-shore area may differ considerably from the on-shore area. The whole of this off-shore region, from opposite the Carnarvon Basin in the west, to the Arafura Sea in the north, is being explored by various geophysical surveys (mainly company and some B.M.R.), and Boutakoff (1963) has recently reviewed the geology.

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OIL SHALES

Oil shales may be regarded as sources of hydrocarbons although from sources different to those already described. The main reference used is David (op. cit.).

The main areas of oil shale in Australia are in the Sydney Basin and are associated with the Permian coal measures. The best deposits contain torbanite and may yield up to 150 gallons of oil per ton on distillation; these have been worked commercially in the past, but the most economical prospects have now been depleted.

Tasmania also has Permian oil shales ('tasmanite') in the northern part, west of Launceston, but these were formed mainly in marine or paralic environments.

Queensland occurrences vary in age from

Permian - associated with coal measures in the Bowen Basin;

and Jurassic - also with coal measures in the Surat Basin, and north-west of Toowoomba in the Ipswich - Clarence Basin;

to Tertiary - small areas along old river valleys or in lacustrine environments.

The Tertiary deposits occur west of Rockhampton near the eastern edge of the Bowen Basin, south-east of Rockhampton between the mainland and Curtis Island, two small areas north of the Maryborough Basin, and near Ipswich in the Ipswich - Clarence Basin.

GENERAL DISCUSSION

The sedimentary basins of Australia may be grouped geographically. These groups have similarities of deposition and structure.

1. Basins along the western side of Australia - the Bonaparte Gulf, Canning (South Canning and Fitzroy), Carnarvon, and Perth Basins.

Sedimentation occurred throughout the Palaeozoic, with some major time breaks, in all of these basins, and thick Mesozoic sedimentation occurred in the Carnarvon and Perth Basins. The sediments are mostly shallow marine clastics, with some carbonate and evaporite rocks (including reef complexes), and the basins could possibly be regarded as epicontinental (or even intracratonic, Schneeberger, 1964); however, deep water sediments were deposited at times. Freshwater sediments with coal measures in the Permian, (and, in the Perth Basin, also in the Jurassic) are subordinate; glacial sediments occur in the Upper Carboniferous to Lower Permian. Volcanic detritus is absent or insignificant.

The margins of the basins and of subdivisions in the basins are mostly controlled by faults. Normal faulting, forming major grabens or half-grabens, is most common, but thrusting and shearing have been recognized in places. Movements apparently took place throughout the Palaeozoic with the main orogenies possibly in the Carboniferous. Some anticlines are considered to be drape or drag structures over basement ridges or horsts, or are otherwise associated with the faulting. In contrast, compressional folding was most common after the Palaeozoic. Structures formed by sedimentation around reefs, and salt diapirs are also known.

The entrapment of oil and gas is anticlinal in Lower Carboniferous, Permian, Jurassic and Cretaceous sediments. Good indications of oil and gas were obtained from the Triassic, and minor shows were found in the Ordovician and Devonian.

All basins extend off-shore, and although lithologies may change laterally, the general successions are probably mostly marine and the structures similar to those on-shore.

2. <u>The intracratonic basins of central Australia</u> - the Amadeus, Georgina, Daly and Wiso, Ord, Gnalia, Pirie-Torrens Basins, and possibly the Officer Basin which is largely unknown. Infra-basins with older Palaeozoic sediments, such as the Lake Frome Embayment, below the western part of the Eromanga Basin may also fall within this category.

Sedimentation is mostly lower Palaeozoic to Precambrian. The Precambrian to Lower Cambrian section consists of clastics, carbonates, evaporites, and basic volcanics, with minor glacial sediments, and hydrocarbons have been found in these rocks. However, the Cambro-Ordovician, which is mostly marine, is considered to have the best hydrocarbon potential. The Cambrian succession is different in the Georgina Basin and other basins to the north, where carbonates predominate, from that in the Amadeus Basin where facies changes occur from mainly carbonates in the north-east to sandy beds in the west, with much interfingering of clastics and carbonate rocks between. The marine clastics and subordinate carbonate rocks of the Ordovician are not so widespread as the Cambrian, and are known mainly from the northern part of the Amadeus Basin and south-western side of the Georgina Basin. A change to continental sandstone occurs in the Upper Ordovician. Thick Devonian clastics, mainly non-marine, occur in places, and Lower Permian marine and freshwater clastics up to 3000 feet thick are preserved in depressions in older Palaeozoic rocks below the Eromanga Basin, but within this general region.

Important folding and faulting are only known in the Amadeus and southern part of the Georgina Basins. The effects of thrusting are prominent in some exposed structures, and major deformation is believed to have occurred twice - in late Upper Proterozoic or early Cambrian time, and in Upper Devonian or Lower Carboniferous time. Nappe structures have been recognized in the Amadeus Basin; evaporite beds were squeezed into many of the anticlines during the Devonian orogeny, but some salt diapirs may have resulted from density differences in the sediments.

Significant discoveries of wet gas with condensate have been made in the interbedded Ordovician sandstones and mudstones of the Amadeus Basin; oil shows and residues, and some gas have also been found in Precambrian to Ordovician rocks of the region, (Amadeus, Georgina, and Pirie-Torrens Basins, and from the area around the Ord Basin). The gas flows in the western part of the Eromanga Basin are from Lower Permian sediments in a possible infra-basin, and although the Permian is regarded as the main source of the hydrocarbons, Cambrian carbonate rocks may also have contributed.

3. Basins along the eastern side of Australia - twelve basins have been described from this region, but only five have given good indications of hydrocarbons - the Bowen Basin from which production is obtained, a significant dry gas flow from the Adavale Basin, and dry gas and oil shows from the Sydney, Ipswich-Clarence, and Drummond Basins.

The geological history of all these basins appears to be associated with the development of the Tasman Geosyncline which includes various types of geosyncline developed during the Palaeozoic. Some of the basins are exposed, but others occur below the Great Artesian Basin, or are partly overlapped by its sediments.

The rocks are Devonian to Triassic but only the Yarrol Basin has rocks representative of all these Periods. Clastics predominate, but volcanics are common. Marine rocks occur mostly in the Palaeozoic interbedded with thick freshwater sequences; subordinate carbonate rocks and calcareous beds are both marine and freshwater, and evaporite beds are recorded from marine Devonian. Coal measures are present throughout the Permian and Triassic.

Diastrophism was intense at times in many parts of eastern Australia from Devonian to Triassic, and igneous activity was common, even into the Cainozoic. Devonian and Carboniferous rocks have been locally metamorphosed. Thrusting from the east in the late Carboniferous formed the Bowen and Sydney Basins; further important uplifts occurred late in the Permian and the Ipswich-Clarence and Maryborough Basins were formed. Consequently many of the basins are faulted and deepest along their eastern or north-eastern margins; their western margins are depositional. In spite of the intense folding and faulting, more gentle buckling formed many structures attractive for hydrocarbon exploration.

The Permian and Triassic beds of the Bowen Basin have produced oil and gas; the Permian may have also provided oil and gas in the Jurassic sandstones of the Surat Basin. Gas from the Adavale Basin is from the Devonian. Minor oil shows were found in the Carboniferous? of the Drummond Basin, and in the Permian below the Coonamble Basin; Permian and Triassic sediments have given dry gas shows in the Sydney and Ipswich-Clarence Basins. Reservoirs are sandstones, and in the Bowen Basin at least, are generally in combined structural and stratigraphic traps.

4. Broad downwarps over the eastern half of Australia - the Great Artesian and Murray Basins. The small Laura Basin on the coast of northern Queensland was linked with the Great Artesian Basin in the Upper Jurassic - Lower Cretaceous.

The Great Artesian Basin sediments are freshwater and marine clastics, ranging from Permian and Triassic in the Eromanga Basin, and from the Jurassic elsewhere, into the Cretaceous. Thin Lower Cretaceous marine beds are overlain by Tertiary paralic and marine deposits in the Murray Basin. Clean permeable sandstones in the Jurassic form excellent reservoirs in places and supply the oil of the Moonie field and oil and gas in other parts of the Surat Basin. (The source of these hydrocarbons, as mentioned above, could be from the Permian). But over most of the

Great Artesian Basin, the Jurassic sandstones are water-filled or too argillaceous to form reservoirs, and the best chance of oil occurrence is in the basins covered by the Great Artesian sediments.

Some gentle folding and minor faulting have occurred in the Great Artesian Basin but some of the structures in depth lack section over basement "highs".

5. Basins along southern Australia - the Gippsland, Bass, Otway, Saint Vincent, and Eucla Basins. They are Mesozoic and Tertiary in age, but only the Otway, Gippsland, and probably the Bass Basin contain thick sediments of these ages. The Bass Basin is on the continental shelf; the other basins are marginal but extend off-shore.

Cretaceous marine, paralic and freshwater sediments, mainly lithic sandstone (rich in volcanic detritus) and mudstone, are overlain by Tertiary freshwater clastics with coal measures, marine clastics, and carbonate rocks.

Most of the basins were affected by faulting from the Mesozoic into the Tertiary, and horsts and grabens were formed. Subordinate folding is known. Volcanic intrusions in the Mesozoic and during the Tertiary have locally altered the sediments.

Wet gas with condensate has been obtained from the Tertiary in the off-shore part of the Gippsland Basin, and restricted occurrences of low gravity oil have been found on-shore. Minor oil and gas flows in the Otway Basin were from the Cretaceous.

The stratigraphic occurrences of hydrocarbons in the sedimentary basins of Australia are shown in Table I; some minor occurrences are shown as well as the significant discoveries. The five groups of basins, just discussed, all have producing or possible producing fields, although in the Great Artesian Basin, the producing horizons are in, or closely associated with infrabasins. The ages of horizons with significant hydrocarbon flows are as follows:

(1) Western Australia - Lower Carboniferous, Permian, Jurassic, and Cretaceous, (oil and gas), with good indications from the Triassic;

(2) central Australia - Ordovician, Permian, (wet gas with condensate), minor shows in the Cambrian and Precambrian;

(3) eastern Australia - Devonian (dry gas), Permian, Triassic, (oil, wet and dry gas), small amount of oil from Carboniferous;

(4) Great Artesian Basin - Jurassic (oil and gas) in the Surat Basin;

(5) southern Australia - Tertiary (wet gas with condensate, small oil supply), minor oil and gas from Cretaceous.

It could be regarded as encouraging that hydrocarbons have been found in every period except the Silurian.

From the above, it will be noted that sedimentation in Australian basins has been mainly clastic, and that apart from some of the Palaeozoic of central and western Australia, carbonate developments are uncommon; all of the indicated potential reservoirs to date are sandstones.

Throughout Phanerozoic time generally, there have been long periods of continental emergence separated by marine sedimentation in shallow seas. Apart from regional downwarp, the central part of Australia has been fairly stable since the late Palaeozoic. In the east, accumulations of freshwater clastics with red beds and coal measures formed, particularly in the latter part of the Palaeozoic and early Mesozoic. Marine incursions are prominent up to the end of the Palaeozoic but are subordinate thereafter. Conditions throughout the Tasman Geosynclins region of eastern and south-eastern Australia were much more complex than elsewhere. Tectonic activity and vulcanicity were intense. The lower Palaeozoic rocks are mainly metamorphosed and volcanics are common in the younger sediments. The only region which shows fairly continuous marine influence, with some evidence of deeper water conditions, is along the western margin of the continent.

Naturally, the exploration for hydrocarbons to date has been for structural entrapments, and only in the Surat Basin has it gone much beyond this stage. In the Surat Basin the search for stratigraphic and permeability traps has been in progress for some time.

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TABLE I: OCCURRENCE OF HYDROCARBONS IN SOME OF THE SEDIMENTARY BASINS OF AUSTRALIA.

BASINS	CAINOZOIC	MESOZOIC			PALAEOZOIC						Pre Є	REMARKS
	T	K	J	Ŧ	P	C	D	S	O	Є		
BONAPARTE GULF						☼						wet gas
CANNING - FITZROY						◒	✢		✢			minor occurrences
CARNARVON		(1)✦ (1)✹				(2)✢						(1) wet gas with condensate; oil, 39°-42° A.P.I. (2) minor occurrence
PERTH			✧	✢	✹							dry and wet gas with condensate; oil, 34° A.P.I., initial flow declined.
PIRIE - TORRENS	◒									◒		residue
OTWAY		✧ ✢										wet gas with condensate; oil, 38° A.P.I.
GIPPSLAND	(1)✢ (2)☼											(1) dry gas; oil, 15.7° A.P.I. (2) wet gas with condensate.
SYDNEY				✧	✧ ✧							dry gas (with trace of oil reported from Triassic)
IPSWICH - CLARENCE			✧	✧ ✧								dry gas (with traces of oil).
DRUMMOND						✢						oil, 43° A.P.I.
BOWEN				(1)✹	(2)✺ (3)☼		(4)◒					(1) wet gas, 2 producers and 40 potential; (2) wet gas, small oil flow; (3) wet and dry gas; (4) oil in fractd. basement; (5) oil and wet gas, 20 oil producers.
SURAT			(5)✹									
COONAMBLE					◒							minor occurrence
ARCKARINGA					✺					◒		wet gas with condensate; oil stain in Cambrian
ADAVALE							☼					dry gas
AMADEUS									(1)☼ (2)✺	(3)◒ (4)◒	(5)✧	(1) wet gas; (2) wet gas with condensate, some free oil; (3) asphaltic residue; (4) oil saturation, 43° A.P.I. (5) dry (methane) gas.
GEORGINA									◒ ◒	◒ ✢		bituminous residues.

✹ oil and gas

☼ gas

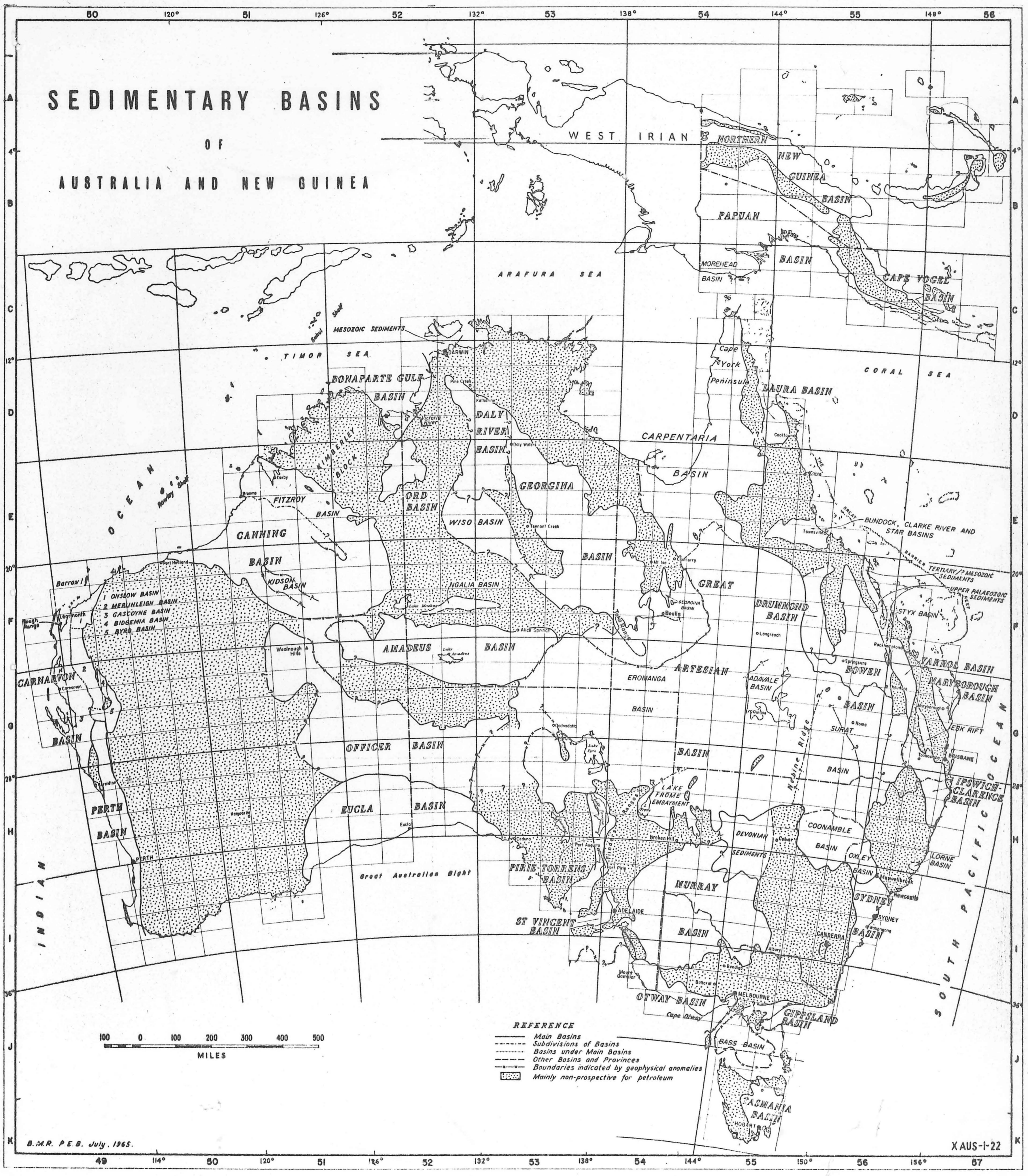
✦ oil with show of gas

✺ gas with show of oil

✢ show of oil and gas

◒ show of oil

✧ show of gas


SEDIMENTARY BASINS
OF
AUSTRALIA AND NEW GUINEA
WEST IRIAN
NORTHERN NEW GUINEA BASIN
PAPUAN BASIN
MOREHEAD BASIN
CAPE VOGEL BASIN
ARAFURA SEA
TIMOR SEA
CORAL SEA
MESOZOIC SEDIMENTS
BONAPARTE GULF BASIN
DALY RIVER BASIN
KIMBERLEY BLOCK
ORD BASIN
FITZROY BASIN
CANNING BASIN
KIDSON BASIN
WISO BASIN
GEORGINA BASIN
NGALIA BASIN
CARPENTARIA BASIN
LAURA BASIN
Cape York Peninsula
BUNDOCK, CLARKE RIVER AND STAR BASINS
TERTIARY / ? MESOZOIC SEDIMENTS
UPPER PALAEOZOIC SEDIMENTS
STYX BASIN
GREAT ARTESIAN BASIN
DRUMMOND BASIN
AMADEUS BASIN
EROMANGA BASIN
ADAVALE BASIN
BOWEN BASIN
SURAT BASIN
YARROL BASIN
MARYBOROUGH BASIN
ESK RIFT
IPSWICH-CLARENCE BASIN
OFFICER BASIN
EUCLA BASIN
Great Australian Bight
LAKE FROME EMBAYMENT
PIRIE-TORRENS BASIN
ST VINCENT BASIN
DEVONIAN SEDIMENTS
COONAMBLE BASIN
OXLEY BASIN
LORNE BASIN
SYDNEY BASIN
MURRAY BASIN
OTWAY BASIN
GIPPSLAND BASIN
BASS BASIN
TASMANIA BASIN
Nebine Ridge
CARNARVON BASIN
PERTH BASIN
1 ONSLOW BASIN
2 MERLINLEIGH BASIN
3 GASCOYNE BASIN
4 BIDGEMIA BASIN
5 BYRO BASIN
Barrow I.
Rough Range
INDIAN OCEAN
SOUTH PACIFIC OCEAN
Rowley Shelf
Sahul Shelf
DARWIN
ADELAIDE
MELBOURNE
SYDNEY
BRISBANE
PERTH
CANBERRA
HOBART
REFERENCE
Main Basins
Subdivisions of Basins
Basins under Main Basins
Other Basins and Provinces
Boundaries indicated by geophysical anomalies
Mainly non-prospective for petroleum
100 0 100 200 300 400 500
MILES
B.M.R. P.E.B. July, 1965.
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