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Record 1974/178

SUMMARY OF PHANEROZOIC SEDIMENTARY BASINS OF AUSTRALIA AND ADJACENT REGIONS, 1974

by

Sedimentary Basins Study Section, Petroleum Exploration Branch of the Bureau of Mineral Resources, Geology and Geophysics

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Plate 1 - Phanerozoic sedimentary basins and bathymetric features of Australia and adjacent regions.

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INTRODUCTION

The Sedimentary Basins Study Section of the Petroleum Exploration Branch of the Bureau of Mineral Resources (BMR) completed a first compilation of geological and geophysical information on Australian and Papua New Guinea sedimentary basins between mid-1972 and mid-1973. This compilation was issued as a restricted BMR Record in 1973. The information in the Record has been revised, expanded, and updated in this Record. The exploration and study of sedimentary basins is a continuing process, and this Record represents a further stage in the compilation of data on sedimentary basins.

Only Australian basins, and one closely adjacent basin (Papuan Basin), that are prospective for petroleum and contain Phanerozoic sedimentary rocks as all or part of their fill are described. The offshore areas are generally described to the shelf break at about the 200 m bathymetric contour. A number of smaller basins have been excluded because they are too small to be regarded as prospective for petroleum or because information on them is not readily available.

The information included was obtained within BMR and from the published and unpublished reports listed at the end of each section on a sedimentary basin. In addition, we have referred to the annual reports of the Directors of Mines of the individual States; the annual Australian Mineral Industry Reviews; the Geological Society of Australia 1:5 000 000 Tectonic Map of Australia and New Guinea, 1971; and the explanatory notes and maps of the Groundwater Resources of Australia, which are being prepared by the Technical Commission on Underground Water. Extensive use has been made of the final reports of drilling and geophysical operations carried out under the Commonwealth Petroleum Search Subsidy Act, 1959-1973. Other information has been obtained from press reports; commercial scouting services; and the Petroleum Newsletter, issued quarterly by BMR. BMR publications and unpublished records that were used as general references are listed at the end of this section. Basin boundaries are shown in Plate 1.

Sedimentary basins

Areas of sediments have been recognized in Australia since geologists started field mapping, and in due course they have been named for the obvious reason of ready reference. Most of these areas have by now been named as basins, but there is confusion because not all authors confer a name on sedimentary areas from the same point of view or with the same degree of geological understanding. In addition, there is a large degree of subdivision of the major basins which may be misleading unless the basis of it is clearly understood. For these reasons terminology needs constant revision and each revision must be formally accompanied by adequate definition.

When unqualified, the term 'basin' has a number of definitions. The term 'sedimentary basin' also has a number of meanings. For example, it may be used to distinguish an area in which sedimentary rocks are preserved from areas in which igneous and metamorphic rocks are preserved. Again it may refer to the palaeogeographic area of sedimentation.

We have followed as closely as possible the nomenclature on the Geological Society of Australia Tectonic Map of Australia and New Guinea, 1971. Sedimentary basins shown on this map are structural rather than depositional, though not necessarily basin-shaped, and their boundaries are mostly outcropping or subcropping unconformities and faults and the crests of buried elevated areas of basement.

Widespread angular unconformities or time-breaks within the sedimentary sequences are used in some areas to differentiate sedimentary sequences belonging to different basins. Good examples of this usage are in the Eromanga, Galilee, and Adavale Basins: the sequence in the Adavale Basin is overlain by the sequence in the Galilee (or the Cooper) Basin, which is in turn overlain by the sequence in the Eromanga Basin. In other areas, such as the Officer and Canning Basins, sedimentary sequences have not been differentiated into separate basins, even though widespread angular unconformities occur in them.

Structures such as faults or buried elevated areas of basement constitute the dividing features between many basins and sub-basins as defined in this Record. Thus, for example, the Carpentaria, Eromanga, and Surat Basins are separated at the crests of elevated areas of basement.

An example of confusing nomenclature is seen in early definitions of the Bowen, Surat, Oxley, and Sydney Basins. The Sydney and Bowen Basins are probably contiguous, and both contain Permian and Triassic rocks on which the Jurassic and Cretaceous rocks of the Surat Basin rest unconformably or disconformably. However, a structural basin in the southern Surat Basin has been named the Oxley Basin, and both Permo-Triassic and Jurassic-Cretaceous sequences have been included in it. In this case it seems better to abandon earlier definitions, and treat the Oxley Basin as a southerly lobe of the Surat Basin and assign the underlying Permo-Triassic rocks either to the Sydney Basin as we have done or to a new sedimentary basin.

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Subdivision of sedimentary basins

Ideally, sedimentary basins are subdivided into provinces, such as sub-basins, by structures such as faults and folds. Unfortunately, geological and geophysical data have sometimes accumulated at a faster pace than they have been properly analysed and integrated on a regional basis, with the result that a piecemeal terminology has developed that is applied for different reasons and from different points of view:

It should be obvious that, irrespective of scale, geological structure cannot be adequately resolved without proper appreciation of the age and stratigraphic relations of the associated rocks. Therefore, terms (such as 'depression', 'platform', shelf', terrace', and 'ridge') that may be used for example, on maps showing interpreted depths to magnetic basement should not be taken to imply the presence of a structural depression or other form of geological structure without further supporting evidence. Similarly, these same terms as applied on Bouguer gravity maps should not be transposed onto structural maps unless there is adequate other evidence for doing so.

Terms such as 'sub-basin', 'platform', 'shelf', and 'terrace' are rarely defined by authors and commonly have several meanings.

Definition of terms: The following terms have been used to describe large-scale structures. The definitions given immediately after the terms are from the International Tectonic Dictionary (Dennis, 1967); other dictionaries have been used for alternative meanings.

arch: a large, open, elongate anticlinal structure in any geological surface or family of surfaces

block: not defined; see fault block

fault block: a mass bounded on its sides, completely or in part, by faults

feature: not defined. Various meanings, including: distinctive or prominent article; visible effect of face; distinctive or characteristic part of a thing. Should not be used in naming a structure

high: not defined. Should not be used as a noun to describe a structural subdivision such as an elevated area

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hingeline:	trend across which rate of thickening of sediments changes markedly; judged to represent downwarp of the thicker side with respect to the thinner side
platform:	platform areas are those parts of the continents which are covered by flat-lying or gently tilted rocks, mainly sedimentary, which are underlain at varying depths by a basement. Definitions from other sources: an elevated structure between basins that nevertheless lies below base level and on which a thin sequence of sediments may accumulate; the area of thinner sediments adjoining a geosynclinal wedge of thicker equivalent beds
ridge:	not defined. A relatively narrow elevation which is prominent on account of the steep angle at which it rises
rise:	not defined. A long broad elevation of the sea floor
shelf:	shallow continental sea-floor; partial synonym of platform
sill:	a tabular sheet of igneous rock injected parallel with layering in the host rock. Definition from another source: a submarine ridge or rise
structural terrace:	steplike or shelflike flattening of the dip in more steeply inclined strata
sub-basin:	not defined. Useful structural subdivision of a basin
trough:	various meanings depending on context. Fault trough: a structure formed by a relatively depressed rockmass lying between more or less parallel-striking faults or fault zones. Other sources - any long, narrow, or shallow channel or depression.

Approach to a better terminology

We recommend that terms such as feature, sub-basin, high, platform, ridge, rise, and shelf should be avoided when describing or naming structural subdivisions, and more attention given to the use of terms such as basin, uplift, dome, arch, block, syncline, anticlinorium, and anticline.

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According to Trowbridge Grose (1972) the recognition and definition of any given set of tectonic units is largely a matter of the scale on which they are to be shown. A single large structural subdivision covering hundreds of square kilometres, such as a fault block, arch, or 'sub-basin', commonly incorporates distinctly smaller characteristic subdivisions - folds and fractures of local importance - which are usually related geometrically, temporally, and genetically to the larger unit. Criteria considered as a general basis for a practical classification of structural units in any region are necessarily relative, gradational, and arbitrary. Structural relief (uplift, dome, basin) is the controlling criterion in many areas, and horizontal displacement (autochthone, allochthone, nappe, klippe) may be a criterion in a few areas.

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ADAVALE BASIN

The Adavale Basin is a structurally depressed remnant of a formerly more widespread Devonian sequence of shallow marine and terrestrial rocks which were laid down in the shelf area of the Tasman Geosyncline. It covers an area of about 60 000 km^2, entirely concealed beneath the Eromanga and Galilee Basins in Queensland. Seismic interpretation and a few wells suggest that the Adavale Basin extends north and northeast of the area indicated on the Tectonic Map of Australia and New Guinea, 1971.

The boundaries of this indicated extension are unknown. It extends from the northeastern flank of the Blackall Ridge towards Hughenden. In the rest of the basin (excluding the Warrabin Trough, which is considered in a separate section) depositional margins are preserved only in the northwest where the sediments unconformably onlap a gently sloping basement (Yaraka Shelf) of pre-Devonian rocks. The northeastern boundary is partly an unconformable contact with basement rocks on the southwestern flank of the Blackall Ridge. Part of the eastern margin is a north-easterly-trending fault (Warrego Fault). The southeastern and southern margins are irregular and partly faulted. The Canaway Ridge is a fault-bounded divide between the Adavale Basin and its western continuation, the Warrabin Trough.

The basement rocks consist of granite, basalt, indurated sediments, and metamorphics. The sediments in the Adavale Basin, which are thicker in the middle and eastern parts and thinner in the western, range in age from Early to Late Devonian. The oldest rocks consist of up to 800 m of acid continental volcanics, and very minor sediments of presumed Early Devonian age. These are overlain conformably by a 1700-m-thick sequence of Middle Devonian marine shale, limestone, and labile sandstone, grading to fluviatile sandstone at the top. These are overlain with angular unconformity by up to 900 m of Middle Devonian rock salt, dolomite, varicoloured sandstone, shale, and siltstone, which were deposited in evaporitic, marine, and terrestrial environments. Up to 2500 m of Upper Devonian continental and shallow marine redbeds overlie the Middle Devonian rocks conformably.

Late Carboniferous block-faulting with hundreds of metres displacement produced a strong northeasterly trending series of anticlines and horsts traversing the length of the basin. The rock salt was mobilized into small diapirs. Downfolding and downfaulting has formed a series of lobes in the southern edge of the basin, namely the Quilpie, Cool-addie, and Westgate Troughs, and the Wanka and Langlo Embayments.

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Geological mapping

All the Sheet areas that cover the Adavale Basin were mapped by BMR and the Geological Survey of Queensland in 1964 to 1968. The good-quality mapping revealed that some of the major folds and faults in the Adavale Basin are reflected at the surface as low-amplitude anticlines and monoclines.

Drilling

Twenty-four exploratory and development wells, the deepest of which was about 4420 m, have been drilled into sediments of the Adavale Basin since 1961. Most are located in the central part of the basin and passed through the Eromanga and Galilee Basin sequences before entering sediments of the Adavale Basin.

Correlation

The volcanics at the base of the sequence have not been adequately dated, and their age is assumed by superposition and a potassium-argon date. The Middle Devonian sediments are reliably dated. The Upper? Devonian sediments are not adequately dated as fossils are rare; the only fossiliferous sample is Givetian or Frasnian.

Aeromagnetic surveys

The basin was completely covered by aeromagnetic surveys in the 1960s by Phillips Australian Oil Co., Magellan Petroleum Aust. Ltd, and BMR. 1:250 000 total magnetic intensity maps have been prepared but are unpublished. It has proved impossible to contour magnetic basement over much of this area because of the paucity of magnetic anomalies suitable for depth analysis, but the broad basinal structure was confirmed.

Gravity surveys

The first surveys were made by Shell (Qld) Development Pty Ltd (1940 to 1951), and later by BMR (1957-1966) and American Overseas Petroleum Ltd (1963-1965). 1:500 000 Bouguer anomaly maps have been published by BMR and 1:250 000 dyeline prints are available. There is excellent qualitative correlation between the gravity pattern and the subsurface geology: gravity 'lows' correspond to areas of pre-Permian sediments in the main Adavale Basin and its subsidiary troughs; steep gravity gradients correspond to the faulted and steeply truncated margins of these areas. However, some structures such as the Gilmore Trend and the Etonvale Dome have no obvious gravity expression.

Seismic surveys

The existence of the Adavale Basin was revealed by a seismic survey in 1958 by Oklahoma-Australia Oil Co. The general geometry of the basin was determined in 1961 by Phillips-Sunray during three surveys covering nearly 2000 line-km. This was accomplished by the interpretation of a good shallow reflector in the Cretaceous, and of reflectors of variable and varying quality that later turned out to be from near the base of the Permian, the base of the Buckabie redbeds, near the base of the Etonvale Formation, near the base of the Log Creek Formation, and the top of the basement. The Rockwell survey of 1965 revealed the existence of the unconformity within the Middle Devonian sediments. Altogether, Phillips-Sunray ran 23 seismic surveys to the end of 1966 which, in conjunction with data from wells drilled by the same company, provided a considerable amount of data to be fitted into the overall picture.

American Overseas Petroleum carried out a number of seismic surveys in the northeast part of the basin between 1962 and 1967, partly to investigate gravity leads. The latest of these, the Ravensbourne Seismic Survey, was a weight-drop seismic survey which mapped horizons in the Upper Permian and Middle Devonian, and in the Lower Devonian, where the horizon proved to be unreliable.

A BMR seismic survey in 1971, and another for Anerican Australian Energy Ltd in 1972, confirmed the extension of the Adavale Basin north of the Blackall Ridge and as far east as the Belyando Feature.

Economic geology

Petroleum: The Gilmore gas field was discovered by Phillips in 1964. It is in a structural trap in Middle Devonian sediments. Shale and limestone within the Middle Devonian are thought to be the source rocks and the reservoir is sandstone. Shale and dolomite are the caprocks. Recoverable reserves of gas are estimated at 589×10^6 m^3, but the field is isolated and has not been developed.

The unconformity within the Middle Devonian has eroded part of the Reservoir sandstone, but sandstone beds above the unconformity are also potential reservoir rocks. The high salinity of water from non-productive sandstone beds may indicate that they have not been flushed by meteoric water.

Evaporites: Cores containing halite and thin seams of sylvite have been obtained from Bonnie No. 1, Bury No. 1, and Boree No. 1. Halite was intersected in Stafford No. 1 and Alva No. 1.

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Recent activities

Hartogen Exploration Pty Ltd conducted two seismic surveys in 1971 to 1973, and drilled a well to 3986 m in 1972. The well was completed as a water well.

A tripartite consortium is planning to prospect for petroleum on the eastern edge of the basin.

Deficiencies in geological knowledge

The geology of the main part of the basin is fairly well known. The northern extension, north of the Blackall Ridge and as far east as the Belyando Formation, has been postulated from the seismic results only. A stratigraphic hole near the Belyando Feature would test this postulate and test the prospectivity of the pre-Galilee Basin sequence in the area. Seismic reflections work would probably assist in providing information on the northern extension if the seismic lines made proper ties between, and north of, existing wells.

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Warrabin Trough

The Warrabin Trough, a sub-basin of the Adavale Basin, contains Middle Devonian to Lower Carboniferous sediments preserved in a north-trending depression entirely concealed beneath the Cooper and Eromanga Basins in central Queensland. It covers an area of about 10 000 km^2.

The eastern margin is interpreted as a faulted contact between sediments of the trough and basement rocks in the Canaway Ridge. In the southwest the sediments in the trough pinch out between basement and Permian sediments on the northeastern flank of the Harkaway Anticline in the Cooper Basin. The full extent of the trough to the north and south is unknown.

Basement consists of steeply dipping indurated shale, siltstone, and sandstone of presumed lower Palaeozoic age.

The oldest sediments in the trough are Middle Devonian marine siltstone, sandstone, and shale interpreted on seismic evidence to be 600 m thick, of which only 100 m has been drilled in Bodalla No. 1.

Overlying these sediments with local unconformity is a thin marine dolomite bed overlain conformably by over 1000 m of Middle Devonian to Lower Carboniferous continental and possibly shallow marine sandstone, shale, and siltstone. The thin dolomite is a good seismic reflector.

The Devonian to Carboniferous sediments were uplifted and eroded along the Canaway Ridge late in the Carboniferous. The trough is a structural remnant of a once continuous area of shelf sediments laid down in the western part of the Tasman Geosynclinal Zone. Further periods of mild diastrophism followed in the late Triassic, after deposition of the Permian and Triassic rocks of the Cooper Basin, and at the end of the Cretaceous.

Geological mapping

The Warrabin Trough is covered by the Eromanga and Windorah 1:250 000 Sheet areas, which were mapped by BMR in 1966 and 1967 and have been published with explanatory notes. The surface mapping gives an indication of the deeper structure. The stratigraphy revealed by the petroleum exploration wells is discussed in the explanatory notes and the sediments within the Trough are shown on the cross-sections that accompany the maps.

Correlation

No basin wide correlation is available.

Drilling

Four subsidized petroleum exploration wells, Bodalla No. 1, Cumbroo No. 1, Chandos No. 1, and Chandos South No. 1 were drilled into sediments of the Warrabin Trough in the years 1966 to 1969. The wells are situated in a northerly trending line on or near the crests of the Chandos and Tallyabra surface anticlines. All four wells penetrated sediments of the Eromanga and Cooper Basins before entering sediments of the Warrabin Trough. One well was drilled to basement and the other three reached total depth within basin sediments.

Aeromagnetic surveys

BMR surveyed the area in 1968, and dyeline prints of 1:250 000 and 1:500 000 total magnetic intensity maps are available. Magnetic basement is interpreted as consisting of lower Palaeozoic metamorphic rocks, but few magnetic anomalies are suitable for depth analysis. Magnetic basement is elevated over the mapped position of the Canaway Ridge and deepens rapidly westward beneath the Warrabin Trough. The rapid deepening of the Magnetic basement indicates the possibility of a faulted boundary. The petroleum exploration wells lie outside the area contoured.

Gravity surveys

L.H. Smart Exploration Co. Pty. Ltd. in 1961, and Alliance Oil Development in 1963, conducted subsidized gravity surveys within the area. BMR made regional traverses in 1959 and completed regional coverage during a survey in 1964; 1:250 000 and 1:500 000 Bouguer anomaly maps have been published. The results are discussed in a BMR Record, and a part of the results are discussed in a BMR Report.

The Warrabin Gravity Low corresponds roughly to the position of the Warrabin Trough.

Seismic surveys

Seismic surveys have been carried out by BMR in 1959, and subsidized seismic surveys have been carried out by a few private companies from 1959 to 1967.

The earlier surveys showed that surface anticlines persist at depth; the later surveys indicated about 1600 m of Mesozoic and up to 3000 m of Palaeozoic sediments in the

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Warrabin Gravity Low, and that the surrounding steep gravity gradient corresponds to a marked truncation of the Palaeozoic sediments at the unconformity at the base of the Eromanga Basin. Strong reflections, probably arising from coal seams within the Cooper Basin, tend to mask reflections from the sediments in the Warrabin Trough, but good reflections have been obtained from a thick Middle Devonian marine dolomite.

Economic geology

None of the wells drilled had their prime objectives within the Warrabin Trough. Chandos South No. 1 penetrated 37 m, Cumbro No. 1 possibly 34 m, Chandos No. 1, 406 m, and Bodalla No. 1, 775 m of sediments within the trough. There were no hydrocarbon shows, the sequence was impermeable almost throughout, and no good source rocks were encountered. Anticlinal, fault, and stratigraphic traps are possibly present, but the hydrocarbon potential is rated as low.

Recent activities

Nil.

Deficiencies in geological knowledge

The complete basin sequence has yet to be established.

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AMADEUS BASIN

The Amadeus Basin is an east-trending elongate downwarp of about 145 000 km^2 in the Northern Territory and Western Australia. It contains Adelaidean, Cambrian, Ordovician, Silurian?, Devonian, and Carboniferous? sediments resting unconformably upon predominantly crystalline Precambrian basement rocks. The basement is made up of all rocks older than the Adelaidean Heavitree Quartzite.

The northern margin is an outcropping unconformable or faulted contact between Adelaidean sediments and either basement rocks or the fronts of basement-cored nappes. The southwestern margin is the front of the basement rocks in the Petermann Ranges Nappe. The southern to southeastern margin is concealed beneath superficial deposits and its nature is unknown. In the west, Adelaidean sediments of the basin trend unconformably beneath Permian sediments of the Canning Basin, and the margin is arbitrarily selected as the outcropping unconformable contact. In the east and southeast the sedimentary sequences trends unconformably beneath sediments of the Pedirka and Eromanga Basins, and from thereon becomes part of the Warburton Basin sequence.

About 9000 m of sedimentary rocks is preserved. The Adelaidean succession consists of a basal quartzite sequence, and a dolomite, siltstone, and evaporite sequence which is more or less unchanged through the basin, and a varied sequence of continental marine, paralic, and glacio-aqueous sediments, which is thickest (about 4500 m) in the south-central part of the basin. The only known volcanics interbedded with the sediments occur in the northeast and in the southwest in the dolomite, siltstone, and evaporite sequence.

Extensive overthrusting and folding of basement and cover uplifted the southwestern margin during the Petermann Ranges Orogeny late in the Precambrian or early in the Cambrian, and gave the southwestern margin its present form. During the orogeny the more competent Adelaidean strata were detached from the underlying strata and slid northwards on a decollement surface.

The Cambrian sediments were deposited unconformably over the Adelaidean in the southwest but conformably in the northeast. The sediments consist of red fluvial cross-bedded sandstone to the south and southwest adjacent to an ancient shoreline, and marine shale and carbonate to the northeast.

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The middle Upper Cambrian to Upper Ordovician rocks are interbedded thick marine orthoquartzite and shale, and the Silurian? to Carboniferous? rocks are continental (or transitional) orthoquartzite and continental redbeds. Diastrophism and erosion at the end of the Ordovician and in the Middle to Upper Devonian are recorded by gentle angular unconformities adjacent to the present northern margin. Uplift of the northern margin in Devonian to Carboniferous time provided a source for the continental redbeds. The strongest diastrophism occurred during the Alice Springs Orogeny in the Carboniferous, when thrusting occurred through the crust in the northern margin, nappes composed of basement and cover rocks grew at places along the northern margin, and the sedimentary rocks within the basin were transported southward over two surfaces of detachment and deformed into Jura-type folds. One surface of detachment lies within the Adelaidean dolomite-siltstone-evaporite sequence and the other, locally, in Cambrian evaporites in the northeastern part of the basin.

Geological mapping

All the basin has been mapped at 1:250 000 scale, and all first-edition Sheets have been published with explanatory notes. This good-quality regional mapping, which is also presented in colour at 1:500 000 scale in BMR Bulletin 100, forms the basis for the present understanding of the basin.

Correlation

This mapping of strata, well exposed in numerous anticlines, has produced an exceptionally reliable set of basin-wide lithological correlations.

Time correlation of Adelaidean strata is poor because of poor fossil control. The presence of glacigenic detritus in one formation may be used for interbasin and intrabasin time correlation assuming that the glacigenic rocks were deposited contemporaneously. Sparse isotopic dating of basement rocks and of shale within the sequence provides another basis for placing limits on the possible age.

Fossils are largely restricted to Cambrian and Ordovician marine and Devonian non-marine strata. The age of the strata has been assessed at many widely separated localities, but with insufficient accuracy in most places to determine whether or not the rock units are diachronous. In general, therefore, the time-framework for the basin is not established.

Drilling

By early 1974, twenty-five petroleum exploration wells had been completed. Most wells were drilled in the northern part of the basin. None was drilled west of the Mereenie Anticline. They penetrated Palaeozoic and Proterozoic strata. Their main value, apart from petroleum discoveries, was that they provided unweathered samples for study, and confirmed the occurrence of thick halite deposits in Proterozoic and Cambrian strata.

In 1968, BMR drilled one hole to 260 m, and in 1970 two holes to 300 m and another to 100 m, to investigate evaporite deposits. The holes were located on outcrops of gypsum in the Adelaidean dolomite, siltstone, and evaporite sequence to determine if other evaporites occurred at depth. One well intersected halite at 100 m depth. The others intersected gypsum, anhydrite, and dolomite at depth. Analyses of the cores gave insignificant potassium values, and no native sulphur was noted. In 1963, BMR drilled a number of holes for phosphate; one hole discovered an oil show in Ordovician sandstone.

Aeromagnetic surveys

A magnetic survey was flown by BMR over the greater part of the basin in 1965. An interpretation of depth to magnetic basement, and of magnetic basement structure, is published in Bulletin 100.

Gravity surveys

Gravity coverage of the entire basin was made by BMR helicopter gravity surveys in 1961 and 1962, and 1:1 000 000 Bouguer anomaly maps have been published in Bulletins 100 and 144. Quantitative interpretation of the regional data has been made for a small area on the northern margin (Bulletin 100). Bulletin 144 suggests how the surface structure and Bouguer anomalies may be related, but suggests deep seismic profiling is necessary to confirm the relation. Further studies are being carried out at BMR. Magellan Petroleum (NT) Pty Ltd has interpreted detailed gravity data to provide leads for seismic work. The Gardiner Range Gravity Survey of Magellan Petroleum (NT) Pty Ltd, completed early in 1974, provided some indications of faulting and other structure, but was difficult to interpret because of the geological complexity of the area.

Seismic surveys

The Missionary Plain and Mount Rennie/Ooraminna seismic surveys by Magellan Petroleum (NT) Pty Ltd in 1965-1966, supplemented by shorter surveys by BMR, Exoil Pty

Ltd, and Magellan, have provided a reconnaissance seismic grid 500 km long from east to west along the northern portion of the basin. The quality of the data generally is good, and the reflection character is consistent. The reflections, which have been tied into correlative surface outcrops and several wells within reasonable limits of accuracy, provide a reliable picture of the stratigraphy and structure which was already reasonably well known from geology. Seismic evidence helps confirm the decollement theory, and indicates thickening and thinning of units, thrusting, and diapirism.

Consistent reflections were not obtained deeper than the Adelaidean dolomite, siltstone, and evaporite sequence. Some areas of poor reflection have been encountered, typically near anticlines.

Seismic surveying in the southern part of the basin is limited. BMR shot about 130 line-km of refraction depth probes and scattered continuous reflection limes along or near the Alice Springs railroad, from Polhill in the north to Finke in the south, in 1961. The survey indicated at least 3300 m of reflecting section near Bundooma. Finke Oil Company Pty Ltd carried out a seismic survey of about 140 line-km in 1964 to detail subsurface structure revealed by the BMR survey. The record quality was fair.

A survey for Magellan Petroleum (NT) Pty Ltd near the Seymour Range in 1971 recorded 40 line-km of 6-fold multiple coverage and 10 km of single-fold data. Record quality varied between fair and poor.

Seismic surveying gives good results in the Amadeus Basin and is useful despite the fact that the sequence is well exposed in anticlines and synclines. Surface mapping over the Mereenie Anticline suggested that there was no closure; seismic data of only fair to poor quality suggested that closure developed at depth, and drilling proved, not only that this was so, but that it was due to thickening of subsurface strata in the direction opposite to the plunge visible at the surface.

Radiometric surveys

An airborne radiometric survey of the Amadeus Basin was made by BMR in conjunction with the 1965 airborne magnetic survey.

Economic geology

Water: The area is arid and settlements and pastoralists in the area rely on groundwater obtained mainly from shallow bores. No attempt has been made to assess water resources.

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<u>Evaporites</u>: Thick halite and anhydrite sequences have been intersected in petroleum exploration wells and BMR holes, and gypsum crops out in diapirs and the cores of some anticlines. The evaporites occur in the Gillen Member of the Adelaidean Bitter Springs Formation and in the Lower Cambrian Chandler Limestone.

<u>Phosphate</u>: Pelletal phosphorites occur in the Adelaidean, Cambrian, and Ordovician sequences, but the best deposits occur in the Lower Ordovician Stairway Sandstone, in which there are large reserves of phosphate but no known potentially economic deposits.

<u>Petroleum</u>: One gas and oil field (Mereenie) and one gas field (Palm Valley) have been discovered. Eight wells have been drilled on the Mereenie Anticline and three on the Palm Valley Anticline. The main producing formation in both anticlines is the Cambrian to Ordovician Pacoota Sandstone, with smaller gas production from the Ordovician Stairway Sandstone and the Ordovician Horn Valley Siltstone in the Palm Valley Anticline. Tests on the Mereenie wells produced condensate at rates ranging from 5 to 54 barrels per million cubic feet of gas. The gas column is about 327 m and the oil column has a minimum thickness of 97 m (East Mereenie No. 4 intersected oil pay from 643 to 740 m subsea). Oil production rates from East Mereenie No. 4 (the first well to encounter free-flowing oil) ranged from 160 to 350 barrels per day, depending on choke size. Acidization and fracturing in the well eliminated some of the formation damage of the initial completion, and demonstrated that the Pacoota reservoir responds favourably to conventional stimulation methods. Gas has flowed at rates ranging from about 3 to 30 million cubic feet per day from the Pacoota Sandstone at Mereenie.

Gas occurs over an interval of about 300 m in Palm Valley No. 1, with production chiefly from fractures in the lower Stairway Sandstone and upper Pacoota Sandstone. Palm Valley No. 1 had a calculated open-flow potential of 6.3 million cubic feet per day, but calculations from build-up pressure data showed that its capacity would have been about ten times higher had there not been extensive formation damage. Palm Valley No. 2, drilled with air to minimize well damage, tested 69.7 million cubic feet per day gas through a 2¼-inch orifice plate after penetrating only 0.6 m into the Pacoota reservoir. Palm Valley No. 3 was completed as a shut-in gas producer in March 1973, after a two-fold increase in the rate of initial flow (5 MMcfd) was obtained by hydraulic fracturing of the Pacoota Sandstone reservoir. Also an improved gas flow occurred after fracturing in Palm Valley No. 1.

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Possible source rocks include carbonate and shale in the Adelaidean and Cambrian sequences and shale in the Ordovician sequence. The Ordovician sandstone beds are proven reservoirs. Cambrian sandstone is a potential reservoir. There are many anticlinal traps, though all of the known suitable ones have been drilled and the remainder are breached to the Adelaidean. Fault and stratigraphic traps are untested possibilities. Providing the Cambrian sandstone beds are permeable, the area in which they interfinger with marine shales may provide stratigraphic traps. The only really prospective area is the Missionary Plain/ Mount Liebig area in the north.

Copper: Minor copper has been reported in the Cambrian and Ordovician sediments.

Recent activities

BMR and the United States Geological survey have made a detailed geological and geophysical study of Gosses Bluff Astrobleme. Detailed mapping by BMR and the Australian National University is continuing in areas of complicated structure along the northern margin of the basin. One detailed gravity traverse across the Arltunga Nappe Complex was carried out by BMR in 1973.

In 1973 and 1974 Magellan Petroleum (NT) Pty Ltd carried out the central Amadeus seismic survey, which was an extensive survey to extend seismic control over a number of structures between Mereenie and Alice Springs.

For recent drilling activity see Petroleum.

Deficiencies in geological knowledge

The basin has been evaluated regionally. Large areas in the south, where petroleum prospects are poor, have no outcrops and have not been seismically surveyed. Large-scale thrusting has been demonstrated in the margins of the basin. The basin seems an ideal area in which the relation between surface structure and deeper crust and mantle structure may be investigated by deep seismic profiling and gravity interpretation. Most surface anticlines have been drilled. A reassessment of existing seismic information is necessary to give a true picture of the structure of the sediments at depth because there is evidence of large horizontal variations in vertical velocities, e.g. Palm Valley to Tyler. Such a reassessment may indicate buried structures worthy of further investigation.

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ARCKARINGA BASIN

The Arckaringa Basin is an irregularly shaped Carboniferous and Permian basin covering an area of 64 000 km^2 in central South Australia. The southern and eastern parts contain the northwest-trending Boorthanna and Phillipson Troughs and the northeast-trending to east-trending Wallira Trough. The basin is mainly concealed beneath a cover of Mesozoic and Cainozoic sediments and it partly overlies the Officer and Warburton Basins. Its margins have been determined by interpretation of seismic, aeromagnetic, and gravity data. The nature of the concealed margins is poorly known, but they are probably partly faulted subcropping unconformable contacts.

The eastern margin if a partly outcropping but mainly subcropping unconformable contact between Permian sediments and either Adelaidean sediments or Precambrian metamorphic and igneous rocks of the Denison Block and the Kingston, Algebuckina, and Mount Dutton inliers. South of the Denison Block the basin margin swings to the southeast where Adelaidean sediments of the Stuart Shelf bound the basin. Ordovician sandstone of the Warburton Basin, encountered in Oodnadatta No. 1, occurs to the north of the basin and the metamorphic and igneous rocks of the Gawler Block occur to the south. Rocks of the Gawler Block and Cambro-Devonian sediments of the Officer Basin are present to the west of the basin. The southwestern and southeastern margins zigzag around areas of elevated basement, on which the Permian sediments are either absent or very thin, and those limits are based on drilling and on gravity, seismic, and aeromagnetic interpretation. The northeast-trending Mabel Creek Gravity High is located over the elevated area of basement which separates the Wallira Trough from the central Arckaringa Basin. The northwest-trending Mount Woods Gravity High corresponds to an elevated area of basement which partly outcrops and probably continues beneath the east-trending Coober Pedy Gravity Ridge between the Boorthanna Trough and the Wallira and Phillipson Troughs.

Weedina No. 1 intersected 883 m of Devonian sediments of the Warburton Basin beneath the Boorthanna Trough.

The basin contains more than 1520 m of Upper Carboniferous and Lower Permian, predominantly non-marine sandstone, shale, dolomite, and siltstone with minor amounts of coal unconformable on basement. The basal unit, an Upper Carboniferous to Sakmarian fluvio-glacial, lacustrine, and swamp sequence 0 to 300 m thick, thins towards the elevated

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areas of the basin and is absent in the central part of the basin in Mount Furner No. 1. Marine shale, siltstone, and sandstone of Sakmarian age overlie the basal unit or basement; in addition, anhydritic siltstone was penetrated in Cootanoorina No. 1. This unit varies between 27 and 260 m thick. The uppermost unit is an Artinskian fluviatile and lacustrine siltstone and sandstone that becomes coal-bearing and more shaly in its upper part; it is 390 m thick in Mount Furner No. 1.

Early Carboniferous diastrophism preceded deposition of the basin sediments. Downfaulting of the Wallira and Phillipson Troughs and rejuvenation of the Boorthanna Trough began in the late Carboniferous, and was followed by syndepositional faulting that continued into the middle of the Sakmarian. The sediments are flat-lying and only very gently deformed.

Geological mapping

Regional field mapping by the South Australian Geological Survey (SAGS) commenced in 1962 and is still in progress. One 1:250 000 map is published, and three maps have been issued as preliminary editions; three others are being prepared for publication. Detailed mapping of the Peake and Denison Ranges, on the eastern margin of the basin, was carried out in 1953, and six 1:63 360 maps were published in 1954 and 1955.

Most of the basin is concealed beneath Mesozoic sediments and the mapping is of little value, except near that part of the basin margin where basement rocks are exposed.

Drilling

Pexa Oil NL drilled one petroleum exploration well and Occidental Minerals Corporation Australia drilled one mineral exploration well in the Boorthanna Trough in 1970. The South Australian Department of Mines (SADM) drilled six stratigraphic wells between 1967 and 1970, and a number of water bores have been drilled. Drilling was concentrated in the eastern and central part of the basin. Most of the exploration and stratigraphic wells reached basement. No wells have been drilled in the western part of the basin and the only wells in the Phillipson and Wallira Troughs are in their northern ends where basement is less than 915 m deep.

All that is known about the lithology and age of all the sediments, except outcropping tillites along the eastern margin, has been determined by the drilling.

Correlation

No basin-wide correlations are available. SADM has made a lithological correlation of most of its stratigraphic wells; it has published gamma-ray/neutron log correlations between three wells, and a discussion of the lithological and palaeontological correlation of the sediments within the Phillipson and Boorthanna Troughs. The Permian sediments have been dated by their microflora, leaf remains, Foraminifera, and gastropods.

Aeromagnetic surveys

The whole basin was covered during aeromagnetic surveys flown by BMR, SADM, Delhi Australian Petroleum Ltd, and Exoil Pty Ltd between 1958 and 1968. 1:250 000 total magnetic intensity maps of all except the western end of the basin were published by SADM in 1971, and 1:63 360-scale maps covering areas flown by BMR and SADM in the southern and western parts of the basin are available.

The total magnetic intensity maps are most useful for defining the thickness of Arckaringa Basin sediments in the central part of the basin, where the sediments are directly underlain by magnetic rocks of the Gawler Block, but they are less definitive in the east and west where the Basin sediments are underlain by sediments of the Warburton and Officer Basins.

Gravity surveys

Murumba Oil NL carried out a gravity survey in the western end of the basin in 1970. Pexa Oil NL measured gravity in the Boorthanna Trough in the same year. SADM conducted gravity surveys over most of the basin from 1967 to 1972. A 1:1 000 000 Bouguer anomaly map of the whole basin is available and three 1:250 000 maps of the southern part of the basin have been published. 1:250 000 maps of the rest of the basin are being prepared.

The gravity data are of particular value around the margins of the basin and in the trough areas. The elevated areas of basement coincide with positive Bouguer anomalies, and the troughs coincide with the areas of negative Bouguer anomalies.

Seismic surveys

Exoil carried out a subsidized seismic survey of the western edge of the basin in 1962. Pexa Oil NL carried out two subsidized seismic and gravity surveys in 1970, both in the Boorthanna Trough. Record quality was fair to poor. Two horizons, the Lower Permian and the top of the Devonian, were mapped and Permian sediments up to 1830 m thick were indicated in the Boorthanna Trough. Most of the basin has been covered by seismic surveys conducted by SADM from 1961 to 1973.

The seismic data indicated three deep troughs partly faulted and separated by areas of elevated basement. The Permian is generally less than 610 m thick north of the Mabel Creek Gravity High. The seismic data are valuable as they indicate the structure of the basin.

Economic geology

Coal: A major coal deposit was recently discovered in Permian strata at Lake Phillipson. Several seams of medium-grade to low-grade steam coal are present, but it has a high overburden ratio. Early estimates indicate a total tonnage that could exceed 500 million tonnes. Coal quality is higher than presently mined in the Leigh Creek fields of the Arrowie Basin. At Mount Toondina the coal is overlain by clinker deposits resulting from prehistoric destruction of coal above the water-table by spontaneous combustion. The coal deposits are remote from market and occur in seams of limited thickness. They have not been exploited.

Petroleum: No significant hydrocarbon shows are reported from any well. Drill-stem tests in the Cootanoorina No. 1 recovered slightly gas-cut water from Permian sediments.

Porous sandstone is present both in the basal and in the upper units. Coal measures in the upper unit are potential source rocks. Devonian marine sediments underlying the eastern part of the basin are also potential source rocks.

Structural traps are present and stratigraphic traps may also occur. Structural traps in the Boorthanna Trough were tested by SADM and Pexa Oil NL Petroleum potential is untested in large areas of the basin. The hydrocarbon prospects of the thin sediments in shallow platform areas underlain by crystalline rocks are at best marginal because burial has been too shallow for the migration and generation of hydrocarbons. It is possible that hydrocarbons were generated in the deeper parts of the basin and these could be trapped in porous sandstone draped over structurally elevated areas. In general the petroleum prospects appear low.

Recent activities

SAGS is continuing regional field mapping and seismic surveys are being carried out in the western part of the basin.

Deficiencies in geological knowledge

Least is known about the western part of the basin which has not been drilled. Drilling is also needed in the deeper parts of the Phillipson Trough.

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ARROWIE BASIN

The Arrowie Basin is an easterly trending Cambrian basin in east central South Australia; it is situated largely within the Adelaide Geocyncline. The basin covers an area of about 45 000 km^2. The western edge is the Stuart Shelf. The eastern limit shown on the Tectonic Map of Australia and New Guinea 1971 coincides with a sinuous gravity gradient on the eastern margin of a closed northerly trending gravity depression. More recent interpretation shows that there is no reason to suppose that the eastern edge of the Arrowie Basin coincides with the gravity gradient, and the Cambrian sediments may extend eastwards to the Bancannia Trough or the Warburton Basin. The southern and northern margins lie within the Adelaide Geosyncline.

The basin contains up to 6000 m of Cambrian sediments, resting with a low-angle unconformity on the underlying uppermost Adelaidean Pound Quartzite along the western flank of the Flinders Ranges. In the central part of the basin the Cambrian rocks are either disconformable or conformable on the Adelaidean. Towards the edge of the basin where the Pound Quartzite is absent the Cambrian is underlain by older Adelaidean sediments.

Up to 4000 m of shallow marine limestone, shale, sandstone, and dolomite were deposited in the basin in the early Cambrian. The rocks vary in thickness and facies. The basal unit is a coarse-grained sandstone. The overlying limestone, sandstone, shale, and greywacke intertongue locally with each other across the basin. The carbonate facies predominates in the west, and the clastic sediments are more abundant in the east. Most of the clastic sediments were derived from the Willyama Block, in the southeast, although the Mount Painter Block, in the north, locally contributed finer-grained sediments.

Lower to Middle Cambrian marine redbeds, at least 300 m thick, conformably and disconformably overlie the early Cambrian. Thin beds of tuffaceous siltstone occur near the base. The redbeds are overlain by about 120 m of limestone, which is overlain by marine and non-marine Middle to possible Upper Cambrian redbeds over 3600 m thick. The marine redbeds include sandstone, siltstone, shale, and minor limestone. The uppermost unit, which is assumed to be Cambrian although no fossils have been found, is a fluvial conglomeratic cross-bedded quartz sandstone conformable on the underlying redbeds. The redbeds are probably molasse from the first orogenic movements leading to the final deformation of the Adelaide Geosyncline during the Delamerian Orogeny in the late Cambrian and early Ordovician.

The sediments are moderately to strongly folded, and many folds have a core of intrusive diapiric breccia. It is believed that extensive reactivation of old basement faults was, in some way, responsible for the diapiric intrusions and also produced a series of discontinuous faults aligned in a regular network within the sediments. The folding and faulting occur in the Flinders Ranges, but there was little deformation of Cambrian sediments in the Arrowie Basin to the east or west.

The Arrowie Basin was buried partly beneath younger basins in the Mesozoic and Tertiary. The late Triassic intermontane basins in the Flinders Ranges are the most important economically as they contain the Leigh Creek Coal Measures, the only commercial coal deposit in South Australia. The Leigh Creek Coal Measures consist of carbonaceous shale and coal seams containing interbeds of red ferruginous siltstone and lenticular sandstone underlain by a basal conglomerate. These freshwater basins were small isolated depositional sites that received up to 600 m of sediment.

The Lake Frome Embayment of the Eromanga Basin covered the eastern Arrowie Basin during the Jurassic, Cretaceous, and Tertiary, and the Pirie-Torrens Basin buried the western Arrowie Basin in the Tertiary.

Geological mapping

Most of the basin was mapped by SAGS between 1960 and 1971. The Copley 1:250 000 Sheet area was mapped between the early 1950s and 1970. 1:250 000 maps covering the whole basin are available; five are published and three have been issued as preliminary editions. Twelve 1:63 360 maps were published between 1952 and 1967.

The mapping is most valuable in the Flinders Ranges, where the sediments are well exposed. The lithology and age of the sediments are known mostly from the outcropping sections.

Drilling

Thirty-four petroleum exploration wells have been drilled in the western and eastern parts of the basin where Cambrian sediments are concealed beneath younger rocks.

Zinc Corporation Ltd drilled five wells east of Lake Frome in the eastern end of the basin in 1949 and 1950. Santos Ltd drilled 26 holes between Lake Torrens and the western edge of the Flinders Ranges in 1956 and 1957; 24 of these were sited in the Wilkatana area, in the southwestern end of the basin, where oil was reported from a water-bore in 1934. Three subsidized wells were drilled by Delhi Australian Petroleum Ltd near Lake Frome in 1968; they reached total depths of about 780 m in either Middle or Lower Cambrian sediments.

Well data indicate the age and lithology of the sediments in the concealed parts of the basin. The units exposed in the Flinders Ranges may be correlated with units in the eastern and western ends of the basin.

Correlation

No basin-wide lithological or time correlations are available. Lithological correlations have been prepared between subsurface sediments in the eastern end of the basin and outcrop sections of the Flinders Ranges in the centre of the basin. The outcropping Cambrian sediments are dated by macrofossils. The uppermost unit, of Cambrian to Ordovician? age, is unfossiliferous.

Aeromagnetic surveys

The whole of the basin was covered by aeromagnetic surveys by BMR and SADM between 1956 and 1966. Interpretation of all BMR surveys is contained in BMR Records. SADM has published 1:250 000 and 1:63 360 total magnetic intensity maps covering all of the basin. Magnetic data are of little value in defining the thickness of the Arrowie Basin sediments because the basin is underlain by Proterozoic sediments of the Adelaide Geosyncline, and magnetic basement does not coincide with the top of these.

Gravity surveys

The whole basin was covered by subsidized and unsubsidized regional and detailed gravity surveys carried out by Santos Ltd, Delhi Australian Petroleum Ltd, Crusader Oil NL, BMR, and SADM between 1956 and 1970. Before this time detailed gravity was measured in the Leigh Creek coal area.

A 1:1 000 000 Bouguer anomaly map of the basin is available and three 1:250 000 maps of the western end of the basin are published.

As indicated previously the eastern limit of the basin shown on the Tectonic map of Australia and New Guinea 1971 coincides with a sinuous gravity gradient on the eastern margin of a closed northerly trending gravity depression. On magnetic and surface geological evidence the gravity 'low' appears to be caused by granite in the basement, rather than by Cambrian sediments. Furthermore the trend of the gravity 'low' is northerly, parallel to Adelaidean trends, whereas the Arrowie Basin is elongated easterly. There is no reason to suppose that the eastern edge of the Arrowie Basin coincides with the gravity gradient, and the Cambrian sediments may extend eastwards to the Bancannia Trough or the Warburton Basin.

Seismic surveys

Santos Ltd conducted a subsidized seismic survey in the eastern part of the basin in 1960, but no usable reflections were received from the Palaeozoic. Combined seismic and gravity surveys were carried out in the eastern part of the basin by Delhi Australian Petroleum Ltd and Crusader Oil NL in 1966 and 1969 respectively. These subsidized surveys outlined the structure of the Palaeozoic sediments. Seismic surveys were conducted in both the eastern and the western part of the basin by SADM from 1964 to 1966.

The seismic surveys indicate structure and thickness of the subsurface sediments in the eastern and western parts of the basin.

Economic geology

Coal, barite, and metallic minerals are the main economic resources in the area of the Arrowie Basin.

Coal: Deposits of Triassic sub-bituminous black coal in the Copley Basin are mined from the Telford and North Field Basins, which overlie the Arrowie Basin.

Copper: Widespread secondary copper mineralization occurs in the Flinders Ranges. The copper is closely associated with shale diapirs, and most mines are situated within these structures, in adjacent rim rocks, or on faults which radiate from them. Most of the copper has been obtained from upper Proterozoic sediments, but local concentrations of copper carbonates occur within the Lower Cambrian.

Silver, lead, and zinc: Lead and zinc with minor amounts of silver occur in the Lower Cambrian carbonates in the Flinders Ranges. Galena, carrying silver, was mined from several areas in the late 1800s and early 1900s.

Minor amounts of lead and zinc have been produced from cross-cutting tabular vein deposits in Adelaidean shale and siltstone. The deposits are mostly small and low-grade.

Several new deposits, including the high-grade zinc deposit near Puttapa, have been located in the last 5 to 10 years. One million tonnes of willemite containing up to 52 percent zinc with some lead has been proved by drilling.

Gold: Gold is a minor associate of some copper ores in the Flinders Ranges. Minor amounts of gold have been mined from placer deposits near Boolooroo, Mount Ogilvie, and Angepena.

Iron and manganese: Superficial secondary pods of partly manganiferous limonite and hematite overlying Lower Cambrian limestone were mined between 1880 and 1900. From the Copper King ochre mine, various shades of iron ochre from Cambrian limestone was used as paint pigment. The deposit passes into siderite from which 2000 tonnes have been produced.

Minor amounts of manganese oxides have been produced from deposits overlying basal Cambrian rocks.

Barite: Barite has been mined from many areas in the Flinders Ranges. The enclosing rocks range in age from Proterozoic to Lower Cambrian. The deposits occur as widened fissure lodes in fault zones generally radiating from or marginal to diapirs.

Limestone and dolomite: Large reserves of high-grade Lower Cambrian limestone and dolomite suitable for metallurgical use crop out along the Flinders Ranges. Diamond drilling east of Brachina tested uniformly high-grade limestone, exceeding 98 percent $CaCO_3$, and low-silica dolomite.

Petroleum: Small amounts of dark semi-solid hydrocarbons and 26 API gravity crude oil were recovered from vuggy dolomite by Santos Ltd near Wilkatana. Traces of free oil were recorded from a borehole drilled in the Leigh Creek area to test coal measures. Both source and reservoir rocks are present in the Lower Cambrian. Lower Cambrian limestone is bituminous along the eastern Flinders Ranges and gives off a fetid odour when broken.

Structural traps are present, but most of the structures are small, have inadequate or fault-controlled closures, or are of low relief. Stratigraphic traps are also probably present. The Cambrian strata are breached to the Proterozoic in the Flinders Ranges and the only petroleum potential is in the western and eastern ends where the Cambrian sediments are concealed beneath the Pirie-Torrens and Eromanga Basins.

Gypsum and salts: Brines occur in porous Cambrian dolomite in the Wilkatana area. An attempt to exploit these saturated brines during drilling was abandoned.

Recent activities

GSSA recently completed mapping the basin, and 1:250 000 maps are being prepared. Mineral exploration and mining continues in the Flinders Ranges.

Deficiencies in geological knowledge

Least is known about the western part of the basin, where seismic coverage is limited and no new wells have been drilled since 1957. Lithological and time correlations should be compiled.

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BANCANNIA TROUGH

The Bancannia Trough is a small, elongate, north-northwest-trending trough in northwestern New South Wales. It covers an area of 9600 km^2 and contains up to 4500 m of Cambrian, Ordovician, and Devonian sediments, partly concealed beneath the Jurassic, Cretaceous, and Cainozoic sediments of the Eromanga and Murray Basins.

The eastern margin is an unconformable contact with schist, phyllite, quartzite, minor dolomite, and amphibolite of the Wonaminta Block, and the western boundary is an unconformable contact with Precambrian quartzite, shale, conglomerate, granite, schist, gneiss, and amphibolite of the Broken Hill District. The full extent of the Bancannia Trough sediments beneath the Eromanga and Murray Basins is unknown, and the limits of the trough in the north and south are arbitrarily chosen as follows: in the north, as the northernmost outcrop of Cambrian and Ordovician sediments in the Mount Arrowsmith district; and in the south, as the southernmost extent of Lower Ordovician and Devonian sandstone in the Scopes Ranges. North and south of these localities the extensions of the Bancannia Trough lie unconformably beneath Mesozoic sediments.

The oldest sediments in the trough are at least 450 m of shallow marine Cambrian shale, siltstone, tuffaceous sandstone, and massive grey limestone resting unconformably on Precambrian basement.

Up to 450 m of mainly shallow marine Ordovician cross-bedded sandstone, mudstone, siltstone, and thin beds of minor dolomitic limestone unconformably overlie the Cambrian. The proportion of shale and carbonate in the sediments increases to the northwest.

Lower Devonian fluviatile plant-bearing sandstone and conglomerate up to 775 m thick unconformably overlie Precambrian sediments in a small area of the central-eastern part of the trough.

Upper Devonian fluviatile sediments, up to 220 m thick, disconformably overlie Ordovician and Lower Devonian sediments. Frasnian conglomerate, orthoquartzite, and silty sandstone are overlain disconformably, and in places unconformably, by Fammenian to Tournaisian red sandstone up to 3000 m thick.

The sediments were broadly folded and in places faulted during the Kanimblan Orogeny in the Carboniferous.

Geological mapping

The whole of the trough was mapped by the New South Wales Geological Survey (NSWGS) from 1963 to 1965 and in 1967. All seven 1:250 000 Sheets covering the area have been published, and explanatory notes are available for one. Two 1:500 000 maps have been published. The mapping is reconnaissance and regional, incorporating airphoto-interpretation with a few ground traverses. Detailed mapping was carried out between 1969 and 1972, but none of the 1:100 000 maps has been published yet.

Correlation

There are no lithological or time correlations available.

Drilling

Five petroleum exploration wells were drilled between 1968 and 1970. They are evenly distributed throughout the basin. The deepest well was 3409 m.

Three of these wells were subsidized, and the final reports show that some penetrated outliers of Mesozoic sediments and all bottomed in Devonian sediments. The remaining two wells were drilled by New South Wales Oil and Gas Co. NL, and stratigraphic information is contained in their confidential final reports. There were no significant hydrocarbon shows in any of the wells.

The wells yielded stratigraphic information on the Devonian sediments only. The total thickness of the Devonian sediments and the nature of the Cambrian and Ordovician sequence in the subsurface have yet to be defined.

Aeromagnetic surveys

One subsidized aeromagnetic survey was flown over the basin in 1964 by Planet Oil Co. NL at 600 m altitude along northeasterly trending traverses. The results indicated that the major structure of the area is a graben whose regional strike is northwest. In the graben, over 3600 m of sediments are interpreted in two elongate depressions separated by a saddle. Magnetic basement is Precambrian high-grade metamorphic rocks.

Gravity surveys

Two subsidized gravity surveys were carried out in the Bancannia Trough. One survey in 1966 by American Overseas Petroleum had 10 905 stations; it did not reveal a distinct regional gravity trend, and local anomalies did not show consistent trends. The other survey, by Planet Exploration Co. Pty Ltd, was a small survey consisting of 103 stations combined with a seismic survey; the gravity results could only be partly correlated with the seismic results.

In 1973 BMR extended regional helicopter gravity coverage over the area, but final results are not yet available.

Seismic surveys

Six subsidized seismic surveys have been carried out and are evenly distributed throughout the trough. They were carried out between 1965 and 1969 by Planet Oil NL, Beach Petroleum NL, and NSW Oil and Gas Co. NL. The data and interpretations are on average of poor quality, with little correlation being attempted between the survey results and known geological information or information gained from other surveys. One of the surveys, the Bancannia seismic survey, mostly provided good reflection data, although there were problems of multiple interference. It indicated 6100 m of sediments. The most recent survey, the Pincally seismic survey in 1969, was a refraction survey in which a refractor with a velocity of 5500 m/s was recorded from depths of 900-1500 m over much of the survey area; the age of the refractor is not known.

Economic geology

Petroleum: No significant hydrocarbon shows have been found in wells drilled. Porous intervals have been drilled within the Upper Devonian to Lower? Carboniferous fluviatile sediments which could be suitable reservoir rocks. Adequate cap rocks and rocks of recognizable source potential are unknown. The hydrocarbon potential of the Cambrian and Ordovician sequences is unknown.

Water: Overall the salinity of the underground water in the Bancannia Trough is between 1000 and 3000 mg per litre. The yield and quality of water make it suitable for all livestock and limited domestic and industrial use. However, in the south the salinity is greater than 14 000 mg per litre, making it totally unsuitable even for livestock.

Recent activities

The area is being mapped at 1:100 000 scale by NSWGS.

Deficiencies in geological knowledge

The major deficiency is the lack of knowledge on the subsurface nature and extent of the Cambrian and Ordovician sediments.

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BASS BASIN

The Bass Basin is a northwesterly trending basin lying mainly offshore in Bass Strait in Victoria and Tasmania. The basin covers an area of 65 400 km^2 and contains at least 6100 m of sedimentary rock unconformably overlying basement.

The northwestern boundary of the Bass Basin with the Otway Basin is the Selwyn Fault, which trends northwesterly between King Island and Mornington Peninsula. The northern boundary with the Gippsland Basin is an arbitrary line between Mornington Peninsula and Wilsons Promontory. The northeastern boundary, also with the Gippsland Basin, is an elevated area of basement called the Bassian Rise. This boundary is partly an exposed or subsea unconformable contact between sediments and basement rocks on the southwestern flank of the Bassian Rise and partly the crest of the Rise where it is covered by sediments. The southern boundary is an unconformable contact between basin sediments and basement close to the north Tasmanian coast. The southwestern boundary between the Bass Basin and the King Island Sub-bain of the Otway Basin is an elevated area of basement, the King Island High, on which thinner sediments occur and which trends northwesterly between the northwest corner of Tasmania and King Island.

Basement rock types are known only from outcrops around the perimeter of the basin. Ordovician and Silurian sediments and Upper Devonian granite occur in the northwest on Mornington Peninsula, and Silurian and Devonian sediments and Devonian granite are exposed on the Bassian Rise. The basement exposed in Tasmania adjacent to the southern margin is complex, and includes Silurian and Devonian sediments and Devonian granite in the southeast; Permian and Triassic sediments of the Tasmania Basin in the south; and Precambrian metamorphics and minor mafic intrusives of the Rocky Cap Geanticline, and lower to middle Palaeozoic sediments, volcanics, and granite of the Dundas Trough, in the southwest; volcanics and granite out on King Island.

Seismic surveys have revealed up to 6100 m of sediments unconformably overlying a strongly faulted basement. Stratigraphic information has been released for only four wells, the deepest of which bottomed in Eocene sediments at 3352 m. Upper Cretaceous sediments have been penetrated in another subsidized well. Seismic evidence suggests that there is at least 1500 m of pre-Upper Cretaceous sediments in the southern part of the basin.

Up to 1800 m of Upper Cretaceous to lowermost upper Eocene fluvio-deltaic coal, siltstone, carbonaceous shale, and quartzose sandstone occur in the basin.

A thin marine upper Eocene sandstone unconformably overlies the fluvio-deltaic sediments, and 150 m of upper Eocene marine silty mudstone conformably overlies the sandstone.

At least 600 m of Oligocene marine silty mudstone, siltstone, and minor sandstone and volcanics unconformably overlie the Eocene rocks.

Up to 900 m of Miocene marine calcareous mudstone, calcarenite, and tuff conformably overlie the Oligocene sediments, and are disconformably overlain by Pliocene shallow-water marine to terrestrial sand, ferruginous grit, and ironstone in the northern part of the basin. Upper Pliocene to Quaternary basalt caps the sequence in parts of Tasmania and Victoria.

The Bass Basin began to develop in the Cretaceous during the rifting apart of the Gondwanaland Craton. In the Cretaceous, differential movement between the main Australian plate and the Tasmanian Subplate produced an elliptical faulted graben which evolved as the Bass Basin. The upper Cretaceous to Eocene section has been block-faulted. The main movement occurred in the early Tertiary when the central part of the basin subsided. Minor faulting also occurred in the late Oligocene and middle Miocene; later sediments are relatively flat-lying and unfaulted.

Geological mapping

Part of the onshore area in Tasmania was mapped by the Geological Survey of (GST) Tasmania between 1959 and 1968. Twenty-one 1:63 360 maps cover the area; six have been published, three with explanatory notes.

The onshore area in Victoria was mapped by the Geological Survey of Victoria (GSV) in 1966 to 1971. The two 1:250 000 Sheet areas involved have been published. The mapping was based on airphoto-interpretation and detailed ground traverses. Detailed mapping was carried out in 1963 and 1965. Three 1:63 360 maps have been published.

Correlation

Basin-wide lithological correlations are not available.

Planktonic foraminiferal zonules in Barracouta No. 1 (Taylor, 1966) in the Gippsland Basin are recognizable in the Bass Basin and may be used for time correlation; this zonal sequence only applies to the upper Eocene to upper Miocene rocks. Onshore Tertiary sediments in Tasmania and Victoria have been correlated using foraminiferal faunal units derived by Carter (1959). Taylor has shown the relation of his scheme to Carter's.

Drilling

Seventeen petroleum exploration wells drilled between 1965 and 1974 are concentrated in the central part of the basin. Stratigraphic information is available from the four subsidized wells, for which information has been released; they penetrated Tertiary and Upper Cretaceous sediments.

Eleven unsubsidized wells were drilled in 1970, 1972, 1973, and 1974 by Esso Exploration and Production Australia Incorporated, and Hematite Petroleum Pty Ltd. Stratigraphic information from these wells is contained in confidential company reports. One well, Pelican No. 1, had significant gas shows.

Aeromagnetic surveys

Two subsidized aeromagnetic surveys and one combined marine seismic and magnetic survey, also subsidized, give a reasonable magnetic coverage of the basin.

The two aeromagnetic surveys were flown over the Bass Basin in 1961. The first, Andersons Inlet aeromagnetic survey in the northern half of the basin, indicated shallow basement at 600 m. The second survey, the Bass Straight/ Encounter Bay aeromagnetic survey, which covered the whole basin, provided a regional outline of the structure of the basin and indicated the presence of a considerable thickness of sediments in the central part of the Basin.

Magnetic surveys are of limited use in the Bass Basin because magnetic basement does not always coincide with economic basement. Magnetic basement may be Tertiary basalt, Jurassic dolerite, Palaeozoic intrusions, or Precambrian metasediments. Another problem is the presence within the sedimentary section of volcanic rock masses which resemble reefs on seismic sections. Where these volcanics are relatively non-magnetic it is difficult to distinguish them from reefs without drilling.

Gravity surveys

The only gravity readings were made in the centre of the basin along one easterly trending line, 192 km long, by BMR in 1972. Interpretation of the data from this survey has not been published.

Seismic surveys

Ten marine seismic surveys, one of which incorporated a magnetic survey, between 1963 and 1973 give a good coverage of the basin. The earlier surveys for Hematite Petroleum mainly yielded poor results, but six surveys done for Esso, and the most recent survey, the Flinders Seismic survey carried out for Hematite Petroleum in 1973, provided generally good-quality reflection results down to a horizon within the Eastern View Coal Measures. The latter survey proved closure on five structures known from previous surveys. In 1972 BMR ran a combined seismic, magnetic, and gravity traverse 192 km long in an easterly direction across a portion of the basin as part of the Continental Margins Survey.

Economic geology

Coal: Brown coal occurs in Tertiary fluvio-deltaic sediments on the northwest coast of Tasmania from Table Cape (25 km northwest of Burnie) to Waratah. The seams are less than 3 m thick, of poor quality, and have at least 6 m of overburden.

Petroleum: No commercial hydrocarbons have been located in the basin, although significant shows of wet gas were reported to have been obtained in Pelican Nos 1 and 2 from Eocene reservoirs. Narimba No. 1, a subsidized well, was drilled in 1973 on trend with the Pelican structure, but no hydrocarbons were encountered in the equivalent horizons. Although the basin contains fluvio-deltaic rocks similar in type and age to the source and reservoir rocks of the hydrocarbon fields in the Gippsland Basin, the absence of large Tertiary closure appears to be a significant factor in the lack of accumulation of commercial hydrocarbons.

Water: In the onshore areas of Tasmania and King Island, and Mornington Peninsula in Victoria, the salinity is less than 1000 mg per litre and although the quality is good for most uses the yield is inadequate for town supplies, industry, and irrigation. In Victoria the salinity is mostly between 1000 and 3000 mg per litre and the yield and quality are generally suitable for all livestock and for limited domestic and industrial uses. On Wilsons Promontory, although the salinity is less than 1000 mg per litre, the yield is inadequate for most purposes.

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Recent activities

Drilling is continuing in the basin. The only other activity at present is mapping of the perimeter of the basin by the Tasmanian Geological Survey and the Victorian Geological Survey.

Deficiencies in geological knowledge

Available knowledge of the offshore stratigraphy is restricted, and details are known only from the four subsidized wells for which information has been released.

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BONAPARTE GULF BASIN

The Bonaparte Gulf Basin covers a triangular area of 18 000 km^2 onshore and 245 000 km offshore to the edge of the continental shelf, in Western Australia, Northern Territory, the Australian Territory of Ashmore and Cartier Islands, and a small area in Indonesia. About 17 000 m of Cambrian, Ordovician, Devonian, Carboniferous, Permian, Mesozoic, and Cainozoic sediments are preserved in the basin.

The southwestern margin, onshore, is the exposed unconformity between Palaeozoic sediments and Proterozoic rocks of the Kimberley Basin. It continues offshore along the seafloor outcrop of the contact between Phanerozoic and Precambrian rocks. It then follows the crest of the Londonderry Arch and continues, via the crests of discontinuous rises in the ocean floor and the southern edge of the Sahul-Ashmore Block, to the edge of the continental shelf. The northwestern margin is entirely offshore, and is not defined.

The onshore eastern margin is a partly faulted and partly unconformable contact between Palaeozoic sediments and Precambrian rocks. Offshore the eastern limit of Permian or Triassic subcrop defines the margin as far north as Bathurst Island. This line together with an arbitrary line running north-northwest from Bathurst Island, along Van Diemen Rise, and through Sunset Shoal to the edge of the continental shelf, separates the Bonaparte Gulf and Money Shoal Basins.

The basin has been structurally subdivided: onshore, the Pincombe Range, a north-northeast-trending Precambrian inlier, divides the basin into the Carlton Basin in the west and the Burt Range Syncline in the east; the main basin offshore, the Petrel Sub-basin, is a graben similar to the Fitzroy Trough of the Canning Basin.

The axis of the basin bifurcates offshore, the northwesterly extension being the Sahul Syncline and the northeasterly extension being the Matita Graben. The so-called Sahul Ridge is an elevated area of basement overlain by thinner sediments (less than 4500 m thick) lying between the two axes, and with physiographic expression as a rise in the ocean floor. The elevated area corresponds approximately to the southwestern part of the Sahul Regional Gravity High; it contains several broad anticlines and synclines, and is bounded by hingelines. Seismic interpretation suggests that thinner Cretaceous sediments unconformably overlie Jurassic? sediments on the ridge.

The Sahul-Ashmore Block lies within the western part of the basin. The structural province contains block-faulted and deeply eroded Triassic sediments and thin Jurassic sediments overlain unconformably by Cretaceous sediments thinner than in neighbouring areas of the Bonaparte Gulf and Browse Basins, and a thickness of Tertiary sediments similar to that in the outer parts of the Bonaparte Gulf and Browse Basins. The southern and southeastern margins are a hingeline and the eastern margin is a normal fault.

The Londonderry Arch, which separates the Bonaparte Gulf and Browse Basins, is an elevated area of basement rocks extending northwestwards from the Kimberley Basin. A thinner sequence of sediments occurs over the arch and the sea-floor rises above it (Londonderry Rise).

The Northeast Londonderry Ridge is an elevated area of basement on which thinner sediments extend northeast from the shallower Londonderry Arch. The northwestern margin of the ridge is a normal fault.

The Cartier Trough is a horst and graben province lying between two sets of northeasterly-trending faults near the outer edge of the continental shelf. It broadens southward into the Browse Basin, but the northeastern extension is unknown. Calculations of depth to magnetic basement suggests that up to 6000 m of sediments is present in the basin.

The Bathurst Terrace is a relatively flat surface containing thin sediments that rims part of the eastern margin of the basin. Hingelines separate it from the main basin on the west and north and from the Darwin Shelf on the east.

The Darwin Shelf is a gently sloping surface containing thinner sediments than the Bathurst Terrace. Both the shelf and terrace continue eastwards into the Money Shoal Basin where the shelf borders Lower Proterozoic sediments of the Pine Creek Geosyncline.

Precambrian rocks adjacent to the eastern margin lie within the Fitzmaurice/Halls Creek Mobile Zone. The zone contains moderately folded and intensely faulted Adelaidean or Carpentarian sediments, or both; Carpentarian granite and gabbro; lower Proterozoic metasediments and volcanics metamorphosed to the greenschist, amphibolite, and granulite facies of metamorphism; and inliers of Archaean or lower Proterozoic rocks.

The Kimberley Basin, adjacent to the southwestern margin, contains Carpentarian volcanics, quartz sandstone, siltstone, shale, and dolomite, and Adelaidean tillite, siltstone, shale, dolomite, and sandstone.

The oldest rocks in the Bonaparte Gulf Basin are 30 to 150 m of Adelaidean or Lower Cambrian? continental basalt, tuff, and agglomerate with minor interbedded sandstone. The volcanics crop out extensively in the south and east of the basin where they overlie the Precambrian basement with an angular unconformity. Up to 1200 m of Cambrian and Lower Ordovician marine sandstone, sandy dolomite, and stromatolitic dolomite unconformably overlie the volcanics onshore.

Onshore, at least 3000 m of Upper Devonian and Lower Carboniferous marine deep-water shale, siltstone, and minor sandstone are rimmed on the southeast by shallow-water sediments consisting of up to 3100 m of conglomerate, sandstone, dolomite, limestone (including reef complex), and shale, and on the southwest by up to 1980 m of shallow-water sandstone, dolomite, marl, limestone (including reef complex), and shale. Offshore, 935 m of Lower Carboniferous shallow marine siltstone, shale, and minor oolitic limestone were penetrated in Pelican Island No. 1.

The Upper Devonian and Lower Carboniferous sequence is disconformably overlain onshore by 100 m of Upper Carboniferous terrestrial quartz sandstone with minor conglomerate and siltstone. Offshore, Lower Carboniferous sediments are overlain unconformably by Upper Carboniferous marine pyritic and calcareous quartz sandstone, siltstone, and dolomite in Lacrosse No. 1, and conformably by up to 830 m of similar sediments in Pelican Island No. 1.

Onshore, Lower Permian rocks disconformably overlie the Upper Carboniferous and unconformably overlie the Precambrian basement in the east. Offshore they overlie Upper Carboniferous sediments with a possible disconformity. Up to 1750 m of Lower Permian rocks consist of continental silicified sandstone (in places containing phenoclasts of glacial origin), siltstone, and shale overlain by deltaic sandstone with interbeds of coal which pass upwards into marine shale and sandstone.

Offshore up to 510 m of Upper Permian marine quartz sandstone, siltstone, and shale occur in Petrel No. 1 and 375 m of deltaic sandstone with minor coal occur in Lacrosse No. 1.

Triassic estuarine laminated siltstone and fine-grained sandstone up to 110 m thick conformably overlie the Permian sediments in the northeastern part of the basin onshore. Offshore, up to 1950 m of Triassic sediments conformably overlie the Permian. They consist of: Lower Triassic marine shale and siltstone in Sahul Shoals No. 1; Lower Triassic non-marine carbonaceous sandstone, siltstone, and shale in Petrel No. 1; and Middle Triassic marine sandstone, shale, limestone, and Upper Triassic deltaic sandstone and shale with minor beds of marine calcarenite, calcilutite, and marl in Sahul Shoals No. 1. Interpretation of seismic records and well data shows a westward thickening of Triassic sediments from Petrel No. 1 to Sahul Shoals No. 1.

Offshore in Gull No. 1, 239 m of probable Lower Jurassic sediments unconformably overlie the Triassic. Elsewhere offshore Triassic sediments are disconformanly overlain by Upper Jurassic sediments consisting of up to 900 m of non-marine multicoloured sandstone, siltstone, and shale in Petrel No. 1, and up to 35 m of volcanics and thin marine calcarenite, lithic sandstone, and shale in Ashmore Reef No. 1. Interpretation of seismic records shows that the Jurassic sediments maintain a constant thickness within the Cartier Trough and over the Northeast Londonderry Ridge.

Onshore, up to 30 m of Cretaceous marine sandstone, siltstone, and conglomerate unconformably overlie Triassic and older rocks. Offshore, up to 2125 m of Cretaceous marine quartz sandstone, shale, and minor limestone conformably overlie the Jurassic, except on the Sahul- Ashmore Block, where up to 130 m of Lower and Upper Cretaceous marine calcilutite, shale, and marl unconformably overlie the Triassic. In Petrel No. 1, an unconformity occurs within the Lower Cretaceous rocks and a disconformity separates the Lower and Upper Cretaceous rocks in Sahul Shoals No. 1. The Upper Cretaceous sediments thin in a westerly direction from 576 m in Gulf No. 1, via the Northeast Londonderry Ridge and Cartier Trough, to 290 m in Ashmore Reef No. 1.

Offshore up to 2000 m of Tertiary calcilutite, marl, and calcarenite conformably and unconformably overlie the Cretaceous rocks. Interpretation of seismic records shows that Tertiary sediments are thickest in the Cartier Trough. Cainozoic sediments onshore consist of alluvium, travertine, laterite, soil, and sand.

The sediments have been folded, faulted, and intruded by salt diapirs. The Malita Graben, Sahul Ridge, Cartier Trough, Sahul-Ashmore Block, and Northeast Londonderry Ridge developed after Middle Jurassic deposition and before recommencement of deposition in the Late Jurassic. Upper Jurassic and Lower Cretaceous sediments thin over the Sahul Ridge and the Northeast Londonderry Ridge, and are largely missing from the Sahul-Ashmore Block.

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No compressional folding occurred in the basin. Anticlines were caused by movement of evaporites or by drape and differential compaction. Evaporites occur over a broad area in the southeast, and two wells, Sandpiper No. 1 and Pelican Island No. 1, intersected massive salt. The salt is at least pre-Late Devonian in age. Other salt diapirs are interpreted on seismic sections.

Geological Mapping

Geological maps at 1:253 440 scale and 1:1 013 760 scale have been published in BMR Bulletin 27 and cover the onshore part of the basin. The mapping was carried out in 1949 and 1952. First edition 1:250 000 geological maps and accompanying explanatory notes of the five Sheet areas covering the onshore part of the basin have been published after remapping, mostly by BMR and partly by the Geological Survey of Western Australia, between 1963 and 1968. A composite first edition 1:250 000 geological map of most of the onshore area of the basin is included in BMR Bulletin 97.

The quality of the 1:250 000 mapping varies from reliable detailed coverage with many traverses in the south-eastern part of the basin to airphoto-interpretation in the central coastal area.

BMR Bulletin 83 adequately describes the morphology and sediment types in the offshore part of the basin, and includes text-figure maps at a scale of 1:6 735 000.

A 1:1 000 000 geological map (3 sheets) of the whole offshore part of the basin, and offshore basins to the southwest, was published by BMR in 1973 after a marine survey in 1971.

Drilling

Fifteen subsidized and twenty-one unsubsidized petroleum exploration wells were drilled in the basin between 1962 and 1974. The onshore wells are mostly concentrated on the Port Keats and Cambridge Gulf 1:250 000 Sheet areas. They penetrated Permian, Carboniferous, and Devonian sediments, one bottoming in Precambrian basement.

Both subsidized and unsubsidized wells are spread over a large area in the offshore part of the basin. In 1973-74, drilling was concentrated in the western part of the basin, north of the Londonderry Arch. Thick Permian to Devonian sequences were penetrated in the near-shore wells, whereas the outer wells penetrated thick Tertiary and Mesozoic sequences. The offshore wells together with seismic interpretation can be used to gain a good understanding of the distribution, structure, thickness, and relations of the sediments. The poor quality of seismic data onshore hampers the correlation and extrapolation of onshore well data.

Correlation

No systematic well correlation is available although the appendices of well-completion reports contain some stratigraphic information for correlation.

Aeromagnetic surveys

An aeromagnetic survey of the onshore part of the basin was flown by BMR in 1958, and the offshore part was covered by four subsidized aeromagnetic surveys in 1963 and 1965. They indicate relatively shallow basement near the Darwin Shelf, Sahul Ridge, Sahul-Ashmore Block, and Londonderry Arch. A depth to magnetic basement map at 1:506 880 scale, which covers the onshore and part of the offshore part of the basin, was issued with BMR Record 1966/12.

Subsequent drilling in the Sahul-Ashmore Block revealed that magnetic basement is Jurassic volcanics.

Gravity surveys

The whole basin was covered by BMR surveys in 1956, 1957, 1958, 1965, and 1967. 1:250 000 and 1:500 000 Bouguer anomaly maps are available for the offshore area, and a 1:253 440 is available for the onshore area.

Two subsidized gravity surveys were carried out in the Carlton Sub-basin in 1967 and 1969.

The Bouguer gravity data has not been quantitatively analysed but it appears useful as a reconnaissance tool, particularly in the offshore area.

Seismic surveys

BMR carried out an onshore seismic survey in 1956, and two marine surveys in 1965 and 1967. The onshore survey delineated the Carlton Basin and Burt Range Syncline, and the offshore surveys outlined the extension of the basin.

Up to 1974, forty-siz subsidized seismic surveys had been done in the basin, of which 22 were onshore. Since 1969 a considerable amount of unsubsidized seismic mileage has been shot offshore. Gravity readings were taken on a

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number of the onshore seismic surveys, including the most recent, the Quins seismic and gravity survey, in 1973.

Seismic reflection data quality is poor over much of the onshore basin, particularly in the north, and some of the interpretations are of questionable reliability. Seismic record quality offshore is generally fair to good, and modern seismic techniques have achieved deep penetration.

Except in the poor-reflection areas of the onshore portion of the basin, seismic surveys have been valuable in determining the structural framework of the whole basin, and the distribution, thickness, structure, and relations of the Mesozoic and Tertiary strata in the offshore part of the basin. A considerable number of drilling prospects have been mapped offshore, and a number of them have already been drilled.

Economic geology

Petroleum: In 1964 an uneconomic flow of 43.6 MCF/D of gas was recorded from a Lower Carboniferous sandstone in Bonaparte No. 2 (onshore). Hydrocarbon shows were recorded from Lower Carboniferous and Lower Permian sediments in Kulshill No. 1 (onshore) and from Lower Permian sediments in Lacrosse No. 1 (offshore), In 1971, substantial flows of gas were reported from depths of several thousand metres in Petrel No. 2 and in Tern No. 1, both unsubsidized wells in the southeastern offshore part of the basin. Petrel No. 1 encountered gas in Upper Permian sediments. In mid-1974 oil was discovered in Puffin No. 2 on the Londonderry Arch; although it flowed at a high rate (4600 bpd, ½ in choke), the reservoir is reported to be small. In August 1974 a flow of nearly 10 MMCF/D of gas was reported from Troubadour No. 1, in the northeastern corner of the basin east of Timor. Hydrocarbons have been encountered in Upper Jurassic, Upper Cretaceous, and Eocene sediments offshore.

The Tertiary sediments may be too shallow to be source rocks. Mesozoic marine shales and Lower Carboniferous and Lower Permian shales are potential source and cap rocks. The Lower Carboniferous and Permian clastic sequences and Mesozoic fluviatile and deltaic sequences contain potential reservoir rocks.

Substantial flow-rates of both gas and oil, albeit from restricted reservoirs, have been obtained in widely separated parts of the basin. As porous clastics together with thick laterally extensive organic shale are associated with fault and diapir-related anomalies, and constitute stratigraphic trap possibilities, parts of the basin are moderately to highly prospective for petroleum.

Coal: Coal measures occur in Lower Permian sediments in the Cape Scott and Port Keats 1:250 000 Sheet areas. In 1967, Theiss Bros Ltd drilled five shallow bores (Kuriyippi Nos. 1-5) for coal. The results were disappointing. No thick coal seams of wide lateral extent were found within 1000 m of the surface. The only seam of any lateral extent was 60 cm thick; all other seams were less than 20 cm thick.

Underground water: Spirit Hill No. 1 petroleum exploration well was completed as an artesian well with a flow of fresh-water at 8.54 litres/minute from Lower Carboniferous sediments. This is the only known record of pressure water in the basin. Good-quality water has been obtained from bores in Permian and Upper Carboniferous sediments.

Recent activities

ARCO and BOC continue to drill offshore.

BOC of Australia Ltd carried out a marine seismic survey over part of the Darwin Shelf early in 1973. ARCO continued to extend its seismic grid with several unsubsidized marine seismic surveys in 1973 and 1974.

BMR collected samples from Upper Devonian and Lower Carboniferous rocks in 1972 for sedimentological, geochemical, and micropalaeontological study. A large area onshore is under intensive investigation by private companies searching for copper-lead-zinc deposits of the Mississippi Valley type.

Deficiencies in geological knowledge

The major deficiency is lack of comprehensive basin study.

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BOWEN BASIN

The Bowen Basin is a northerly trending elongate basin containing up to 11 300 m of Permian and Triassic rocks that underlie an area of about 158 000 km^2 in eastern Queensland and New South Wales. The southern half of the basin is concealed beneath the Surat Basin.

The northwestern boundary is the outcropping unconformable contact between basin sediments and: lower Palaeozoic schist and gneiss in the Anakie Inlier; Devonian to Lower Carboniferous sediments and volcanics in the Drummond Basin; Upper Carboniferous volcanics in the Bulgonunna Wedge; and Devonian and Carboniferous granite. Farther south, mainly beneath the Surat Basin, the Bowen Basin connects with the Galilee Basin to the west across the Nebine Ridge. Between the Nebine Ridge and the southern margin of the basin, in New South Wales, the western margin is the subcropping edge of the Permo-Triassic sediments beneath the Surat Basin. The southern margin is the traverse Narrabri Structural High, over which the Bowen Basin connects with the Sydney Basin.

The eastern margin is an outcropping unconformable contact between the Permo-Triassic basin sediments, and the Devonian to Carboniferous volcanics and Carboniferous igneous and metamorphic rocks in the Connors and Auburn Arches. Between these arches the Bowen Basin connects with the Yarrol Basin. Farther south, beneath the Surat Basin, the eastern margin is a faulted boundary with Carboniferous rocks of the New England Fold Belt.

Basement rocks are the folded sediments and volcanics of the Drummond Basin and the heterogeneous rocks of the Lachlan and New England Fold Belts.

The Permian sequence, which is up to 4900 m thick, consists chiefly of deltaic, marginal, and shallow marine sandstone, with thick basic to intermediate volcanics at the base in the east. Coal measures are widespread.

Triassic non-marine sediments, up to 5400 m thick, rest conformably and disconformably on the Permian rocks. They include lithic and quartzose sandstone and mudstone. The youngest sedimentary rocks in the basin are Late Triassic.

Within the basin there are intrusions of serpentinite; sills, stocks, and batholiths of Permian and Cretaceous granodiorite; and plugs and flows of Tertiary basalt.

The main folding occurred in the Late Triassic. The folds vary from tight, almost isoclinal folds, to very open and gentle folds. There was another folding in the north during the Cretaceous. Thrust, reverse, and normal faults are known, some being as young as Tertiary.

Geological mapping

All of the twenty-three 1:250 000 sheet areas that cover the basin have been mapped and compiled by BMR, GSQ, and GSNSW. The BMR/GSQ mapping of the Queensland portion (including all of Goondiwindi and Saint George) was carried out between 1960 and 1969, and all the sheets have been published at 1:250 000 scale with explanatory notes. A 1:500 000 first edition map of the northern part of the basin is included in BMR Bulletin 130.

The New South Wales sheets were compiled in 1968 and have been published at 1:250 000 scale.

The mapping, particularly in Queensland, is good-quality regional, and, in the northern (outcropping) part, has provided the main basis for the present understanding of the basin.

Drilling

By the end of 1972 a total of 32 petroleum exploration wells had been drilled in the northern part of the basin. Most of the 360 wells drilled in the Surat Basin also penetrated some Bowen Basin strata, and were invaluable in indicating the extent and geology of part of the concealed southern half of the basin.

From 1963 to 1968, GSQ conducted an extensive stratigraphic drilling program to enable companies to correlate their subsurface sections with type sections in the northern outcrop.

Mining companies are still carrying out extensive drilling programs in the coalfields.

Correlation

A basin-wide combined fossil, lithological, and seismic correlation is included in BMR Bulletin 130.

Aeromagnetic surveys

The whole of the basin has been surveyed. The northern part was surveyed by BMR in 1961 to 1963; maps of total magnetic intensity have been published, and a Record,

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including a map of depth to magnetic basement, has been issued. The southern part of the basin was covered during a subsidized survey for Union Oil Development Corporation in 1962; the final report includes 1:250 000 total magnetic intensity maps and a preliminary 1:506 880 map of interpreted depth to magnetic basement.

The structure outlined by the depth to magnetic basement contours in the north is in reasonable agreement with the major structural units outlined by mapping, although Tertiary basalt hampers interpretation in some areas. In most of the concealed southern half of the basin the aeromagnetic data provide the most reliable indication of depths to economic basement.

Gravity surveys

Gravity has been read by BMR on a grid of one station per 130 km over the whole basin. 1:500 000 Bouguer anomaly maps are published and 1:250 000 prints are available. Interpretation is discussed in two BMR records (Lonsdale, 1965; Darby, 1966).

Linear gravity anomalies parallel the trend of the basin, but their origin is uncertain. A gravity maximum coinciding with the Mimosa Syncline east of Surat may arise from a thick pile of high-density volcanics at the base of the Bowen Basin sequence or from a shallower mantle. Major gravity anomalies in the Roma area have been interpreted as arising from intrabasement density contrasts, rather than from elevations and depressions of basement.

The full value of the data will not be realized until more of the available geological and geophysical data are synthesized and the crust and mantle structure are determined.

Seismic surveys

Many surveys have been carried out over the central part of the basin by companies searching for coal and petroleum, and by BMR, but the northern part of the basin and the subsurface part in New South Wales are only sparsely covered by seismic surveys. Reflection quality beneath the coal-bearing formations is poor owing to energy absorption or reflection by the coal, and in consequence the interpretation of deeper levels is unreliable; however, reflections from the coal measures of the Blackwater Group have offered good control for determining the overall structure of the central part of the basin. Seismic reflection surveys have revealed many structures with no surface expression.

Economic geology

Coal: The Bowen Basin contains major deposits of coking coal and smaller amounts of other coal. The coal ranges in rank from high-volatile bituminous non-coking coal to semi-anthracite. In a few places the coal has been damaged or destroyed by igneous intrusions.

Metallurgical coking coal is being mined extensively from coal measures within the Upper Permian Blackwater Group and the German Creek Coal Measures. Steaming coal is produced from Lower Permian coal measures.

Petroleum: Six gas discoveries and one gas-with-condensate discovery have been made within Permian sediments, and ten gas fields and one oil field have been discovered within Triassic sediments. Proven reserves are small.

The marine sediments and the coal measures within the Permian are potential source rocks for petroleum. Oil shale within Permian strata at Carnarvon Creek has yielded 45 to 270 litres of oil to the ton.

The Permian reservoirs throughout the succession are thin sandstones that are fairly widely distributed in the central and southern parts of the basin. The hydrocarbons have been discovered in combined structural and stratigraphic traps. Permeability decreases towards the tectonically disturbed eastern part of the basin, and the best prospects for future discoveries lie along the south-western flank of the basin, where an increased thickness of the sandstones has been predicted from palaeogeographic studies.

The Triassic reservoirs are sandstones. The hydrocarbons occur in the Roma-Surat district, mainly in stratigraphic traps. The prospects of finding further small fields are good, but the prospects of finding large fields are poor.

In the northern and eastern parts of the basin, increasing coal rank, local tight folding, the presence of igneous intrusions, and poor permeability lower the chances of finding hydrocarbons. The western and southern parts of the basin are considered the most prospective and since 1967 petroleum exploration has concentrated on and near the Denison Trough.

Recent activities

A small geophysical survey was made in 1972 in the northern part of the basin. Seismic data quality was poor, but there were indications of closure on a north-south anticline, and drilling was recommended.

Deficiencies in geological knowledge

The complicated structure in the eastern part of the basin requires further work and study. A few deep wells are required to give information on the concealed part of the basin. Further detailed basin study and deep crustal seismic work are recommended.

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BREMER BASIN

The Bremer Basin, which covers an area of 5000 km^2 onshore (consisting of isolated outcrops) and a probable area of 30 000 km^2 offshore, is located in the southern part of Western Australia. A thin cover of Tertiary sediments is all that crops out onshore.

Onshore the margin of the Basin is an exposed unconformity between Tertiary sediments and Precambrian crystalline rocks of the Albany-Fraser Block. The western margin of the basin offshore is probably the southerly extension of the Darling Fault, the southern boundary is undefined, and the eastern boundary is an arbitrary line extending southwards from Esperance.

Basement rocks onshore consist of Adelaidean metamorphics of the granulite facies, and granite of the Albany-Fraser Block.

Onshore less than 100 m of Eocene marine, siltstone, spongolite, limestone, and minor lignite unconformably overlie Precambrian basement rocks.

Geological Mapping

Preliminary editions of three 1:250 000 geological maps have been published. The Geological Survey of Western Australia mapped the areas in 1965, 1967, 1968, and 1971. The quality of mapping is good, and relied on both regional traversing and airphoto-interpretation. However the sedimentary sequence mapped is very thin and restricted in area.

Drilling

No deep wells have been drilled.

Geophysical surveys

BMR carried out an onshore reconnaissance gravity survey in 1969; 1:250 000, 1:500 000, and 1:2 534 400 Bouguer anomaly maps have since been published.

Esso carried out an aeromagnetic survey of the basin in 1972 and this was followed by a marine seismic survey in 1974. Both of these surveys were unsubsidized.

In late 1972, BMR carried out a marine gravity, magnetic, and seismic sparker survey over the offshore part of the basin, with north-south profiles roughly 50 km apart extending from the shelf out to the deep sea-floor. Unfortunately the seismic results were poor, particularly on the shelf, but there were indications of thicknesses of more than 1000 m of sediments in some areas seawards of the 200 m bathymetric contour. Local areas of decreased Bouguer gravity anomalies possibly indicate areas of thicker sediments on the continental rise.

Economic geology

Beach concentrates of zircon and rutile are reported from several localities in or near the basin; the main areas are Denmark, Torbay Inlet, and Cheyne Bay.

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BROWSE BASIN

The Browse Basin is an elongate northeasterly trending basin covering an area of 140 000 km^2 entirely offshore from the Kimberley Basin in Western Australia. The Basin contains Ordovician?, Devonian?, Carboniferous, Permian, Mesozoic, and Cainozoic sediments.

The northern margin of the basin follows the crest of the Londonderry Arch, then trends west-northwestwards via the crests of discontinuous rises in the ocean floor and continues along the southern edge of the Sahul-Ashmore Block to the edge of the continental shelf. From the edge of the shelf the southern margin trends eastwards along 16^{o}S latitude across the Leveque Shelf and Platform to the eastern limit of Mesozoic and Tertiary sediments. The seafloor outcrop of the unconformity separating Upper Cretaceous to Holocene sediments from Precambrian basement rocks defines the eastern margin of the basin.

The basin has been subdivided into a number of structural units. The Londonderry Arch, Browse Shelf, Leveque Platform, and Leveque Shelf are subdivisions within the eastern area of the basin in which thin sediments unconformably overlie an irregular basement surface.

Extending northwards as a prolongation of the Leveque Shelf is the Buccaneer Nose which is interpreted on seismic sections as a fault-bounded area of elevated basement over which Mesozoic and Tertiary sediments are arched. It is separated from the Leveque Shelf by a saddle.

The existence beneath Mesozoic sediments adjacent to the Browse Shelf of a north-trending graben (Rob Roy Graben) containing Upper Carboniferous and Permian sediments has been postulated from seismic records and drilling. Three sides of the graben are faulted: two of them trend northerly; the third northeasterly, forming part of the outer margin of the Browse Shelf. Basement rocks are probably similar to the Precambrian rocks within the Kimberley Basin to the east. Precambrian quartzite was penetrated in Rob Roy No. 1.

About 11 000 m of sediment overlies basement. The oldest sediments drilled consist of 713 m of Upper Carboniferous and lowermost Permian marine claystone, sandstone, and minor limestone which unconformably overlie basement in the Rob Roy Graben. Yampi No. 1 bottomed in Lower Permian siltstone (probably non-marine) at 4176 m in the central part of the basin, 100 km southwest of Rob Roy No. 1.

On the western margin of the Leveque Shelf, Lynher No. 1 penetrated 85 m of Upper Permian marine sandstone and siltstone until total depth. Seismic interpretation indicates that probable Permian, Carboniferous, Devonian, and Ordovician sediments occur beneath total depth in Lynher No. 1.

Scott Reef No. 1 reached total depth after penetrating 375 m of Upper Triassic deltaic and marine claystone with dolomitic sandstone and recrystallized limestone immediately beneath a major regional angular unconformity. In the centre of the basin, Yampi No. 1 intersected 183 m of Upper Triassic fluvio-deltaic sediments.

In Lynher No. 1, 210 m of Upper Triassic deltaic sandstone and minor siltstone unconformably overlie the Upper Permian sediments. Seismic interpretation demonstrates that this unconformity beneath Upper Triassic sediments is continuous with the unconformity above the Upper Triassic sediments in Scott Reef No. 1, thereby demonstrating that the faulting and folding indicated by the unconformity occurred in the Upper Triassic.

At Rob Roy No. 1 Jurassic sediments are unconformable on Permian sediments.

Drilling and interpretation of seismic sections suggest that a thick Jurassic sequence, in excess of 2000 m in places, is present over much of the basin. Up to 1090 m of Jurassic marine and deltaic sandstone, claystone, siltstone, and minor coal occur in the southern part of the basin, where they conformably overlie Upper Triassic sediments, and in the centre of the basin, where there is an unconformity. In the east, Lower Jurassic deltaic sediments unconformably overlie Lower Permian and Upper Carboniferous sediments, and, in the west, Lower and Middle Jurassic marine sandstone and claystone unconformably overlie Upper Triassic sediments. In the east, 92 m of Upper Jurassic basalt, conglomerate, and marine glauconitic sandstone, claystone, and shale with thin dolomite beds unconformably overlie Precambrian basement (gabbro in Leveque No. 1). In the centre of the basin it appears that the basalt is Middle Jurassic.

Interpretation of seismic records with the available well control indicates that probable Upper Cretaceous sediments unconformably overlie basement in the Londonderry Arch area, and that a more complete Cretaceous sequence, over 3300 m thick, occurs in the depocentre of the basin.

In Leveque No. 1, 460 m of marine Cretaceous sandstone, claystone, calcisiltite, and calcilutite conformably overlie the Upper Jurassic sediments. An intra-Upper Cretaceous disconformity occurs between Santonian and underlying Cenomanian sediments.

Lynher No. 1 penetrated 845 m of Cretaceous marine claystone and minor marl and sandstone disconformably overlying Jurassic sediments. Within the Cretaceous marine sequence, Santonian sediments are disconformable on Turonian.

In Yampi No. 1, about 1500 m of Lower and Upper Cretaceous clastics were intersected; at least part of this is probably marine.

In Scott Reef No. 1, 762 m of Cretaceous marine sediments disconformably overlie Upper Jurassic sediments. Turonian calcilutite and marl disconformably overlie Lower Cretaceous claystone and sandstone.

In Rob Roy No. 1, 780 m of Cretaceous marine claystone, sandstone, and minor siltstone disconformably overlie the Lower Jurassic sediments. Minor disconformities occur within the Neocomian and between the Neocomian and Aptian, and an angular unconformity occurs between the Aptian and Albian.

The thickest Tertiary sequence penetrated was 3460 m of calcilutite, marl, calcarenite, calcisiltite, and reefal limestone (1411 m thick) disconformable on Cretaceous rocks in Scott Reef No. 1. Rob Roy No. 1 penetrated 130 m of Palaeocene marginal marine sandstone with minor coal and claystone conformably overlying Cretaceous sediments; thin Pliocene to Recent calcarenite, minor calcisiltite, sandstone, and dolomite disconformably overlie the Palaeocene rocks. In Lynher No. 1, upper Palaeocene and Eocene calcareous sediments; Miocene to Recent carbonate rocks unconformably overlie the Eocene sediments. In Leveque No. 1, 249 m of Miocene marine limestone, sandstone, and dolomite, and Pliocene calcarenite and calcilutite unconformably overlie Upper Cretaceous sediments. About 900 m of Cainozoic strata were encountered in Yampi No. 1.

Widespread folding and faulting occurred in the Carboniferous and Upper Triassic. The Rob Roy Graben developed in the late Carboniferous and the earliest Permian. Numerous regional unconformities have been recognized in Mesozoic and Cainozoic sediments in the central part of the basin (Yampi No. 1).

Faulting, initiated in the Palaeozoic and periodically rejuvenated locally in the Mesozoic and Tertiary, produced the northeast-trending faults which delineate the western margin of the Browse Shelf. The faults are normal, with downthrows toward the basin.

The margin between the Leveque Platform and basinal area was folded and faulted in the lower Miocene.

Geological mapping

A 1:1 000 000 geological map (3 sheets) of the whole basin and adjoining offshore areas was published in 1973 after a marine geological survey by BMR in 1971.

Drilling

Five subsidized and three unsubsidized wells were drilled between 1970 and 1974, on the Leveque Platform, on the outer edge of the Leveque Shelf, on the Scott Reef Structural Trend, in the Central part of the basin, and in the Rob Roy Graben. Of the subsidized wells, two bottomed in Precambrian basement, one in Upper Triassic sediments, one in Upper Permian, and one in Lower Permian sediments. The deepest of the unsubsidized wells, Heywood No. 1, bottomed at 4572 m in the northeastern part of the basin.

Correlation

No basin-wide correlation is available, but seismic correlation should be possible down to the unconformity at the base of the Permian to Upper Carboniferous sequence. The Cainozoic and Mesozoic sequences penetrated in the four wells drilled have been reliably dated and could form a framework for a time correlation. There are insufficient data for a reliable lithological correlation.

Aeromagnetic surveys

Woodside (Lakes Entrance) Oil Co. NL flew several regional reconnaissance traverses across the basin in 1963. This survey revealed the presence of a thick sedimentary sequence and delineated areas of shallow magnetic basement (less than 4500 m).

Gravity surveys

BMR measured gravity over most of the basin during the 1968 marine survey. A 1:2 543 400 Bouguer anomaly map is available, and a preliminary interpretation has been made. The true value of the data cannot be assessed until a more complete interpretation is made.

Seismic surveys

Fourteen subsidized seismic surveys were carried out between 1964 and 1973. The Browse Basin survey is particularly useful, as stratigraphic control was obtained from Scott Reef No. 1, Rob Roy No. 1, Leveque No. 1, and Lynher No. 1. The surveys provide good regional coverage. The record quality is generally good and a reliable interpretation may be made.

BMR conducted an offshore survey in 1968, but useful seismic reflections were rarely obtained at depths greater than 1500 m below sea bottom. In shallow water, ringing and multiples frequently masked any reflections that did exist, and hence only the near-surface reflections were observable.

BMR carried out a marine seismic, gravity, and magnetic survey over most of the basin in 1968. Traverses were oriented predominantly easterly and spaced about 16 km apart. A 1:2 543 400 map of total magnetic intensity contours is available and a preliminary interpretation has been made. The true value of the data cannot be assessed until a more complete interpretation is made.

Economic geology

In 1971 a major discovery of gas with condensate was made in Scott Reef No. 1. Reservoirs occur in Lower to Middle Jurassic and Upper Triassic sediments. The largest flow of gas recorded was 18.2 MMCF/D with 20 bbl/MMCF of condensate at 4290 m. Leveque No. 1 encountered minor amounts of hydrocarbons, including butane, within a net 140 m of tight Cretaceous sandstone.

In Yampi No. 1, near the centre of the basin, potential source rocks occur in the Upper Permian, Jurassic, and Cretaceous sequences (high gas readings, plus residual oil in a core).

Because the lower and middle Palaeozoic sediments have not been drilled and their thickness, distribution, and structure have not been established, their petroleum prospects are unknown. The Lower Permian to Upper Carboniferous sequence contains potential source and reservoir rocks in Rob Roy No. 1, but thickness, distribution, and structure are not well known.

The Mesozoic sequence contains thick marine shale that is a potential source for petroleum, and shoreline, deltaic, and fluviatile sands that may be reservoirs. The major diastrophism is faulting and folds may be developed adjacent to faults or over fault blocks. The stratigraphic trap potential is unknown.

The Cainozoic sequence is probably too shallow to generate hydrocarbons in most areas.

The potential for further discoveries is probably moderate or high.

Recent activities

BOC of Australia drilled four wells in 1973-74. In 1973 BOC completed the Mermaid-Cartier seismic survey, which included work in the Browse Basin. The survey extended knowledge of the Scott Reef trend farther to the north and detected a number of isolated structures within the basin. However, most of these structures are in water depths greater than 3000 metres.

Deficiencies in geological knowledge

The major deficiency is lack of knowledge of the rock types deposited in large areas of the basin, and of the thickness, distribution, age, structure, and lithology of the Palaeozoic rocks. A basin study is required to evaluate the data available.

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CANNING BASIN

The Canning Basin covers an onshore area of 430 000 km^2, and an offshore area of 165 000 km^2 to the 200 m bathymetric contour, in Western Australia. It contains a maximum aggregate thickness of about 17 000 m of Palaeozoic, Mesozoic, and Cainozoic sediments.

The northeastern margin of the basin is the exposed outcrop of the unconformity between Phanerozoic sediments and Precambrian rocks of the King Leopold/Halls Creek Mobile Zones. Offshore it continues as the subsea outcrop of Jurassic to Lower Cretaceous sediments on Precambrian rocks as far north as latitude 16°S. The margin has been extended arbitrarily westwards along latitude 16°S latitude across the Leveque Platform, Leveque Shelf, and Rowley Sub-basin to the edge of the continental shelf, separating the offshore Browse Basin from the Canning Basin.

The northwestern margin has not been delineated in deeper water as thick sediments continue to the west of the shelf break.

From the shelf break at 18°30'S the southwestern margin trends arbitralily eastwards to the northern tip of the North Turtle Arch, where it deviates southwards along the crest of the arch. A southerly trending line extends from the end of the arch to the subsea outcrop of the unconformity between Jurassic to Lower Cretaceous sediments and Precambrian rocks of the Pilbara Block to complete the western margin. The southwestern margin continues eastwards from near Turtle Island to the present coastline. From there it extends eastwards and then southeastwards as the outcrop of the unconformity between Mesozoic or Permian sediments (excluding outliers) and the Precambrian rocks of the Pilbara Block and Paterson Province.

The southern margin with the Officer Basin is arbitrarily selected as the crest of the Warri (Gravity) Ridge, which gravity and aeromagnetic interpretation suggest is an area of elevated basement covered by thinner sediments.

The eastern margin is the outcrop of the partly faulted unconformity between predominantly Permian sediments and Precambrian rocks.

Onshore the basin has been subdivided into a number of structurally distinct provinces based originally on an interpretation of the depth to magnetic basement. The structural provinces are separated by either faults which penetrate part of the Phanerozoic sequence or by elevated areas of basement. The subdivisions currently recognized onshore are: Lennard Shelf, Billiluna Shelf, Betty Terrace, Fitzroy Trough, Jurgurra Terrace, and Barbwire Terrace in the north; Mid-Basin Platform, consisting of Broome Platform and Crossland Platform, in the central part of the basin; and Willara Sub-basin, Kidson Sub-basin, Samphire Depression, Wallal Platform, Wallal Embayment, Pilbara Shelf, and Tabletop Shelf in the southern part of the basin. Several of the onshore subdivisions extend offshore.

Additional provinces distinguished by interpretation of gravity data are from north to south: the Jones Arch and the Bulka Arch, lying between the Fitzroy Trough and Gregory Sub-basin; the Munro Arch, lying between the Willara Sub-basin and Kidson Sub-basin; and the Anketell Ridge, lying between the Broome Platform and the Samphire Depression.

Interpretation of seismic records indicates other structural units offshore. These are from north to south: Leveque Platform, Leveque Shelf, Rowley Sub-basin, and Bedout Sub-basin.

The Basins Study Group is currently reviewing nomenclature of the basin's structural sub-divisions.

Basement rocks adjacent to the northeastern margin (King Leopold Mobile Zone) are strongly cleaved, folded, and faulted Archaean and Lower Proterozoic metasediments intruded by Lower Proterozoic granite batholiths and mafic and ultramafic dykes, sills, and stocks. Carpentarian porphyry and tuff overlie the metasediments and some of the intrusives. Similar rocks underlie a major portion of the northern part of the Canning Basin.

Basement rocks in the eastern part of the basin consist of Adelaidean and Carpentarian sediments and Precambrian crystalline igneous and metamorphic rocks. The southern part of the basin is floored largely by Archaean and Carpentarian igneous and metamorphic rocks. In the central portion of the Canning Basin (Broome Platform) a basement of Precambrian phyllite, gneiss, and granite has been drilled.

Up to 2000 m of Ordovician marine sediments was penetrated in Willara No. 1. The sediments, which unconformably overlie Precambrian basement, consist of a basal glauconitic sandstone overlain by siltstone, shale, limestone, and dolomite. Ordovician sediments are widespread, and exceed 1000 m in thickness throughout much of the basin.

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Up to 2700 m of restricted marine and continental claystone, anhydrite, halite, limestone, dolomite, red-brown sandstone, siltstone, and dolomitic limestone overlies the Ordovician sediments in Kidson No. 1. The upper continental sandstone part of the sequence is of Early to Middle Devonian age. The underlying evaporites are probably Devonian, but may be as old as Upper Ordovician. This evaporite/continental sandstone sequence appears to be absent only in the marginal shelves; it is thickest in the Kidson Sub-Basin and Mid-Basin Platform.

An extensive Middle and Upper Devonian reef complex overlies Precambrian and Ordovician rocks on the Lennard Shelf and the Barbwire Terrace. Middle to Upper Devonian dolomite 1160 m thick was encountered in Matches Springs No. 1 on the Barbwire Terrace.

Up to 2036 m of Upper Devonian deep-water interbedded siltstone, shale, limestone, and fine-grained sandstone is present in the area of the Jurgurra Terrace. The relation between the shale sequence (deeper-water equivalent of the reef complex) and the probably underlying evaporite/continental sequence is unknown.

Carboniferous marine and non-marine sediments conformably overlie Devonian sediments in the Fitzroy Trough and near the northeastern edge of the Lennard Shelf. The sequence, up to 3000 m thick in Yulleroo No. 1, consists of marine fossiliferous grey siltstone and limestone overlain by estuarine multicoloured siltstone alternating with shale, buff sandstone, and minor limestone, dolomite, and anhydrite. Middle Devonian to Lower Carboniferous sediments are virtually contained to the northeastern part of the basin, where their maximum thickness exceeds 4000 m.

Upper Carboniferous and Permian sediments are the most widespread in the basin and attain a maximum aggregate thickness of 2400 m in the area of the Fitzroy Trough. They conformably and unconformably overlie Carboniferous sediments in the Fitzroy Trough, but elsewhere overlie older rocks with strong angular unconformity. Glacial striated pavements are exposed beneath Upper Carboniferous to Permian sediments adjacent to the southwestern and eastern margins of the basin. Presumed Lower Permian tillite containing striated phenoclasts within a clayey matrix, and varved shales, unconformably overlie Precambrian rocks near the southwestern margin. Within the basin, the Permian sequence contains marine and nonmarine units, and units of mixed origin. The marine units contain sandstone, calcarenite, limestone, shale, and siltstone, and the nonmarine units contain conglomerate, plant-bearing sandstone, and minor coal.

By contrast, Triassic strata are much more restricted in extent, and onshore are almost confined to the Fitzroy Trough/Gregory Sub-basin area. Up to 570 m of Lower Triassic marine shale and Lower to Middle Triassic fluvial sandstone conformably and disconformably overlies Permian rocks in the area of the Fitzroy Trough and Lennard Shelf, and disconformably overlies Permian sediments in the Wallal Platform area.

Offshore 110 m of Lower to Middle Triassic marine multicoloured sandstone and claystone overlies altered pyroclastic and volcanic rocks of uncertain age on the Bedout High, which may be a fault block. Interpretation of seismic records indicates that sediments of probable Late Triassic age overlie Lower? Triassic and Palaeozoic sediments with angular unconformity in the Bedout Sub-basin. The oldest dated sediments so far penetrated offshore are of Triassic age.

Up to 750 m of Lower Jurassic deltaic multicoloured claystone, sandstone, siltstone, and coal conformably overlie the Upper Triassic in the Bedout Sub-basin offshore. Lower Jurassic deltaic sediments overlie Palaeozoic sediments with strong angular unconformity in Lacepede No. 1A in the offshore extension of the Fitzroy Trough.

Offshore, up to 440 m of Middle and Upper Jurassic deltaic sandstone, siltstone, shale, and coal, and some marine sediments, conformably overlie Lower Jurassic rocks. Onshore relatively thin Middle and Upper Jurassic deltaic and marine sediments overlie with angular unconformity Lower Triassic and older rocks in the areas of the Fitzroy Trough and the Lennard Shelf, and are widespread elsewhere in the basin, where they disconformably overlie older rocks.

In the Bedout Sub-basin, 853 m of Cretaceous marine claystone, sandstone, marl, and calcilutite conformably overlie the Jurassic rocks. Within the Cretaceous sequence, dipmeter evidence indicates that an unconformity exists between sediments of early and late Neocomian age on the Bedout High; and palaeontological evidence indicates two disconformities, one between Albian and Aptian sediments, and the other between Turonian and basal Cenomanian sediments. A disconformity exists between the Albian and Cenomanian in Lacepede No. 1A in the offshore extension of the Fitzroy Trough.

Onshore, Lower Cretaceous marine sandstone disconformably overlies the Jurassic in the Fitzroy Trough area near the present coast. Thin marine Lower Cretaceous sandstone and claystone are widespread throughout the southwestern half of the basin, and link up with similar strata in the Officer Basin.

Offshore, up to 150 m of Palaeocene and Eocene marine glauconitic sandstone, calcilutite, and minor dolomite conformably overlie Upper Cretaceous sediments in the area of the Bedout High. An hiatus is present between the lower and upper Palaeocene in the same well.

Up to 450 m of Miocene to Recent marine calcarenite, calcirudite, dolomite, claystone, and sandstone disconformably overlie Eocene rocks in Bedout No. 1 and Upper Cretaceous sediments in Lacepede No. 1A.

Seismic interpretation shows that the Cainozoic sediments thicken westwards from a zero isopach near the present coastline to up to 2000 m in the depocentre of the Rowley Sub-basin. The sediments have been faulted, folded, and intruded locally by salt diapirs, dolerite sills?, and lamproite plugs. The intrusions are known so far only from the immediate environs of the Fitzroy Trough. The salt was probably intruded in the Late Triassic. Early and Late Triassic isotopic ages have been obtained for the dolerites; Jurassic and Miocene isotopic ages have been obtained for the lamproites.

Most faults in the basin trend northwest. Graben-generating fault movements formed the northwest-trending Fitzroy Trough in the Late Devonian and Carboniferous, and continued into the Permian. Net vertical displacement along the Pinnacle and Fenton Faults north and south of the trough totals 6000 m in places. Ordovician sediments in the areas of the Lennard and Billiluna Shelves were uplifted and eroded before the Middle Devonian. Reef growth began on some faulted blocks in the Middle Devonian. Regional uplift and erosion, expressed in basin-wide unconformities, occurred in the Late Carboniferous and Late Triassic. The Late Triassic diastrophism in the Fitzroy Trough area included moderate folding (ESE-trending folds) and complementary minor meridional faulting which are thought to have been caused by major right-lateral wrench movements along the bounding faults of the trough. Elsewhere in the basin there has been little folding.

Local faulting occurred during sedimentation on the southwestern margin of the Broome Platform during the Ordovician, and caused sediment thickening on the south-western downthrown side of northwesterly trending normal faults. Faulting in this zone recurred in the Early Permian.

During the Early Cretaceous, both the onshore and offshore areas of the basin were uplifted and eroded. The offshore extension of the Fitzroy Trough area was uplifted and eroded between the early Palaeocene and early Miocene. In the Bedout Sub-basin, uplift and erosion occurred in the Late Triassic, Late Jurassic, and between the Eocene and early Miocene. Offshore geophysical data indicate that near the margin of the continental shelf the structures have a northeasterly trend, parallel to the present coast. All isopachs offshore down to at least the Lower Jurassic (data for older strata offshore is scanty) roughly parallel the present coastline, whereas onshore the isopachs for Triassic and older strata generally trend at right angles to the coast.

Geological mapping

A geological map of the entire onshore part of the basin was published at a scale of 20 miles to one inch (1:1 267 200) by BMR in 1961.

Geological maps of part of the Fitzroy Trough, southwest Canning Basin, and northeast Canning Basin are published at 1:253 440 scale with explanatory notes. The four 1:250 000 Sheet areas covering most of the Fitzroy Trough (Derby, Lennard River, Mount Anderson, and Noonkanbah) were mapped by BMR between 1948 and 1952. A 1:506 880 map, covering the same four Sheet areas, has also been published.

A 1:633 600 preliminary map covering five 1:250 000 Sheet areas in the southwestern part of the Canning Basin was published after mapping by BMR in 1954. Four of the five Sheet areas (Yarrie, Anketell, Paterson Range, and Tabletop) are published at 1:253 440 scale with explanatory notes.

BMR mapped the northeastern part of the Canning Basin in 1955, and published a 1:633 600 preliminary map covering the Mount Bannerman, Billiluna, Cornish, Lucas, and Stansmore Sheet areas. 1:253 440 maps covering the same five Sheet areas are published. These maps also incorporate some mapping carried out in 1957. BMR and the Geological Survey of Western Australia (GSWA) remapped Billiluna, Lucas, and Stansmore in 1972. Crossland, Mt Bannerman, Cornish, Dummer, Helena, and Webb were mapped by BMR and GSWA in 1973. Preliminary editions of Billiluna, Lucas, Stansmore, Dummer, and Webb 1:250 000 Sheets were available by September 1974. The Noonkanbah 1:250 000 Sheet was remapped by GSWA and BMR in 1974. BMR mapped the McDonald and Rawlinson Sheet areas in 1960 as part of a regional survey of the Amadeus Basin. Both Sheets are published at 1:250 000 scale with explanatory notes.

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GSWA mapped four Sheet areas (Nullagine, Port Hedland, Scott, and Bentley) in 1956-1957, 1960-1961, and 1966-1967 and they are published as 1:250 000 and 1:253 440 maps. In 1966 GSWA published 1:100 000 maps of the Devonian reef complexes and environs along the Lennard Shelf.

BMR and GSWA mapped Lansdowne, Mount Ramsay, Yampi, Warri, Cobb, and Lennard River between 1962 and 1964, 1966 and 1967, and in 1971. The Lennard River Sheet was published as a second edition. The remainder are published as 1:250 000 first editions or are issued as preliminaries.

The earlier mapping (before 1960) was based largely on airphoto-interpretation with only a few traverses. Remapping of these areas and new mapping is in progress by BMR and GSWA. The newer mapping at 1:250 000 scale is reliable and based on closer spaced traverses.

A 1:1 000 000 geological map (3 sheets) taking in the offshore part of the basin was published by BMR in 1973, after a marine survey in 1971.

Drilling

Seventy-five subsidized and unsubsidized petroleum exploration wells and 21 BMR stratigraphic holes have been drilled. An unknown number of water bores (some deeper than 300 m) have been drilled. Petroleum exploration drilling began in 1922 and the most valuable information is provided by the wells drilled after 1955. The greatest drilling depth reached so far is 4517 m below sea level. Most onshore wells were drilled on the Lennard Shelf, where Permian and Devonian sediments overlie Precambrian basement. Wells in the Fitzroy Trough penetrated predominantly thick sequences of Permian and Carboniferous sediments. Those on the western end of the Jurgurra Terrace and Broome Platform penetrated Cretaceous, Jurassic, Permian, and older Palaeozoic sediments. The deepest well in the Kidson Subbasin bottomed in Ordovician sediments (4431 m KB depth).

Offshore, one well bottomed in Palaeozoic sediments after passing through Cainozoic and Mesozoic sediments. The other well drilled offshore penetrated Cainozoic and Mesozoic sediments.

Much of the basin is covered by flat-lying Mesozoic and Permian strata and the wells together with seismic data provide the basis for understanding the subsurface geology.

Correlation

The sedimentary Basins Study Group of BMR has assembled draft basin-wide lithological and time correlations.

Aeromagnetic surveys

BMR and West Australian Petroleum Pty Ltd flew aeromagnetic surveys in 1962. A subdivision of the basin into structural provinces resulted from an interpretation of magnetic basement after these surveys. Eleven subsidized surveys were flown between 1963 and 1972. Two surveys indicated the offshore extensions of the structural provinces.

BMR carried out a marine survey in 1968 and produced a 1:2 543 400 map of total magnetic intensity contours.

Gravity surveys

BMR carried out five surveys between 1956 and 1963. One of the survey reports is accompanied by a 1:2 543 400 Bouguer anomaly map which covers most of the onshore part of the basin.

Twelve subsidized surveys were carried out between 1962 and 1967. Six were on a regional scale in the Lennard Shelf, Broome Platform, Willara Sub-basin, Kidson Sub-basin, and Gregory Sub-basin areas. Subsequent seismic interpretation showed that the so-called 'Munro gravity arch' was caused by intrabasement density contrasts, rather than elevation of basement. BMR carried out a marine gravity survey in 1968 and produced a 1:2 543 400 Bouguer anomaly map. The value of this information has not been adequately assessed.

Seismic surveys

BMR carried out nine surveys in the Fitzroy Trough and Broome Platform between 1953 and 1961. In 1968 BMR carried out a shipborne seismic, gravity, and magnetic survey covering most of the offshore area.

Eighty-five subsidized seismic surveys had been carried out in the basin by mid-1974. The quality of the record sections has improved with advances in recording and processing technique and type of energy source used. In general the data gathered before 1968 is poor and of little value in regional interpretation.

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Forty of the 69 onshore surveys were completed in the six years from 1968 to 1973, the best coverage being on the Lennard Shelf. The Broome Platform and Jurgurra Terrace are well covered by regional seismic traverses, but regional coverage of the eastern and southwestern margins, the Crossland Platform, Kidson Sub-basin and Gregory Sub-basin is inadequate.

Offshore, record quality improved with the advent of the Aquapulse and Maxipulse energy sources. Regional coverage is good. Stratigraphic control of horizons is derived from seven offshore wells - five within the basin and two just to the north - and onshore ties with two wells.

The data gathered since 1968 is generally of good quality, especially offshore, and sufficient in most areas to enable basin evaluation to be carried out.

Economic geology

Petroleum: Meda No. 1, on the Lennard Shelf, produced 850 MCF/D gas during a 2.5 hours test in 1958. The reservoir rocks consisted of recrystallized Upper Devonian calcarenite. In the same well, Lower Carboniferous sandstone (DST 9) yielded 14 litres of 37.8^{o} API gravity oil. In 1965, Lower Carboniferous sandstone in St George Range No. 1 (Fitzroy Trough) yielded a flow of 2.9 MCF/D between 3150 and 3280 m.

In Mimosa No. 1 (1973) on the Lennard Shelf a thick Upper Devonian potential source-rock section containing significant gas shows, oil-staining, and fluorescence was intersected below 2376 m. Minor gas shows, oil-staining, and fluorescence were indicated in Mt Hardman No. 1 (1973) at the northern margin of the Fitzroy Trough, but the Lower Carboniferous target formation was of low porosity and permeability. A minor oil show was recorded in Thangoo No. 2 (1973) on the Broome Platform, in a thin Lower Permian sandstone bed.

Potential source rocks include Ordovician shale, Devonian shale (predicted), Carboniferous, Permian, Triassic, Jurassic, and Cretaceous shale. The Cainozoic is presumably too shallow to have generated hydrocarbons, but includes potential cap rocks.

The most likely reservoir rocks include Ordovician dolomite, Devonian carbonates, Carboniferous sandstone, Lower Permian sandstone, Triassic sandstone, possible permeable sandstone within the Jurassic deltaic sediments, and Neocomian sandstone.

The Ordovician to Upper Triassic sediments are folded, particularly in the Fitzroy Trough, and anticlinal traps exist onshore and offshore; a number of traps have been unsuccessfully drilled.

The Upper Triassic to Recent sediments dip offshore at gentle angles over large areas and contain few anticlinal or fault traps. On the Bedout 'High', where closure has been unsuccessfully tested, the sediments appear to be draped over a fault block. Fault-controlled anticlines near the margin of the Leveque Shelf and in the Rowley Sub-basin have been tested by Lacepede No. 1A and East Mermaid No. 1. There are numerous pinchouts beneath disconformities, however, and these may form stratigraphic traps. Other stratigraphic trap possibilities, owing to facies change, occur in the Ordovician on the eastern margin of the basin, in the Neocomian offshore, and in the Devonian along the boundary zone between the Lennard Shelf and the Fitzroy Trough.

The area is large and has not yet been adequately evaluated. Petroleum prospects appear moderate. Improved seismic data and coverage, obtained in recent years, should allow better drilling targets to be selected in the future.

Underground water: Artesian aquifers have been penetrated in oil exploration wells and bores in the coastal area between Broome and Port Hedland and in the valley of the Fitzroy River. The best aquifers are sandstones within the Permian, Jurassic, Cretaceous, and Cainozoic sediments.

Evaporites: Halite has been drilled in Frome Rocks No. 1 and an evaporitic sequence occurs in the subsurface of a large area of the basin. The shallowest halite was penetrated at 650 m in McLarty No. 1 on the Broome Platform.

Lead-zinc: Two deposits of lead-zinc-silver ore, chiefly sulphides, occur in the fore-reef facies of Upper Devonian rocks at Narlarla, near Barker Gorge, in the northwestern part of the Lennard River Sheet area. Both deposits have been mined.

Recent activities

Six subsidized wells - two of them offshore - and one unsubsidized offshore well were drilled in 1973. One unsubsidized offshore well was drilled in 1974. Thangoo No. 2 was drilled on the Broome Platform, and Mimosa No. 1 and Mount Hardman No. 1 near the boundary between the Fitzroy Trough and the Lennard Shelf. Contention Heights No. 1 proved that the subsurface Ordovician and Devonian section

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of the Kidson Sub-basin extends to the present southeastern edge of the basin. Offshore, Kerandren No. 1 was drilled in the Bedout Sub-basin and Wamac No. 1 in the northwesterly extension of the Fitzroy Trough; both were subsidized wells drilled in 1973. Dolerite sills of minimum early Triassic age were intersected in Wamac No. 1, leading to abandonment of the well short of the target, a seismically-defined Palaeozoic 'high'. A reappraisal is now required of other Palaeozoic structures in the area. Keraudren No. 1 tested the centre of the Bedout Sub-basin; it proved a Middle to Upper Triassic sequence at least 1384 m thick containing thick porous sandstones, and a probable unconformity in the Upper Jurassic, further supporting the importance of late Jurassic diastrophism in this area. In 1973 a fault-controlled anticline was tested by an unsubsidized well (E. Mermaid No. 1) near Mermaid Shoal in 388 m of water. Minilya No. 1, also unsubsidized, was drilled in 1974 off the northern end of the North Turtle Arch.

Except for Mimosa No. 1, Mount Hardman No. 1, and Thangoo No. 2, no other wells drilled in 1973-4 contained hydrocarbon shows.

Nine subsidized seismic surveys (one of them offshore) were carried out in 1973. One offshore combined seismic and magnetic survey, also subsidized, was carried out in 1973, and another in 1974.

The most significant onshore seismic survey carried out recently was the Thornton seismic survey for Associated Australian Resources. This was a survey of 673 km in the southeastern part of the Canning Basin in 1973-74. Data ranging from poor to good gave a general outline of the structural and stratigraphic relations of the area on three mapped horizons tentatively identified as: Grant Formation, Carribuddy Formation, and basement. Several structurally elevated areas of interest were indicated. Some of these are thought to represent reefs at the Carribuddy level. The other onshore seismic surveys were done for WAPET. These were mostly small surveys aimed at detailing structural leads indicated by previous work.

The Mermaid-Cartier seismic survey for BOC of Australia included work in the outer offshore portion of the Canning Basin in 1973. Poor to fair quality data allowed mapping of four horizons from the base of the Tertiary to beneath the base of Mesozoic unconformity, although the deepest horizon may not be completely reliable. Two extensive structurally elevated trends were detected: along the Leveque Margin structural trend and along the edge of the continental shelf. Some regional faults were detected in the south, but generally the area (Rowley Sub-basin) has been shown to be a basin of low tectonic activity. The results of the subsidized offshore seismic survey done in June 1974 were not available at the time of writing.

Exploration companies have recently diamond-drilled prospective areas of Devonian limestone on the Lennard Shelf for lead and zinc, and are investigating the coal potential of the basin. The Sedimentary Basins Study Group of BMR is studying the basin. The Noonkanbah 1:250 000 Sheet area was remapped by BMR and GSWA in 1974 as part of a remapping program designed to cover the entire basin by 1979. The Geological Branch of BMR has recently completed a detailed sedimentological, stratigraphic, and geochemical study of the Devono-Carboniferous Fairfield Group on the Lennard Shelf.

In 1973-4, BMR, in conjunction with the Division of National Mapping's bathymetric survey in the offshore Canning Basin area, recorded total intensity magnetic data along northwest lines 3000 m apart. The magnetic data is only available as charts. Preliminary analysis indicates that the broad-scale pattern is similar to that shown by the wide-spaced survey by BMR in 1968. However there is considerably more detail available, particularly in the low-amplitude anomalies (10-50 gammas).

Deficiencies in geological knowledge

Remapping of Permian strata in the Mid-Basin Platform would provide better stratigraphic control for seismic ties. Deep stratigraphic drilling is needed to clarify the relation between the Devonian Babrongan Beds and the underlying sediments on the Jurgurra Terrace. There are few seismic ties between onshore and offshore areas, and the extent of Ordovician to Permian strata offshore cannot yet be reliably determined.

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CAPRICORN BASIN

The Capricorn Basin is a narrow northwesterly trending half-graben beneath the Capricorn Channel, offshore from Queensland. It covers an area of at least 32 000 km^2 and contains up to 3000 m of Mesozoic to Cainozoic sediments.

To the northeast the basin is separated by normal faults from the Swain Reefs High, which is an area of shallow Palaeozoic? basement overlain by undated volcanic rocks. To the southwest the basin is separated from the Maryborough Basin by the Bunker-Capricorn High, which is an area underlain by Mesozoic Volcanics. The southeasterly extent of the basin beyond the 200 m bathymetric contours is unknown.

Up to 400 m of Upper Jurassic to Lower Cretaceous conglomerate and volcanic rocks are preserved unconformably on Palaeozoic? basement in the southeastern portion of the basin, near the edge of the continental shelf.

At least 900 m of Upper Cretaceous non-marine to shallow marine sandstone, shale, and conglomerate unconformably or disconformably overlie these sediments.

At least 600 m of lower Tertiary, initially shallow marine followed by deltaic, paralic, and restricted marine, unconsolidated shale, lignitic shale, sandstone, and minor anhydrite, unconformably? overlie the Upper Cretaceous sediments.

The lower Tertiary sediments are overlain disconformably by at least 1200 m of Miocene to Recent marine unconsolidated marl, limestone, claystone, and calcisiltite.

Early in the basin's history the Upper Jurassic to Lower Cretaceous sediments within the Capricorn Basin were probably continuous with those in the Maryborough Basin. The present form of the Capricorn Basin was initiated in the Early Cretaceous by block-faulting, and continued downfaulting allowed the Upper Cretaceous and the thick Tertiary sediments to be deposited between the Bunker-Capricorn High and the Swain Reefs High.

Geological mapping

BMR mapped superficial sediments in the area during a marine geological reconnaissance in 1970.

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Correlation

There is insufficient data on which to base basin-wide lithological or time correlations.

Drilling

Two subsidized petroleum exploration wells were drilled in 1967 and 1968 by Australian Gulf Oil Company in the central and eastern part of the basin; both were plugged and abandoned with no shows of hydrocarbons. The first well, Capricorn No. 1A, penetrated a predominantly marine Tertiary sequence lying unconformably on Cretaceous? volcanics, which were penetrated from 1575 m to total depth at 1682 m. The second well, Aquarius No. 1, penetrated a predominantly marine Tertiary sequence to 1675 m. This rests unconformably? on non-marine conglomerate and claystone which was penetrated to 2601 m. The well was abandoned at 2608 m in slightly metamorphosed Palaeozoic? shale.

Humber Barrier Reef Oils Pty Ltd drilled Wreck Island No. 1 on the Bunker-Capricorn High, on the western margin of the basin at Wreck Island in 1959. The well penetrated Tertiary sediments to 547 m and volcanic breccia from 547 m to total depth at 578 m.

Aeromagnetic surveys

The whole of the Capricorn Basin is covered by parts of two large regional subsidized aeromagnetic surveys.

The first survey was flown for Australian Oil and Gas Corporation Limited in 1962. The data were extremely poor and indicated fairly shallow depths to magnetic basement in part of the Capricorn Basin. The magnetic anomalies on which the depth estimates were made may be due to volcanics within the sedimentary sequence.

The second survey was flown for Australian Gulf Oil Company in 1964. Interpretation of good quality data indicated that magnetic basement lies at depths of between 3000 and 4500 m, with the deepest portions occurring south of Swain Reefs.

The eastern margin of the basin was covered by BMR during the continental margin survey in 1972.

Gravity surveys

In 1958 and 1959, BMR carried out a limited number of regional gravity readings in the Capricorn Basin, includ-

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ing two east-west traverses. Local anomalies thought to be due to features in Palaeozoic rocks were observed near the coast. Seawards, an easterly rise in gravity which culminated near the reef islands of the Capricorn and Bunker Groups was observed. There was a decrease in gravity eastwards from the reefs. This is consistent with the hypothesis that the reefs have grown from a basement ridge with positive gravity expression.

The 1972 BMR continental margin survey covered the eastern edge of the basin. Some interpretation of data from this survey by J.C. Mutter will shortly be available as a BMR Record.

Seismic surveys

Two subsidized seismic surveys were shot in the Capricorn Basin and the adjacent Maryborough Basin by Australian Gulf Oil Company in 1965 to 1966. Overall the data quality was good and a fairly reliable interpretation can be made.

The first survey, Swain Reefs seismic survey, was a reconnaissance line, 640 km of which covered the Capricorn Basin. The survey indicated that 2400 m of possible Tertiary sediments overlies basement.

The second survey, Capricorn Channel marine seismic survey, also known as Swain Reefs Seismic Project Phase II, was a detailed follow-up survey shot on a 7.4 km grid, covering a total of 604 line-km. The interpretation indicates an embayment, open to the southeast, that contains from 1500 to 2500 m of sediments. Two horizons were mapped, upper Tertiary and base of Tertiary. The upper horizon is continuous and smooth, whereas the lower horizon is generally sharply undulating and broken. One prominent fault was found and a large area in which reef growth may have occurred was outlined to the east of the basin.

The eastern margin of the basin was covered by BMR during the continental margin survey in 1972.

Economic geology

Petroleum: No indications of petroleum were discovered in any of the wells drilled. All zones of interest are water saturated, and the water generally has a high salinity. Much of the sequence penetrated in Aquarius No. 1 contains excellent reservoir rocks. With the exception of the uppermost Recent reef limestone the sequence is predominantly unconsolidated to poorly consolidated. No typical source rocks were penetrated. A thick reddish-brown claystone between 1698 and 2433 m that was more indurated and partly greyish in colour in the lower half may indicate source beds nearby. The anhydrite layer in Aquarius No. 1 might provide a cap rock.

Aquarius No. 1 drilled a velocity anomaly arising from a shallow reef, rather than a valid structural high. There are possible folds within the Cretaceous sediments. Insufficient work has been carried out to properly evaluate the area's petroleum prospects.

Recent activities

There has been no petroleum exploration activity in the Capricorn Basin since Aquarius No. 1 was drilled in 1968 and BMR carried out the geophysical survey in 1972. A BMR Bulletin on the mrine geology of the Capricorn Channel area was with the editor in September 1974.

Deficiencies in geological knowledge

The major deficiency is lack of well data.

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CARNARVON BASIN

The Carnarvon Basin covers 110 000 km^2 onshore and 190 000 km^2 offshore to the edge of the continental shelf in Western Australia. The basin contains Palaeozoic, Mesozoic, and Tertiary sediments resting on a sedimentary, metamorphic, and igneous basement.

Onshore the eastern margin is either a sedimentary onlap onto or a faulted contact with rocks of the Precambian shield. It continues offshore along the subsea outcrop of the unconformable or faulted contact between basin sediments and Precambrian rocks. The boundary continues northwards along the crest of the North Turtle Arch and then arbitrarily due west along latitude 18°30'S to the edge of the continental slope. In the east-southeast the Yandi-Madeline Hinge separates the Carnarvon Basin from the Perth Basin. The margin continues along the northwestern side of the Northampton Block and offshore along the Hardabut Fault.

Onshore the basin contains a number of sub-basins separated by so-called ridges based on gravity and aeromagnetic interpretation. The sub-basins are the Gascoyne, Merlinleigh, Bidgemia, Exmouth, and Onslow. Part of this terminology has been revised by West Australian Petroleum Pty Ltd. The ridges are the Ajana, Wandagee, Carrandibby, Weedara, Bullara, and Yanrey.

Several faults (called hingelines) were recognized (on seismic sections) along the margins of the gravity and aeromagnetic ridges. They are: the Yandi-Madeleine Hinge (on the eastern side of the Ajana and Carrandibby Ridges); the Mooka Hinge (on the eastern side of the Wandagee Ridge); and the Learmonth Hinge (on the western side of the Bullara Ridge).

The three sub-basins offshore (other than the offshore extensions of the Exmouth and Gascoyne Sub-basins) are the Barrow, Dampier, and Beagle Sub-basins. The three sub-basins are a major Mesozoic downwarp. There is no marked structural boundary between the Barrow and Dampier Sub-basins, and the De Grey Nose only partly separates the Dampier Sub-basin from the Beagle Sub-basin.

The Enderby Fault Zone separates an area of thick Mesozoic sediments in the west from an area of thinner Mesozoic sediments to the east.

The Rankin Platform, a northeast-trending series of horst blocks forms the western boundary of the Beagle, Dampier, and Barrow Sub-basins. It consists of Upper

Triassic and in places thin Lower Jurassic block-faulted sediments unconformably overlain by Cretaceous and Tertiary sediments.

Archaean metasediments of the Pilbara Block, Lower Proterozoic sediments of the Hamersley Basin, Carpentarian granite and metamorphics of the Gascoyne Block, Adelaidean outliers from the Bangemall Basin, and gneisses of the Yilgarn Block occur along the eastern side of the onshore Carnarvon Basin from north to south, respectively. An Adelaidean granulite inlier (Northampton Block) lies between the Carnarvon and Perth Basins.

The maximum aggregate thickness of sediment in the Carnarvon Basin may exceed 20 000 m, although the maximum thickness at any one place is probably not more than 11 000 m.

The oldest sediments are up to 6200 m of Ordovician and Silurian non-marine? red sandstone unconformably overlying Adelaidean granulite in the southern part of the Gascoyne Sub-basin. Similar sediments have been drilled in the Merlinleigh Sub-basin.

Up to 740 m of Silurian marine and evaporitic dolomite, limestone, halite, shale, anhydrite, and claystone conformably overlies the Ordovician to Silurian sediments in the Gascoyne and Merlinleigh Sub-basins.

Devonian rocks consisting of up to 1400 m of deltaic sandstone overlain by marine calcarenite, calcilutite, siltstone, quartz sandstone, and conglomerate unconformably onlap Precambrian rocks on the eastern margin of the Merlinleigh and Bidgemia Sub-basins. The nature of the contact with underlying Silurian sediments in the subsurface is uncertain. Pendock ID No. 1 (offshore portion of Gascoyne Sub-basin) penetrated 742 m of Devonian sediments, including over 300 m of reef complex.

Carboniferous sediments overlie the Devonian sediments in the Gascoyne, Merlinleigh, and Onslow Sub-basins. The nature of the contact is uncertain; it may be an unconformity or a disconformity. The sediments consist of up to 880 m of marine calcarenite, cross-bedded sandstone, siltstone, and conglomerate overlain by marine pebbly sandstone with minor interbeds of oolitic calcilutite.

Permian sediments rest with major regional angular unconformity on Palaeozoic and Precambrian sediments and on Precambrian crystalline rocks. They are present in all the onshore sub-basins, but are absent or thinly developed on the basement ridges. Up to 4600 m of sediments crop out along the eastern margin of the basin. They consist of 2400 m of marginal marine sandstone with glacigenic deposits, and are disconformably and unconformably overlain by marine Lower Permian quartz sandstone and minor siltstone. The only Permian rock known offshore is a rhyolite penetrated at total depth in Enderby No. 1 in the Dampier Sub-basin.

The Triassic sediments, over 1240 m thick in places, occur in the Exmouth and Dampier Sub-basins, on the Rankin Platform, and on the Pilbara Shelf. The lower part of the sequence consists of marine shale, and the upper part of interbedded fluvio-deltaic sandstone and claystone.

Interpretation of seismic records indicates that up to 3000 m of sediments of probable Jurassic age is present in the Dampier and Beagle Sub-basins. Jurassic rocks are also present in the Gascoyne, Dampier, Exmouth, Barrow, and Onslow Sub-basins, where they conformably and disconformably overlie Triassic and unconformably overlie Permian rocks. 3400 m of marine shale and siltstone were penetrated in Cape Range No. 2, and deltaic sandstone, siltstone, claystone, minor coal and lignite are present elsewhere.

Marine Cretaceous sediments crop out onshore in all sub-basins except the Bidgemia Sub-basin, and occur in the offshore sub-basins. The sequence consists of sandstone, siltstone, claystone, shale, calcilutite, and marl. Cretaceous marine beds up to 1290 m thick conformably and unconformably overlie Jurassic sediments and unconformably overlie Triassic rocks on the Rankin Platform.

Tertiary rocks at least 2380 m thick conformably and unconformably overlie Cretaceous sediments in the Exmouth, Barrow, Dampier, and Beagle Sub-basins. The sediments, which thicken regionally westwards (seawards), consist of marine clastics overlain by carbonates.

Quaternary deposits are largely coastal calcareous eolianite and marine carbonates.

The sediments have been faulted and folded over large areas late in the Carboniferous or early in the Permian. Extensive faulting broke the area up into the sub-basins. The Yandi-Madeleine and Mooka Hinges were active during Palaeozoic sedimentation; the Learmonth Hinge, in the northeast, was active during the Mesozoic. The major folds in the Carnarvon Basin are the sub-basin downwarps and the anticlinal drapes over the basement ridges and over faulted horst blocks. The Rankin Platform, a northeast-trending series of horst blocks, probably developed in the Jurassic. Several anticlines in the Gascoyne, Exmouth, and Barrow Sub-basins formed in the late Tertiary to Pleistocene.

Geological mapping

Two 1:500 000 geological maps cover the whole onshore part of the basin; they were issued after BMR mapping between 1948 and 1956. First edition 1:250 000 maps covering eight Sheet areas were published with explanatory notes after mapping by GSWA, West Australian Petroleum Exploration Company, and BMR in 1949, 1953, 1955, 1959, and 1962, 1964.

The quality of the mapping varies from detailed traversing in the Cape Range area to largely airphoto-interpretation with some traversing in the remaining areas.

Drilling

172 petroleum exploration wells (including 42 subsidized wells) and five BMR stratigraphical test wells have been drilled. The first was drilled in 1934; 52 between 1953 and 1960; and 119 between 1961 and September 1974.

Most wells were drilled onshore in the Cape Range area and in the northern offshore part of the basin. Only a few wells have been drilled in the southern part of the onshore basin.

Onshore, the wells in the Onslow Sub-basin penetrated Miocene and Cretaceous sediments which unconformably overlie eroded block-faulted Triassic and or Palaeozoic sediments. The sequence penetrated in the Exmouth Sub-basin included Tertiary, Cretaceous, Jurassic, and Permian rocks. In the Barrow Sub-basin, wells have bottomed in the Jurassic after penetrating Tertiary and Cretaceous sediments. In the Dampier Sub-basin, wells have penetrated Tertiary, Cretaceous, and Jurassic sediments. On the Rankin Platform, wells have bottomed in Upper Triassic sediments after penetrating the Tertiary, Cretaceous, and Jurassic sediments.

The offshore wells, in particular, have identified seismic horizons and have provided a much better understanding of the geology.

Correlation

Condon produced a lithological correlation between wells drilled before 1965. Time data in the palaeontologic-

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al appendices of well completion reports can be used for time correlation.

Aeromagnetic surveys

BMR flew a reconnaissance survey over part of the basin in 1960. Three subsidized surveys flown offshore between 1965 and 1969 indicated shallow basement (Bernier Platform) in the Gascoyne Sub-basin and deep basement in the offshore extension of the Onslow Sub-basin.

Gravity surveys

BMR conducted regional gravity surveys onshore in 1969, 1971, and 1972. Published 1:250 000 Bouguer anomaly maps are available for the area north of latitude 24°S, and preliminary maps are available for the area to the south. Published 1:500 000 maps are available for the whole of the onshore basin. A BMR marine gravity survey in 1968 outlined a large area of positive Bouguer anomalies over the Rankin Platform. Only two subsidized gravity surveys have been carried out in the basin; both were carried out in the south and helped delineate the Ajana-Wandagee Gravity Ridge between the Coolcalalaya and Gascoyne Sub-basins. One was detailed, gravity being measured on a 0.5 by 0.5 mile grid.

Seismic surveys

BMR carried out five seismic surveys between 1954 and 1967. Forty-seven subsidized seismic surveys were carried out in the basin to the end of 1973. The pattern has shifted from predominantly onshore surveying before 1968 to mainly offshore surveying since 1968.

A large proportion of the twenty-three onshore surveys was carried out in the Gascoyne and Exmouth Sub-basins, whereas only two surveys were carried out in the Merlinleigh Sub-basin. Generally an explosive source (dynamite) gave fair results whereas the weight-drop method gave poor results. Most surveys produced fair to good-quality records onshore, but most of the surveying is local and ineffective for regional control.

Offshore record quality has generally been good, and has improved with the advent of the Aquapulse energy source in 1968 and the Maxipulse energy source in 1970. Most surveys were carried out in the northern offshore sub-basins, where they provided good regional control as well as considerable detail on the Rankin Platform.

Economic geology

Bentonite: Bentonite clay occurs interbedded with siltstone in the Lower Cretaceous rocks along the exposed axial region of the Giralia-Cardabia anticline in the northern part of the Gascoyne Sub-basin. The clay and siltstone beds are estimated to be 112 m thick.

Gypsum: Three million tonnes of gypsum per vertical foot, with a grade ranging from 79 to 98 percent, were estimated in a playa lake near Boologooro in the southern part of the Gascoyne Sub-basin.

Coquinite: Recent and Pleistocene coquinite, containing up to 99.86 percent calcium carbonate, occurs at Hamelin Pool. The deposits have an average width of 0.8 km and a thickness of 6 m.

Radiolarite: The Lower Cretaceous radiolarite is an almost pure silica rock of low density, high porosity, moderate permeability, and fine grain, which has many uses. It crops out in the central part of the Giralia Anticline, in the low scarps west of Winning Pool, in mesas in the southeastern parts of Winning and Mia Mia stations, along the west side of Kennedy Range, and from the Gascoyne River near Winnemia to near the southern boundary of Jimba Jimba station.

Petroleum: Petroleum was first discovered in 1954 in the Rough Range Anticline, when 500 BOPD was tested from the basal Cretaceous sandstone.

In 1964, a Jurassic mudstone in the parallel Cape Range Anticline proved to be gas-productive. The Barrow Island oil/gas field, which was discovered in the same year, was producing at an average rate of 42 000 BOPD in the last quarter of 1972. Total reserves remaining in Barrow Island field to 30/6/72 were 130.04 million barrels of oil and 2.3 billion cubic metres (81 000 MMCF) of gas.

Legendre No. 1, in the Dampier Sub-basin, established the presence of 600 m net of potential Jurassic and Lower Cretaceous reservoir sandstone in 1968. Seven metres of the Lower Cretaceous sandstone below 1890 m provided a maximum flow of 1014 BOPD of 44.7° API gravity oil on testing. The Middle and Upper Jurassic sandstone contained thick asphaltic bitumen veins. The predominance of odd-numbered carbon atoms in n-alkanes indicates that the sediments are too immature to constitute good source material. However, Jurassic sediments in Madeleine No. 1 are excellent source rocks, having a high proportion of saturated hydrocarbons to total soluble organic constituents.

North Rankin No. 1 was suspended as a gas/condensate discovery in 1971. A gross hydrocarbon column of 830 m was indicated (2420-3250 m) within the basal Tertiary, Upper Cretaceous, and Upper Triassic sediments in the well. The basal Tertiary sandstone (18 m) and Upper Cretaceous calcilutite (110 m) lacked significant permeability, but 310 m of net Upper Triassic sandstone pay with porosities up to 28 percent and permeabilities up to 2200 md were proved. The presence of up to 300 000 million cubic metres (10 trillion cu. ft) of recoverable gas in the proved, probable, and possible categories has been indicated in the drilling of three follow-up wells (North Rankin Nos. 2, 3, and 4). Condensate production from the various drill stem tests of Triassic strata ranged from 27 to 37 bbls per MMCF.

Rankin No. 1 and Goodwyn No. 1 encountered gas/ condensate accumulations in Upper Triassic sandstone in 1971. Rankin No. 1 also encountered a thin oil column. DST No. 1, over the interval 2952-2954 m in Rankin No. 1, produced 1062 BOPD of 34^{o} gravity oil with 309 000 m^3 per day (10.91 MMCF/D) of gas and some water through ½-inch top-hole and 5/8-inch bottom-hole chokes. DST No. 2, over the interval 2932-2938 m, produced gas at the rate of 452 000 m^3 per day (15.96 MMCF/D) with 650 bbls per day of condensate through 5/8-inch top-hole and bottom-hole chokes. The maximum flow of gas recorded in Goodwyn No. 1 was 323 000 m^3 per day (11.4 MMCF/D) plus 490 bbls per day condensate through a 5/8-inch top-hole choke and a 3/8-inch bottom-hole choke.

Angel No. 1, drilled in the Dampier Sub-basin in late 1971 and early 1972, encountered hydrocarbons in Upper Jurassic sediments. A flow of 374 000 m^3 per day (13.2 MMCF/D) of gas and 685 BOPD of condensate through 5/8-inch bottom-hole and top-hole chokes were recorded.

The first discovery of heavy oil (29.3^{o} API) in considerable quantity in Australia was reported in 1972 during the drill-stem testing of Eaglehawk No. 1 on the Rankin Platform. The well flowed oil at 1645 BOPD and gas at 11 600 m^3 per day (0.41 MMCF/D) during one test.

A company estimate of the recoverable gas in the Rankin Platform of 500 000 million m^3 (20 trillon cu ft) was based on wells and seismic work completed at the end of 1972. No figures have been published to date for offshore oil reserves.

Recent activities

The basin has been actively explored, mainly offshore in the northern sub-basins. In late 1972 to early 1973 a large subsidized marine seismic survey (Steamboat-Spit seismic) was done for BOC of Australia. Four horizons

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from the base of the Tertiary to the Jurassic were mapped. A considerable number of structures were explored and some of these were indicated as drillable prospects. In 1973 a smaller subsidized marine seismic survey (De Grey Nose seismic) was also done for BOC. Fair-quality data were obtained where basement was fairly shallow on the De Grey Nose structure, but record quality deteriorated where basement plunges rapidly to the northwest along a northeast-southwest hingeline. Some known structures were downgraded as a result of the new data, but, in the extreme northeast part of the area, indications were obtained of a large structural-stratigraphic trap warranting further investigation.

In 1973 three small subsidized onshore seismic surveys were done for WAPET, one on Barrow Island and two near the coast in the North West Cape area. These surveys provided more detailed information on previously known structures.

Thirteen wells (7 subsidized) were drilled in 1973, and five (2 subsidized) were drilled to September 1974. The recent wells in the various sub-basins are as follows:

Rankin Platform: Egret No. 1 (1973), the only recent subsidized well on the platform, brought to light the first occurrence of oil here in Upper Jurassic sediments. Oil of 39° API flowed at 2729 bpd in a drill stem test of the interval 3119-3129 m. Lambert No. 1 (1974), drilled 20 km to the northeast, was completed as a potential oil producer (374 bpd, 51° API). Dockrell No. 1 (1973), 80 km southwest of Lambert No. 1 and near Rankin No. 1, is a potential gas, condensate, and oil producer. Goodwyn No. 3 (1973) discovered both gas and oil (2730 bpd, 41.7° API from 3014 to 3025 m), and Goodwyn No. 4 (1973) is a potential gas-condensate producer. No indications of hydrocarbons were reported in Lowendal No. 1 (1974), 20 km southwest of Dockrell.

Dampier Sub-basin: Rosemary No. 1 (1973), the only recent subsidized well, was drilled at the southwestern end of the Rosemary-Legendre Trend. Potential reservoirs and high gas readings were obtained in Upper Jurassic sandstone, but all zones proved to be water-bearing. Angel No. 3 (1973) was a gas-condensate discovery. Nelson Rocks No. 1, drilled at the northeastern end of the Rosemary-Legendre Trend, was dry. A small gas flow was obtained from a shallow depth in Hampton No. 1 (1974), drilled near Enderby No. 1 near the southeastern edge of the basin, only 40 km from the coast.

Beagle Sub-basin: Ronsard No. 1 (1973) drilled on an outer platform (Ronsard-Picard Trend) analogous to the Rankin Platform, penetrated a sequence similar to that predicted,

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but encountered no significant hydrocarbon shows. Depuch No. 1 (1974), drilled deep (4300 m) 75 km to the northeast on the same trend, was also dry. The third recent well (Poissonnier No. 1, 1973) drilled 50 km east-southeast of Depuch, just west of the North Turtle Arch, was unsubsidized; it too was dry.

Barrow Sub-basin: West Tryal Rocks No. 1 (1973), about 85 km southwest of Dockrell No. 1 on an extension of the Rankin Trend, encountered hydrocarbon shows from 90 m of possible hydrocarbon pay in an Upper Triassic/Lower Jurassic sandstone. Barrow Deep No. 1 (1973) tested the sequence below the Upper Jurassic and Cretaceous oil-producing horizons on Barrow Island. Drilling was abandoned at 4877 m (16 000 ft) in Middle Jurassic strata when the well entered an overpressured zone. Bottom-hole temperature was 350°F. Seismic work has indicated a total thickness of about 4500 m of Jurassic sediment in the area; this, plus the new information from Barrow Deep, shows that pre-Jurassic rocks must lie deeper than 6600 m. Hilda No. 1 (unsubsidized 1974) was drilled to test the Triassic 80 km west-southwest of Barrow Island, on the southwestern flank of the sub-basin. Mechanical difficulties forced abandonment in May 1974 at 1546 m; Hilda No. 1A was drilling nearby in September, 1974.

Gascoyne Sub-basin: Traces of gas were observed between 869 m and 911 m in Silurian strata in Tamala No. 1 (1973), which was drilled on the southern shore of Shark Bay. Results from this well throw doubt on the geophysical interpretation of the area, which must now be reappraised. Expected Mesozoic strata were absent, and a Silurian unit was penetrated some 900 m higher than predicted. Kalbarri No. 1 (1973), drilled some 90 km to the southeast, entered the Silurian unit about 1600 m higher than predicted. There were no shows of hydrocarbons in either well. Both wells were subsidized.

Deficiencies in geological knowledge

The major deficiency is lack of a basin study.

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CARPENTARIA BASIN

The Carpentaria Basin contains up to 1200 m of Mesozoic sediments covering an area of about 125 000 km^2 onshore, mainly in Queensland, and about 375 000 km^2 offshore in the adjacent areas of Queensland, Northern Territory, Iran Jaya, and Papua New Guinea; 345 000 km^2 offshore is within Australian jurisdiction.

In the north the basin connects with the Moreland Basin of the Papuan Basin across a broad shallow stable basement which has an irregular surface and stretches from the Cape York/Oriomo Ridge to Frederik Hendrik Island. In the west the basin is contiguous with the Money Shoal Basin across a similarly irregular basement which stretches from the Wessel Islands to Frederik Hendrik Island in Irian Jaya. Onshore the western margin is an unconformable contact between basin sediments and Adelaidean sediments of the Arafura Basin, and older Proterozoic sedimentary, metamorphic, and igneous rocks in the McArthur and South Nicholson Basins and the Mount Isa Geosyncline. The southern margin is the Euroka Arch, an elevated area of basement on which only the lower units of the Carpentaria Basin sequence occur. The irregular eastern margin is an unconformity between basin sediments and Precambrian metamorphics and Precambrian and Palaeozoic granite and volcanics, which form the Georgetown Inlier, the Yambo and Coen Inliers (Peninsula Ridge), and the Cape York/Oriomo Ridge. The Peninsula Trough, between the Coen Inlier and the Cape York/Oriomo Ridge, and the Olive River Basin (a local geophysical feature between the Coen Inlier and the Cape York/Oriomo Ridge) are not included in the Carpentaria Basin; and in this area the boundary lies a small distance west of the Great Dividing Range.

The few wells that have been drilled in the Carpentaria Basin have bottomed in Permian? tillite or tilloid sediments, dolomite of inferred Proterozoic age, Precambrian metamorphic rocks, and granite or unknown age.

The oldest onshore sedimentary rocks are Middle? and Upper Jurassic continental quartzose sandstone, and subordinate siltstone and conglomerate, up to 80 m thick. Up to 800 m of mainly marine Cretaceous sandstone, shale, limestone (in places phosphatic and bituminous), and coarse-grained sandstone conformably overlie the Jurassic sediments. Seismic interpretation suggests that the Mesozoic sediments, which possibly extend up into the Cenomanian, thicken to at least 1200 m offshore in the middle of the basin.

Tertiary freshwater clayey sand, gravel, and sandy clay, which are up to 200 m thick onshore in the Gilbert-Mitchell Trough, overlie the Lower Cretaceous disconformably. This essentially Cainozoic cycle of deposition (which occurred in two distinct episodes) may have begun in the latest Cretaceous. Pleistocene marine clay up to 8 m thick occurs locally in the offshore part of the basin.

The thickened Jurassic sediments are onshore in two separate shallow depressions in the south, and in the north near Weipa. Later strata are regional in extent, the greatest thickness (including Cainozoic sediments) having accumulated in the Staaten River Embayment, a broad depression trending northwest from the Georgetown Inlier to the gulf. A widespread regression in the Late Cretaceous resulted in erosion before deposition of the Tertiary beds. In late Tertiary times irregular uplift along the eastern margin of the Carpentaria Basin resulted in tilting and minor block-faulting. The Staaten River Embayment was downwarped to form the Gilbert-Mitchell Trough, regarded as a suprabasin, which was filled with late Cainozoic beds. The basin sequence is practically flat-lying except around the edges, which have been uplifted by several hundred metres.

Geological mapping

The Carpentaria Basin was mapped at 1:250 000 scale by BMR and the GSQ during the years 1969 to 1974. Sheet areas D54/15; E54/3, 6, 7, 10, 14, 15, 16 have been published with explanatory notes. Preliminary editions of D54/3, 4, 7, 8, 11, 12, 16, E54/1, 2, 4, 5, 8, 9, 11, 12, and F54/2 have been issued with BMR Records. Preliminary editions of C54/12, 15, 16 are in preparation, and will complete the coverage of the onshore part of the basin.

Earlier mapping of the margins is reported in BMR Bulletins 51, 84, and 135.

The geological mapping is up-to-date and good-quality regional. The mapping was undertaken in conjunction with a program of wireline logging of water bores. However, over much of the area outcrop of the flat-lying sequence is poor and there are few bores, limiting the value of the information obtained.

Drilling

Eight petroleum exploration wells have been drilled onshore - seven in the southern and one in the eastern parts of the basin. All reached pre-Jurassic basement at depths of about 800 m. The wells are valuable: they provide additional detailed information about the stratigraphy of the basin and confirm the stratigraphy predicted from outcrop.

Correlation

Lithological correlation has been achieved onshore by mapping, and the lithological units penetrated in the wells have been correlated. Cross-sections are intruded on all the geological maps. Most units have been dated by fossils, but no basin-wide time correlation is available.

Aeromagnetic surveys

Between 1962 and 1968 six major aeromagnetic surveys were carried out at the head of the Gulf of Carpentaria, on York Peninsula, and across and around the shores of the gulf by private companies. These surveys give very broad coverage over most of the basin. Depth to magnetic basement contours compiled by BMR agree roughly with basement contours from seismic surveys except that they are greater by about 1000 m in the centre of the gulf. Aeromagnetic basement is probably metamorphic basement, whereas seismic basement could be Proterozoic sediments.

BMR has published several 1:250 000 total magnetic intensity maps covering part of the margin of the basin.

BMR carried out a reconnaissance aeromagnetic survey over the Cloncurry, Westmoreland, and Georgetown 1:250 000 Sheet areas in 1973. Cape York Peninsula was expected to be completed in 1974 and the Red River Sheet area in 1975.

Gravity surveys

Gravity was measured over all the onshore part of the basin by BMR in 1964 to 1970 on an 11-km grid, and over the Gulf of Carpentaria by the US Naval Oceanographic office in 1967 on a line spacing of about 80 km in an irregular pattern. BMR has prepared 1:250 000 and 1:500 000 Bouguer anomaly maps of all the Queensland onshore area, and plans to cover the offshore area in 1975.

The Bouguer anomaly contours on land seem to reflect density variation in the crystalline basement, rather than the thickness of the sediments. The contours in the gulf show a smooth undisturbed pattern, suggesting that the sediments overlying the crystalline basement may be much thicker than the 1500 m estimated from seismic data.

Seismic surveys

In 1958, BMR carried out a series of seismic investigations in the coastal belt between the Nicholson River and the Mitchell River. The survey showed that the sediments gradually thickened to a maximum of about 1000 m in the southeast of the gulf, and that the east and west margins are not faulted. The sediments were shown to be practically horizontal in most places. Gravity anomalies did not correspond with basement relief, although the basement does have local irregularities. The sediments are faulted.

The Seripps Institute Argo Expedition in 1960 carried out refraction profiling in the north of the Gulf of Carpentaria. A 5600 m/s refractor at about 1500 m depth was interpreted as a Mesozoic/Cambrian interface, and a 6300 m/s refractor at 6000 m depth was interpreted as a Cambrian/Proterozoic interface.

In 1963 a survey covering about 362 line-km was made for Mid-Eastern Oil Pty Ltd over much of the onshore area in the southeastern part of the basin. The survey indicated about 1000 m of low-velocity sediments extending into the gulf to the north.

In 1964 a marine seismic survey of about 320 line-km was made for Farmout Drillers offshore from Gove. A strong reflector, interpreted as the top of Proterozoic basement, was overlain by up to 800 m of low-velocity Mesozoic sediments.

Marathon Petroleum Ltd carried out a marine seismic survey in 1964 in the western Torres Strait. The seismic basement was found to dip westerly from 600 m to 1200 m depth across the survey area.

Several traverses were made on Cape York Peninsula for Australian Aquitaine Petroleum Ltd in 1965. This survey showed that the Mesozoic sequence thickens with minor faults and undulations from zero in the east to 850 m at Weipa.

A marine seismic survey of about 1850 line km was made for Marathon Petroleum Ltd in 1966 in the northeastern part of the basin; it indicated a northerly trending trough filled with up to 1500 m of Mesozoic and Tertiary sediments.

Economic geology

Petroleum: The Toolebuc Formation (Albian) shows hydrocarbon traces in many water-bores, and the lower part is an oil shale. Traces of hydrocarbons have been obtained from Lower Cretaceous sandstone in the exploratory wells. The onshore potential of the basin is low, as the sediments are probably too thin to have generated hydrocarbons, although the younger mudstones in the sequence are potential source

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and cap rocks. The Mesozoic and Tertiary sediments are thicker offshore, but still may not be sufficiently thick to have generated significant quantities of hydrocarbons.

Water: Jurassic and Cretaceous sandstones are aquifers for artesian and subartesian water. More than a hundred bores tap the aquifers.

Bauxite: Cainozoic/lateritic bauxite covers over 1000 km^2 on the west coast of Cape York, and is mined at Weipa. 7 000 000 tonnes were mined in 1972.

Coal: Coal occurs in places in Middle and Upper Jurassic sediments, but no economic deposits are known.

Oil shale: Large reserves of low-grade oil shale occur in a Lower Cretaceous unit in the south where the Carpentaria Basin merges with the Eromanga Basin. The oil shale, which also contains vanadium (see below) has been investigated in the Julia Creek area by a consortium of private companies.

Vanadium: Analyses indicate that oil shale deposits in the Julia Creek area contain up to 0.5 percent vanadium by weight. Present indications are that the oil shale is more likely to be a by product of vanadium extraction.

Manganese: A large high-grade manganese deposit occurs in sediments of Early Cretaceous age on the western side of Groote Eylandt in the Gulf of Carpentaria, near the ill-defined western margin of the basin. The deposit is largely pisolitic and was formed syngenetically in a restricted marine or lagoonal environment in topographic depressions in the underlying Carpentarian sandstone.

The deposit is being mined by open-cut methods by Broken Hill Pty Ltd. The grade of metallurgical lump ore is 48 to 50 percent. Reserves have not been published but the deposit is stated to be of major international significance.

Recent activities

BMR is compiling a synthesis of the geological and geophysical information available. BMR plans a combined magnetic, seismic, and gravity survey over part of the offshore area in 1975.

Beaver Exploration Australia NL shot over 900 km of unsubsidized Aquapulse seismic survey in the northwestern part of the Basin in 1972.

Palynological and foraminiferal determinations of outcrop, well, and bore samples are being carried out at BMR and at the University of Queensland.

Deficiencies in geological knowledge

More subsurface information is necessary along the boundaries with the Money Shoal and Papuan Basins. Further drilling and seismic surveying will be required before the basin can be adequately evaluated. A separate, superimposed, Cainozoic sedimentary basin may be recognized in the area and its outline should be determined.

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CLARENCE-MORETON BASIN

The Clarence-Moreton Basin contains Triassic and Jurassic rocks covering an area of about 38 000 km^2 largely onshore in southeastern Queensland and northeastern New South Wales.

The basin is contiguous with the Surat Basin over the Kumbarilla Arch. The northeastern, southwestern, and eastern margins are exposed unconformable contacts between basin sediments and heterogeneous rocks of the New England Fold Belt. A small part of the eastern margin lies offshore.

All the sedimentary rocks were laid down in paludal, fluvial, and deltaic environments within an intermontane basin. The basal rocks consist of Middle to Upper Triassic conglomerate, coarse-grained sandstone, andesite, tuff, and thick coal measures (Ipswich Coal Measures); together totalling 1200 m in thickness.

Upper Triassic to Lower Jurassic Sandstone, siltstone, shale, and conglomerate up to 2000 m thick rest both unconformably and disconformably on the Upper Triassic beds. They are overlain conformably by up to 600 m of Middle Jurassic sandstone, siltstone, shale, and coal (Walloon Coal Measures).

Upper Jurassic to lowermost Cretaceous sandstone and siltstone, with minor conglomerate, limestone, and coal, with a total thickness over 600 m, rest conformably on the older Jurassic beds.

A few basalt flows and tuff beds occur within the sediments. The sedimentary rocks are intruded by a complex of Tertiary dykes, cone-sheets, and sills. Tertiary basalt flows cover a broad belt of country from the northwest corner of the basin to Cape Byron.

A zone of folding and faulting extends southward through the basin in line with the faulted eastern margin of the Esk Trough. Beds as young as the Tertiary have been deformed in this zone, beyond which the strata dip much more gently, most commonly at about 2° or 3°. There has also been considerable doming and dislocation of the rocks owing to large igneous intrusions. There are several normal faults, with displacements of up to 750 m, in the south of the basin.

Geological mapping

The whole of the Clarence-Moreton Basin was mapped at 1:250 000 scale between 1962 and 1969. Of the eight

1:250 000 Sheet areas, four have been published with explanatory notes and four have been issued as preliminary maps. In addition, selected areas of the Ipswich Coalfield have been mapped at 1:63 360 scale by GSQ, from whom dyeline copies of the maps may be obtained.

Drilling

About 55 petroleum exploration wells have been drilled since 1923, mostly in Queensland and mostly between 1950 and 1968. Targets were Jurassic and Triassic sandstone, and drilling commonly stopped when basal Triassic volcanics were encountered; very few wells penetrated into the Palaeozoic basement.

From 1968 to 1971, GSQ drilled 19 stratigraphic boreholes in the Ipswich Sheet area. The Triassic strata encountered were described as having poor source and reservoir characteristics.

One petroleum exploration well, Hogarth No. 4, was completed in June 1974 as a gas producer in the New South Wales part of the basin (TD 3850 m), and further step-out wells are planned.

Correlation

There is no lithological correlation of the basin as a whole. Much work of local significance has been done in lithological correlation in the coalfields of the Moreton Basin.

N.J. De Jersey, in numerous GSQ publications from 1960 onwards, has established palynological correlations in much of the Moreton Basin sequence.

Aeromagnetic surveys

The Clarence Basin (i.e. that part of the basin in New South Wales) has been covered by aeromagnetic surveys for the Australian Oil and Gas Corp. Ltd and for Mid-Eastern Oil NL in 1965. Total magnetic intensity contour maps do not reflect the structure of the Mesozoic rocks very closely, probably owing to masses of igneous rock of both Palaeozoic and Cainozoic age.

Gravity surveys

Gravity has been measured over the whole basin by BMR, and 1:250 000 and 1:500 000 Bouguer anomaly maps are available. The maps delineate the basin clearly (the 'Clarence Gravity shelf') and can be used as a guide to sedimentary thickness and structure, and to the disposition of igneous rocks.

Seismic surveys

A few short seismic traverses have been carried out in the Ipswich coalfield by Australian Oil and Gas Corp. Ltd, Phillips Petroleum Company, and Union Oil Development Corp., and in the northern part of the Clarence Basin by Mid-Eastern Oil NL, Clarence River Basin Oil Exploration Co. NL, and Alliance Petroleum Australia NL in 1964 to 1971. Most of the basin has not been surveyed. There are good reflecting horizons within and at the base of the Mesozoic sequence which, together with close geological surveying and numerous coal-bores, have allowed a fairly good interpretation of the basin to be made.

Economic geology

Petroleum: The Triassic and Jurassic coal measures are potential source rocks. There are several permeable sandstone beds that may act as reservoirs, and impermeable shale beds that may act as cap rock. The chief target has been a Lower Jurassic sandstone that has been correlated with the chief producing bed (Precipice Sandstone) of the Roma area. Domes constitute potential traps (e.g. Hogarth Dome in NSW).

Gas has been discovered in many wells, especially in NSW, but the yield has been low. Plans to supply gas from Hogarth No. 2 to the Dairy Co-operative in Casino were announced in 1973.

Coal: The Triassic coal of the Ipswich area is medium-volatile to high-volatile and bituminous with some coking types, but ash is generally high. Reserves are about 350 million tonnes. About three-quarters of the 2 000 000 tonnes annual production is obtained by shaft-mining, and one-quarter by open cut. Only one seam has been worked in New South Wales.

The Jurassic coal of the Rosewood area is perhydrous, very high-volatile, bituminous, and non-coking; ash is very high. Reserves are about 6 million tonnes, and production is small and declining. There has been only minor production in New South Wales.

Recent activities

Apart from the drilling of Hogarth No. 4 and activities arising from plans for local consumption of gas, no recent developments are known.

Deficiencies in geological knowledge

The geology of the basin is relatively well known. Least is known in the subsurface of the central Clarence Basin.

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COOPER BASIN

The Cooper Basin is a northeasterly trending Permian and Triassic basin entirely concealed beneath the Jurassic and Cretaceous sediments of the Eromanga Basin. It covers an area of about 100 000 km^2 in the northeast of South Australia and the southwest of Queensland.

The positions of the margins have been determined by geophysics. They are subcropping unconformable contacts with basement, except in the northeast where the basin connects with the Galilee Basin over the Cannaway Ridge, and in the southwest where a connexion with the Pedirka Basin is possible.

Basement rocks include those of the lower to middle Palaeozoic Warburton Basin, the middle Palaeozoic Warrabin Trough of the Adavale Basin, Carboniferous granite, and Proterozoic volcanics. In Queensland the basement is mainly low-grade metamorphics of probable Ordovician age.

The Cooper Basin contains up to 1300 m of non-marine Lower Permian to Lower Triassic sediments. At the base about 390 m of glacigenic sediments rest with angular unconformity on basement. These are overlain disconformably by about 330 m of interbedded sandstone, shale, siltstone, and coal (Gidgealpa Group). The upper beds consist of up to 570 m of Lower Triassic shale, sandstone, siltstone, and minor coal. The whole sequence was deposited in fluviatile, lacustrine, and deltaic environments.

Anticlines with hundreds of metres of relief are present over basement blocks. The Permian sediments onlap basement on the flanks, and some of the anticlines are bald-headed. Smaller folds are ascribed to differential compaction of thicker sediments in interblock depressions. Movements in the mid-Tertiary produced large dome-like structures in the overlying sediments of the Eromanga Basin, and some folding adjacent to faults.

Geological mapping

All twelve 1:250 000 sheet areas that cover the basin have been mapped by BMR, GSQ, and GSSA. Earlier mapping by R.L. Jack in the 1920s, and by Santos Ltd geologists in the 1950s, outlined about eight large anticlines in the overlying Mesozoic strata.

The seven 1:250 000 Sheet areas in Queensland have been published with explanatory notes. One Sheet area in South Australia has been published with explanatory notes and dyelines of three of the other sheets are available from GSSA.

The mapping is up-to-date and good-quality regional, but was restricted to the recognition of surface structure in the Eromanga Basin. This structure can be expected to extend, in modified form, into the underlying Cooper Basin, and it was the recognition of the structure that stimulated the further exploration of the region.

Drilling

About 113 petroleum exploration wells were drilled between 1959 and 1973. No drilling has been reported in 1974. The wells were concentrated mainly in South Australia, in the southwestern part of the basin, close to the border with Queensland. The wells all penetrated the sediments of the overlying Eromanga Basin. All the wells in Queensland were drilled to basement. Some of the wells in South Australia are drilled to basement and the others have reached total depth within the Permian glacigenic sediments.

The information from the wells is particularly valuable as the sediments of the basin do not crop out.

Correlation

A similar lithological sequence appears to fill the whole basin, and a similar broad lithological subdivision has been described in the wells drilled. Recently, however, a new and more detailed subdivision of the sequence has been introduced, and only the well completion reports for the most recent wells contain this terminology. BMR is preparing a regional stratigraphic assessment of the Queensland part of the basin.

Aeromagnetic surveys

The whole basin has been covered by subsidized surveys for private companies and by BMR.

A large part of the basin was covered for Delhi Australian Petroleum Ltd during surveys in 1961 and 1962, and the results are published (Delhi Australian Petroleum Ltd, 1965). Using data from these surveys GSSA has published 1:250 000 total magnetic intensity maps of the five Sheet areas that cover the basin in South Australia.

Philips Petroleum Company covered a small part of the basin in the northeast during a survey in 1959 to 1960.

BMR surveyed two Sheet areas in Queensland in 1968 and also flew several traverses across the basin. The surveys were valuable in that they indicated where thick sediments may occur beneath the cover of Eromanga Basin sediments. However, magnetic basement will lie below the floor of the Cooper basin where non-magnetic sediments of the Warburton and Adavale Basins are present.

Gravity surveys

All the basin has been covered by regional gravity surveys carried out either for private companies under the Petroleum Search Subsidy Acts or by BMR. All the data is available as contoured 1:250 000 and 1:500 000 Bouguer anomaly maps.

Interpretation of a gravity traverse in 1947 first suggested the presence of a sedimentary sequence thicker than the known Mesozoic sequence. However, the gravity effects of the Cooper Basin are difficult to separate from the gravity effects of the other sedimentary rocks in the area.

Seismic surveys

The Cooper Basin, and especially the South Australian part of it, has been covered by a fairly close network of seismic traverses. Nevertheless, many of the small structures revealed by mapping the sediments of the Eromanga Basin in Queensland still have no seismic coverage.

A survey carried out in 1957 by BMR demonstrated that there were 3600 m of gently dipping sediments in the area. Since then many subsidized surveys have been carried out by private companies with generally good results. Good basin-wide reflections have been obtained: at the base of the Cretaceous sequence of the Eromanga Basin, from coal seams near the top of the Permian, and from the pre-Permian unconformity at the base of the sequence. Seismic data combined with data from the petroleum exploration wells has provided the basis for the understanding of the geology of the basin.

Economic geology

15 gas and oil fields have so far been discovered. Two of these, Moomba and Gidgealpa, supply gas to Adelaide. The others are under investigation and development for marketing in Sydney. At least 42 exploration and development wells had substantial flow-rates of gas, and six had significant amounts of gas and oil. Both source and reservoir rocks are Permian, and Triassic beds form the cover rocks. GSSA considers that gas emplacement occurred shortly after deposition of the Lower Triassic beds. Traps occur in culmination where onlap has buried pre-Permian topographic

highs. The average depth of the Gidgealpa Group hydrocarbon horizon is 2100 m. GSSA has shown that it has been flushed to some extent by artesian water.

Both coal and underground water are known to exist in the basin, but have not been exploited.

Recent activities

Three exploration wells were completed in 1973, all of them subsidized. Durham Downs No. 1, which was drilled in the northeastern part of the basin in Queensland at a considerable distance from previous discoveries, produced substantial flows of gas from Permian reservoirs, and has thus significantly enhanced the production potential of the basin. Wolgolla No. 1, 140 km to the south-southwest and also in Queensland, tested sediments which thin in an anticline draped over a basement high in an area where several other structures have been successfully tested; a gas-flow rate of 1.9 MMcfd was obtained over a 28-metre interval. Kanowana No. 1 was drilled on an anticline in the extensively drilled Patchawarra Trough in South Australia, and was tested at 8.5 MMcfd. Production is possible from several Permian sandstone beds.

Five subsidized seismic surveys were completed in 1972, one in 1973 and two in 1974. One aeromagnetic survey, in the far northeastern corner of the basin was completed in 1974.

Deficiencies in geological knowledge

The western portion of the Cooper Basin in South Australia is comparatively poorly known and a connexion with the Pedirka Basin is open to question.

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DALY RIVER BASIN

The Daly River Basin is a shallow northwest-trending depression extending over about 40 000 km^2 in the Northern Territory. It is bounded to the northeast by the Pine Creek Geosyncline and the McArthur Basin and to the west by the Victoria River Basin. It connects with the Wiso and Georgina Basins in the south over elevated areas of basement that serve as a southern boundary. It is a lower Palaeozoic basin partly overlain by flat-lying Lower Cretaceous sediments.

The basal rocks are a sequence of up to 240 m of Lower? Cambrian basalt flows with interbedded sediments resting with angular unconformity on practically unmetamorphosed Adelaidean sandstone and siltstone to the west; on Lower Proterozoic metasediments, amphibolite, and granite to the northeast; and practically unmetamorphosed Middle Proterozoic sediments to the east.

At least 640 m of Middle Cambrian to Lower Ordovician sediments has been proved by drilling. They are flat-lying and overlie the Lower? Cambrian basalts with slight angular unconformity and the basement rocks with angular unconformity. The Middle Cambrian consists of fossiliferous limestone with sandstone and siltstone, and the Lower Ordovician of limestone and sandstone. The relations between the Middle Cambrian and the Lower Ordovician rocks is unknown.

Most of the Lower Cretaceous is thin flat-lying plant-bearing sandstone.

Geological mapping

The basin was mapped at 1:250 000 scale by BMR: four Sheet areas in 1951-60, and two in 1966 (Larrimah and Delamere). Since then drilling has been carried out, but remapping at 1:250 000 scale with better logistics is required to better detail the rock sequence and provide proper palaeontological control.

Drilling

BMR drilled four shallow holes, three in the Larrimah and one in the Katherine 1:250 000 Sheet areas, in 1966. The Water Resources Branch of the Northern Territory Administration drilled about 16 holes in 1967 to 1971. They penetrated to depths between about 150 and 600 m. Several completion reports have been published by the Northern Territory Geological Survey. The deeper wells penetrated most of the sequence and provide valuable information on the subsurface stratigraphy.

Correlation

The lithological correlation of the Palaeozoic sequence (except the basalts) is questionable as the outcrop is poor and the sequence is flat-lying.

Only a few fossils have been described. Early Middle Cambrian fossils have been recognized in one formation, and Lower Ordovician fossils in the formation above it, but the contact between the two formations has been described as conformable.

Aeromagnetic surveys

BMR has flown three isolated metalliferous surveys that cover parts of the northern and western margins of the basin. One regional survey covering part of the Pine Creek Sheet area was flown at 0.5-mile spacing in 1963. A total magnetic intensity map has been produced and the results discussed in a BMR Record. The Delamere 1:250 000 Sheet area was flown for BMR in 1967. Contours of total magnetic intensity have been published, but no report has been prepared. A small area, straddling the boundary between the Fergusson River and Katherine Sheet areas, was flown in 1953. A contour map of total magnetic intensity has been published and a Record has been prepared.

The surveys covered only small areas of shallow sediments, and none provide information of value in assessing the basin geometry.

Gravity surveys

BMR made regional gravity measurements (one station per 130 km or better) over the whole of the basin in 1967. 1:250 000 preliminary Bouguer anomaly maps are available.

Seismic surveys

No seismic surveys have been carried out.

Economic geology

Petroleum: The Cambrian sequence contains marine fossiliferous rocks that are a potential source of petroleum. Depth of burial probably never exceeded 300 m so that hydrocarbons are unlikely to have been generated. There is a lack of permeable strata, and potential traps, stratigraphic or structural, are unknown. The volcanics are economic basement.

Water: Permanent surface water is not abundant and is generally restricted to the larger streams. Cattle stations and public utilities depend on supplies of groundwater. Water is obtained from aquifers in the volcanics and all the Middle Cambrian carbonate units.

Copper: Copper mineralization is known in the Lower? Cambrian volcanics.

Recent activities

There have been no recent activities.

Deficiencies in geological knowledge

The identification of the Palaeozoic lithological units is questionable in some areas. The relation between the Cambrian and Ordovician rocks is not known.

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DARLING BASIN

The Darling Basin in northwestern New South Wales contains Upper? Silurian, Devonian, and Lower? Carboniferous sediments covering an area, both surface and subsurface, of at least 114 000 km^2.

The basin lies within the Lachlan Geosyncline and includes all Upper? Silurian, Devonian, and Lower? Carboniferous sediments lying west of the Silurian and Ordovician rocks of the Cobar area and the Wagga Metamorphic Belt, and lying east of the Precambrian schist, phyllite, quartzite, and minor dolomite and amphibolite of the Wonaminta Block and the Cambrian shale, limestone, siltstone, and sandstone of the Bancannia Trough. Also included are similar Upper? Silurian, Devonian, and Lower? Carboniferous sediments of unknown extent lying beneath upper Palaeozoic, Mesozoic, and Cainozoic sediments of the Murray Basin, to the south, and Mesozoic and Cainozoic sediments of the Eromanga Basin, to the north.

The sediments of the Darling Basin rest unconformably on Lower Silurian and Ordovician granite, sediments, and metasediments except near the western margin where they rest on Carpentarian and Cambrian rocks.

Lower Devonian sediments in the outcropping area of the basin west of Cobar consist of up to 3600 m of sandstone and shale of fluvatile origin in the west, of deltaic origin in the centre, and of marine origin in the east.

Conglomerate, sandstone, and acid volcanics in the southeastern part of the basin, west of the Wagga Metamorphic Belt, have been tentatively dated as Late Silurian to Early Devonian.

Minor movements during the Bindi Phase of the Bowning Orogeny occurred in some parts of the basin late in the Lower Devonian, and Upper Devonian to Lower Carboniferous sediments are both disconformable and unconformable on the Lower Devonian sediments.

The Upper Devonian to Lower? Carboniferous sediments consist of up to 4500 m of fluviatile red conglomerate, sandstone, and shale derived from source areas in the west and southwest.

The sediments were folded into broad synclines and anticlines during the Carboniferous Kanimblan Orogeny. Faulting, which is very common, probably occurred synchronously.

Geological mapping

The whole of the Darling Basin was mapped by the New South Wales Geological Survey from 1963 to 1967. Fourteen 1:250 000 Sheet areas cover the basin; eleven maps have been published, three with explanatory notes. Two 1:500 000 maps have been published and two are available as preliminary editions. The mapping is reconnaissance and regional combining airphoto-interpretation with a few ground traverses.

Correlation

Both time and lithological correlations are available for the Darling Basin; they were derived by Strusz, Pickett, Roberts, and Webby. They show both interbasin and intrabasin correlations.

Drilling

Seven wells have been drilled in the Darling Basin, all in the central-western part of the basin near the contact with the Murray Basin. The wells were drilled between 1965 and 1969, and the deepest well penetrated to 3021 m. No significant hydrocarbon shows were found in any of the wells. Four wells were subsidized and mainly penetrated Devonian strata. Stratigraphic information on the remaining three wells is contained in confidential company reports of Texam Oil Corporation.

These wells delineated the lithology and degree of alteration of Devonian sediments below the zone of weathering and, in two cases, beneath the Tertiary sediments of the Murray Basin.

Aeromagnetic surveys

Four subsidized aeromagnetic surveys were flown over parts of the Darling Basin in 1962 and 1963. They are concentrated in the northwestern part of the basin. The data quality is poor and the interpretation unreliable.

Gravity surveys

Six subsidized gravity surveys covering parts of the Darling Basin were carried out between 1963 and 1969. The data and interpretation are of poor to moderate quality. The surveys indicate that the sediments are up to 2500 m thick. They mainly cover the northwestern part of the basin. BMR has recently extended regional gravity coverage over the area, but final results are not yet available.

Seismic surveys

Seventeen subsidized seismic surveys were shot in the Darling Basin between 1962 and 1970; the surveys mainly cover the northwestern part. The data are usually of good quality and may be reliably interpreted; up to 5300 m of Devonian sediments have been indicated.

Economic geology

Petroleum: No significant hydrocarbon shows have been encountered during drilling. Although the marine Lower Devonian sediments are possible source rocks, the porosity and permeability of the sediments are extremely low as the sediments are tightly cemented with silica.

Water: The overall salinity of groundwater in the basin is high. In most of the basin the salinity is 3000 to 7000 mg per litre, and the water is suitable for most livestock and for limited domestic and industrial use. In the northwest of the basin the salinity is 7000 to 1400 mg per litre, making it suitable for limited livestock use, whilst in the northeast the salinity is greater than 14000 mg per litre and the water is unsuitable for livestock.

Recent activities

The most recent oil exploration activity in the Darling Basin was the Mount Emu seismic survey carried out in 1970.

Deficiencies in geological knowledge

A basic deficiency in geological knowledge is the subsurface extent of the basin beneath the Eromanga and Murray Basins.

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DRUMMOND BASIN

The Drummond Basin contains Upper Devonian and Lower Carboniferous sediments laid down in a large intermontane basin within the Tasman Geosyncline. It crops out in central Queensland in a north-northwesterly trending belt covering 36 000 km^2 to the east and west of the Anakie Inlier (also called Anakie High) and a further 15 000+ km^2 are concealed beneath the Eromanga, Surat, Galilee, and Bowen Basins.

The southern margin is an unconformable contact between basin sediments and basement rocks on the northern flank of the Nebine Ridge. The western boundary is an unconformable and faulted contact adjacent to a lineament, the Belyando Feature, comprising fault-induced monoclines and fracture zones, and marked by linear steep gravity gradients and basalt vents. This lineament may have been the original western margin of the Drummond Basin. The eastern margin lies beneath the Bowen Basin. The northern margin is an exposed unconformable contact with basement rocks on the southern side of the Ravenswood Arch.

Basement rocks crop out in the Anakie Inlier and Ravenswood Arch, and have been intersected in numerous petroleum exploration wells west and south of the Drummond Basin outcrop belt. Basement consists mainly of low-grade metasediments of early Palaeozoic age, small isolated areas of Middle Devonian sediments and volcanics, and Middle Ordovician to Lower Devonian granite.

Sedimentation in the Drummond Basin began in Late Devonian time with the deposition of about 700 m of shallow marine siltstone, shale, sandstone, tuff, chert, and conglomerate in the north, unconformable on basement.

The Lower Carboniferous sediments include up to 12 000 m of predominantly fluviatile and lacustrine conglomerate, sandstone, mudstone, volcanics, and limestone.

In the Middle Carboniferous the sequence was folded into many gentle anticlines and synclines, with a zone of tight folding in the north to the west of the Anakie Inlier. The folding was accompanied by extensive faulting, much of it reversed, and by decollement at the base of the basin sequence. The sediments were intruded by granite in the Late Carboniferous.

Geological mapping

The Drummond Basin was mapped by BMR and GSQ in 1961 to 1966. The five 1:250 000 Sheet areas have been published with explanatory notes, and BMR has published a Bulletin on the mapping. The mapping is up-to-date and good-quality regional. Further detailed work is required to better understand the depositional environments and the structural development.

Drilling

A large group of wells has been drilled to the west and south of the Drummond Basin outcrop belt, primarily to test the Galilee, Eromanga, and Surat Basin sequences. Three drilled between 1964 and 1968 penetrated up to 240 m of the Drummond Basin sequence at depth. The wells have been valuable in indicating the subsurface extent of the Drummond Basin. Wells drilled to the east of the Anakie Inlier indicate that the basin sequence does not extend far to the east below the Bowen Basin sequence.

Correlation

The geological mapping has achieved a lithological correlation, which is least reliable for the basal units that crop out in different parts of the basin.

The basal beds have been dated by marine fossils. The higher units are dated partly by plant fossils and partly by their stratigraphic position.

Aeromagnetic surveys

BMR surveyed most of the southern and eastern part of the basin in 1962 during the Bowen Basin survey (Wells & Milsom, 1966), and Exoil Pty Ltd and Magellan Petroleum Corporation surveyed the northern part also in 1962. Magnetic basement is thought to coincide with the crystalline basement.

BMR has published 1:250 000 maps of total magnetic intensity for most of the basin.

Gravity surveys

The whole basin was covered during reconnaissance surveys by BMR in 1963, 1964, and 1966. 1:250 000 and 1:500 000 Bouguer anomaly maps are available.

The Drummond Gravity Shelf is an area of positive anomalies that corresponds with the exposed part of the Drummond Basin. Local anomalies probably arise from density contrast between the sediments in the Drummond Basin and the Anakie Metamorphics in the basement.

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Seismic surveys

Very little of the outcrop area has been surveyed, but about half of that concealed beneath the Galilee Basin was surveyed by oil companies between 1963 and 1968. The surveys indicated parallel northwest-trending anticlines in pre-Permian beds up to 4000 m thick. However, data from a BMR survey in 1971 suggest that the sediments of the Drummond Basin only extend to about 20 km west of the Belyando River, and that pre-Permian sediments further west belong to a previously unrecognized extension of the Adavale Basin.

Economic geology

Petroleum: No hydrocarbons were discovered within the Drummond Basin sequence in the three wells drilled. Suitable source rocks may exist in the underlying Devonian beds, but the sediments in the Drummond Basin are typically arenaceous and do not include thick sequences of likely source rock. The numerous sandstone strata could form reservoir rocks but they generally lack porosity. The Drummond/Galilee unconformity, folds, and stratigraphic pinchouts may provide traps. The hydrocarbon potential is rated as low.

Phosphate: Two beds of calcareous feldspathic sandstone, 10.5 m and 24 m thick, containing up to 4 percent P_2O_5, occur near the base of the sequence.

Deficiencies in geological knowledge

The limits of the basin beneath the Galilee and Bowen Basins have yet to be resolved. The tectonics of the areas near the Anakie Inlier are poorly known.

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DUARINGA BASIN

The Duaringa Basin is an elongate northwest-trending trough within the Bowen Basin in Queensland. It covers an area of about 7700 km^2, and seismic surveys across the basin indicate that it contains a maximum thickness of 1060 m of Tertiary sediments overlying up to 150 m of Mesozoic sediments and folded Permian rocks of the Bowen Basin. The Tertiary sediments were deposited in a terrestrial environment. The sediments in the basin apparently are not folded. The western margin is a normal fault.

A minor occurrence of low-grade oil shale has been reported.

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DUNTROON BASIN

The Duntroon Basin is a downfaulted area containing Mesozoic and Tertiary sediments. Wholly offshore in the Great Australian Bight south of Eyre Peninsula and west of Kangaroo Island, in South Australia, the basin covers an area of 24 000 km^2 on the continental shelf and slope.

The northeastern margin is an en echelon system of northwesterly and westerly trending major faults. The much more irregular eastern boundary is formed by a system of westerly-plunging basement blocks bounded by faults which probably follow the east-west Adelaide Geosyncline trend as observed in Kanmantoo Group rocks on Kangaroo Island. The southern margin is an area of elevated magnetic basement on the continental slope. The basin probably extends westwards from the upper continental slope across the Ceduna Terrace.

Two different types of basement rock underlie and bound the basin. Carpentarian high-grade metamorphic and igneous rocks of the Gawler Block underlie the basin in the north and northeast, and the metamorphosed and granite-intruded rocks of the Cambrian to Ordovician Kanmantoo Group floor the basin in the east.

Upper and lower sequences of sediments are recognized; they are separated by an angular unconformity. The two wells that have been drilled in the basin penetrated Tertiary and Mesozoic sediments, but the lithology of the sediments is unknown.

The lower sequence, about 4600 m thick, rests with angular unconformity on basement. By analogy with the development of the Otway and Gippsland Basins, a Jurassic to Cretaceous age is postulated for this sequence.

The upper sequence, which is 1500 m thick, overlies the Mesozoic with angular unconformity. A middle Eocene to early Miocene age is inferred by analogy with the depositional history of the nearby St Vincent Basin. Seismic interpretation indicates a basal sequence that thickens towards the southwest to more than 300 m and appears to wedge out to the northeast. Near the margins of the basin the Tertiary overlaps the Mesozoic and rests unconformably on basement.

The postulated break-up of the Gondwana plate began in the Jurassic, when a rift zone, Otway Rift Valley, developed. The axis of the rift valley lay south of and parallel to the present Australian shoreline. Early rifting along this valley is inferred to have formed the Duntroon Basin in the late Jurassic. Rifting continued in the Cretaceous during which block-faulting and folding of the lower sequence probably occurred. Movement along the faults ceased in the Eocene.

The lower sequence is folded into a series of southeast-trending anticlines that parallel areas of elevated basement. Seismic interpretation suggests the sediments may be eroded and therefore thin over these areas of shallower basement. Some local thinning may have arisen from uplift of fault-bound basement blocks during deposition. Overlying Tertiary sediments are gently folded.

Geological mapping

The basin is unmapped.

Correlation

No lithological or time correlations are available.

Drilling

Two unsubsidized wells were drilled by Shell Development in 1972, one in the northern part of the basin and the other in the central part; both were drilled in water depths of more than 130 m. The wells reached total depths of 3832 m and 3892 after drilling through Tertiary and Mesozoic sediments, without encountering significant shows of hydrocarbons.

Aeromagnetic surveys

Shell Development flew a subsidized regional aeromagnetic survey covering the whole basin in 1966; it outlines the area of thickest sediments, and was followed by an unsubsidized shipborne magnetic and seismic survey in 1970 and 1971. BMR conducted a combined marine magnetic, seismic, and gravity survey in 1972; good data were obtained, but the results are not yet available.

Gravity surveys

Gravity coverage of the whole basin was obtained by BMR during the combined marine gravity, seismic, and magnetic survey in 1972. The data quality throughout the basin is fair to good. Lines were oriented northerly with a spacing of 40 to 45 km. The results are not yet available.

Seismic surveys

Shell Development carried out three subsidized regional seismic surveys in 1966 and 1968, and five unsubsidized surveys between 1969 and 1973. Record quality for the 1966 survey was poor, but improved results were obtained in the 1968 surveys. Four horizons were contoured in sediments over 6100 m thick. BMR carried out a combined marine seismic, gravity, and magnetic survey in 1972; record quality was fair in the southwestern part of the basin along the continental slope, but high noise levels and interference from multiples resulted in poor record quality over the continental shelf. The results are not yet available.

Economic geology

No significant hydrocarbons were found in either of the wells drilled. The source and reservoir potential is confidential. Fold and fault traps are probably present. A large area of the basin lies beneath water depths in excess of 200 m.

Recent activities

An unsubsidized seismic survey was carried out over the basin in 1973 by Shell Development after the two wells were drilled in 1972. Palynological examination by GSSA of sidewall cores from the Echidna and Platypus wells indicated that the sediments range in age from Eocene to Early Cretaceous. Interpretation of the BMR continental margin survey indicates that the Duntroon Basin probably extends westwards across the Ceduna Plateau.

Deficiencies in geological knowledge

Availability of geophysical and lithological data is the main deficiency. Lithological data is held confidential by Shell, and the BMR survey results are not yet available.

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EROMANGA BASIN

The Eromanga Basin is a large basin of irregular outline containing flat-lying to gently folded Jurassic and Cretaceous sedimentary rocks up to 3200 m thick. It covers about 1 200 000 km^2 in Queensland, Northern Territory, South Australia, and New South Wales.

The basin connects with the Carpentaria Basin across the Euroka Arch and with the Surat Basin across the Nebine Ridge and the Cunnamulla Shelf. Elsewhere, the boundary is an outcropping or shallow subcropping unconformity separating basin sediments from older rocks. The older rocks lie within the: Mount Isa Geosyncline, Georgina Basin, Arunta Block, and Amadeus Basin to the northwest; Adelaide Geosyncline, Gawler Block, Officer and Arckaringa Basins, and Musgrave Block in the west and south-west; Bancannia Trough, Darling Basin, Lachlan Geosyncline, Willyama Block, and Wonaminta Block to the south, and the Galilee Basin, Georgetown Inlier, and the Lolworth-Ravenswood Block in the northeast.

The older rocks exposed around the margins extend beneath the basin where they form its basement. In addition sediments of the Cooper Basin, Adavale Basin (including Warrabin Trough), Warburton Basin, and Pedirka Basin are almost entirely concealed beneath the Eromanga Basin.

The oldest sedimentary rocks in the basin are up to 1200 m of Jurassic fluviatile, lacustrine, and deltaic sandstone, siltstone, and thin coal seams. Volcanic detritus within the upper part of this sequence was probably derived from volcanoes within the drainage basins of the streams.

The Jurassic sediments are overlain conformably by up to 2000 m of Cretaceous deltaic, marine, and lacustrine sandstone, mudstone, siltstone, limestone, and minor coal, deposited during a major transgression and regression of the sea.

Drape folds occur over basement ridges and basement blocks, and monoclines are developed locally in the upper part of the sequence and grade down into faults. Over large areas the sequence dips at angles below 7^{o}.

Geological mapping

The Eromanga Basin is covered by ninety-six 1:250 000 Sheet areas: 10 in New South Wales, eight in the Northern Territory; 49 in Queensland, and 29 in South

Australia. All the Sheet areas in the Northern Territory, Queensland, and New South Wales were mapped by BMR, GSQ, and GSNSW between 1958 and 1968, and all the 1:250 000 Sheets have been published by BMR and GSNSW, except G53/4, 8, and F55/1, 14, for which preliminary maps have been issued by BMR. BMR has issued 1:1 000 000 preliminary maps of the northern, central, and western Eromanga Basin. Mapping was carried out in South Australia before 1930, and Santos Ltd mapped large areas in the mid 1950s. The results of the Santos Ltd mapping have been published only in summarized form (Sprigg, 1958; Wopfner, 1960). GSSA, since 1965, and GSSA and BMR, in 1970, have mapped all the basin in South Australia. At least six of the 1:250 000 Sheets have been published, two have been issued as preliminary editions, and dyeline copies of most of the remainder are available at GSSA. GSSA have published seven of the 1:100 000 maps making up the Warrina Sheet area, and two of the 1:100 000 maps making up the Curdimurka Sheet area.

The value of the surface mapping is limited by the lack of exposure over large areas, and the flat-lying attitude of the sediments, but a large proportion of the mapping was undertaken in conjunction with a program of wireline logging of water-bores and an assessment of the results of drilling and geophysics, so that a very large amount of information has been compiled and interpreted.

Drilling

About 400 petroleum exploration wells and thousands of water-bores have been drilled. Most of the petroleum exploration wells have been drilled since 1960, with targets in the underlying basins, such as the Cooper, Adavale, Galilee, Pedirka, Georgina, and Arckaringa. GSSA has drilled a number of stratigraphic wells.

Correlation

A lithological and seismic correlation has been prepared for the entire Queensland portion of the basin, and structure contour and isopach maps are available at BMR and will be issued with the 1:1 000 000 preliminary geological maps. GSSA has published structures contour maps covering South Australia. A basin-wide lithological correlation has been prepared as part of the BMR and Bureau de Recherches Geologiques et Minieres (GRGM) hydrogeological study.

Aeromagnetic surveys

Almost all the basin has been surveyed since 1960, about one-half by BMR and the remainder in subsidized surveys for private companies. The gaps in coverage are in

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New South Wales and in Queensland adjacent to the New South Wales border. A large area of the basin was flown for Delhi Australian Petroleum Ltd, and large areas have been flown for Philips Petroleum Company, Exoil Pty Ltd, Planet Exploration Co. Pty Ltd, and Mid-Eastern Oil N.L. All the data is available but little has been published.

A large area of the basin is underlain by sedimentary rocks within deeper basins and in these areas magnetic basement does not coincide with the floor of the Eromanga Basin.

Gravity surveys

The whole basin has been covered by BMR and by subsidized surveys for private companies. All the data is available as contoured Bouguer anomaly maps, except the most recent coverage in northwestern New South Wales.

The gravity data gave little useful information about the Eromanga Basin, except that it helps to indicate areas where the basin may be underlain by thick sedimentary rocks.

Seismic surveys

A large amount of seismic surveying has been carried out by private companies since 1960, mainly to investigate the various infrabasins. There is little or no coverage in northwestern New South Wales; on the Lake Eyre, Curdimurka, and Abminga Sheet areas of South Australia; in the northernmost part of the basin in the Northern Territory and Queensland; and in the southeastern extremity in Queensland.

Good reflections are generally obtained from near the base of the Cretaceous. Where infrabasins are absent, reflections are commonly obtained from the basal unconformity, and, where infrabasins are present, reflections are generally obtained from the top of the Permian.

The seismic data has been invaluable in correlating the subsurface strata and indicating their thickness and structure.

Economic geology

Water: The basin underlies an arid region, where rainfall is low and unreliable and surface water supplies are inadequate. Development of the groundwater resources of the basin began with the discovery of artesian water in New

South Wales in 1878. Since then about 4700 flowing artesian water wells and over 20 000 non-flowing artesian (subartesian) water wells have been drilled in the whole of the Great Artesian Basin, of which the Eromanga Basin is a large part). Flows of over 5000 m^3/day have been recorded from wells up to 2000 m deep and, in addition, important quantities are obtained by pumping from subartesian wells. Good-quality water for domestic use and stock is obtained from water-bearing sediments of Cretaceous (Winton and Mackunda Formations) and Jurassic (Hooray, Adori, and Hutton Sandstones) age. The upper confined aquifer system (Cretaceous) extends over most of the central part of the Great Artesian Basin, and the lower confined aquifer (Jurassic) extends over the whole of the Great Artesian Basin. The aquifers are predominantly continental sandstones and they are separated by semiconfining beds of siltstone and mudstone. The uppermost confining beds are Cretaceous marine mudstone.

A hydrogeological study of the Great Artesian Basin is being made in Canberra by BMR and BRGM.

Petroleum: Only minor traces of hydrocarbons have been encountered in wells and bores.

Source rocks occur in the infrabasins, potential source rocks occur in the Jurassic sequence, and oil shale occurs in the lower Cretaceous. Good aquifers occur within the Cretaceous and Jurassic sediments. They are potential petroleum reservoirs, but to date they have all proved to be water-flushed.

The hydrogeological study of the Great Artesian Basin by BMR and BRGM may indicate areas of potential petroleum accumulation.

Oil shale: Large reserves of low-grade oil shale occurs in the lower Cretaceous Toolebuc Formation in the northern Eromanga Basin and the southern Carpentaria Basin. The oil shale, which also contains vanadium in (see below), has been investigated in the Julia Creek area by a consortium of private companies.

Opal: Opal occurs as infillings and replacements in the Cretaceous Winton Formation. The deposits are mined in southwestern Queensland, northwestern New South Wales, and in South Australia.

Coal: Coal occurs in Middle Jurassic sediments, but no economic deposits have been found.

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Uranium: Uranium occurs 16 km east of the piedmonts of the Flinders Ranges in sand lenses within fine-grained unconsolidated argillaceous sediments of Miocene age. The Miocene sediments lie unconformably on Cretaceous sediments of the Eromanga Basin within the Lake Frome Embayment.

Reserves of 17 500 tonnes of U_3O_8 have been established in the Beverley Uranium Deposit, recoverable from three open cuts.

No significant mineralization has been found in the Cretaceous sediments, which are similar to the Tertiary sediments.

Vanadium: Analyses indicate that Cretaceous oil shale deposits in the northern part of the basin contain up to 0.5 percent vanadium by weight. Present indications are that the oil is more likely to be a byproduct in vanadium extraction.

Recent activities

A hydrogeological study of the Great Artesian Basin is being made by BMR and BRGM in order to prepare a digital computer model which simulates the groundwater hydrodynamics and thus allows for long-term prediction. BMR is preparing a Bulletin on the geology of the basin.

Various activities related to infrabasins are presently in progress (see Adavale, Cooper, Galilee, Pedirka, Arckaringa, and Warburton Basins).

Deficiencies in geological knowledge

The basin has been mapped, and gravity, magnetic, and seismic coverage is fairly complete. The major deficiency is lack of a synthesis of this information.

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ESK TROUGH

The Esk Trough (Esk Rift, Brisbane Valley Trough) is a narrow elongate part of the Tasman Geosyncline containing terrestrial Triassic rocks up to 2000 m thick and covering an area of about 5000 km^2. The western boundary of the trough is a fault zone separating the downthrown Triassic rocks from the upthrown Yarraman Block of Silurian and Permian rocks. On the eastern side of the trough is the d'Aguilar Block, also Silurian and Permian, against which the Triassic rocks are downfaulted in the south, and upon which they rest with strong angular unconformity in the north. The trough extends an unknown distance to the south beneath the Clarence-Moreton Basin sediments, which overlie it unconformably.

The basal sedimentary unit is 1000-1500 m thick and consists of conglomerate and sandstone, and shale which contains Middle Triassic spores. This unit is overlain by about 500 m of andesite lavas and pyroclastics and associated lahar deposits, conglomerate, and shale. The uppermost sedimentary unit is made up of conglomerate, sandstone, shale, and tuff totalling about 300 m; this unit also contains Middle Triassic spores.

The sediments are strongly folded and faulted, and are intruded by pre-Jurassic dykes, sills, and plugs of andesite, dacite, and gabbro.

Geological mapping

Two 1:250 000 Sheet areas cover the basin. GSQ issued a preliminary edition of the Ipswich Sheet in 1973 and was compiling the Gympie Sheet in July 1974. A report on the mapping of the Ipswich Sheet area is in preparation. The mapping is good-quality regional and includes the results of several detailed mapping projects by university students and staff.

Drilling

No petroleum exploration wells have been drilled.

Correlation

GSQ is understood to have established a generalized basin-wide correlation, but the extent to which the spore datings can be applied throughout the trough is unknown.

Aeromagnetic surveys

No specific survey is known to have been undertaken, but the trough was crossed by four BMR regional flightlines in 1963. The results have not been interpreted, but 1:500 000 dyeline maps are available showing magnetic profiles along the flightlines.

Gravity surveys

BMR included the Esk Trough in a regional survey in 1964. 1:250 000 and 1:500 000 Bouguer anomaly maps are available. The gravity method is of little value in interpretation owing to lack of density contrast between basin sediments and basement. Small gravity maxima may overlie gabbro intrusions.

Seismic surveys

No seismic surveys have been carried out.

Economic geology

No hydrocarbon occurrences have been reported. The abundance of volcanics within the sequence, the presence of igneous intrusions, and the severity of folding and faulting suggest that any original petroleum accumulations would have been dissipated. The underlying Permian strata and some of the Triassic strata may contain potential source rocks, but the whole sequence is probably impermeable.

Recent activities

GSQ completed mapping the trough at 1:250 000 scale in 1973. The mapping was supplemented by several shallow stratigraphic drill holes.

Deficiencies in geological knowledge

Unknown, pending the release of reports on the recent GSQ mapping.

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EUCLA BASIN

The Eucla Basin is filled with a thin layer of Mesozoic and Tertiary sedimentary rocks covering an onshore area of 217 000 km^2 and an offshore area of 141 000 km^2 to the edge of the continental shelf in Western Australia and South Australia. The maximum drilled thickness of sediment in the basin is 640 m, and marine seismic surveys indicate that the strata thicken to about 1000 m near the edge of the continental shelf.

The limit of exposed Tertiary sediments defines the margin of the basin onshore. To the west the basin is flanked by Precambrian igneous and metamorphic rocks and minor Adelaidean sediments of the Fraser Block. In the north it is flanked by the Palaeozoic? and Adelaidean sediments of the Officer Basin. In the east it is flanked by Precambrian metamorphic and igneous rocks of the Gawler Block. The western offshore margin is an imprecisely located line trending south from the easternmost shoreline outcrop of gneiss of the Fraser Block. An easterly trending fault in pre-Tertiary sediments is the margin between the Eucla Basin and the Polda Trough in the southeast.

Basement rocks are Precambrian gneiss, granite, quartzite, and schist; and Adelaidean and Palaeozoic? rocks of the Officer Basin in the north. Mallabie No. 1, in the northeastern part of the basin, penetrated 100 m of Permian and 900 m of pre-Permian sediments before entering granitic gneiss.

Seismic interpretation shows that five north-trending to northeast-trending buried valleys extend offshore from Twilight Cove. These valleys may represent an old drainage system. The longest channel is at least 100 km long and 3 to 13 km wide. The sediments in these channels are the oldest known in the basin and it is possible that they are of Permian age and of glacial origin. However, there is no evidence to support this hypothesis and they may be filled by Cretaceous sediments.

Lower Cretaceous (early Neocomian) non-marine calcareous sandstone (over 109 m thick) unconformably overlies Precambrian basement rocks in bores along the transcontinental railway line. In the same bores and along the Eyre Highway, over 350 m of Lower to Upper Cretaceous (Neocomian-Senonian) marine claystone, shale, siltstone, and sandstone conformably overlie the early Neocomian sediments and unconformably overlie Precambrian basement rocks. Seismic interpretation suggests that they may thicken to over 600 m offshore from Twilight Cove, near the Edge of the continental shelf.

Middle Eocene marine, limonitic and calcareous, glauconitic sandstone (over 85 m thick) disconformably overlies the Upper Cretaceous sediments near the centre of the basin onshore and onlaps unconformably onto Precambrian rocks in the west. Upper Eocene shallow marine chalky bryozoan limestone covers most parts of the basin, and upper Eocene well sorted cross-bedded bryozoan calcarenite is limited to the southwest. A possible disconformity between the upper Eocene and the Cretaceous rocks is interpreted on marine seismic sections. Towards the edge of the continental shelf this disconformity becomes an angular unconformity.

Lower Miocene transgressive marine cross-bedded bryozoan calcarenite disconformably overlies the upper Eocene rocks onshore in the central part of the basin. Sediments measured at outcrop are over 90 m thick. The lower Miocene sediments are disconformably overlain by foraminiferal calcarenite also of lower Miocene age. Time correlative sandstone, claystone, and minor limestone occurs in the northern part of the basin.

Interpretation of marine seismic records indicates an angular unconformity between probable lower Miocene and upper Eocene sediments.

The sediments in the basin are flat-lying and unfaulted.

Geological mapping

The Western Australian part was mapped by GSWA in 1965 to 1971. Of the eleven 1:250 000 Sheet areas, eight first edition and three preliminary edition maps have been published. All of the South Australian part except one Sheet area (Cook) was mapped by the GSSA in 1967 to 1972. Preliminary editions of eight 1:250 000 Sheet areas have been published.

The coastal Sheet areas were mapped in part with detailed traversing, whereas the inland sheet areas were compiled mainly from airphoto-interpretation with a few traverses.

Drilling

Three subsidized and five unsubsidized petroleum exploration wells were drilled between 1959 and 1969. Most wells were located in the southern onshore part of the basin. Most wells intersected a Tertiary and Cretaceous sedimentary sequence before bottoming in Precambrian crystalline rock. The stratigraphic information from the wells is most valuable in this area of poorly exposed flat-lying rocks.

No wells have been drilled offshore.

Correlation

GSWA has published a time correlation chart and a lithological correlation chart for the Western Australian part of the basin.

Aeromagnetic surveys

BMR flew two surveys in 1958 and 1970. The latter indicated three major northwest-trending depressions in the basement in the Cook, Ooldea, and Barton Sheet areas.

Two subsidized surveys, flown over the eastern offshore part of the basin in 1966, indicated that most of the area was underlain by basement at shallow depth.

Gravity surveys

BMR measured gravity over the basin on a regional grid in 1969 and 1970. Five 1:250 000 Bouguer anomaly maps have been published (Cape Arid, Malcolm, Balladonia, Zanthus, and Cundeelee) and ten preliminary editions are available (Wyola, Cook, Coompana, Maurice, Ooldea, Nullabor, Barton, Fowler, Nuyts, and Streaky Bay). The Western Australian maps are also printed at 1:500 000 scale.

A subsidized survey indicated a possible extension of the Officer Basin beneath the Eucla Basin in 1965.

Seismic surveys

Five subsidized surveys were carried out offshore between 1966 and 1970. The quality of the record sections is generally good and they may be reliably interpreted. Coverage is poor and limited mostly to the southwestern part of the basin.

In 1973 the Scorpion Bight seismic and gravity survey was done onshore near the coast to determine if a trough of sediments interpreted from the Offshore Eyre seismic survey in 1971 extended onshore. It was confirmed that a trough about 10 miles wide with up to 2000 m of sediments did extend inland.

Economic geology

Underground water: Groundwater with salinity low enough for domestic use has been found in few areas in the basin. Only four of the bores in Western Australia that reached basement or basal Cretaceous rocks encountered water suitable for stock.

The salinity, depth, and yield of supplies from Tertiary sediments are largely controlled by the conditions of local intake, the permeability of the limestone, and the distribution of the basal sandstone. These vary from one area to another, and are described under six regions by Lowry (1970).

Petroleum: The prospects of finding reserves of petroleum in the Eucla Basin are poor because of the thin sedimentary sequence, lack of source rocks, and lack of closed anticlines. The only likely source rocks are Cretaceous marine siltstone and shale.

Draping of Cretaceous sediments over elevated areas in the irregular Precambrian basement is recognized on marine sections but is very slight. Stratigraphic traps are possible where basal Cretaceous sandstone abuts elevated areas of Precambrian rocks. This sort of trap may occur in the buried valleys south of Twilight Cove.

Limestone: Limestone was mined near Naretha from about 1929 to 1966 for the production of calcium hydroxide for use in gold extraction. Large quantities of limestone are available with about 97 percent calcium carbonate and one or two percent magnesium carbonate.

Abrasives: Sand rich in garnet has been found on the beach near Point Culver. The deposit is thought to be a local concentration in the modern swash zone and to be of little economic significance.

Recent activities

BMR carried out a marine seismic, magnetic, and gravity survey in 1972 and flew an aeromagnetic survey over Coompana, Nullabor, and Fowler 1:250 000 Sheet areas in 1972 and 1973.

Deficiencies in geological knowledge

The age of the older sediments in the offshore channels is unknown.

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GALILEE BASIN

The Galilee Basin contains almost 3000 m of uppermost Carboniferous, Permian, and Triassic sediments covering an irregular area of about 200 000 km^2 in central Queensland. Most of the basin sediments of the Eromanga Basin (up to 1200 m thick), but scattered outcrops occur in a narrow belt along the northeastern and eastern margins.

The margins of the basin are partly faulted and partly unconformable contacts between basin sediments and Precambrian schist, gneiss, and granite in the north and west, and folded Devonian and Carboniferous sediments and volcanics of the Adavale and Drummond Basins in the east and south. In the southeastern corner the basin sediments continue into the Bowen Basin across the Springsure Shelf, and in the southwestern corner they continue into the Cooper Basin over the Canaway Ridge.

Basement rocks include thin Carboniferous sediments of the Drummond Basin in the northeast, Devonian sediments of the Adavale Basin in the south and in the possible northern continuation of unknown extent, and a complex of older Palaeozoic and Precambrian crystalline rocks.

The Galilee Basin contains predominantly terrestrial sediments deposited in lakes and on flood plains. The Upper Carboniferous and Lower Permian sequence is up to 1800 m thick. Basal sandstone and conglomerate containing glacial erratics and interbeds of tuff are overlain conformably and disconformably by siltstone and sandstone. Upper Permian mudstone, siltstone, sandstone, and coal, up to 600 m thick, overlie the Lower Permian beds with a regional unconformity.

Triassic varicoloured shale, siltstone, and sandstone, up to 1180 m thick, overlie the Upper Permian beds conformably.

The sediments in the Galilee Basin are very gently folded, although they have been downwarped sharply into a monocline along the present northeastern margin of the basin. The warping and folding took place at the end of the Early Permian and at the end of the Triassic.

Geological mapping

The area overlying the Galilee Basin was mapped by BMR and GSQ from 1961 to 1968. Of the 20 relevant Sheet areas, 18 have been published and two have been issued as preliminary editions.

The mapping is valuable only in the exposed north-eastern and eastern margins, and even here extensive areas are covered by Cainozoic deposits.

Drilling

About 50 petroleum exploration wells, most of them subsidized, have been drilled into the Galilee Basin, but less than half of these had sediments of the Galilee Basin as their prime objective. Most of the wells were drilled to basement. The wells are fairly evenly distributed throughout the basin.

GSQ has drilled a number of stratigraphic holes in the basin.

Correlation

Little of the Upper Carboniferous and Permian sequence can be reliably correlated on lithology, apart from the named formations on the Springsure Shelf. For most of the sequence, various alternative correlations can be made, and marked lithological changes are characteristic. The correlation that has been made is based on gross lithological similarities, and identification depends heavily upon palynological dating.

The Triassic consists of a basically similar lithological sequence that may be correlated throughout the basin.

Aeromagnetic surveys

The whole basin has been surveyed. BMR surveyed the western part of the area in 1960 and 1968. The remainder was covered during subsidized surveys carried out for The Catawba Corp., Exoil Pty Ltd, Magellan Petroleum Corp., Oil Structure Survey Ltd, and Philips Petroleum Co.

There is insufficient control for close contouring of the interpreted depth to magnetic basement. Some of the interpretation has been verified by drilling and seismic surveys, but in other areas it has not been substantiated. In the remainder of the basin there are plausible interpretations for which there is at present no verification. Where infrabasins such as the Adavale Basin occur, magnetic basement does not coincide with the base of the Galilee Basin.

Gravity surveys

The whole basin was covered by BMR from 1963 to 1971. Several petroleum companies have also carried out

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limited surveys. BMR has published 1:250 000 and 1:500 000 Bouguer anomaly maps.

The anomalies are considered to arise mainly from density contrasts within the basement and consequently the gravity data are of little value in interpreting the basin geology.

Seismic surveys

Reconnaissance seismic surveys by private companies cover almost the whole basin. Unfortunately, for large parts of the basin, the surveys provide little useful data from below the P reflector at the top of the Permian sequence, but this can probably be rectified in future by use of more modern multiple-coverage techniques. The present knowledge of the basin is based largely on the interpretation of seismic data and drilling results.

Economic geology

Petroleum: The best hydrocarbon show reported was in Lake Galilee No. 1, where 3 m of 44.6° API gravity oil and some gas was recovered during a drillstem test of the interval 2645 to 2668 m. The oil was recovered from a tight reservoir in a thick sandstone sequence in the lower half of the Upper Carboniferous sequence. The well was drilled for deep stratigraphic information, but tested a seismically defined closed anticline. Several other minor oil and gas shows were encountered including gas from a depth of 2949 m in Koburra No. 1. Most of the shows are in the northern half of the basin.

These shows of oil and gas and the results of coal rank studies show that the environment is favourable for the generation of hydrocarbons.

The location of the shows in the basal upper Palaeozoic sandstone in Lake Galilee No. 1 and Koburra No. 1 suggest that shale within the underlying Devonian and pre-Upper Carboniferous beds may have been the source for the hydrocarbons. Alternatively, the upper Palaeozoic shale which overlies the sandstones in both wells may have been the source.

Sandstone within the lower part of the upper Palaeozoic sequence is generally tight, but the sandstone has quartz overgrowths suggesting that the loss of porosity and permeability may have occurred after petroleum migration. Potential reservoirs are sandstones within the main part of the upper Palaeozoic sequence.

Petroleum may be retained within anticlines (some of which had long-continued growth as a result of movement on flanking faults during sedimentation), fault traps, and stratigraphic traps. Stratigraphic trap possibilities include abutment of upper Palaeozoic sandstone against basement, and porosity trends within sandstone of the coal measures.

The Galilee Basin appears to have sufficient hydrocarbon potential to warrant further exploration.

Coal: GSQ has established large inferred reserves of non-coking sub-bituminous coal in two areas, Wendouree and Degulla. The rank and quality of the coal makes it particularly suitable for use in the production of synthetic hydrocarbons.

Oil shale: A small but rich lens of torbanite (maximum grade 592 litres/tonne) enclosed by a pod of canneloid coal occurs in Lower Permian strata 47 km south-southeast of Alpha. Minimum reserves are estimated at 2 million tonnes. The deposit has not been worked. It is conceivable that other such deposits await discovery in the area (Connah, 1964; Swarbrick, 1974).

Recent activities

BMR carried out a seismic and gravity survey east of Lake Galilee No. 1 in 1971. Two subsidized surveys were carried out and three subsidized wells were drilled in 1972. One subsidized seismic survey was carried out in 1974. GSQ is continuing its program of stratigraphic drilling in 1974 and has initiated sedimentological investigations of the eastern Galilee Basin sequence. Two Authorities to Prospect have been granted over the areas in which the coal reserves are located.

Deficiencies in geological knowledge

A major deficiency is a lack of good seismic data below the P reflector. The history of generation and migration of petroleum in relation to the development of structure is incompletely understood, as are the environmental controls which govern the distribution of reservoirs and permeability barriers.

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GEORGINA BASIN

The Georgina Basin is a large lower and middle Palaeozoic sedimentary basin trending northwest from western Queensland into the Northern Territory. The basal beds are of early Middle Cambrian age, and the basin contains Cambrian and Ordovician marine sediments and Devonian non-marine sediments.

Precambrian rocks crop out along the southwestern, western, northern, and eastern margins of the basin, but the northwestern margin is obscured by Mesozoic sediments which conceal a probable connexion with the Daly Basin; the southern margin is concealed by Mesozoic sediments of the Eromanga Basin, but the extent of the Palaeozoic sediments has been outlined by geophysical surveys and some drilling. In the west, the probable connexion with the Palaeozoic Wiso Basin is concealed by Quaternary sand. The basin covers an area of 325 000 km^2.

The Cambrian and Lower Ordovician sediments consist predominantly of carbonate rocks, the Middle Ordovician sequence mainly of sandstone and siltstone, and the Devonian of sandstone. The only volcanics known are Middle Cambrian basalts near the northern margin in the Mount Drummond Sheet area.

Most of the northern half of the basin contains a thin blanket of Middle Cambrian marine carbonate rocks with minor shale and sandstone which is generally less than 300 m thick and contains no pronounced fold structures, except for the Lake Nash Anticline, and no faults except in a narrow zone along the northern margin.

The thickest exposures of Cambrian and Ordovician marine sequences are in the south of the basin, where 1200 to 1800 m have been measured. These rocks and the overlying Devonian were deformed in Carboniferous? time during the Alice Springs Orogeny, but in the Boulia area of Queensland, which was not affected by this orogeny, the main diastrophism occurred in the Early Ordovician, with a mild recurrence of faulting near the end of the Early Cretaceous.

The effects of the Alice Springs Orogeny are seen mainly south of latitude 22°S, but some faults continue northward to about latitude 21°30'S. Major faults developed with a northwesterly trend. The faults are normal, with the downthrow to the northeast, and some have throws of more than 1000 m. They shaped the southwestern margin of the basin and were responsible for the asymmetry of the Dulcie and Toko Synclines. Minor complementary faults trend east-northeast. Folding was slight during the orogeny.

Geological mapping

All of the basin has been mapped at 1:250 000 scale. The eastern margin was mapped by BMR between 1950 and 1954, when five 1:250 000 Sheet areas were mapped during a metalliferous survey of the Cloncurry complex. The major part of the basin was mapped systematically by BMR from 1957 to 1965. Some 1:250 000 Sheet areas were mapped during the Eromanga Basin survey, and two Sheet areas in the north were mapped as parts of metalliferous surveys. All the 1:250 000 Sheet areas have been published with explanatory notes, except Tennant Creek and Alcoota. Alcoota has been issued as a preliminary edition, but Tennant Creek is not yet issued. First edition 1:500 000 geological maps covering all of the outcropping part of the basin have been published and the results of the mapping summarized in BMR Bulletin 111.

The discovery of phosphate deposits in the northeastern part of the basin in 1966 stimulated a detailed stratigraphical and palaeontological study of the Cambrian sediments in this area. Detailed mapping was carried out by BMR and companies with leases in the area. BMR and the Geological Survey of Queensland mapped the Burke River Outlier in 1967 and the Cambrian of the northeastern corner of the Barkly Tableland in 1968. In 1969 BMR mapped the eastern margin of the basin in the Mount Isa/Urandangi area. This completed the mapping of the known phosphogenic areas. The results are summarized in several BMR publications.

The mapping is most valuable as it provides the main basis for the present knowledge of the basin.

Drilling

BMR drilled at least 49 stratigraphic holes between 1962 and 1965 and in 1968, and companies have drilled 13 petroleum exploration wells. Hundreds of waterbores have been drilled and they are distributed over most of the basin. Most drilling has been carried out in the search for phosphate deposits in the eastern part of the basin.

Three BMR wells penetrated to depths over 450 m. These three wells and the 13 petroleum exploration wells penetrated Palaeozoic strata; nine reached Precambrian basement and four reached Adelaidean sediments. Most of them are near the southern and southeastern margins, but five widely spaced wells were drilled in the remaining area of the basin.

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The drilling is valuable as it reveals the thickness, age, and lithology of the sediments in areas where they are concealed.

Correlation

Reliable geological mapping in the well areas exposed uptilted southern part of the basin in the Northern Territory and on the Glenormiston, Mount Whelan, and Boulia Sheet areas of Queensland has provided excellent lithological correlations. The early mapping of part of the Queensland portion of the basin used an unsatisfactory mixture of lithostratigraphic and biostratigraphic units of little value in lithological correlation. This was realized in the later detailed mapping and partly rectified, but some of the 1:250 000 geological maps need amendment (Lawn Hill, Camooweal, Mount Isa, Urandangi, and Duchess).

The fossil fauna has been widely collected and studied (by comparison with other basins in the region) and the outcropping marine Palaeozoic sequence is fairly well dated. A basin-wide fossil zonation is being established at BMR.

Aeromagnetic surveys

BMR and private companies have surveyed the whole basin, except the Duchess Sheet area in Queensland, and Beetaloo, Tanumbirini, and part of the Barrow Creek Sheet areas in the Northern Territory. BMR covered most of the area in 1963 and 1964 with traverses at 2-mile (3-km) intervals. Total magnetic intensity and depth to magnetic basement contour maps are available. Aeromagnetic surveys of Boulia and Springvale were flown by BMR in 1965. These two Sheet areas are not interpreted, but total magnetic intensity maps have been published. Alcoota was surveyed in 1972, and depth to magnetic basement contours of this area have been prepared for a Record. Companies covered part of the area in 1964 and 1965 during subsidized surveys.

In some areas, thick sequences of non-magnetic Adelaidean rocks overlying magnetic basement seriously reduce the effectiveness of the method in predicting depth to economic basement.

Gravity surveys

Ground traverses by Narain and BMR preceded regional reconnaissance helicopter surveys, which by the end of 1965 had covered the whole of the basin on a 10-km grid with additional stations where necessary. Interpretation of results is still not complete. Lack of density contrast between the Palaeozoic carbonate rocks and the Precambrian igneous and metamorphic basement has made interpretation difficult.

Seismic surveys

Little of the basin has been covered by seismic surveys; sparse surveying has been carried out almost entirely in the southeastern quadrant. The majority of the surveys are concentrated in the Toko Syncline and adjacent to the southeastern margin.

In general, poor results have been obtained from reflection traverses in areas underlain by thick sequences of cavernous and fractured Palaeozoic carbonate rocks. BMR conducted experimental surveys in areas of carbonate rocks near Camooweal and in the Tobermory/Lake Nash areas in 1961 and 1965, but the results for both were poor.

Little work has been carried out in the outcropping part of the basin in Queensland. Phillips shot several lines in 1960 and 1961. The South Australian Mines Department shot one reflection and refraction line into the area in 1960. BMR conducted reconnaissance reflection surveys in 1963, 1964, and 1965. The French Petroleum Co. (Aust.) Pty Ltd carried out three subsidized seismic surveys in the southeastern extension of the Toko Syncline in 1963, 1964, and 1965, and Alliance Oil Development Australia NL shot about 140 line-km of single coverage data in the Toko Syncline in 1970. Reflection quality of the last survey was generally poor to fair.

The search for structure by seismic exploration has been generally unsuccessful.

Economic geology

Phosphate rock: The Georgina Basin contains most of Australia's resources of phosphate rock. Reserves exceeding 2000 million tonnes, at an average grade of 17% P_2O_5, occur in ten deposits in the Queensland portion of the basin. The phosphorite deposits are of early Middle Cambrian age and were formed in a shallow-water shelf environment free from the influx of clastic material.

Metalliferous deposits: No metalliferous deposits have been mined, but a few prospects have been tested for lead and manganese. Galena is not uncommon in the carbonate rocks, and galena and arsenopyrite have been reported in samples from water-bores.

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Beds of oolitic ironstone and concentrations of manganese occur in the sediments.

Petroleum: Traces of hydrocarbons were recorded in many of the wells drilled. Potential source beds are present throughout much of the succession, particularly in the Middle Cambrian part, and oil shale of Middle Cambrian age has been recorded in a water-bore. Permeable rocks, mainly carbonates, are common in parts of the sequence, and cap rocks are present in many formations.

There are few anticlinal structures suitable for petroleum accumulation, the dominant structure being normal faults in the southwestern margins of the Toko and Dulcie Synclines.

Most of the northern part of the basin contains thin flat-lying sediments and hence has poor petroleum prospects. The sequence in the southern part of the basin is thicker, but a large part of it is exposed at the surface and most of the surface anticlines have been drilled unsuccessfully.

Groundwater: There is a general lack of surface water and the pastoral industry depends on supplies of bore water. Water is produced almost exclusively from Palaeozoic sediments in the outcrop area of the basin, but some successful bores produce from Cainozoic aquifers, and a lesser number from the Mesozoic. Artesian water is not obtained from the Georgina Basin sediments.

Recent activities

Alliance Oil Development Australia NL commenced drilling Ethabuka No. 1 well in the Toko Syncline in the Mt Whelan Sheet area of Queensland in 1973, and this is expected to be completed in 1974.

Deficiencies in geological knowledge

The structure and stratigraphy of the Palaeozoic rocks at depth are poorly known over most of the basin, although in many areas the structure may be predicted by surface mapping. This deficiency can best be overcome by seismic surveying provided an improved technique can be developed for those large areas underlain by limestone and dolomite. Surface source techniques with 12-fold coverage may improve record quality. The distribution of rock types in part of the area in Queensland is incorrectly depicted on some geological maps and this area will require remapping.

Adequate palaeontological zonation is required to establish the extent to which the sequence is diachronous and to confirm the duration of breaks in deposition.

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GIPPSLAND BASIN

The Gippsland Basin is a wedge-shaped basin located mainly offshore from the southeastern coast of Victoria. It is narrowest onshore to the northwest and broadens offshore to the southeast. The basin covers an area of 63 000 km^2 to the 200-m bathymetric contour and contains up to 12 000 m of upper Mesozoic to Cainozoic sediments.

The northern boundary is an exposed unconformable contact between basin sediments and rocks of the Tasman Geosyncline, and the northwestern boundary with the Otway Basin is the Selwyn Fault on Mornington Peninsula. The western boundary with the Bass Basin is an arbitrary line between Mornington Peninsula and Wilsons Promontory. The southwestern boundary, also with the Bass Basin, is partly an exposed or subsea unconformable contact between basin sediments and basement rocks on the northeastern flank of an elevated area of basement, the Bassian Rise, and partly the crest of the rise where it is covered by sediments. The eastern boundary (and offshore limit) of the basin is undefined. Basin sediments extend beyong the shelf break at about the 200-m bathymetric contour.

Basement rock types are known only from outcrops around the perimeter of the basin. These consist of Ordovician to Middle Carboniferous metamorphics, sediments, volcanics, granite, and granodiorite of the Tasman Geosyncline.

Up to 3000 m of uppermost Jurassic and Lower Cretaceous non-marine, deltaic, and fluvatile sandstone and siltstone unconformably overlie basement. They occur in a belt about 90 km wide that extends about 160 km easterly from Westernport Bay to the shelf break. This area of sediments has been referred to as the Strezlecki Basin.

At least 4500 m of Upper Cretaceous to Eocene fluvio-deltaic sandstone, shale, siltstone, lignitic to subbituminous coal, and thin mafic volcanics rest unconformably on the Upper Jurassic to Lower Cretaceous sediments. The centre of deposition of the fluvio-deltaic sediments progressively migrated from the southeast to the northwest, and simultaneous erosion of the sediments that began in the southeast during the Palaeocene affected the whole of the basin by the end of the Eocene. Complex channel systems incised the top of the fluvio-deltaic sediments during the early and late Eocene. A marine incursion in the Eocene led to the deposition of conglomerate, sandstone, calcareous mudstone, glauconitic mudstone, and shale. These sediments rest unconformably on the fluvio-deltaic sediments and are up to 760 m thick in channel areas and 60 to 150 m thick in parts of the interchannel areas.

At least 2800 m of Oligocene to Miocene marine sediments unconformably overlie the fluvio-deltaic sediments and channel-fill sediments. The marine sediments consist of 600 m of mudstone overlain by 2200 m of sandstone, limestone, and marl. Another period of uplift, erosion of canyons, and infill with calcareous mud pyroclastic rocks, minor micritic limestone, and calcareous quartz sandstone occurred in the middle Miocene in the eastern part of the basin.

The Oligocene to Miocene marine sediments are conformably overlain by 100 m of Pliocene marginal marine glauconitic to limonitic sand, silt, and clay and these in turn are overlain by 75 m of non-marine Pleistocene gravel.

The basin began to develop in the Jurassic with the separation of the Australian Plate and the Antarctic Plate of the Gondwanaland cratonic block. The uppermost Jurassic and Lower Cretaceous sediments were deposited in a narrow westerly-trending trough which is possibly a continuation of the Otway Rift Valley, which also developed at this time. These sediments were folded and block-faulted in the Late Cretaceous. Throughout the deposition of the Upper Cretaceous to Eocene fluvio-deltaic sediments, the basin was subjected to normal faulting and block-faulting. Much of the faulting was contemporaneous with deposition especially in the Late Cretaceous and Palaeocene, and the dominant fault trend was northwesterly during this time. However the type and direction of the structures developed changed from the Late Eocene to the late Miocene. In the northern part of the basin a series of easterly to northeasterly trending anticlinal folds and wrench faults developed. Post-Miocene sediments are mostly flat-lying and undeformed.

Geological mapping

The onshore part of the basin in Victoria was mapped at 1:250 000 scale between 1966 and 1972. All five Sheet areas are published, three in a provisional form. The mapping was both reconnaissance and detailed combined with airphoto-interpretation. Mapping at 1:63 360 scale was carried out in 1969 and 1970. Eight of these maps have been published.

No 1:250 000 scale mapping has been carried out by GST on Flinders and Cape Barren Islands.

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Correlation

The time correlation chart for the Gippsland Basin is based on microfossils and can be divided into two parts: the zones for the Oligocene to Pliocene marine sediments, and the zones for the Cretaceous to Eocene non-marine sediments. The zones for the marine sediments are a refinement of planktonic foraminiferal zonules originally defined by Taylor (1966) for Barracouta No. 1. The non-marine Cretaceous zones are based on Dettman & Playford's (1969) spore-pollen zones for the Cretaceous of Australia, and the Palaeocene and Eocene zones were derived by James & Evans (1971), who also modified the uppermost Cretaceous zones of Dettman & Playford.

Basin-wide lithological correlations after Esso Exploration and Production (Australia) Incorporated are available.

Drilling

About 230 oil exploration and stepout wells which have been drilled in the Gippsland Basin are concentrated onshore in Victoria and offshore in the northern central part of the basin. Most wells were drilled from 1956 onwards. The deepest well was drilled to 3794 m.

As commercial hydrocarbons have been discovered, numerous development wells have been drilled from the offshore Kingfish A, Kingfish B, Marlin, Barracouta, and Halibut platforms. The 22 subsidized wells penetrated sequences ranging in age from Tertiary to Late Jurassic. Stratigraphic information on the remaining 208 wells is contained in confidential company reports of Esso Exploration and Production (Australia) Incorporated, Alliance Oil Development Australia NL, BOC of Australia, Woodside Oil NL, Amalgamated Oil Syndicate, Arco Ltd, Frome Lakes Pty Ltd, Lake Wellington Oil Wells, Midfield Oil Co., Oil Search Ltd, Single Hill Exploration, Lexland Oil Co., Valve Oil Wells, Westralian Oil Ltd, Victoria State Mines Dept, Austral Oil Syndicate, Dome Oil and Minerals Syndicate NL, Gippsland Oil Co. Ltd, Kalemna Oil Co. Ltd, Lakes Entrance Development Co. Pty Ltd, Lakes Oil Ltd, Lake View Co., Midfield Oil Co., Midwest Oil Co., Point Addis Co., Tangil No. 1 Co., Tangil No. 2 Co., Ashburton Oil NL, Endeavour Oil NL, Halliday Enterprises Pty Ltd, and NSW Oil and Gas Co. NL. These wells have delineated the subsurface geology of the basin.

Magnetic surveys

Three aeromagnetic surveys and three shipborne combined magnetic and seismic surveys have been carried out.

BMR surveyed the onshore area in Victoria in 1951-1952 and the northern offshore area in 1956. The data quality was good and the data were qualitatively interpreted. The anomaly trends of the total magnetic intensity contour map can be correlated with several known geological structures in the basin. A contour map of estimated depths to magnetic basement shows a trough containing up to 4500 m of sediment east of Lake Wellington. Depth estimates in parts of the western edge of the basin are uncertain owing to the presence of magnetic basalt flows in the sedimentary sequence.

In 1962, Hematite Exploration Pty Ltd flew an aeromagnetic survey over the southern part of the basin, extending the BMR survey. Results obtained were consistent with the BMR results.

The three shipborne magnetic surveys were of little importance. They were carried out in restricted parts of the basin, mainly near the western edge. The results were similar to those already gained from the airborne surveys and generally confirmed that the areas mapped were undisturbed magnetically.

Gravity surveys

Numerous gravity surveys were carried out onshore by BMR in 1943, 1948-1951, and 1958. BMR carried out a shipborne survey on easterly trending lines spaced 32 km apart in 1971 and 1972, over the offshore area. Interpretation of this data is not yet available. BMR completed helicopter gravity coverage of the onshore area on an 11.2-km grid in 1974.

Two major company surveys have been carried out: the first in 1949 by Lakes Oil Ltd, and the second in 1966 by Woodside Oil NL. The latter was a subsidized detailed survey in the central onshore part of the basin. The survey detailed the form of the Bouguer anomaly field which is a regional south-dipping gravity gradient interrupted by a local positive anomaly.

Seismic surveys

Twenty subsidized seismic surveys and six BMR seismic surveys have been carried out between 1952 and 1971, including twelve offshore. Three were combined marine magnetic and seismic surveys. They provided good overall coverage of the basin and about 20 000 line km were shot. A number of unsubsidized marine seismic surveys have also been

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done for Esso-B.H.P. Seismic surveys have been invaluable in delineating the stratigraphy and structure of this predominantly offshore basin, and they located the channels against which the petroleum is commonly trapped. Seismic data quality is generally fairly good down to the Top Latrobe horizon, but is much poorer below.

Overall the surveys were useful as magnetic basement corresponds to economic basement, except where magnetic volcanics occur within the sedimentary sequence.

Economic geology

Petroleum: Gas and oil have been found in commercial quantities offshore in the northern half of the basin. Proved and probable oil reserves in the Kingfish, Halibut, and other fields are about 2 billion barrels, and gas reserves from the Barracouta and Marlin fields plus other indicated discoveries are about 10 trillion cubic feet.

The source and reservoir rocks for most of the oil and gas fields are the Upper Cretaceous to Eocene fluvio-deltaic rocks. Most hydrocarbons in the Basin are trapped (within anticlines) at the top of the lower to upper Eocene sediments in highly porous and permeable, and generally massive, sandstones. The cap rock is generally the Oligocene to Miocene marine mudstone and shale, and also partly the channel-fill sediments; thus, the hydrocarbons are trapped at the erosional surface which developed on the top of the fluvio-deltaic sediments. Hence, the nature of the erosion surface is important, as is the configuration of the channels and the permeability of the sediments deposited in them. However, the lower Eocene oil of the Barracouta field and the Palaeocene gas and oil of the Marlin-Tuna trend are trapped (by anticlines) beneath caprock shales within the fluvio-deltaic sediments.

Bauxite: Forty small deposits of bauxite occur within an area of 50 km^2 around Boolarra. They are a fossil laterite on an unconformity in the Tertiary sediments. The aluminium is mainly present as gibbsite with minor boehmite. Reserves are somewhat less than 1 000 000 tonnes.

Coal: Brown coal occurs in the Upper Cretaceous to Eocene fluvio-deltaic sediments. The coal measures in the Latrobe Valley have been drilled over an area of about 600 km^2 and reserves consist of 46 000 million tonnes measured and 42 000 million tonnes inferred. The seams are up to 165 m thick, have an overburden of about 16 m, and are worked by open cut. The ash content of the coal is low, usually less than 2 percent, and there is a general increase in quality with depth.

Brown coal in the Welshpool-Alberton area occurs as a seam of variable thickness up to 91 m, has a moisture content of 66 percent, and an ash content of 6 to 10 percent.

Narrow, highly lenticular black coal deposits occur in the Upper Jurassic to Lower Cretaceous non-marine sediments at Wonthaggi. The coal seams are faulted and thus difficult to work. The coal is a non-coking bituminous variety of relatively low rank. The field comprises two basins: the eastern basin contains two seams, one and two metres thick, 150 m apart; the western basin contains eight lenticular seams within 300 m of sediments, but only two seams, with a maximum thickness of four metres and one-and-a-half metres, are workable. Production ceased in 1968.

Limestone: Extensive deposits of middle Tertiary limestone suitable for building occur in a belt south of Sale and Rosedale. Total reserves in the basin total 0.765 million m^3.

Water: Overall the salinity of the water in the Gippsland Basin is low, except for two small areas near Lakes Entrance where the salinity is high, and the water is suitable for most livestock and for very limited industrial and domestic use. In the far northwestern and northeastern part of the basin the salinity of the water is between 1000 and 3000 mg per litre, making it suitable only for livestock, some domestic, and limited industrial use. For the rest of the onshore area of the basin in Victoria the salinity is less than 1000 mg per litre. Here the yield is adequate and the quality good, making the water suitable for towns, industry, livestock, and most crops and pastures. However, on Flinders and Cape Barren Islands and on Wilsons Promontory the yield is inadequate for towns, industry, and irrigation.

Recent activities

The offshore part of the basin is being actively explored for petroleum. Ten wells were drilled in 1973 and three to September 1974.

Of the wells drilled in 1973, Marlin Nos. 4 and A24 further evaluated Palaeocene and Eocene reservoirs within and below the Marlin field, and intersected gas-bearing sands. The drilling of Mackerel No. 4 enabled the Mackerel Field to be declared commercial, with estimated recoverable reserves of 200 million barrels of oil. Kingfish No. 4 investigated structure and stratigraphy in the western part of the Kingfish field. Hydrocarbon shows were reported from Flounder No. 4, but none was reported from the

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remaining five wells (Pike No. 1, Stonefish No. 1, Bullseye No. 1, Dart No. 1, and Sole No. 1), all of which were wildcats, mostly tens of kilometres from previously drilled wells.

In 1974 Turrum No. 2, drilling near Marlin, intersected several wet-gas and condensate-bearing reservoir sands beneath the Marlin structure. Sunfish No. 1, a wildcat midway between Marlin and the coast, intersected shows of oil and gas. No data has been released for Kingfish No. 5.

The most recent subsidized seismic survey was a reflection-refraction survey done for Magellan Petroleum in 1973 in the eastern offshore part of the basin. Data quality was good but no substantial structures or stratigraphic traps were indicated.

Deficiencies in geological knowledge

There seem to be no major deficiencies in the geological knowledge of the basin.

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HILLSBOROUGH BASIN

The Hillsborough Basin is a narrow asymmetrical southeasterly trending graben, which underlies an area of about 900 km^2, largely offshore, in Queensland. The onshore area of the basin underlies the Proserpine lowland. The graben is seven to 15 km wide, up to 80 km long, and it contains up to 3000 m of probably entirely Tertiary sedimentary rocks. Although the name "Proserpine Basin" is used on the Tectonic Map of Australia and New Guinea, 1971, the name 'Hillsborough Basin' is preferred because it was used on the BMR/GSQ 1:250 000 map and explanatory notes and in the BMR Report on the regional mapping.

The margins are almost entirely concealed beneath the sea and beneath Quaternary coastal plain deposits. The northeastern margin is a fault, prominent on seismic sections, which separates the downthrown sediments of the basin from Devono-Carboniferous, Lower Permian, and Lower Cretaceous volcanic and sedimentary rocks and Lower Cretaceous granite. The southwestern margin is a step-fault system separating basin sediments from the Devono-Carboniferous strata exposed along the coast. Seismic interpretation suggests that the graben terminates abruptly to the northwest at Proserpine. A marked thinning of sediments east of Cape Hillsborough is taken as the southeastern limit of the basin.

Basement is presumed to be similar to the older rocks exposed around the margins of the basin.

A sequence of Oligocene volcanic rocks and Palaeocene? to Middle? Oligocene age continental sedimentary rocks about 600 m thick crops out in a fault bounded area at Cape Hillsborough. Oligocene intrusions occur nearby. 1282 metres of probable Tertiary continental shale, labile sandstone, and minor conglomerate overlying volcanic breccia of unknown age were penetrated in Proserpine No. 1. The sediments have been faulted and tilted, but no folding has been recognized.

Geological mapping

The basin occurs wholly within the Proserpine 1:250 000 Sheet area, which was partly mapped by Ampol Exploration in 1962 and mapped at 1:250 000 scale by BMR and GSQ in 1962, 1965, and 1966. A first edition geological map is included in BMR Report 144 and the map has also been published with explanatory notes. The area of the basin is also covered by a 1:1 000 000 geological map (Burdekin - Townsville Region), published, together with an explanatory booklet, by the Geographic Section of the then Commonwealth Department of National Development in 1972. BMR issued a 1:500 000 preliminary edition map of the Burdekin River Region in 1971.

The mapping is good-quality regional, but its value is limited because there is only one area in which basin sediments crop out. Nevertheless the mapping has delineated the onshore margins, where older rocks are exposed, and cross-sections of the basin, based mainly on geophysical data, are included with the 1:250 000 maps.

Drilling

Three petroleum exploration wells, one stratigraphic bore, and two shallow bores have been drilled, all onshore.

Mackay Oil Prospecting Syndicate drilled two wells in 1956 and 1957 near sea level at Cape Hillsborough. The deeper well penetrated about 210 m of Tertiary sandstone and shale before entering volcanics of probable Devono-Carboniferous age. In 1965 Ampol Exploration Ltd drilled the only real test of the relatively thick sedimentary column in the axial zone of the basin, 12 miles southeast of Proserpine. This subsidized stratigraphic well (Proserpine No. 1) penetrated 1282 m (where seismic data indicated 1350 m) of probable Tertiary shale and subordinate lithic sandstone and conglomerate before bottoming in Palaeozoic? volcanic breccia.

A stratigraphic bore, GSQ Proserpine 1-2RA, was drilled by the GSQ on the coast near Cape Hillsborough in 1971. The bore spudded near sea level in Tertiary volcanics. Total depth was reached at 453 m, after passing through 430 m of Palaeocene? to middle? Oligocene mudstone, shale, sandstone, and minor oil shale.

Two shallow holes were drilled for coal on Newry Island, on the southwestern edge of the basin, in 1912. They passed through about 26 m of sandstone, pebble conglomerate, and shale before entering basement volcanics.

In the late 1960s an offshore stratigraphic test (Mackay No. 1) proposed by JAPEX (Aust) Pty Ltd in the Hillsborough Channel attracted adverse publicity on environmental ground, and a Royal Commission was established to report on the environmental implications of exploring for petroleum in the region of the Great Barrier Reef. The final report of the enquiry had been compiled by September 1974, but had still to be presented to the Australian Parliament.

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Correlation

Lithological and time correlation have not been possible because of the restricted outcrop and the paucity of wells drilled. Seismic correlation is difficult because of the large number of faults, many of which appear to have been active during deposition.

Aeromagnetic surveys

The whole basin was covered in 1962 by subsidized airborne magnetic surveys carried out for Australian Oil and Gas Ltd (ADG) and Ampol Exploration Ltd.

The AOG survey consisted of only two siz-zag flight-lines and the basin was not detected on these. The Ampolex survey was flown along flight-lines 1.6 km apart. The interpretation confirmed the existence of the basin and indicated that it is divided by cross-faults into several subsidiary troughs. The survey also indicated a possible shallower analogue of the basin to the southeast, offshore from Mackay, and a further analogue to the northwest of Proserpine.

Magnetic basement lies at about 2200 m below sea level onshore, just south of Proserpine. It shallows to the southeast and then deepens again to a maximum of 1250 m offshore in an area later found by seismic survey to coincide with the widest and deepest part of the basin. Here seismic basement lies at about 3000 m, suggesting that magnetic basement may be either thin volcanics interbedded with the sequence or igneous rocks intrusive into the lower part of the Tertiary sequence.

Gravity surveys

A few gravity traverses were made in an offshore area to the northeast of the basin during the BMR regional Underwater survey in 1958. The results are available in Records 1959/70 and 1963/163. The onshore part of the basin and some islands offshore were covered as part of the BMR helicopter gravity program for 1963 (Report 138). Ampol Exploration Ltd made gravity readings along a seismic traverse across the basin in 1963.

The offshore area is too sparsely covered for any estimate of the gravimetric effects of the basin sediments to be made. The onshore area of the basin coincides with a marked Bouguer gravity minimum. The gravity data obtained along the seismic traverse confirm that the northeastern margin is faulted.

Seismic surveys

Ampol Exploration Ltd surveyed the whole basin during two subsidized seismic surveys, one carried out onshore in 1963 and the other offshore in 1964. The poor to fair quality of the data obtained enabled a more precise delineation of basin structure. The surveys indicated the presence of a sedimentary trough up to 14 km wide parallel to the coast and containing up to 3000 m of sediments. No large anticlines were indicated, but fault traps for petroleum could be present. Seismic surveying has proved the most reliable method of evaluating this largely concealed sedimentary basin. Structure contour maps are published in Report 144.

Economic geology

Petroleum: No significant hydrocarbon shows have been discovered in the wells drilled. Proserpine No. 1 encountered sporadic traces of gas and bitumen and the Mackay Oil Prospecting Syndicate reported an unspecified, but presumably thin, intersection of greasy laminated shale containing 8 percent volatiles including sulphur and higher hydrocarbons.

No suitable reservoir rocks are known. The basin was probably a largely land locked sediment trap within which there was little opportunity for adequate sorting of the detritus. Contemporaneous volcanic activity on the southwestern margin of the basin and probably within it contributed detritus that further reduced the permeability of the sediments. Reservoir rocks may occur in the untested sediments offshore.

Wedge-like bodies, that could be buried reefs, are interpreted on seismic sections, flanking the northeastern fault-boundary, but these are more likely to be alluvial fans. No large simple anticlines are known, but there are small faulted anticlines and prospects of fault and stratigraphic traps.

The petroleum prospects are rated as low at this stage because, although there may be potential source rocks, no potential reservoir rocks are known and the traps appear small.

Oil shale: A bed of Tertiary oil shale, in places more than 2 m thick, is exposed in patches on the coast near Cape Hillsborough, and thin seams were intersected over three intervals in GSQ Proserpine 1-2RA 3 km to the southeast. The material is low-grade, occurs below sea level, and therefore has no direct commercial significance.

Recent activities

The proposal by JAPEX (Aust) Pty Ltd to drill an offshore well (Mackay No. 1) has been postponed pending the results of the Royal Commission.

Deficiencies in geological knowledge

The main deficiency is lack of an offshore well to assess the reservoir potential. Basin-wide lithological and time correlation cannot be attempted without further subsurface information.

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LAURA BASIN

The Laura Basin lies beneath an irregularly shaped northerly trending area of 17 000 km^2 onshore and at least 6000 km^2 offshore on the eastern side of Cape York Peninsula in Queensland. It contains at least 1000 m of Jurassic and Lower Cretaceous sediments.

Onshore, the margin of the basin is an outcropping angular unconformity separating basin sediments from folded low-grade middle Palaeozoic sediments and Upper Permian granite of the Hodgkinson Basin to the south and east, and Precambrian metamorphic and igneous rocks to the west. A small connexion with the Carpentaria Basin to the west is concealed beneath Quaternary deposits. The offshore boundary has not been defined.

Basement is predominantly low-grade middle Palaeozoic metasediments, Upper Permian granites, and Permian sediments.

The oldest sediments in the basin are up to 600 m of Jurassic terrestrial sandstone and minor coal. The Jurassic sediments are overlain conformably by up to 470 m of Lower Cretaceous shallow marine glauconitic sandstone and siltstone and minor coal.

The sediments are largely undeformed. The sequence is faulted in some localities and dips of up to 80° have been observed along the major Palmerville Fault in the west.

Geological mapping

All the five 1:250 000 Sheet areas that cover the onshore area of the basin were mapped by BMR and GSQ in 1962, 1963, and 1967. Two of the Sheet areas have been published with explanatory notes, and preliminary editions of the other three have been issued and explanatory notes are in preparation. A 1:500 000 geological map covering most of the basin is published in BMR Bulletin 84.

BMR and GSQ remapped the eastern margins of the basin between 1967 and 1974. The mapping, in conjunction with the drilling, has provided the main basis for the evaluation of the basin.

Drilling

Three petroleum exploration wells have been drilled, all onshore in the southeastern quadrant of the Ebagoola 1:250 000 Sheet area.

Marine Plains No. 1, drilled in 1962, penetrated Tertiary, Cretaceous, Jurassic, and Permian? sediments before entering altered sheared basalt at 1130 m. Breeza Plains No. 1, drilled in 1970, penetrated Tertiary, Cretaceous, and Jurassic sediments and reached Permian? sediments at 933 m. Lakefield No. 1 penetrated 921 m of Tertiary, Cretaceous, and Jurassic sediments before entering granitic basement.

BMR drilled one stratigraphic hole to 214 m in the western part of the Laura Basin and one to 106 m in the connexion between the Carpentaria and Laura Basins in 1972. Cores were recovered for examination and artesian water was found in several aquifers in the Jurassic sequence.

Two water-bores have been drilled to about 350 m each in the Cooktown Sheet area.

The wells have provided valuable information on the lithology in the deeper part of the basin, have indicated the thickness of sediments in the basin, and have discovered Permian? sediments beneath the basin that may be prospective for petroleum or act as a source for petroleum.

Correlation

A lithological correlation has been achieved by the mapping and the subsurface information obtained from drilling.

Aeromagnetic surveys

The whole offshore area of the basin has been covered during two subsidized aeromagnetic surveys carried out in 1962 and 1968 for Gulf Interstate Overseas Ltd and for Corbett Reef Ltd. Interpretation of the earlier survey suggested that magnetic basement lay 2000 m below sea level in Princess Charlotte Bay, east of the Palmerville Fault, and rose to an inferred 600 m below sea level to the east and west. Depth to magnetic basement contours from the 1968 survey are summarized in BMR Record 1973/132; the contours indicate an easterly thickening wedge of sediments of unknown age.

Gravity surveys

BMR made submarine observations in 1959 and 1963 over a small part of the offshore area, but coverage is too sparse for an interpretation to be made. The whole of the onshore area of the basin was covered during a regional helicopter survey carried out by BMR in 1966. The gravity anomalies show no correlation with the features of the basin.

Seismic surveys

A small onshore area surrounding the three petroleum exploration wells was covered by two subsidized surveys in 1963 and 1969, and a larger adjoining area, offshore in Princess Charlotte Bay, was covered in another subsidized survey in 1969. There is also sparse coverage of the basin from seismic surveys carried out in 1965 and 1969 farther north along the Great Barrier Reef.

The Marina Plains reflection seismograph survey by Marathon Petroleum Australia Ltd in 1963, and the Breeza Plains seismic survey for Crusader Oil NL in 1969, recorded a good reflector from within the Jurassic that occurs at about 740 m depth and is flat-lying throughout most of the survey area, but rises to 400 m at the east and west margins. About 600 m below the Jurassic reflector, seismic sections show an angular unconformity below which the reflections dip westward to a maximum depth of 8000 m at the Palmerville Fault. These reflections are fairly continuous and may represent sediments. Using information from the three exploration wells, metamorphic basement was mapped at about 900 m in the deepest part of the onshore basin (see BMR Record 1973/132).

The offshore survey for Exoil NL in Princess Charlotte Bay did not record any seismic reflections; a refraction probe, however, recorded a velocity of 5592 m/s at 912 m, which may represent metamorphic basement. The marine refraction profiles obtained for Gulf Interstate Overseas Ltd in 1965 recorded a refractor with a velocity of about 4500 m/s at a depth of 500 m to 900 m, and another of 5600 m/s velocity about 400 m deeper. The first refractor could represent the top of Lower Jurassic or Permian sediments and the lower refractor possibly metamorphic basement. Fair reflection data were obtained during the Offshore Laura Basin survey for the Endeavour Oil Company NL in 1969. The interpretation suggests an easterly thickening wedge of sediments up to 1200 m thick overlying basement. Several possible faults were mapped and a possible anticline was indicated.

Economic geology

No significant hydrocarbons have been discovered. Jurassic shale and minor coal are possible sources for petroleum, but their maturity has not been established. Permian sediments that underlie the basin may contain source rocks. Permeable Jurassic sandstones are potential reservoir rocks.

Breeza Plains No. 1 and Lakefield No. 1 were drilled on culminations on a north-northwest-trending anticline. There are indications from seismic work of fault traps and possibly of anticlines. Stratigraphic pinchouts may occur where the Jurassic sediments overlap high basement.

The sedimentary sequence is thin and the petroleum prospects are rated as low.

Recent activities

There has been some prospecting for coal and uranium by private companies.

Deficiencies in geological knowledge

Very little is known of the offshore geology. Onshore there are unidentified seismic reflections beneath the Permian or Jurassic, at about 1000 m, which dip at about 10° and terminate at the Palmerville Fault at a depth of 8000 m. These reflections may arise from Permo-Carboniferous sediments because their projected subcrop shows that they would lie above the Hodgkinson Formation in the basement, and because of their structural simplicity compared to the Hodgkinson Formation. Further seismic surveying has been recommended to solve this problem.

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MARYBOROUGH BASIN

The Maryborough Basin is a north-northwesterly trending depression containing at least 7400 m of Jurassic and Lower Cretaceous rocks. It underlies an area of at least 30 000 km^2, of which one third lies onshore between Bundaberg and Maryborough, in southeastern Queensland.

The western margin, onshore, is a partly faulted outcropping abutment unconformity between basin sediments and Permian and Triassic sediments and granite. The offshore boundaries are not well known and have been selected from inconclusive geophysical evidence. The northern boundary is assumed to be near the Capricorn Reef, the eastern to lie off the east coast of Fraser Island, and the southern to lie at about latitude 26°S where a connexion with the Nambour Basin is suspected.

The nature of the basement is not known except in outcrops along the western margin.

The oldest sediments in the basin are about 2000 m of Jurassic sedimentary and volcanic rocks. A basal fluviatile orthorquartzite, about 500 m thick, is overlain by about 1500 m of coal measures with volcanics interbedded near the top. Neocomian? continental volcanic rocks and tuffaceous sedimentary rocks, about 1300 m thick, conformably overlie the Jurassic rocks, and are in turn overlain disconformably by about 2300 m of Aptian? shallow marine shale, siltstone, and fine-grained sandstone, and 1800 m of Lower Cretaceous (Aptian?) coal measures.

Small hypabyssal masses, probably comagmatic with the Lower Cretaceous volcanics, intrude the Jurassic sediments in the southeast.

The sediments have been strongly folded into asymmetric northwest-plunging anticlines and synclines with flank dips of about 30°, and faulted into blocks, especially in the west.

Geological mapping

The basin is covered by five 1:250 000 Sheet areas (Bundaberg, Sandy Cape, Maryborough, Wide Bay, and Gympie). All of the onshore part of the basin was mapped by GSQ between 1962 and 1966. A 1:250 000 preliminary edition of Maryborough is available and the preliminary editions of Bundaberg and Gympie are in preparation.

Drilling

Ten petroleum exploration wells have been drilled, six in the 1920s and four since 1954. Numerous shallow coal bores have been drilled in the Cretaceous coal measures.

Lucky Strike Drilling Company drilled Cherwell No. 1 in 1954 and 1955, penetrating about 3000 m of Lower Cretaceous sediments, and Susan River No. 1 in 1956, penetrating about 1600 m of similar rocks. Both wells bottomed in volcanics of presumed early Cretaceous age.

Humber Barrier Reef Oils Pty Ltd drilled Wreck Island No. 1 in 1959 on Wreck Island in the Capricorn Group near the assumed northern margin of the basin. The well penetrated Miocene to Recent limestone and sandstone and bottomed in volcanic breccia (Lower Cretaceous?) at 597 m.

Shell Development (Aust) Pty Ltd drilled Gregory River No. 1 in 1967. It penetrated 3100 m of Lower Cretaceous rocks and also bottomed in the volcanics.

Correlation

No basin wide lithological or time correlations are available. Lithological correlation has been established for the Cretaceous sequence onshore.

Aeromagnetic surveys

Australian Oil and Gas Ltd carried out a subsidized survey along the Queensland coast in 1962 that covered all of the offshore part of the basin and part of the onshore. The survey included six easterly and three northerly traverses from 16 to 64 km apart over the basin. Australian Gulf Oil Company carried out a subsidized survey in the northern offshore part of the basin in 1964.

Interpretation of the AOG survey suggested that the western margin of the basin may be a fault (not confirmed by mapping) and that magnetic basement (probably the Neocomian volcanics) lies at up to 5000 m below sea level in Hervey Bay, and rises to 150 m to 300 m along an elevated area beneath the Bunker and Capricorn Islands. The Australian Gulf Oil survey indicated shallow magnetic basement extending from Wreck Island to Fraser Island and deeper basement to the west, where 3600 m of sediments are interpreted. However, as with the earlier survey, magnetic basement is thought to be the Neocomian volcanics.

The magnetic method has provided a useful reconnaissance tool, but because magnetic basement lies within the sequence, it is unlikely to be able to define the true configurations and extent of the basin.

Gravity surveys

The onshore area of the basin was covered by BMR during a regional survey of southern Queensland in 1965 (Record 1965/251). Shell Development made gravity measurements on the mainland and on Fraser Island in 1963 during an unsubsidized survey. BMR made submarine gravity measurements along a single traverse across part of Hervey Bay in 1959 (BMR Record 1959/68).

The basin lies within a broad zone of irregular highs and lows known as the Coastal Gravity Complex and many of the gravity anomalies are attributed to density contrasts within the basement and easterly thinning of the crust towards the edge of the continent. Some of the Bouguer anomaly gradients and areas of high gravity onshore are thought to arise from fault-controlled horsts and troughs within the basin. Similar gravity features offshore may have a similar origin, but it is not known whether the higher density material giving rise to the gravity maxima is basement or Lower Cretaceous volcanics.

Seismic surveys

Seismic coverage is concentrated offshore in the Hervey Bay area and west of a line from the northern tip of Fraser Island to Wreck Island. This area is covered by a grid of survey lines averaging about 10 km apart. Onshore coverage includes the Susan River area and Fraser Island.

About 180 km of seismic reflection line was shot for the Lucky Strike Drilling Company onshore in the Susan River area in 1953. The survey outlined the Susan River anticline on which a well was later drilled. Shell Development carried out a subsidized survey of about 520 line-km of reflection traverse onshore in 1963. This survey included the Susan River area and Fraser Island and other areas about Hervey Bay onshore. Quality ranged from poor to fair but it achieved a reasonable correlation of subsurface geology between the mainland and Fraser Island, and outlined the structure.

The offshore coverage was achieved by Shell Development during a small subsidized survey in the Bunker Islands area in 1964, larger subsidized surveys in the Hervey Bay area in 1964 (1100 line-km) and 1969 (206 line-km), and an unsubsidized survey in the same area in 1970. Australian Gulf Oil Company carried out the Swain Reefs seismic survey in the north of the basin in 1965 as a follow-up to their aeromagnetic survey.

Record quality offshore is generally very poor to fair. The surveys indicate that probable Lower Cretaceous sediments up to 5000 m thick occupy a northwest-trending symmetrical syncline in the Hervey Bay area. The syncline is crossed by an east-dipping fault with a throw of up to 1500 m. The Swain Reefs survey indicated that most of the area is underlain by a formation of fairly high velocity that may be Jurassic or Cretaceous volcanics. Probable Tertiary sediments, up to about 2500 m thick, occupy a broad lobe on the eastern side of the survey area.

The seismic method has been useful in indicating the general extent of the Lower Cretaceous sediments offshore, but it is limited by the poor quality of much of the data, by the lack of reliable ties to onshore wells, and by the probable presence of volcanics within the sequence.

Economic geology

Petroleum: The search for hydrocarbons has been restricted to the post-volcanic Cretaceous sequence. The Jurassic coal measures may be a source for petroleum. Gregory River No. 1 encountered small quantities of methane near the base of the Lower Cretaceous post-volcanic sediments, but permeability is low. Several anticlines occur onshore and probably offshore.

Insufficient is known about the basin to adequately evaluate its petroleum prospects, but they appear low.

Coal: The Lower Cretaceous coal measures, which are the youngest beds in the basin onshore, crop out in the northwest-trending synclines. One of these, the Burrum Syncline, has been systematically prospected and the major seams are known to be continuous but variable in thickness so that the workable parts are lenticular. The seams being mined are from less than one to 1.5 m thick. About eight million tonnes have been produced, and reserves were estimated at six million tonnes in 1968. The coal is high volatile, bituminous, and strongly coking, with an average ash content of about ten percent and a lower than average sulphur content.

No economic deposits have been found in the Jurassic coal measures.

Clay: Clay is quarried from the Aptian sediments and is used for making bricks and earthenware pipes and fittings.

Beach sands: Low-grade deposits of ilmenite-zircon-rutile-bearing sands occur on Fraser Island.

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Recent activities

The most recent activity was the unsubsidized seismic survey by Shell Development (Aust) Pty Ltd.

Deficiencies in geological knowledge

The major deficiency is lack of knowledge of the geology of the Jurassic part of the sequence, particularly offshore, and lack of lithological data for the entire offshore sequence.

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MONEY SHOAL BASIN

The Money Shoal Basin extends over about 390 000 km^2 offshore (230 000 km^2 in Australian adjacent area) in the Arafura Sea in adjacent areas of the Northern Territory of Australia and Indonesia, and 1000 km^2 onshore north of the Pine Creek Geosyncline and McArthur Basin.

The eastern margin is the Wessel Rise extending northward from the Wessel Islands toward Frederik Hendrik Island in Irian Jaya. The northern boundary, in Irian Jaya, is the Merauke Rise between the Aru Islands and Frederik Hendrik Island. The northwestern boundary beyond the edge of the continental shelf (Arafura Shelf) has not been defined, and the southwestern boundary adjoins the Bonaparte Gulf Basin along a somewhat arbitrary line running north-northwesterly from Bathurst Island along the Van Diemen Rise. The southern margin abuts the Pine Creek Geosyncline and McArthur Basin onshore, and the Adelaidean Arafura Basin offshore.

The Aru Islands form part of the Australian continental plate and consist of possible Precambrian granitic basement beneath Mio-Pliocene limestone. In the northern part of the Northern Territory, near the Wessel Islands, Adelaidean sandstone, siltstone, and shale of the Arafura Basin, Carpentarian sediments, and early Carpentarian granite crop out adjacent to the southern margin.

Little is known of the type of sediment fill within the basin as only a few wells have been drilled, and marginal outcrops occur only on the Aru Islands, Frederik Hendrik Island, and the northern part of the Northern Territory. Seismic interpretation with the available geological control suggests that the fill is predominantly of Mesozoic and Tertiary age.

Significant thicknesses of Palaeozoic sediments may be present within or beneath the basin. Recently, Middle Cambrian fossils were discovered on Elcho Island in fine-grained sandstones unconformably overlying rocks of presumably Proterozoic age. It seems probable, therefore, that Cambrian sediments extend offshore. Silurian non-marine sandstone, about 100 m thick, was drilled in Money Shoal No. 1 well overlying sedimentary rocks of probable Precambrian age. Permian sediments are known from Petrel No. 1, 200 km to the southwest in the Bonaparte Gulf Basin, and may be expected to extend into part of the Money Shoal Basin. A pre-Mesozoic graben, interpreted from seismic records, occurs in the east. Although good reflections are recorded from within the graben, the age of the infilling sediments is not known.

There is an almost complete lack of mappable seismic reflections in a large area of the basin below an intra-Lower Cretaceous seismic reflecting horizon, and the thickness and interval velocities of the sedimentary sequence below this horizon cannot be measured. The lack of reflectors suggests a thick clastic sequence, inferred from regional stratigraphic considerations to be mostly Lower Cretaceous and Upper to Middle Jurassic shale grading into a deeply buried Lower Jurassic and Triassic sand and shale sequence.

Money Shoal No. 1 was unsubsidized and only the broadest details about the sedimentary sequence penetrated have been released. The Jurassic and Lower Cretaceous sequences, about 1300 m thick in Money Shoal No. 1, were deposited in predominantly fluviatile and paralic environments, and they contain good potential reservoir rocks. They rest unconformably or disconformably on the Silurian, and contain two internal disconformities. The sediments thicken across a hinge-zone toward the depocentre of the basin, where they are probably mostly shale. Lower Cretaceous siltstone, claystone, and sandstone unconformably overlie Precambrian basement onshore.

Upper Cretaceous predominantly fluviatile and deltaic sediments, about 900 m thick, disconformably overlie the Lower Cretaceous in Money Shoal No. 1, and contain two internal disconformities. They include a basal Upper Cretaceous shale cap rock. The sediments thicken gradually toward the basin depocentre. They crop out on Bathurst Island, Melville Island, and Cobourg Peninsula.

The Cainozoic sediments are divided into two sequences by an internal disconformity. About 100 m of predominantly deltaic sediments were drilled in Money Shoal No. 1. They thicken in a wedge to about 1400 m near the shelf break, where they are probably mainly carbonates.

The major deformation in the basin is regional tilting and faulting, but there has been some folding. A hinge-zone, across which the rate of thickening of the Mesozoic and Cainozoic sediments increases, separates an area of comparatively shallow (less than about 3500 m) undisturbed sediments in the south and southeast from a thicker (over 6000 m) more disturbed sequence in the northwest. The eastern extension of the Sahul Ridge, in the far northwest, is a fault-block containing thinner Cretaceous

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sediments unconformable on Triassic? sediments. The hinge-zone is probably fault-controlled and its effect on the sediments becomes less and less pronounced in the Upper Cretaceous and seems to have little effect on depositional trends during the Cainozoic to Recent. The folding along the hinge-zone is preferably regarded as a result of shale flowage in pre-Lower Cretaceous strata. Gentle folding in the deeper part of the basin may be due to either drape over deep-seated fault-blocks that were formed, along with the hinge-zone, during the Jurassic, or shale flowage in response to Tertiary loading.

Geological mapping

The main areas of Mesozoic outcrop were mapped by BMR in 1972 and preliminary 1:250 000 maps of Bathurst Island, Melville Island, and Cobourg Peninsula are available. In addition the Darwin and Alligator River Sheets, which were mapped in 1955 to 1958, are published with explanatory notes. Detailed mapping of these Sheet areas by BMR at 1:50 000 scale, has continued since 1971 and the East Alligator 1:50 000 Sheet has been compiled. BMR carried out a marine geological survey of the Arafura Sea in 1969, and 1:1 000 000 geological maps will be published. The mapping is up-to-date and good-quality regional, but is of limited value in evaluating this mainly offshore basin.

Drilling

The only two petroleum exploration wells drilled offshore, Money Shoal No. 1 and Lynedoch No. 1, were unsubsidized. The data released from Money Shoal No. 1 give valuable information on the stratigraphy in the comparatively shallow and undisturbed part of the basin. Lynedoch No. 1 was drilled to a depth of 3967 m in 232 m of water.

Oil Development NL drilled two coreholes close together on Bathurst Island in 1960 and 1961. Both wells bottomed in Cenomanian sandstone, and the deepest penetrating to about 300 m. Flinders Petroleum NL and Pexa Oil NL drilled one core hole to 583.4 m on the eastern end of Melville Island in 1970 and 1971. The well penetrated marine Upper Cretaceous strata to total depth.

BMR drilled five stratigraphic holes on the Cobourg Peninsula Sheet area in 1973. Two of these wells discovered artesian water.

Correlation

The only basin-wide correlation possible is seismic correlation and this is limited to the Cretaceous and Cainozoic sequences.

Magnetic surveys

An aeromagnetic survey was flown over Melville and Bathurst Islands for Alliance Oil Development in 1963. Results indicate that the magnetic basement coincides roughly with the Precambrian basement. A regional aeromagnetic survey totalling about 12 000 km was flown over the northern part of Arnhem Land and Melville Island for Shell Development in 1965. Depths to magnetic basement increase gradually to the northwest. North of Arnhem Land a basin with depths in excess of 9000 m passing westward into a graben is indicated; the sediments within it probably belong to the Precambrian/Palaeozoic? Arafura Basin. BMR carried out a shipborne seismic, magnetic, and gravity survey as far east as 132°E and as far north as 9°S in 1967. Stacked multiple seismic, magnetic, and gravity profiles are published at 1:500 000 scale. BMR plans to cover the remainder of the Arafura Sea in 1976.

Gravity surveys

In 1956, Santos Ltd carried out a gravity survey over Bathurst Island, and, in 1958, BMR ran an underwater gravity traverse off the coast from Cape Arnhem to Darwin. 1:500 000 Bouguer anomaly maps of the area covered by BMR's shipborne survey in 1967 are published. BMR tentatively plans to cover the remainder of the Arafura Sea in 1976.

Seismic surveys

Early onshore seismic work on Bathurst Island by Oil Development in 1962 indicated a northwesterly dipping refractor presumed to be of Precambrian origin at depths between 360 and 900 m.

The first marine seismic work was a short reflection program in 1964 by Anacapa Corporation in Dundas Strait, which indicated a regional northerly dip. In the same year BOC of Australia Ltd carried out the Cootamundra Shoal marine seismic survey to the north of Bathurst Island, which recorded a strong reflection at the same level as the Proterozoic refractor on Bathurst Island. Another reconnaissance line was run between New Year Island and Cape Wessel by Geophysical Associates for BMR. This line showed an unconformity rising from 0.65 s near New Year Island to 0.15 s in the central part of the line, beyond which the time was constant to near the end of the traverse where a gentle easterly dip was apparent near Cape Wessel. This unconformity was correlated with the base of Mesozoic sediments by extrapolation from onshore.

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Since December 1965, Shell Development and Australian Aquitaine Petroleum Pty Ltd carried out regional and detailed seismic surveys offshore to about 9°30'S between latitudes 130° and 136°E. Three main horizons A, B, and C were mapped as a result of these surveys. Horizon C is a prominent unconformity; although it is shallow near the Australian coast and to the east, it deepens rapidly to the north and west to a probable depth of 6000 m north of Melville Island. From correlation with onshore geology, the unconformity in the east separates basal Mesozoic from folded Proterozoic strata. A graben occurs beneath horizon C in the Money Shoal area. The sequence above horizon C is apparently conformable and undeformed. Within this sequence, Horizon B is believed to be a Mesozoic reflector of possible Late Triassic or Early Jurassic age, and Horizon A is correlated with the base of the Tertiary.

West of Bathurst Island a marine seismic survey near Parry Shoal by Longreach Oil Ltd in 1969 also indicated the basal Mesozoic reflector, below which a strong unconformity, presumed to be the top of the Proterozoic, was mapped. Possible Palaeozoic sediments are thought to occur between these two reflectors in this area by correlation with Petrel No. 1 well, 200 km to the southwest. The shallowest reflector mapped during the Parry Shoals survey was northwesterly dipping and is thought to correspond to an Oligocene transgression.

A marine geophysical survey of the Timor Sea carried out under contract to BMR in 1967 extended as far east as 132°E and as far north as 9°S. Four shallow unconformities were identified in the Tertiary sequence.

Beaver Exploration Australia NL shot about 900 km of unsubsidized Aquapulse seismic survey in NT P 23 east of and over part of the Wessel Rise in 1972.

Economic geology

Petroleum: A small flow of methane was encountered in Bathurst No. 2. Good reservoir rocks occur in the Jurassic and Cretaceous sequences penetrated by Money Shoal No. 1, and shale cap rock occurs at the base of the Upper Cretaceous. Thick sequences of shale probably occur in the depocentre of the basin and may be a source for petroleum. Structural and probably also stratigraphic traps occur in the hinge-zone and in the deeper part of the basin. Suitable structure may be present on the Sahul Ridge. Insufficient study has been made of the available data to adequately assess the petroleum potential of the basin, but it appears sufficiently promising to warrant further exploration.

Heavy minerals: BMR discovered widespread low-grade probably subeconomic heavy-mineral deposits in beach sands on Melville Island during the 1972 mapping.

Bauxite: Aluminous laterite deposits occur at widely separated localities on Cobourg Peninsula and Croker Island. The grades appear to be low and the tonnages small compared with those at Gove.

Water: Subartesian freshwater is available on Bathurst and Melville Islands from Tertiary aquifers. On Croker Island and at Murgenella Forestry Settlement, Quaternary sands and laterite form aquifers from which domestic and stock water is obtained.

Artesian water up to 43 000 litre/hour from basal sandstone overlying basement was discovered in Cobourg Peninsula (BMR) Nos. 2 and 4.

Recent activities

BMR followed up the mapping in 1972 with additional mapping, sampling, and stratigraphic drilling in 1973.

Deficiencies in geological knowledge

Further well control, improved seismic penetration, and increased gravity and magnetic coverage are required.

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MULGILDIE BASIN

The Mulgildie Basin, a lobe of the Surat Basin covers a narrow north-south-trending area of about 1800 km^2 in southeastern Queensland, 120 km west of Bundaberg. It contains Jurassic sediments up to 700 m thick.

The eastern margin of the basin is partly a fault (Mulgildie Boundary Fault) and partly an outcropping unconformity, and the western boundary is an outcropping unconformity. The southern boundary is arbitrarily placed at the junction of the lobe with the Surat Basin, where the Jurassic beds of the two basins are continuous.

Basement consists of strongly folded Devonian, Carboniferous, and Permian sediments of the Yarrol Basin, Upper Permian granite, and tilted Triassic volcanics.

Jurassic sandstone, siltstone, and coal, up to 700 m thick, rest with angular unconformity on the basement rocks. The coal occurs in the Mulgildie Coal Measures which are preserved in a graben in the northeastern part of the basin.

The sediments are very gently dipping except in the graben. The sediments are steeply dipping along the faulted margins of the graben and are folded into a gentle syncline within the graben.

Geological mapping

Both 1:250 000 Sheet areas covering the basin have been mapped by GSQ: Monto from 1962 to 1964, and Mundubbera to 1972. A 1:250 000 preliminary edition of the Monto Sheet area is included in GSQ Report 46. The part of the Mundubberra Sheet area that covers the basin is being compiled, and no report is available.

Drilling

Amalgamated Petroleum's Mulgildie No. 1 and Abercorn No. 1 are the only petroleum exploration wells drilled. Mulgildie No. 1, situated at the town of Mulgildie, penetrated about 700 m of gently dipping Jurassic sediments, about 500 m of steeply dipping Triassic volcanics, and bottomed in massive granodiorite. Abercorn No. 1, situated about 18 km south-southeast of Mulgildie, penetrated about 500 m of Jurassic, 1600 m of Triassic, and 600 m of Permian strata. The wells provided the only information on lithology in the subsurface apart from that furnished by the coal mines, and confirmed the general reliability of the seismic surveys.

The Burnett Colliery and the Irrigation and Water Supply Commission have drilled numerous shallow holes.

Correlation

A broad basin-wide lithological correlation has been achieved by the surface mapping.

Aeromagnetic surveys

Amalgamated Petroleum Exploration Pty Ltd included the basin in an area surveyed in 1962. No depth to basement information was produced, but igneous rocks and faults were interpreted. The company produced a 1:253 440 total magnetic intensity map.

Gravity surveys

BMR conducted a regional survey in 1964 that included the Mulgildie Basin and has published 1:250 000 Bouguer anomaly maps of the Monto and Mundubbera Sheet areas. The value of the information has not been assessed. Two en echelon Bouguer gravity maxima in the central area of the basin probable arise from density differences within the basement.

Seismic surveys

Amalgamated Petroleum surveyed the northern half of the basin in 1962. Two horizons were traced; the upper one is identified by drilling and is close to the unconformity at the base of the Jurassic. A second survey for Amalgamated Petroleum in 1963 confirmed that the Mulgildie Boundary Fault is a thrust with 2400 m of sediments on the western block.

Economic geology

Petroleum: No hydrocarbons have been found. The Evergreen Formation and the Mulgildie Coal Measures contain possible source rocks. The Precipice Sandstone has good porosity and permeability, and under favourable structural conditions would provide an excellent reservoir for the accumulation of hydrocarbons. In addition, the Mulgildie Coal Measures and the Evergreen Formation have slight porosity in some places. No large structural closures are known in the basin, but small favourable structures may exist along the Mulgildie Fault.

Coal: Five groups of coal seams have been found, the individual seams ranging up to 3 m thick. The coal is high-volatile bituminous and was used for steam-raising until

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production stopped in 1966. Estimated reserves are 6 000 000 tonnes.

Recent activities

The Mundubbera Sheet is being compiled.

Deficiencies in geological knowledge

The major deficiency is the lack of a geological map and report on the Mundubbera Sheet area.

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MURRAY BASIN

The Murray Basin is a near-circular onshore basin containing up to 1500 m of upper Palaeozoic to Cainozoic sediments. It covers an area of about 320 000 km^2 in southwestern New South Wales, northwestern Victoria, and Southeastern South Australia.

It is bounded on the southern and eastern side by lower Palaeozoic rocks of the Lachlan Geosyncline, and on the northern and northeastern edge by Devonian sediments of the Darling Basin. The northwestern and western boundary is formed by the Adelaide Geosyncline and the Willyama Block, and in the southwest a prominent flexure, forming the northern boundary of the Gambier Embayment, divides the Murray Basin from the Otway Basin.

Drilling has shown that the Murray Basin sediments unconformably overlie three types of basement which are similar to the rock types of the surrounding margins. In South Australia the basement has affinities with the Adelaide Geosyncline, whereas the basement in Victoria and southern New South Wales resembles metasediments and granites of the Lachlan Geosyncline. In the northern New South Wales part of the basin drill holes have encountered Devonian sediments of the Darling Basin.

The pre-Tertiary sediments occur in three infrabasins which strictly are not part of the Murray Basin. The Murray Basin (sensu stricto as a basin of sedimentation) was not formed until the early Palaeocene, when subsidence of the central part and uplift of the boundaries occurred. The infrabasins have been penetrated only in drill holes and their full extents have not been determined.

Two of the infrabasins contain Permian sediments. These are the Renmark Trough of about 24 000 km^2, centered on Renmark, and the northwest-trending Oaklands Sub-basin of about 16 000 km^2, northeast of Jerilderie, New South Wales. The Permian sediments have a maximum thickness of 460 m. The basal sediments are glaciomarine tillite, sandstone, and claystone of Sakmarian to early Artinskian age. These are overlain conformably by siltstone and shale deposited in a marginal environment. In the Oaklands Sub-basin these latter sediments include coal and have been dated as Tartarian.

The third infrabasin is unnamed. It covers an area of about 91 000 km^2 including most of the Renmark Trough. The northeast-trending basin contains up to 420 m of Jurassic? and Lower Cretaceous sediments disconformable on Permian sediments of the Renmark Trough and unconformable on an older basement. The basal sequence consists of non-marine quartz sandstone, possibly Jurassic in age. This is overlain conformably by marine siltstone and shale of Neocomian to Albian age, deposited during a marine transgression from the northwest.

Sedimentation in the Murray Basin (sensu stricto) commenced in the Tertiary, when over 700 m of sediments were deposited disconformably on the Cretaceous and Permian sediments and unconformably on the older basement. Throughout the Tertiary the sea entered from the southwest near the Padthaway Ridge.

Up to 350 m of Palaeocene and Eocene marginal gravel, sand, and carbonaceous clay cover an extensive area of the basin. Middle Eocene lignite occurs in a restricted area in northwestern South Australia within these beds, and up to 50 m of upper Eocene marine glauconitic marl, fossiliferous limestone, and carbonaceous clay were deposited above the marginal sediments during a minor marine incursion into southwestern South Australia.

Oligocene and Pliocene marine fossiliferous limestone and glauconitic marl cover a large area of the basin. They contain an internal disconformity between middle Miocene and lower Pliocene sediments.

In the late Pliocene marginal micaceous sand, silty sand, and grit up to 70 m thick were deposited in the southern part of the basin. The northern and eastern parts of the basin contain north-trending to northwest-trending sand dunes, possibly barrier dunes of a regressing sea. Lateritization followed in the late Pliocene.

The Quaternary deposits consist of mainly lacustrine clay and limestone in the southwest, aeolian sand dunes in the Mallee Region of Victoria, and fluviatile deposits in the upstream Riverine Plain.

The Murray Basin was relatively stable throughout its depositional history and neither faults nor localized folds are known within it.

Geological mapping

GSNSW mapped all the basin in NSW between 1964 and 1967. Eight 1:250 000 maps and three 1:500 000 maps have been published. Their mapping is based mainly on airphoto-interpretation with a few ground traverses. GSSA mapped parts of the basin in South Australia in 1965 to 1973. One 1:250 000 map is published with explanatory notes, but the reliability is unknown. GSV mapped part of the basin in Victoria between 1966 and 1972. One 1:250 000 scale map has been published and two preliminary editions have been issued. The mapping is based on detailed or reconnaissance ground surveys with airphoto-interpretation.

In summary, 11 of the 26 1:250 000 Sheet areas have been published and two more have been issued as preliminary editions. Three 1:500 000 maps are published as preliminary editions.

Correlation

No stratigraphic correlations are available.

Drilling

About 36 petroleum exploration wells have been drilled. They are distributed throughout the basin, with a slight concentration near Renmark and Jerilderie. Most were drilled between 1957 and 1970. The deepest penetrated to 2289 m. Sixteen of the wells were subsidized; all of them penetrated Tertiary strata, and some also penetrated Cretaceous or Permian sediments, or both.

Stratigraphic information on the unsubsidized wells is contained in confidential company reports of Woodside Oil NL, Exploration Drilling of Australia, Beach Petroleum NL, NSW Oil and Gas Co. NL, North Star Oil Corporation, and Mid-Eastern Oil NL.

The wells provide valuable stratigraphic information in this poorly exposed area of flat-lying sediments and enable the partial differentiation of the Mesozoic and Permian substrata.

Aeromagnetic surveys

Four subsidized aeromagnetic surveys were flown over the Murray Basin in 1962 and 1963. The surveys cover the basin. The data is of poor to good quality and the interpretation may not be reliable.

Gravity surveys

Six subsidized gravity surveys were carried out between 1965 and 1969. In addition, three combined seismic and gravity surveys were carried out between 1962 and 1967. The surveys give reasonable coverage in the northern part of the basin. The NSW and Victorian parts of the basin were covered on a 11.2-km grid by BMR in late 1973 and early 1974.

Seismic surveys

Twenty-nine subsidized seismic surveys were carried out between 1962 and 1970. They are reasonably well distributed throughout the basin and give a regional coverage although there are slight concentrations in the Renmark, Menindee, and Oaklands areas. Most of the data is of poor to moderate quality. Basement generally occurs at about 600 m, although it occurs at about 300 m beneath the Permian of the Renmark Trough. No potential hydrocarbon traps were discovered even in the areas of thicker sediments.

Economic geology

Clay: Friable plastic to sandy Tertiary clays are used in bricks at Deniliquin and Wagga Wagga. White Tertiary kaolin overlying Permian shale in the Oaklands Sub-basin is used in paints, insecticide dusts, ceramics, and as a filler in paper.

Coal: Black coal measures of Tartarian age occur in the Oaklands Sub-basin, beneath the Tertiary sediments. The coal measures are 113 m thick and contain three seams: an upper seam 3.6 to 7.6 m thick; a middle seam 3.3 to 5.2 m thick, and a lower seam 4.2 to 9.1 m thick. The seams are separated by less than 1 m of shale and possibly coalesce. Reserves have been estimated at 50 800 000 tonnes, and when production ceased in 1960 the total produced was 128 000 tonnes. Deposits of brown coal are common in the Tertiary but are of doubtful economic importance. Drilling in the Griffith area has revealed seams of good-quality brown coal up to 9 m thick under 91 m of overburden.

Brown coal also occurs in South Australia at Moorlands and Morgan. At Moorlands the brown coal occurs in six separate areas as beds near the base of the lower Tertiary sequence. The coal beds are up to 120 m thick and reserves total 31 500 000 tonnes. The coal is poor in quality and has a high sulphur content. The seams are thin and are covered by 26 m of overburden. The main seam averages 6 m thick. The deposits are uneconomic.

Gypsum: Gypsum has been recorded from numerous localities, but few are of economic importance. The deposits occur in and around lakes and salt lakes. The principal areas are: the Trida, Menindee, Gypsum Palace, Marlow, Manara, Conoble, Gol Gol, Nulla Nulla, and Lake Wyangan areas in New South

Wales; the Nowingi West, Neds Corner, Swan Hill, Kerang, Yaapeet, and Cowangie areas in Victoria, and the Cragie Plain area in South Australia.

Bentonite: Greenish bentonitic clay occurs in a large swampy claypan 13 km south of Trida. The deposit is 5 m thick and the top 2 m are contaminated. The material also contains kaolinite, illite, and montmorillonite. The low-grade deposit was only worked until 1943.

Petroleum: There have been no significant hydrocarbon discoveries in the basin. Petroleum exploration activities have been concentrated on the pre-Tertiary sediments. The Tertiary sediments are generally shallow and lack both source and reservoir rocks. The Lower Cretaceous basal sands, which are generally well sorted and unconsolidated, have excellent porosity and permeability and offer the greatest reservoir potential of all the formations. Although these have a suitable cap rock, in places, a source rock is lacking. The Permian sequence in the Renmark Trough has no potential source rocks, although some sandstone and conglomerate may be reservoirs.

Although coal is present as a possible source rock in the Oaklands Sub-basin, it is unlikely that it would have been subjected to high enough temperature for hydrocarbons to be generated.

Exploration results obtained so far suggest the area has little petroleum potential.

Water: Overall the salinity of the groundwater is high, making it suitable only for livestock. The yield and quality of the water is good in the southeast of the basin south of the Murray River in Victoria and South Australia and also in the northeastern part of the basin north of the Murray River near the Murrumbidgee and Lachlan Rivers, in New South Wales. In the central part of the area in South Australia and Victoria and in the eastern half of the New South Wales area the salinity is less than 1000 mg per litre, making the water suitable for town supplies, industry, irrigation of most crops and pastures, and watering of stock. Elsewhere in these areas the salinity is 1000 to 3000 mg per litre and the water is suitable for irrigation of salt-tolerant crops and pastures under favourable conditions and for all livestock. The quality of the water generally limits domestic and industrial use. Over the rest of the basin the salinity is greater than 3000 mg per litre, making it suitable only for livestock.

Recent activities

There has been little oil exploration activity in the basin since 1970 when 3 seismic surveys were carried out and eight unsuccessful wells drilled. In 1973 Beaver Exploration carried out the Menindee seismic survey, which was aimed at defining sub-basins beneath the Murray Basin. Some mapping is being carried out in the far western part of the basin by GSSA and around the margin of the basin in the Bendigo/Bridgewater area by GSV.

Deficiencies in geological knowledge

The basin covers three States, but detailed stratigraphy is known only in South Australia. The stratigraphy of the New South Wales and Victorian parts is poorly known.

The extent and content of the Mesozoic and Permian sediments beneath the Tertiary sediments is not well known.

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NGALIA BASIN

The Ngalia Basin is an east-trending elongate downwarped area of about 15 000 km^2 in the Northern Territory. It contains up to 5000 m of Adelaidean, Lower Cambrian, Ordovician?, and Carboniferous sediments resting unconformably on a basement of Precambrian igneous and metamorphic rocks. The basement generally contains moderate to high-grade metamorphic rocks, but low-grade metamorphic rocks occur in the west.

Most of the formations are separated by angular unconformities or disconformities, and a complete sequence is not exposed in any one area. The Adelaidean succession (totalling about 2800 m) consists of a thick widespread basal marine sandstone sequence overlain unconformably by marine siltstone, shale, and dolomite. The siltstone contains ice-rafted phenoclasts.

The Lower Cambrian sediments (up to 1500 m thick) include a thick fluviatile? red-brown sandstone sequence, possibly partly Adelaidean in age, overlain by fossiliferous marine dolomite and siltstone. A low-angle unconformity separates the Lower Cambrian and Adelaidean strata, and a low-angle unconformity marks the overlapping contact between the fluviatile sandstone and the marine dolomite and siltstone.

Ordovician? sediments, up to 1000 m thick, rest unconformably on older rocks and contain an internal disconformity separating a lower marine sandstone and siltstone from an overlying fluviatile sandstone and siltstone.

The Carboniferous rocks are over 2400 m of pale brown and red-brown fluviatile sandstone resting unconformably on older rocks. The unconformity results from uplift along the northern margin.

The most intense diastrophism in the Ngalia Basin occurred after deposition of the Carboniferous rocks, probably during the Alice Springs Orogeny. Basement was thrust over cover in at least some areas along the northern margin, and the sedimentary rocks within the basin were folded and faulted, perhaps thrust over a decollement surface at depth.

The deepest part of the basin occurs adjacent to the northern margin, which is a thrust in many places. The southern margin is generally an unconformable contact between basement and cover, the sedimentary rocks dipping gently northward.

Geological mapping

The whole basin was mapped by BMR at 1:250 000 scale in 1967 and 1968 and geological maps with explanatory notes have been published. The mapping is good-quality regional, and gives the present state of knowledge. A 1:500 000 map of the area is being prepared.

The mapping has not resolved entirely the nature of the suspected large-scale tectonics along the northern margin, and large areas of the basin are covered by Quaternary sand.

Drilling

BMR drilled 22 shallow stratigraphic holes in the Mt Doreen and Napperby 1:250 000 Sheet areas. Six of these bottomed in Cainozoic deposits up to 180 m thick, form in Carboniferous strata, one in Cambrian, nine in Adelaidean, and two in strata of doubtful age. The drilling assisted in seismic interpretation and provided valuable stratigraphic data in areas of no outcrop.

Correlation

A lithological correlation is published in Wells et al. (1972). Reliable time correlation is not possible. The basal rocks are of Adelaidean age and apparently unfossiliferous. Phanerozoic fossils indicate the presence of Cambrian and Carboniferous sediments, but no closer age assignment is possible with the fossils found. K/Ar dating of glauconite has given ages of 1280 m.y. low in the sequence and 450 m.y. (Ordovician?) higher in the sequence.

Aeromagnetic surveys

Aeromagnetic surveys covering a large part of the basin were conducted by BMR in 1963 and by Pacific American Oil Company in 1963. These indicate a wedge-shaped sedimentary sequence which thickens northward to up to 6000 m. Depth to magnetic basement contours are published in Wells et al. (1972).

Gravity surveys

Helicopter reconnaissance gravity surveys covering the whole basin and its margins were carried out by BMR in 1965 and 1967. Pacific American Oil Company measured

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gravity at shot-point locations during the Napperby seismic and gravity survey, and Magellan measured gravity on BMR seismic lines in 1968. This last work included an integration of previous gravimetric data, and assisted the seismic interpretation of structure.

The major result was the delineation of a regional gravity low beneath the basin and extending north of its northern margin; this gravity low is of significance in interpretation of the regional structure. Magellan conducted a regional and semi-detailed gravity survey in 1970. A further semi-detailed survey in the southwestern part of the basin in 1973 indicated two positive gravity features which may warrant seismic investigation.

Seismic surveys

Pacific American Oil Company in 1964, BMR in 1967, 1968, and 1969, and Magellan Petroleum (NT) Pty Ltd in 1971 shot about 920 km of reconnaissance and detailed seismic lines.

Seismic record quality is generally poor to fair in the eastern area, probably owing to complex faulting and the presence of thick unconsolidated Cainozoic deposits. The record quality is better in the western area where faulting is less severe.

The seismic surveys confirmed the presence of a deep basin divided into eastern and western lobes, and added significantly to knowledge of structure.

Most of the work was carried out in the central part of the basin and in the eastern lobe, but isolated traverses at the western extremity confirmed a sedimentary pile of 4800 m thick. A seismic locality map is published in Wells et al. (1972).

Economic geology

Petroleum: Potential source rocks are abundant throughout the sequence, but the most prospective for hydrocarbon generation are Cambrian and Ordovician rocks. Potential reservoir rocks are abundant. The most promising objective is the Ordovician Djagamara Formation, which is exposed by erosion in the anticlines south of Yuendumu in the eastern sub-basin; however, it would be expected under thick cover in the western anticlines.

Uranium: Widespread occurrences of carnotite have been discovered in the last few years in the northern central part of the basin by a consortium led by Central Pacific Minerals NL. The carnotite occurs in certain carbonaceous sandstone horizons of Carboniferous age. Evaluation is continuing.

Evaporites: Evaporites may be present in the lower half of the Adelaidean Vaughan Springs Quartzite.

Water: Small permanent settlements in the area use subsurface water, both for domestic purposes and for livestock. Several hundred shallow waterbores have been drilled in the basin, but the availability of water remains a problem because either many of the bores were failures or the water proved too saline for either human or cattle consumption.

Copper: Small secondary copper concentrations occur in the marine Cambrian dolomite. There is no evidence of extensive mineralization.

Recent activities

Magellan has announced that one month or more of seismic work will be carried out in the basin late in 1973. Magellan also proposes further gravity work in 1973.

Deficiencies in geological knowledge

One deficiency is adequate dating of the sedimentary sequence. The major deficiency is lack of a deep stratigraphic hole near the centre of the basin, where a more complete sequence may be present than in outcrops along the northern margin. The nature, extent, and origin of the suspected major crustal dislocation along the northern margin needs further investigation.

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OFFICER BASIN

The Officer Basin is a large structural depression outlined by geophysical surveys; it underlies about 350 000 km^2 in South Australia and Western Australia. It lies between the Proterozoic Bangemall Basin and the Yilgarn Block to the west, the Canning Basin and the Musgrave Block to the north, and the Eromanga Basin and the Gawler Block to the east. Probable extensions occur beneath the Eucla Basin in the south. It contains up to 6000 m of Adelaidean, Cambrian?, Ordovician?, Siluro-Devonian, Devono-Carboniferous, Permian, and Mesozoic sediments. At present the genetic relations and extent of the sedimentary sequences in the Officer Basin are not known, but, when they are, redefinition into several basins or sub-basins will probably be necessary.

The basement is defined as all rocks older than the Adelaidean Townsend Quartzite/Pindyin Sandstone. It includes crystalline Precambrian metamorphic and igneous rocks adjacent to the Musgrave and Gawler Blocks, volcanics in the western Musgrave Block, Archaean metasedimentary and igneous rocks of the Yilgarn Block and probably older Proterozoic sediments adjacent to the Bangemall Basin.

Stratigraphic correlation of the Adelaidean sediments over the Officer Basin is not possible at present. A marine sandstone (200-400 m thick) occurs at the base and is overlain by a thick, but unmetamorphosed, sequence of mainly sandstone and siltstone with tillite (in WA and SA), Volcanics (in SA), and some carbonates and evaporites (in WA). A sandstone at the top of the sequence in South Australia contains a trace fossil similar to Rangea, suggesting it is of latest Adelaidean age. A thick sequence of conglomerate and arkose of uncertain age was deposited in a graben in the Moorilyanna area of South Australia.

Suspected Cambrian sediments, up to 400 m thick, occur in the northeastern Officer Basin and in Emu No. 1 well. They comprise arkose and feldspathic sandstone near the base, and sandstone, siltstone, and dolomite higher in the sequence. They overlie the Adelaidean rocks with angular unconformity. A widespread tholeiitic basalt unit with minor sandstone extends throughout a large area in Western Australia and a small area in South Australia. Recent isotopic dating indicates a minimum age of 550 m.y. (Lower Cambrian). The unit is up to 117 m thick and overlies Adelaidean rocks unconformably.

Ordovician marine sandstone and siltstone, about 150 m thick, are preserved in the east conformable or disconformable on the suspected Cambrian except where they overlap with angular unconformity onto the northern margin of the basin.

Munyarai No. 1 well in South Australia penetrated about 2000 m of sandstone and shale with a few limestone interbeds. The sequence in the well was dated as Devonian or possibly Silurian. Correlative beds in outcrop overlie the Ordovician with a suspected unconformity.

Officer No. 1 well penetrated an unfossiliferous sequence of sandstone and siltstone (1000 m thick) that may be of Devonian or Devono-Carboniferous age. Correlative rocks in outcrop overlie the Siluro-Devonian sediments. Similar but thinner sequences of post-Lower? Cambrian and pre-Permian rocks occur in Western Australia, where they are separated by a possible unconformity.

Permian and Cretaceous sediments have been traced from the Canning Basin southward into the Officer Basin. Permian fluvioglacial and lacustrine deposits are widespread, but fossiliferous marine Cretaceous strata are confined to the northern part of the basin in WA.

Little is known of the structure. Palaeozoic sediments are gently folded and unconformably overlie more strongly folded Adelaidean sediments. The folding of the Adelaidean sediments is at least partly related to basement faulting. The northern margin with the Musgrave Block is a partly faulted unconformity possibly at the front of an overthrust. In South Australia the deepest part of the basin lies in the north and from there the basin shallows to the south. The Officer Basin is separated from the Canning Basin by the Warri Gravity Ridge, which aeromagnetic interpretation suggests is a concealed area of high basement. The western boundary with the Bangemall Basin is either an as yet poorly defined though probably strong angular unconformity between Adelaidean and older Proterozoic strata, or else the limit of Permian cover. The western boundary with the Yilgarn Block is conveniently chosen at the limit of Permian cover. The basin probably extends to the south beneath the Eucla Basin.

In the east the Adelaidean sediments abut unconformably against the Gawler Block, and pass eastward between the Gawler and Musgrave Blocks to probable connexions with the Amadeus Basin and the Adelaide Geosyncline. An arbitrary boundary must be chosen here: perhaps the boundary with Cretaceous rocks on the western edge of the Eromanga Basin.

Geological mapping

Mapping has been carried out by GSSA in 1960, 1966-68, and 1970; GSWA in 1966 and 1967; and GSWA-BMR in

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1971 and 1972. Of the 36 1:250 000 Sheet areas, 23 are in Western Australia and 13 in South Australia. Two maps (SG/52-15, SG/53-13) have been published with explanatory notes. Recent preliminary editions are available for 24 Sheet areas (SG/1-3, 4, 7, 8, 11, 12, 16: SG/52-1 5, 9, 10, 13, 14, 16; SH/51-3, 4, 7, 8, 11, 12; SH52-1, 2, 4, 6). Dyeline prints are available from GSSA (older mapping) for SH/52-3, 7, 8, 11, 12, 16, and for SH53-1 and 5 (newer mapping). Dyeline prints (photoscale) will be available shortly for SG51-15 from BMR and GSWA.

The current geological mapping has given an incomplete picture because the area is largely covered by Cainozoic deposits and flat-lying Permian or Cretaceous rocks, and the outcrops give little indication of the structure and composition of the sediments in most of the basin.

Drilling

Nine stratigraphic and petroleum exploration wells have been drilled by petroleum exploration companies between 1963 and 1968. Six of these were shallow, drilled to depths ranging between 180 and 600 m. Yowalga No. 2 was drilled to total depth at 989 m, Birksgate No. 1 to 1878 m, and Munyarai No. 1 to 2899 m.

Five of the shallow stratigraphic wells were drilled in Western Australia in the northwest of the basin. One well was drilled in South Australia near the Western Australian border and another three wells were drilled at widely separate localities in the east of the basin. Two wells in Western Australia penetrated to the Lower Cambrian volcanics, and one of these passed through into underlying Adelaidean sediments. Browne Nos. 1 and 2 penetrated to Adelaidean? evaporites in a diapir that may intrude the volcanics. The wells in South Australia penetrated Palaeozoic and Adelaidean sediments.

The wells have contributed to knowledge of the composition of the Palaeozoic sediments in widely separated localities, but the samples collected from them have not been easily dated.

BMR drilled 17 shallow (30-200) stratigraphic holes in the central and northern part of the basin in Western Australia in 1972. The holes penetrated Adelaidean, Palaeozoic and Mesozoic sediments. This drilling, in an area where surface outcrops are sparse and deeply weathered, provided fresh rock samples for palaeontological studies and isotopic dating, and elucidated the relations between the units drilled.

Correlation

There is insufficient data available to draw up reliable basin-wide lithological correlations and the scarcity of fossiliferous outcrops militates against the preparation of basin wide time correlation charts.

Aeromagnetic surveys

BMR flew reconnaissance aeromagnetic lines in 1954. Interpretation of these lines indicated a thick sedimentary sequence. Hunt Oil Company flew a large-scale reconnaissance survey in the Western Australia part of the basin in 1961 and produced a depth to magnetic basement contour map. The basement contours must be regarded as questionable because they are based on interpolations across a flight-line spacing of 48 km, and the volcanics or other shallow basalts in the sequence extend over a large area and may be sufficiently thick and shallow to have an effect on basement depth calculations. The depths in the northeast of the area flown are in agreement with those computed from other geophysical data, whereas those in the southwest are not, as the surface geology and near-surface resistivity measurements indicate higher resistivity (basement) rocks to be at or relatively close to the surface.

In 1964 and 1965 Adastra Hunting flew a survey in South Australia over a large part of the northeastern part of the basin.

The magnetic surveys, despite their limitations, have been invaluable first of all in indicating the presence of a thick sedimentary sequence, and secondly in establishing the general structure and depth of the magnetic basement.

Gravity surveys

The whole of the basin has now been covered regionally by gravity. The South Australian Mines Department carried out a gravity survey in 1960. BMR carried out regional gravity surveys in 1962 and 1972 and a semi-detailed survey was carried out by Hunt Oil Company during 1963-1965. The South Australian Mines Department measured gravity along a single northerly seismic line in 1966. In 1967 Continental Oil Company (Aust.) Pty Ltd measured gravity along seismic lines intended to confirm closure and to define the crest of a structure indicated by the South Australian Mines Department survey.

The South Australian Mines Department measured gravity on a 7.2-km grid in the east of the basin in 1969.

In 1970 Murumba Oil NL measured gravity at 3605 grid stations in the eastern Officer Basin.

The gravity surveys indicate that the Officer Basin is an area of negative Bouguer anomalies flanked to the north and southeast by areas of positive Bouguer anomalies.

Milton & Parker (1973) made a quantitative interpretation of a northerly trending Bouguer gravity profile across the northern margin, and inferred an overthrust of basement onto sediments with a horizontal displacement of 55 km. Assuming a density contrast of 0.45 g/cm^3 between basin sediments and basement, the model only partly explains the Bouguer anomaly gradient. It seems likely that intra-basement density variations are also involved.

Seismic surveys

Seismic reflection and refraction surveys have been made in the northern part of the Officer Basin in Western Australia by BMR in 1961 and 1962, and in the northeast of the basin in Western Australia by the Hunt Oil Company in 1963 to 1965. BMR carried out a single line of combined reflection and refraction profiles in 1972 between the area surveyed by Hunt and the southwestern margin of the basin. These surveys give very sparse coverage of the Western Australia part of the basin. The most recent survey indicates that the sedimentary sequence is about 5000 m thicker than suggested by previous work. The sequence of sediments, probably largely Proterozoic, is about 10 000 m thick near the centre of the basin. The survey results suggested that there are two main Proterozoic sequences, the lower being a probable easterly continuation of the sediments in the Bangemall Basin. The Lower Cambrian volcanics give rise to a prominent reflection and have been recorded at depths up to 1500 m below ground.

Limited seismic work has been carried out in South Australia. The South Australian Mines Department carried out a seismic reflection and refraction survey along a single northerly traverse in 1966 across the deepest part of the basin as indicated by interpretation of magnetic data. The results were poor, but indicated a sequence over 5400 m thick and supported the aeromagnetic interpretation. In 1967 Continental Oil Company (Aust.) Pty Ltd carried out a seismic survey to confirm closure and delineate the crest of a structure indicated by the South Australian Mines Department survey. Munyarai No. 1 was drilled as a consequence of this survey. In 1972 the South Australian

Mines Department carried out several weeks of refraction and reflection profiling along the northern margin of the basin. Reflection profiles shot along an east-west line a few kilometres south of the margin indicate flat-lying sediments to a depth of about 4500 m. Two northerly reflection lines shot from the east-west profile to the northern margin indicate that the sediments dip gently north and suggest that the reflections continue beneath the granites in the northern margin. This relationship suggests overthrusting of basement onto sediments along the northern margin. Further seismic surveying was done in 1973 by the South Australian Mines Department.

The surveys have been invaluable in delineating the structure and thickness of sediments in particular areas of the basin, but further surveying and drilling will be required to provide a regional framework.

Economic geology

Petroleum: Suitable traps are present, but no suitable source rocks have been found and only minor oil and gas shows have been encountered during drilling. Knowledge of the composition, structure, and history of the basin are still so inadequate that a reliable assessment is not possible, but the Palaeozoic sequence appears to be relatively thin and unprospective in Western Australia.

Evaporites: Browne Nos. 1 and 2 were drilled on diapiric structures and intersected interbedded dolomitic limestone, calcareous shale, anhydrite, and gypsum. The Woolnough Hills and Mudley diapirs in the northwest of the basin contain evaporitic core material flanked by stromatolitic dolomite, siltstone, and sandstone of unknown age. At the surface the diapirs intrude Permian and younger sediments.

Recent activities

The most recent activity in the basin is the 1972 geophysical work by BMR.

Deficiencies in geological knowledge

The extent and structure of the Cambrian to Devonian sequence beneath the Upper Palaeozoic, Mesozoic and Cainozoic cover should be determined. Deep stratigraphic drilling penetrating the complete Palaeozoic section, particularly in South Australia where it is thickest, is needed to make a proper basin study. More aeromagnetic work is required to give a proper regional coverage and this could be followed up by seismic surveying to delineate the

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structure and locate further drilling targets. A relatively inexpensive drilling program with several holes to about 300 m would provide valuable information about the two Proterozoic sequences in the southwest.

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ORD BASIN

The Ord Basin covers an area of about 30 000 km^2 in the north of Western Australia and the Northern Territory. It contains up to 2000 m of Adelaidean or Lower Cambrian?, and Middle Cambrian and Devonian rocks. The margin is an unconformable contact with gently folded Adelaidean sediments of the Victoria River Basin in the south, east, and north, but is a partly faulted contact with Precambrian rocks of the Halls Creek Mobile Zone in the west.

Three northeasterly trending structural basins are recognized. From north to south they are the Argyle, the Rosewood, and the Hardman Basins.

Basement rocks consist of Adelaidean marine sediments.

Up to 45 m of Adelaidean Lower Cambrian? continental sandstone with minor siltstone and conglomerate unconformably overlie basement at several localities on the eastern side of the basin. Up to 1000 m of Adelaidean or Lower Cambrian? tholeiitic amygdaloidal basalt flows and agglomerate with irregular lenses of sandstone and siltstone conformably overlies the continental sandstone and unconformably overlies deeply eroded Adelaidean sediments.

570 m of Middle Cambrian marine limestone and shale with crystals of gypsum overlie the volcanic sequence with a slight angular unconformity.

Upper Devonian? (Frasnian?) marine sandstone, up to 400 m thick, unconformably overlies Middle Cambrian sediments except in the northeastern part of the basin, where the sandstone onlaps Lower Cambrian rocks.

The surface of the basin is covered by a thin veneer of Tertiary gravel, sandstone, siltstone, and some laterite.

The main folding and faulting occurred after the Devonian and produced three asymmetrical structural basins with steep dipping northwestern limbs and shallow dipping southeastern limbs.

Geological mapping

A 1:1 013 760 geological map accompanies BMR Bulletin 27 and was a result of mapping in 1949 and 1952. First edition 1:250 000 geological maps and explanatory notes of three sheet areas have been published after mapping by BMR and GSWA between 1962 and 1964. Preliminary editions of two 1:250 000 maps covering the Northern Territory part of the basin are available after mapping by BMR in 1969, and first edition maps with explanatory notes will be issued shortly.

All 1:250 000 maps are of good quality being derived from detailed traversing and airphoto-interpretation, and are the basis for understanding the geology of the basin. However, fossil evidence suggests that some of the formations in the Northern Territory have been misidentified, and biostratigraphic studies and detailed mapping are required to check this possibility (see Jones, 1973, p. 6).

Drilling

The Okes-Durack bore, drilled in 1922, was the only petroleum exploration well drilled in the basin. Located in the northern part of the Hardman Sub-basin it bottomed in Lower Cambrian? volcanics after penetrating Middle Cambrian (Ordian) sediments. The well provides stratigraphic data in the Hardman Sub-basin.

Correlation

The mapping has provided a lithological correlation of the exposed sequence. Fossil dating has cast some doubt on the validity of part of the lithological correlation.

The Lower Cambrian? basalts are undated; they contain stromatolites that indicate a late Precambrian age as an alternative. The fossils from the lower Middle Cambrian sequence all indicate an Ordian age. The Devonian sandstone contains no fossils and is dated by correlation with a unit outside the basin.

Aeromagnetic surveys

No aeromagnetic surveys have been carried out over the basin.

Gravity surveys

Preliminary editions of 1:250 000 Bouguer anomaly maps are available after regional coverage by BMR in 1967.

Seismic surveys

No seismic surveys have been carried out in the basin.

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Economic geology

Underground water: Springs are common along watercourses in the Lower Cambrian? volcanics, which, as they have well-developed open joints, have considerable potential as aquifers.

Petroleum: Asphaltite was discovered in the volcanics near the junction of the Ord and Negri Rivers in 1920. An exploration well drilled north of Ord River Homestead (Okes-Durack Bore) passed through Middle Cambrian limestone and shale, and bottomed in Lower Cambrian? volcanics. No indications of oil were found. However, gas was recorded in the mud sludge while drilling through the basal Middle Cambrian rocks. A likely source of the asphaltite is algal limestone in the underlying succession of Adelaidean and Carpentarian rocks (basement).

The possibility of finding petroleum in commercial quantities is remote, mainly because the sedimentary sequence lacks suitable traps. The gentle synclinal structure of the basin, and the erosional period between the Cambrian and the Devonian, and again after the Devonian, could all have permitted the escape of hydrocarbons.

Recent activities

There have been no activities since the BMR mapping.

Deficiencies in geological knowledge

Biostratigraphic studies and detailed mapping are required to resolve apparent conflict between palaeontological dating and lithological mapping.

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OTWAY BASIN

The Otway Basin is an elongate half-graben covering 34 000 km^2 onshore and 38 000 km^2 offshore in southeastern South Australia and southwestern Victoria. It is a late Mesozoic and Tertiary basin, trending westerly in Victoria and swinging northwesterly into South Australia. The basin is divided into the Gambier, Tyrrendarra, Port Campbell, Torquay, and King Island Sub-basins. The King Island Sub-basin is dealt with separately in this section.

The eastern margin is the Selwyn Fault and its offshore extension, which trend southwest from the Mornington Peninsula to King Island and separates the Otway Basin from the Gippsland and Bass Basins. An elevated area of basement west of King Island is the boundary between the major part of the Otway Basin and the King Island Sub-basin to the southeast. The northern margin is mainly concealed beneath a cover of Cainozoic volcanics and sediments. Interpretation of aeromagnetic, gravity, and seismic data indicates it is an irregular boundary extending westerly from the northwestern side of Mornington Peninsula and through Melbourne to the west of Hamilton. From Hamilton it swings to the northwest along the Kanawinka Escarpment and then northward to Naracoote. From Naracoote it trends westerly, south of the Padthaway Ridge, to Kingston, and continues offshore along the Cape Jaffa Hingeline to the shelf break. The offshore southwestern margin is less well known, but is probably near the upper part of the continental slope beneath which a well defined basement ridge occurs.

The basement is mainly composed of the lower Palaeozoic igneous, metamorphic, and sedimentary rocks that crop out along the northern margin within the Tasman Geosyncline. The metamorphosed and granite-intruded lower Palaeozoic Kanmantoo Group may underlie the northwestern end of the basin, and Palaeozoic sediments and Devonian granite cropping out on King Island probably floor the basin in the southeast. Remnants of Permian glacial, fluvioglacial, and marine sediments which occur north of the basin are also present beneath it.

The oldest sediments are Jurassic deltaic and fluvial mudstone, shale, sandstone, and conglomerate resting unconformably on basement. Dolerite and basalt are interbedded with coaly shale near the base. The sediments occur only in the Gambier and the Port Campbell Sub-basins. A section, 383 m thick, was intersected in Casterton No. 1 in the western part of the basin.

Lower Cretaceous deltaic and fluvial mudstone, shale, sandstone, and coal, up to 4500 m thick, rest unconformably on basement and unconformably and disconformably on Jurassic sediments. Deltaic and partly marine sediments occur in the Port Campbell Sub-basin to the east. A clean quartzose sandstone occurs in the basal and middle parts of these rocks along the northwestern margin of the basin.

Upper Cretaceous marine, deltaic, and fluvial sandstone, mudstone, siltstone, and coal, over 3400 m thick, unconformably overlie the Lower Cretaceous sediments. The Upper Cretaceous wedges out beneath younger rocks towards the northern and western margins of the basin. In the Torquay Sub-basin uppermost Cretaceous sandstone unconformably overlies the Lower Cretaceous and basement rocks.

The Tertiary sequence, Palaeocene to Miocene in age, is composed of marine and deltaic sediments that thicken to over 1800 m in the southwest. Palaeocene to lower Eocene marine, fluvial, and deltaic sandstone, conglomerate, shale, coal, and minor dolomite, up to 450 m thick offshore, disconformably overlie Upper Cretaceous sediments in most of the basin, except in the Torquay Sub-basin where they are conformable on Upper Cretaceous sediments.

Up to 1350 m of middle Eocene to middle Miocene marginal marine limestone, marl, sandstone, claystone, and volcanic breccia disconformably and unconformably overlie the Lower Tertiary sediments. Between these sediments in the Torquay Sub-basin is an internal disconformity/unconformity, diachronous from south to north, that separates middle Eocene to middle Oligocene sediments from upper Eocene to middle Miocene sediments. To the west of the Torquay Sub-basin upper Eocene to middle Oligocene marine sediments are disconformably overlain by Oligocene to Miocene sediments. Locally the Oligocene to Miocene sediments rest disconformably on Palaeocene to lower Eocene rocks.

Sedimentation was initiated in the Late Jurassic by tensional rifting associated with the break-up of Gondwanaland. Rifting appears to have begun in the west and then spread to the east. Rifting continued during the Early Cretaceous and extensive faults developed roughly parallel to the present coastline creating a large half-graben. Several horsts and grabens, trending northwesterly in the western part and northeasterly in the eastern part of the basin, developed in the Late Cretaceous, folding and faulting the Lower Cretaceous. Faulting ceased in the Eocene. The Otway Ranges were uplifted as a block at the end of the Miocene. Tertiary sediments were gently folded in the Pliocene or early Pleistocene.

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Geological mapping

The western end of the basin was mapped onshore by GSSA in 1951 and 1965 to 1969. The rest of the basin was mapped onshore by GSV from 1963 to 1972. Four maps are published at 1:250 000 scale, one at 1:253 440 scale, and nine at 1:63 360 scale. Three 1:250 000 maps are issued as preliminary editions. A 1:1 000 000 map of the whole basin is published in BMR Report 134 and a 1:500 000 map is published in a special Bulletin of the Geological Surveys of South Australia and Victoria.

The mapping is of value in the southern onshore part of the basin, where Tertiary and Cretaceous sediment are exposed, but is of little value in the northern part where the basin sediments are concealed beneath a cover of Cainozoic volcanics and sediments.

Drilling

One hundred petroleum exploration wells have been drilled since 1915. Fifty of these were drilled by 18 exploration companies between 1915 and 1948. Kaniva Syndicate, Oil Development NL, Southern Oil Syndicate Ltd, Beach Petroleum NL, Alliance Oil Development NL, Esso Standard, Esso Exploration and Production (Australia), Planet Exploration Co., Frome-Broken Hill Co. Pty Ltd, Shell Development NL, Pursuit Oil NL, Interstate Oil, Hematite Petroleum, and General Exploration Co. Australia drilled 48 subsidized wells since 1959; 14 of them were offshore.

Most of the wells bottomed in the Cretaceous or in basement rocks. Several were drilled to depths exceeding 3000 m. There are a few wells in the Torquay Sub-basin where the sediments are thinner and mostly non-marine. Most of the wells were sited to test structural traps.

These wells together with coal-bores and water-bores provide invaluable stratigraphic information and regional geological control.

Correlation

BMR has published basin-wide lithological and palynological correlations. GSSA and GSV have published lithological and time correlations for selected areas and sequences.

Aeromagnetic surveys

The whole basin has been covered by aeromagnetic surveys. Total magnetic intensity contour maps covering most of the basin and an index map of surveys flown between 1948 and 1965 are available in BMR Record 1966/170. Shell Development carried out a subsidized aeromagnetic survey over much of the Victorian part of the basin in 1970.

Magnetic basement coincides with economic basement over a large area of the basin. Volcanics produce anomalies in the central onshore part of the basin that reduce the reliability of the identification of magnetic basement. The faulted eastern margin and the northwestern margin of the basin have been outlined by interpretation of magnetic data.

Gravity surveys

Bouguer anomaly maps covering all but the easternmost part of the basin have been compiled from BMR, SADM, and private company surveys carried out between 1949 and 1965, and are available in BMR Report 134. A 1:1 000 000 Bouguer anomaly map of the South Australian part of the basin was published by SADM. A considerable amount of subsidized gravity surveying was done onshore by Shell, Esso, and Planet between 1968 and 1970 to develop leads for subsequent seismic surveys. BMR conducted a shipborne gravity, seismic, and aeromagnetic survey of the offshore basin in 1972. Lines are oriented northerly in the western part of the basin and westerly over the rest of the basin along a 35-40 nautical km spacing. The results are unpublished.

Gravity surveys have been useful in interpreting the position and nature of the northwestern, northern, and eastern margins of the basin. Steep gravity gradients coincide with the northwestern and northern margins. The gravity method has also been useful in indicating intrabasin structures, particularly faults.

Seismic surveys

Seismic surveys, carried out since 1949 by BMR, SADM, and private companies cover most of the basin except the Otway Ranges. Most of the surveys were subsidized. BMR Record 1966/170 contains a seismic locality map for all surveys carried out to the end of 1965. Since 1965 about a dozen subsidized seismic surveys have been done in the basin.

Record quality ranges from good to poor onshore and is generally good offshore. Seismic records are poor to unreadable over areas of cavernous Tertiary limestone, basalt, and sand. Structure contour maps and isochron maps are available in BMR Report 134 and in PSSA final reports.

The seismic surveys together with the wells provide the basis for understanding the stratigraphy and structure of the basin.

Economic geology

Coal, carbon dioxide gas, limestone, dolomite, salt, water, and industrial minerals are exploited.

Coal: Tertiary brown coal is mined at Anglesea and at Bacchus Marsh on a moderate scale; reserve estimates are 400 million tonnes and 100 million tonnes respectively. The Angelsea deposit has an upper seam, 30 m thick, that is underlain by several thinner seams. The coal has a low ash content and a calorific value of 12 200 kJ. The main seam at Bacchus Marsh is 43 m thick with an ash content of 7 percent and a calorific value of 11 600 kJ. Thick coal seams were also mined at Altona, but the overburden is thick and production has ceased. Smaller deposits were mined in the Dean Marsh area until 1959.

Gas: Carbon dioxide gas is produced from Caroline No. 1 in the western part of the basin. The well is capable of gas flows in excess of 2 MMcfD. Gas is produced from an anticlinal trap in Cretaceous sandstone.

Limestone: Tertiary limestone is quarried from several areas for use in the building industry. The Geelong area is the main source of cement grade limestone in Victoria. High quality building stone is quarried from deposits at Mount Gambier.

Dolomite: 10 000 tonnes of high-grade dolomite are quarried annually from deposits near Tantanoola in the western part of the basin for production of plate glass. Reserves are estimated at 1 400 000 tonnes. The overburden is up to 4 m thick.

Water: Underground water is available from shallow aquifers in Cainozoic volcanics and limestone, and from deeper aquifers in Tertiary and Upper Cretaceous sandstones. The groundwater alkalinity increases progressively from the shallow aquifers to the deeper ones.

Petroleum: Nearly 100 petroleum exploration wells were drilled without encountering commercial quantities of hydrocarbons. One well was completed as a carbon dioxide producer in the western part of the basin, and significant hydrocarbons were recorded from five wells in the Port Campbell Sub-basin. Exploration is still in the early stages as extensive areas of the basin are undrilled. Only 12 wells have been drilled in the offshore basin which includes over half of the total area of the basin.

Traces of hydrocarbons occur throughout the Lower Cretaceous and Upper Cretaceous sediments and have also been reported from the Lower Tertiary. Potential source rocks are present in Upper and Lower Cretaceous and Palaeocene to Eocene sediments. Sandstones at the base of the Upper Cretaceous and the base of the Lower Cretaceous are the best potential reservoirs.

The basin is extensively faulted and structural traps are abundant. Stratigraphic traps are also present, but few have been tested.

Industrial minerals: Small quantities of fire clay, diatomite, and siliceous abrasives have been mined from the Bacchus Marsh, Linton, and Port MacDonnell areas, respectively.

Recent activities

Three wells have been drilled to date in the basin in 1974: two onshore by Shell Development NL and one offshore by Esso Exploration and Production NL. Well data have not yet been released. Planet Exploration Co. conducted the Lake Mundi seismic survey over the northern part of the basin to delineate structural traps in 1974. The most recent offshore seismic survey was the Cape Nelson/Cape Otway seismic survey done by Hematite Petroleum in late 1973.

Deficiencies in geological knowledge

Wells are needed in the south and southeastern parts of the basin where least is known about the lithology and age of the sediments.

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King Island Sub-basin

The King Island Sub-basin of the Otway Basin is an elongate, north-northwest-trending area of about 18 000 km^2 located predominantly offshore from the west coast of Tasmania.

The northeastern boundary is an elevated area of basement, the King Island High, which trends southeast from King Island to northwest Tasmania. A similar elevated area trending southwest from King Island forms the northwestern boundary. The western boundary, beyond the continental shelf is not defined. Latitude 42°52' is chosen as the southern offshore boundary because the sediments are thin farther south (Esso, 1969a). In the southeastern corner the basin extends onshore into the Macquarie Harbour Graben. The graben trends southeast for over 180 km, 90 km of which occur onshore within the Dundas Trough. The eastern boundary lies along the coast where lower Palaeozoic rocks of the Dundas Trough crop out in the south and Precambrian rocks crop out to the north in the Rocky Cape Geanticline.

Clam No. 1 is the only well drilled in the sub-basin. Located offshore it penetated Precambrian phyllite overlain unconformably by 1413 m of Phanerozoic sediments. The basal unmetamorphosed sediments in the well consist of 48 m of lower Palaeozoic siltstone unconformably overlain by 190 m of unfossiliferous red conglomerate and minor siltstone.

458 m of Upper Cretaceous sediments unconformably overlie the redbeds. They consist of 353 m of sandstone overlain unconformably by 105 m of conglomerate.

Tertiary sediments overlie the conglomerate conformably. They include: 306 m of Palaeocene sandstone and mudstone, 127 m of Eocene sandstone, 93 m of Oligocene marl, and 191 m of fossiliferous Miocene limestone. The marl and the limestone are the only marine Tertiary sediments in the well.

At least 171 m of Palaeocene to Quaternary lacustrine clay, lignite, silt, sand, and conglomerate occur in the Macquarie Harbour Graben. The total thickness of these sediments and their extent offshore has not been determined.

The King Island Sub-basin developed synchronously with the Otway Basin, beginning in the Late Jurassic with the rifting apart of the Australian and Antarctic cratons. Major faulting associated with this rifting ceased in the

Eocene and thereafter the cratons rapidly separated. Faults and broad south-plunging anticlines developed as a consequence of the rifting. The major structure in the sub-basin, the Macquarie Harbour Graben, formed early in the Tertiary.

Geological mapping

Two of the twelve one-mile Sheet areas covering the onshore part of the sub-basin were mapped by GST between 1958 and 1961 and between 1965 and 1967. They are published at 1:63 360 scale and explanatory notes are available for one of them.

Drilling

One subsidized well (Clam No. 1) has been drilled in the centre of the sub-basin. This was drilled in 1969 and bottomed in Precambrian basement at 1595 m.

Correlation

No basinwide lithological or time correlation is possible as only one well has been drilled and most of the sub-basin lies offshore.

Magnetic surveys

Two aeromagnetic surveys and four combined marine, magnetic and seismic surveys were carried out between 1966 and 1972.

The most recent marine magnetic survey was carried out by BMR in 1972. The lines run easterly and are about 32 km apart. The interpretation of data from this survey is not available.

It is difficult to interpret the type of magnetic basement recorded in these surveys. Magnetic basement includes Tertiary basalt, Jurassic dolerite, Palaeozoic intrusives, and Precambrian crystalline rocks. There is, therefore, little correlation between magnetic basement and the economic basement at the base of the Cretaceous.

Gravity surveys

BMR measured gravity over the whole basin in 1972. The survey lines run easterly and are about 32 km apart. The interpretation of data from this survey is not available.

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Seismic surveys

Five subsidized seismic surveys have been carried out between 1964 and 1972. Three of these were reconnaissance surveys and two were detailed. Overall the quality of the data is good and a reliable seismic correlation can be made. The surveys are evenly distributed throughout the sub-basin.

BMR carried out a survey of the whole sub-basin in 1972. The survey lines run easterly and are about 32 km apart. The interpretation of the data from this survey is not available.

Economic geology

Petroleum: Geophysical surveys have indicated thick sediments and prospective structures. The only well drilled in the basin was plugged and abandoned.

Coal: Brown coal occurs in the Tertiary of the Macquarie Harbour Graben. The seams are thin (less than 3 m), of poor quality, and difficult to exploit owing to the presence of at least 6 m of overburden.

Water: The water resources of the sub-basin have not been assessed.

Recent activities

There has been no petroleum exploration activity in the King Island Sub-basin since the drilling of Clam No. 1 in 1969 and the BMR survey in 1972.

Deficiencies in geological knowledge

Little is known of the nature and distribution of the sediments.

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PAPUAN BASIN

The name Papuan Basin has been applied to an area of unmetamorphosed sediments of Jurassic to Pliocene age onshore and offshore in Papua New Guinea, Queensland, and Irian Jaya. However, it was not a site of continuous sedimentation and the area has had a varied history with many shifts in the locations of the main sites of sedimentation and emergence. The basin underlies an area of 197 000 km^2 onshore in Papua New Guinea, 52 000 km^2 offshore in Papua New Guinea Adjacent Area, and a small area in Australian Adjacent Area.

The northern and northeastern margin is an indistinct boundary between unmetamorphosed Mesozoic and Tertiary sediments and a belt of low-grade regionally metamorphosed sediments within the median orogenic belt. In the southwest the basin sediments are contiguous with those of the Carpentaria Basin beneath the Merauke Rise which extends from the Cape York-Oriomo Ridge to Frederik Hendrik Island. The southeastern margin is not defined. The basin extends beneath the continental shelf in the Gulf of Papua and beneath the upper continental slope and the Moresby Trough.

Acid plutonic basement rocks of possible late Palaeozoic age crop out in western Papua at Mabaduan and in the Strickland River Gorge and in New Guinea in the Kubor Block. They have been drilled in Aramia No. 1 and Komewu No. 2. In the Kubor Range they intrude low-grade regionally metamorphosed basement rocks. Lava flows, probably from within the basement complex, were intersected in Komewu No. 1 and Magobu Island No. 1.

Unmetamorphosed Permian and Upper Triassic sediments are exposed in the Central Highlands of New Guinea but have not been recognized either in outcrop or in the subsurface of the Papuan Basin. Sandstone, arkose, and red beds penetrated in Barikewa No. 1 may be of late Triassic age.

Jurassic sediments (mostly Upper Jurassic) have been mapped in Papua and have been penetrated in many wells. They are predominantly claystone and sandstone up to 2700 m thick. The main basin of marine deposition appears to have been in the present area of the Bismarck Range, in northwest Papua on the northern margin of the basin, and possibly to the east of Barikewa, Komewu, and Magobu Island. The shallow and deep-sea Jurassic sediments thin to the southwest and are absent over southwestern Papua. A number of wells in this area have intersected non-marine sediments.

Volcanics and deep-water marine greywacke of possible Middle Jurassic age occur in the Bismarck Range area of New Guinea. Upper Jurassic reef limestone and shale occur in the Kubor Range in New Guinea.

Lower Cretaceous (Neocomian/Aptian) sediments occur conformably over the Upper Jurassic to the east and west of an area extending northwards from Cape York Peninsula and now drained by the Fly River. Shallow-sea and deep-sea claystone and sandstone, about 600 m thick, were deposited in the southwest (Morehead Basin). Shallow-sea and deep-sea sediments, predominantly claystone, sandstone, and greywacke, up to 1800 m thick, occur in the east. Marine tuff occurs in the Bismarck Range-Waghi Valley area.

Albian and Cenomanian sediments conformably and unconformably overlie older sediments. They have a different distribution pattern from the sediments of Neocomian and Aptian age. They thin to the southeast and are absent beyond an irregular northeast-trending line passing south of Morehead No. 1, Aramia No. 1, and Omati No. 1. The area to the southeast of this line is interpreted as a former landmass. Up to about 1200 m of shallow-sea and deep-sea sandstone and claystone occur north of the interpreted shoreline. The thickest sediments deposited during the Cenomanian appear to occur along a trend running from the northwest corner of Papua eastwards through New Guinea to the Chim Valley and possibly beyond; possibly swinging in a southeasterly direction towards Port Moresby.

Turonian sediments are not widespread. They include about 750 m of marine sandstone and claystone in Cecilia No. 1 and about 100 m of sandstone cropping out in the Kagua Valley. Marine mudstone and sandstone also occur in the headwaters of the Fly River in northwest Papua.

Coniacian to possibly Maestrichtian marine calcareous claystone crop out near Mendi and marine limestone and sandstone crop out near Port Moresby. Marine mudstone crops out in the Fly River headwaters and on Lagaip Valley. Marine volcanics in the Eastern Highlands of New Guinea may also have been erupted during this time span.

All of western Papua seems to have been emergent in the Palaeocene. The only Palaeocene sediments known crop out in the Wabag area of New Guinea and near Port Moresby.

Late Eocene marine limestone, generally less than 100 m thick, occurs east of a line running northwesterly and southerly from near Lake Kutubu. The limestone was probably deposited during a brief period of marine transgression

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during a longer period of emergence in western Papua between Cretaceous and Miocene deposition. It is about 300 m thick in the wells Borabi, Uramu, Iviri, and Muabu in western Papua.

Thin shallow-marine lower and middle Oligocene limestone occurs in the northern part of western Papua, but is absent in the south. Upper Oligocene calcareous clay occurs in Anchor Cay No. 1.

Miocene sediments were deposited throughout the Papuan Basin. They include: about 900 m of limestone with complex interplays of shoal and reef facies in a south-western shelf zone; up to 1300 m of limestone in the north-west; about 10 500 m of greywacke and sandstone in a deep asymmetrical trough (the Aure Trough); and a narrow north-eastern shelf zone containing localized reef and shoal limestone lenses and coarse clastic sediments derived mainly from basic to andesitic volcanics to the north and north-east. Middle and upper Miocene sediments occur in the eastern part of the Aure Trough and shallow marine clastics occur in northwest Papua; the remainder of the Papuan Basin area was emergent.

Early Pliocene marine sediments are widespread and later Pliocene sediments are less widespread. Depositional boundaries in the Pliocene basin are closest to the defined boundaries of the Papuan Basin; sedimentation having occurred after uplift of the Central Highlands. The main basin, which received up to 1500 m of marine claystone, was centred in the Orokolo-Puri-Bwata-Kuru-Wana-Pasca areas with an extension to the northwest. It was bounded to the north by land, and to the south by a small landmass (Darai Hills) and a shallower sea with a small landmass near Mabaduan. Marine claystone, sandstone, and sandy limestone, up to 150 m thick, were deposited in the shallower water.

During the middle and late Pliocene the main basin was centred on what is now the Gulf of Papua, where it is centred today.

The tectonic development of the basin reflects its position between the stable continental platform and the major orogenic zone of the New Guinea mobile belt, which was active throughout the Mesozoic and Cainozoic.

On the Papuan platform in the southwest, where a total sedimentary sequence generally less than 3000 m thick overlies granitic basement, folding is broad and mainly of the basement horst or buried-hill-and-drape type. To the northeast, the asymmetrical folding and thrusting in the

Papuan fold belt is now believed to have developed during the Pliocene by gravity-sliding from northerly uplifted areas in the Kubor Range and the Central Ranges. The presence of competent Miocene limestones overlying incompetent Mesozoic shales probably aided decollement. This style of folding is found as far north and east as the depositional edge of the Miocene shelf limestones, which coincides with both the Mesozoic and the Tertiary hingeline at the margin of the stable continental platform.

Beyond the carbonate front, the thick (11 000 m) lower Miocene to Pliocene fine-grained clastic succession of the Aure Trough is tightly folded; many folds are crestally thrust-faulted, and imcompetent mudstone and siltstone have diapirically ruptured the cores of some folds. Major strike faults in this zone probably have considerable horizontal as well as vertical displacements.

On the narrow northeastern flank, where conglomerate, limestone, and volcanics are present within the sedimentary sequences, folding is more robust and crestal faulting less prevalent than in the thicker, less competent sedimentary pile of the Aure Trough.

Geological mapping

Of the 18 1:250 000 Sheet areas (onshore) 12 have been mapped by BMR, the Geological Survey of Papua New Guinea (GSPNG), GSQ, Continental Oil Co. of Australia Ltd, BP Petroleum Development (Aust.) Pty Ltd, Papuan Apinaipi Petroleum Co. Ltd, Island Exploration Co. Pty Ltd, and Australasian Petroleum Co. Pty Ltd. Mapping has been carried out since before World War II, but recent mapping (1966-1972) has been carried out on the 12 Sheet areas mainly by BMR. One map covering Sheet areas SC/54-8 has been issued as a first edition with explanatory notes. SB/54-7 has been printed and will shortly be issued as a first edition. Sheets SB55-9 and SB55-14 have been issued as preliminary editions. One map covering SC/55-6, 7, and 11, and another covering SC/54-7, 8, and 12, have been issued as preliminary editions. 1:50 000 compilation sheets of SC/55-2 are available from the Port Moresby office of GSPNG. BP Petroleum Development (Aust.) Pty Ltd has prepared a 1:500 000 map of SB/54-12.

GSPNG intends to compile the Lake Kutubu and Kikori 1:250 000 Sheets in 1974 and 1975 on the basis of company mapping supplemented by survey mapping as necessary.

A 1:1 000 000 scale geological map covering the whole of Papua New Guinea was published by BMR in 1973.

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The mapping of almost all Sheet areas is of variable quality. Parts of some Sheet areas are unmapped and the remainder of each Sheet area has been covered by airphoto-interpretation, general reconnaissance, and detailed reconnaissance.

A large area of the basin (particularly the unmapped part) is concealed beneath Quaternary deposits, restricting the value of the surface mapping.

Drilling

At least 52 wells have been drilled by petroleum exploration companies and the Australian Government since 1913. A number of other wells, drilled for structural information or sited on oil seeps, are too shallow or too close together to be included in this number. Twenty seven subsidized wells have been drilled between the inception of subsidy in 1958 and the end of 1973.

The wells are concentrated onshore in a 70 km wide coastal belt extending from northwest of Port Moresby in the east to near the mouth of the Fly River in the west. Only four wells occur out of this belt onshore. Six offshore wells lie within the belt and six lie farther offshore. The main gaps occur in western Papua and in the Gulf of Papua.

Nearly all the wells drilled Cainozoic strata. A number in the west penetrated Cainozoic and Mesozoic strata to basement. The wells in the east penetrated Cainozoic strata and reached total depth in Cretaceous or Jurassic strata.

Correlation

Except for the northern part of the Aure Trough, in which mapping is still continuing, the regional biostratigraphy of the basin is well understood.

Magnetic surveys

Contours of residual total magnetic intensity were produced as a result of the offshore survey by BMR in 1970 and 1971. Their main use has been to complement the seismic interpretation, especially to aid in the identification of basement. They have also been used to calculate depth to magnetic basement.

A large part of the western onshore portion of the basin was covered by aeromagnetic surveys for Union Oil, Texaco, and BP Petroleum in 1968. Some useful indications of structure and depth to magnetic basement were obtained, but the presence of complex structure and volcanic rocks in some areas made interpretation difficult. Aeromagnetic anomalies subsequently investigated by seismic means have generally proved not to represent prospective structures.

Gravity surveys

Free-air and Bouguer anomaly contour maps of the offshore region were produced after the survey by BMR. The free-air contours show a deep low associated with the Moresby Trough. Negative anomalies coincide with areas of thick sediment or troughs and the positives with areas of thin sediments or shallow water. The Bouguer anomalies show a general correlation with water depth and with local (upper crustal) geological features. Their prime use is in detecting variation in the depth of the crust/mantle interface.

A number of gravity surveys have been done onshore, mainly by petroleum companies, either separately or in conjunction with seismic surveys. Overall the gravity coverage is still sparse, readings having been confined by difficulty of access largely to navigable rivers and lines cut for seismic operations. In 1974, Endeavour Oil conducted a large gravity survey near the mouths of the Fly and Bamu Rivers. The gravity method has been useful in indicating structure, for example, thrust faults in the northeast marginal areas of the basin where the seismic method has been largely unsuccessful. On the Papuan platform there are indications that positive gravity anomalies correlate with structurally elevated areas.

Seismic surveys

Almost the entire continental shelf of the Gulf of Papua has been thoroughly surveyed by Phillips Australia Oil Company in search of hydrocarbons in the Miocene limestone reef formations that exist at depth. These reefs are covered by great thicknesses of Pliocene to Recent sediments (2200 m at Pasca No. 1) and were at one time considered highly prospective. The company accurately located the Miocene reefs and mapped the sediments. A lower Miocene barrier reef, similar in type to the modern Great Barrier Reef, was mapped by Phillips southward to about 9°S.

BMR carried out a shipborne seismic, gravity, and marine survey in the Gulf of Papua in 1970 and 1971. The quality of the data varied but was generally good, but extension of shelf geology into deeper water was hampered by lack of deep penetration - less than two seconds of reflection time on average. The interpretation shows the distribution of sediment types and the basement structures seen on the sections and provides profiles across areas of special interest. BMR mapped the Miocene reef farther south than Phillips. South of 9°S the Miocene reef appears to turn easterly directly toward Portlock Reefs - a modern platform reef. Sediments are completely undeformed in the west and folded into broad gentle anticlines in the east.

The offshore extension of the Aure Trough was mapped to the edge of the continental shelf by Phillips Australian Oil Company. It is a belt of strongly and complexly folded sediments over 10 000 m thick lying between the stable western shelf and a mobile zone to the east. Folds with a style characteristic of the Aure Trough were traced by BMR down the continental slope and onto the floor of the Moresby Trough south to nearly 9°S. It is suggested therefore that the Moresby Trough to at least 9°S is a continuation of the Aure Trough.

Onshore many seismic surveys have been done in the basin from the coastal areas to the Southern Highlands. With few exceptions the terrain is unfavourable for seismic work, and up to about 1970 the results obtained were generally very poor. In recent years seismic exploration has been concentrated on the Papuan platform in the southwest of the basin. Much improved results have been obtained in this area using digital recording equipment. Extensive subsidized seismic surveys were done between 1971 and 1974 by Union Oil, Texaco, and Continental Oil, and two wells were drilled by Continental Oil in the Lake Murray area on the basis of seismic and gravity results. A number of prospective structures have been indicated.

Economic geology

Petroleum: Many oil and gas seepages have been discovered. Seven wells, Kuru No. 1, Puri No. 1, Barikewa No. 1, Iehi No. 1, Uramu No. 1, and Pasca No. 1, together with several stepout wells, discovered gas. Production rates ranged from about 4.5 to 108 MMcfD, the gas varying from lean to 100 barrels of condensate/MMcf of gas. Several other wells produced minor shows of gas, and Puri No. 1 also flowed a small quantity of oil that went to water in one day.

Jurassic, early Cretaceous, Pliocene, and Miocene deep-water clays and Miocene argillaceous limestones are potential source rocks. Reservoirs seem to be lacking in the Tertiary over much of western Papua. Kuru No. 1 and Puri No. 1 produced gas from fractured Miocene argillaceous limestone that acted as both source and reservoir. Uramu

No. 1 and Pasca No. 1 produced gas from lower middle Miocene reef limestone. Jurassic and Cretaceous sandstones are potential reservoirs. Barikewa No. 1 produced from early Cretaceous and Jurassic sandstone, and Iehi No. 1 produced from early Cretaceous sandstone.

Numerous fold and fault traps are still untested, and the area appears to have moderate petroleum potential.

Recent Activities

The most recent subsidized activities have been seismic surveys onshore in the southwestern portion of the basin by Union Oil and Texaco; a seismic and gravity survey in the Lavani Valley, in the northern part of the basin, by BP Petroleum; and the Barau gravity survey by Endeavour Oil. All these surveys were completed in 1974.

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PEDIRKA BASIN

The Pedirka Basin trends north to northwest and covers an area of 90 000 km^2 in northeastern South Australia and southeastern Northern Territory. It contains Upper Carboniferous to Triassic? sediments, which overly sediments of the Warburton and Amadeus Basins, and is largely concealed beneath the Eromanga Basin.

The northwestern margin nearly coincides with the arbitrary boundary separating the outcropping Amadeus Basin and the subsurface Warburton Basin. Permian sediments, either of the Pedirka Basin or outliers of it, crop out on the Finke 1:250 000 Sheet area where they are unconformable between Devonian to Carboniferous sediments of the Amadeus Basin and Jurassic? sediments of the Eromanga Basin. In this area the irregular basin boundary is a poorly exposed unconformity between Permian sediments and Devonian-Carboniferous sediments. Beneath the Eromanga Basin the boundary is the subcrop of the unconformity between Upper Carboniferous or Permian sediments and older sediments of the Warburton Basin. The boundary has been imprecisely determined by seismic surveys.

Up to 1000 m of sediments are preserved in the basin. The oldest sediments are up to 600 m of Upper Carboniferous to Lower Permian terrestrial sandstone, tillite, conglomerate, siltstone, and shale with interbedded coal towards the top. Interpretation of seismic records suggests another unit, up to 350 m thick, conformably overlies the Lower Permian sequence in the eastern part of the basin. This sequence, which may be of Permian or Triassic age, has never been drilled.

Several anticlines trending north and northeast have been mapped in the eastern part of the basin. The anticlines are reported to be partly due to differential compaction over buried basement highs and partly due to younger deformation.

Geological mapping

The whole basin was covered by BMR in 1963, 1964, and 1971 and by the GSSA from 1962 to 1971. BMR has published four and issued one 1:250 000 maps covering the Northern Territory part of the basin, and GSSA has published one and issued three 1:250 000 maps covering most of the South Australian part of the basin.

Drilling

Two wells were drilled in the northern part of the basin by Amerada Petroleum Corporation and four were drilled in the western part by French Petroleum without encountering significant hydrocarbon shows. All of the wells were drilled to basement and all were subsidized. They provide nearly all of the stratigraphic information on the basin sediments.

Correlation

SADM has prepared a tentative lithological correlation between outcrops and wells. The eastern part of the basin has not been drilled and in this area the only correlation is seismic. Plant spores are used to date the Permian and Upper Carboniferous sediments.

Aeromagnetic surveys

Delhi Australia Petroleum surveyed most of the South Australian part of the basin in 1961 and 1962, and BMR and Flamingo Petroleum surveyed the Northern Territory part of the basin in 1962 and 1964. 1:250 000 total magnetic intensity maps were produced from these surveys and have been published by BMR and SADM. The maps are of limited value, as magnetic basement is considerably deeper than the oldest Pedirka Basin sediments.

Gravity surveys

The whole basin was covered by subsidized regional gravity surveys carried out by Beach Petroleum NL, French Petroleum Corporation, Flamingo Petroleum, and Associated Freney Oilfields from 1960 to 1970, and by regional surveys by BMR in 1961 and 1962. The results of the BMR surveys are abailable in Records.

The Bouguer anomaly maps are probably of limited use as the Bouguer anomaly patterns may arise from density contrasts within the basement rocks, rather than within the Pedirka Basin.

A 1:1 000 000 Bouguer anomaly map of the South Australian part of the basin is available from SADM, and maps at various scales are available from or have been published by BMR.

Seismic surveys

Seismic surveys carried out by SADM, French Petroleum NL, Amerada Petroleum Corporation, Beach Petroleum

NL between 1962 and 1972 provide seismic coverage for all of the basin except the northwestern end. Record quality varies from fair to good. The more recent surveys are concentrated in the northern part of the basin.

The surveys outlined anticlines in the northeastern part of the basin and enable seismic correlation over most of the basin.

Economic geology

Water: Aquifers in the Permian and Carboniferous sediments mostly produce salty water.

Petroleum: Minor gas shows were recorded in both the Permian and the Cretaceous sediments. The Permian sandstone has good reservoir potential, and coal in the Lower Permian section is a potential source of hydrocarbons. Structural traps are present and stratigraphcc traps are probably present.

The six exploration wells drilled have not fully tested the petroleum potential of the basin. A large area of the basin is undrilled and anticlines in the northeast and at the eastern edge of the basin have not been drilled.

Recent activities

Beach Petroleum NL has announced its intention to drill Colson No. 1, a 3000 m well, to test the Permian sediments for hydrocarbons on Colson Anticline. SADM plans a six-well stratigraphic drilling program; five of these holes will penetrate the southern part of the Pedirka Basin. These wells will test hydrocarbon potential, identify seismic reflectors, and investigate lithology.

In 1974 Delhi International Oil carried out a seismic survey over the eastern part of the basin to define the extent of the Permian sediments in the eastern part and establish structural trends.

Deficiencies in geological knowledge

The stratigraphy of the eastern and southern parts of the basin is unknown except by seismic interpretation. The margins of the basin, particularly in the south and east are poorly defined and additional seismic surveys are needed to delineate them.

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PERTH BASIN

The Perth Basin covers an area of 62 000 km^2 onshore and an area of 52 000 km^2 on the continental shelf (to the 200 m bathymetric contour) in Western Australia. It contains over 12 000 m of Ordovician and Silurian, Permian, Mesozoic, and Cainozoic sediments.

The eastern margin is a prominent fault (Darling Fault) where sediments abut against Precambrian basement. The basin is bounded to the northwest by the southwest-trending Hardabut Fault, the Northampton Block, and the Yandi-Madeline Hinge. The western and southern margins have not been determined.

The basin has been subdivided on the basis of aeromagnetic, gravity, and seismic interpretation into a number of structural units consisting of troughs and sub-basins (grabens) separated by horsts.

Precambrian crystalline basement rocks were penetrated in Jurien No. 1 and Cadda No. 1 on the eastern side of the Beagle Ridge, in Woolmulla No. 1 in the Dandaragan Trough, and in Sue No. 1 on the western margin of the Bunbury Trough.

Up to 1800 m of Ordovician and Silurian non-marine fluviatile red-brown sandstone, siltstone, and conglomerate unconformably overlies basement in the Coolcalalaya Sub-basin in the northeast.

Permian sediments crop out onshore. They unconformably overlie the Ordovician, Silurian, and Precambrian rocks. Up to 1000 m of Lower Permian poorly sorted sandstone, tillite, and black calcareous shale (containing a few faceted and striated boulders) with beds of limestone are overlain by up to 900 m of marine shale with numerous thick limestone lenses, coal measures, and marine and non-marine sandstone and shale. Upper Permian lacustrine to marginal marine sandstone, over 95 m thick, crops out near the Northampton Block and marine to continental sandstone and conglomerate, 75 m thick, have been drilled on the Beagle Ridge to the west. Nineteen hundred metres of Lower and Upper Permian coal measures have been drilled in the subsurface of the Bunbury Trough.

At least 1060 m of Lower Triassic marine black shale occurs in the Dandaragan Trough and up to 300 m of near-shore marine sandstone occurs in the Bunbury Trough, disconformable on the Upper Permian sediments. A thin marine sandstone, which underlies the marine shale around the Northampton Block, unconformably onlaps Precambrian basement rocks. Up to 220 m of Middle Triassic continental to marginal marine sandstone, siltstone, and shale conformably overlie Lower Triassic sediments in the Dandaragan Trough. Over 2200 m of Upper Triassic continental coarse-grained poorly sorted sandstone conformably overlies Middle Triassic sediments in the Dandaragan Trough adjacent to the Darling Fault.

Lower Jurassic continental coal-bearing sandstone, siltstone, and shale which crop out along the western margin of the onshore part of the basin have been identified in the subsurface in all the Sub-basins where they attain a maximum thickness of 2400 m. They conformably and disconformably overlie the Upper Triassic sediments.

Two hundred and forty two metres of Middle Jurassic marine shale was penetrated in Gun Island No. 1 in the Abrolhos Sub-basin, whereas up to 340 m of continental to marginal marine coal-bearing sandstone, siltstone, and shale occur in the Dandaragan and Bunbury Troughs. The rocks conformably overlie Lower Jurassic sediments.

Upper Jurassic continental coarse-grained sandstone and siltstone attains a thickness of at least 4200 m in the Dandaragan Trough; 1200 m in the Abrolhos Sub-basin; 1100 m in the Bunbury Trough; and 3000 m in the Vlaming Sub-basin. They conformably overlie Middle Jurassic sediments in the Abrolhos Sub-basin and disconformably overlie Lower Jurassic sediments in the Dandaragan Trough.

The Upper Jurassic sediments are overlain by up to 6000 m of Lower Neocomian fluvial sandstone and lagoonal or lacustrine sandstone and shale. These non-marine sediments are overlain with a strong angular unconformity in the Vlaming Sub-basin by up to 1500 m of Upper Neocomian near shore predominantly marine sandstone, shale, and minor coal. Tholeiitic basalt is interbedded with Neocomian and Aptian non-marine sediments in the Bunbury Trough. Up to 500 m of Aptian, Albian, and Upper Cretaceous marine sandstone, siltstone, and sandy limestone, unconformably overlie Upper Jurassic sediments in the Abrolhos Sub-basin and in the Dandaragan Trough.

Widespread Tertiary shelf carbonates disconformably overlie Upper Cretaceous sediments in the offshore Vlaming and Abrolhos Sub-basins. They attain a maximum thickness of 1200 m southwest of Perth.

Pleistocene limestone crops out along the full length of the present coastline of the Perth Basin.

Large normal movements of the Darling-Urella Fault System on the eastern margin of the basin, the Dunsborough Fault, and faults flanking the Beagle and Harvey Ridges dominated structural evolution from the Middle Triassic to the Lower Cretaceous. The Dandaragan and Bunbury Troughs are grabens resulting from this faulting.

Faulting and folding occurred in the Vlaming Sub-basin during the Neocomian, and in the Abrolhos Sub-basin and Dandaragan Trough between the Upper Jurassic and Aptian.

A dolerite sill intrudes Sakmarian sediments in Sue No. 1 on the western side of the Bunbury Trough.

Geological mapping

GSWA mapped the Augusta-Busselton Sheet area between 1962 and 1964 and has published a first edition 1:250 000 map. Preliminary editions of five other 1:250 000 Sheet areas were published after mapping between 1965 and 1970. The Collie and Pemberton Sheet areas are unmapped.

The quality of the first edition map is good since it was derived from numerous traverses and airphoto-interpretation.

The youngest sediments in the basin are flat-lying and poorly exposed, and the mapping gives little idea of the subsurface stratigraphy and structure.

Drilling

Thirty subsidized and fifty-two unsubsidized petroleum exploration wells and eleven BMR stratigraphical test wells were drilled in the basin between 1959 and 1972. Most of the onshore wells were drilled in the Dandaragan Trough and typically penetrated a Tertiary, Jurassic, Triassic, and Permian sequence. Most of the offshore wells were drilled in the Vlaming Sub-basin, where they penetrated Tertiary and Cretaceous sediments and bottomed in Upper Jurassic sediments. The stratigraphic information yielded by the wells is most valuable because faults fragment the basin and tracing of marker beds on seismic sections is difficult.

Correlation

Time correlation between wells can be prepared using the appendices of the well completion reports. No basin-wide lithological correlations are available.

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Aeromagnetic surveys

In 1959 and 1963 BMR carried out two onshore surveys which outlined the Dunsborough and Darling Faults. Two subsidized offshore surveys flown in 1969 delineated the Bunbury Trough, Yalingup Shelf, Turtle Dove Ridge, and the Beagle Ridge.

The aeromagnetic surveys were of great assistance in assessing the major structure of the basin.

Gravity surveys

Four subsidized gravity surveys have been carried out in the northern part of the Perth Basin. The surveys collectively delineated the Dandaragan Trough, Gingin Anticline, and the Darling, Geraldton, and Hardabut Faults.

BMR surveys in 1951 and 1965 indicated large downthrow to the west along the Darling-Urella fault system. BMR carried out onshore reconnaissance surveys in 1969, 1971, and 1972. 1:250 000 Bouguer anomaly maps of all the basin are published, and 1:500 000 maps of part of the Dandaragan Trough are also published.

Seismic surveys

Forty-eight onshore and nineteen offshore subsidized seismic surveys have been carried out in the basin. The record quality of the onshore surveys is poor, mainly because of the nature of the surface limestone which is prevalent in the area. The onshore surveys have been located mainly in the Dandaragan Trough and Bunbury Trough. Only one survey has been carried out in the Coolcalalaya Sub-basin and one in the Byro Sub-basin. No seismic surveying has been carried out in the Irwin Sub-basin.

The offshore area has adequate regional coverage. The record quality of the marine surveys is poor to fair.

BMR carried out six surveys between 1956 and 1966. One of the surveys located the Gingin Anticline which contains commercial quantities of gas.

Although seismic surveying together with drilling provides the best method of evaluating this basin the interpretation of the record sections is seriously limited by record quality and faulting.

Economic geology

Petroleum: Wapet discovered commercial quantities of gas in five fields. They are: Yardarino (1964); Gingin (1965);

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Dongara (1966); Mondarra (1968); and Walyering (1971). The five fields are connected by pipeline to Perth. Gingin was producing a daily average of 15 MMcf, Dongara was producing 82 MMcf, and Mondarra was producing 5 MMcf at the end of September, 1972. The Walyering field was shut-in and not producing.

Gas is produced from the basal Triassic marine sandstone in the Yardarino, Dongara, and Mondarra fields and also from the Lower Permian Irwin River Coal Measures and the Carynginia Formation in the Dongara Field.

Lower Triassic shale is a source rock for waxy oil in the northern part of the Dandaragan Trough and Lower Jurassic sediments are the probable source rocks for gas/condensate in the central part of the Dandaragan Trough. Basal Lower Triassic sandstone and Lower to Middle Jurassic sandstone are proven reservoirs. All the commercial hydrocarbons discovered occur in large anticlines. However, stratigraphic traps may occur where the basal Lower Triassic sandstone pinches out beneath the Lower Triassic shale.

Clay: Bentonitic clay has been produced from claypans near Marchagie in the northern part of the basin.

Coal: Black coal occurs in the Permian Irwin River Coal Measures; the seams are highly lenticular, of poor quality, and are not presently economic. Upper Jurassic to Lower Cretaceous brown coal occurs in the Bunbury Sub-basin near Donnybrook, Nornalup, and Pallinup River.

Lime: Lime material for cement-making at Perth has been obtained from Pleistocene? shell beds in the lower reaches of the Swan River. Part of the river bed is a layer, 1 to 2 metres thick, of large oyster shells in a clay matrix.

Beach sands: Heavy mineral beach sands containing ilmenite, rutile, monazite, and zircon occur south of Perth near Yogunup, Capel-Ludlow, and Koombana Bay, and north of Perth at Eneabba.

Water: Over 400 bores have been sunk in the Upper Jurassic to Lower Cretaceous sediments (Yarragadee Formation) for stock and domestic water. Bunbury, Busselton, and Capel obtain water supplies from bores 100 to 300 m deep. Some of the bores have been drilled by the Mines Department of Western Australia and detailed geological and hydrological data are available.

Recent activities

One well was drilled on the Harvey Ridge in 1973 and another is planned in the Abrolhos Sub-basin. In 1973 five seismic surveys were done onshore in the Perth Basin, mostly in the Dandaragan Trough, and one gravity survey was done in the Coolcalalaya Sub-basin. The Erregulla seismic survey was done onshore for WAPET in 1974.

BMR conducted a shipborne seismic, gravity, and magnetic survey late in 1972 and early in 1973. GSWA is preparing a Bulletin on the basin.

Deficiencies in geological knowledge

Basin wide lithological, time, and seismic correlations are not available, and the geological history is not well known.

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POLDA BASIN

The Polda Basin is a narrow linear west-trending trough covering an area of 6200 km^2 onshore and 14 000 km^2 offshore in the Great Australian Bight of South Australia.

The basin is about 280 km long, extending westward from Cleve on the Eyre Peninsula offshore to near the 200 m bathymetric contour. The onshore margins of the Polda Basin are concealed beneath a cover of Quaternary sand, calcrete, and lacustrine gypsiferous mud. Interpretation of Bouguer anomaly maps, however, suggests that the eastern end of the basin branches. One branch trends easterly towards Cleve, its southern margin partly bound by a north-trending gravity ridge. The other branch trends northeasterly, its south-eastern boundary being the Kopi Gravity Plateau, which lies between the two branches.

Aeromagnetic and seismic data have been used to interpret the position and nature of the offshore basin margins. The northern boundary, between the Polda and Eucla Basins, is a fault. Where the fault dies the boudnary is extended arbitrarily westward to the edge of the continental shelf. The southern margin, which is partly faulted, is not clearly defined west of the fault.

The Elliston Trough is the seismically defined graben which comprises most of the offshore Polda Basin. The downfaulted basement within the graben is a tilt-block which rises gradually from the northern to the southern margin of the trough.

Carpentaria high-grade metamorphic rocks of the Gawler Block probably underlie the basin sediments. Up to 4300 m of sediment are present in the western end of the Elliston Trough, the deepest part of the basin. The section thins appreciably onshore. The age and lithology of the sediments are known only at scattered outcrops of Precambrian? rock and one onshore well, Polda No. 1, which intersected Cainozoic and Mesozoic sediments. Three sequences of sedimentary rock separated by unconformities are interpreted on offshore seismic sections. These are tentatively identified as Proterozoic to Cambrian, Jurassic to Cretaceous, and Tertiary in age by analogy with the onshore sediments and nearby basins.

Interpretation of marine seismic data suggests that Proterozoic to Lower Cambrian sediments overlie basement in the eastern half of the basin. Onshore exposures of Proterozoic? fluviatile sandstone and conglomerate, dipping

10^{o}-15^{o} basinward, crop out near the onshore margins of the basin at Talia Caves along the coast, and inland at Mount Wedge, Blue Ridge, and the area northwest of Cleve on the Eyre Peninsula.

Mesozoic sediments, probably similar to the Jurassic lacustrine and fluviatile sandstone and shale which are present in the Otway Basin, unconformably overlie the Proterozoic to Lower Cambrian. Polda No. 1 encountered Upper Jurassic dark coloured lignitic clays over 76 m thick. Seismic interpretation suggests that these sediments probably thicken offshore, overlapping the Proterozoic to Lower Cambrian sediments to rest unconformably on basement in the western part of the basin. Cretaceous sediments although absent onshore are expected offshore, possibly contiguous with Cretaceous sediments in the adjacent Eucla Basin.

Tertiary terrestrial clays and lignitic sandstone, and marine carbonates, overlie the Mesozoic with slight angular unconformity. Over 20 m of middle Eocene terrestrial clastics occur onshore. Analogy with the adjacent Eucla Basin suggests marine carbonates probably occur offshore. The Tertiary is buried beneath flat-lying Quaternary aeolianite sand and clay which extend beyond the basin margins offshore and onshore. Marine seismic data suggest the contact between the Tertiary and the Quaternary strata is an unconformity.

When Gondwanaland began to break up in the Jurassic a major rift zone, called the Otway Rift Valley, formed south of and parallel to the present Australian shoreline. The Elliston Trough represents a subsidiary offshoot that developed off the main rift valley in the Jurassic and Cretaceous. Seismic interpretation shows that major faulting in the Elliston Trough affects only the Mesozoic unit which is overlain with slight angular unconformity by an undeformed Tertiary section.

Geological mapping

The eastern end of the basin was mapped at 1:63 360 scale in 1955 to 1957 and the rest of the basin was mapped at 1:250 000 scale in 1966 to 1967. Two 1:63 360 maps of the eastern part of the basin are published and preliminary editions of two 1:250 000 maps of the whole onshore area are available.

The mapping is of value only in the areas of outcropping Proterozoic? sediments because the younger sediments are concealed beneath a Quaternary cover.

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Drilling

No petroleum exploration wells have been drilled in the basin. The Tertiary and Jurassic sediments are known only from onshore water-bores and Polda No. 1, a shallow stratigraphic well drilled by the GSSA.

Correlation

No basin-wide lithological or time correlations are available. The Tertiary and Jurassic sediments are dated by their microflora. The outcropping Proterozoic? sandstone and conglomerate are unfossiliferous. Correlation with offshore sediments is impossible because no offshore wells have been drilled; however, a broad seismic correlation is possible.

Aeromagnetic surveys

Overlapping regional aeromagnetic surveys were flown at one mile spacing by BMR from 1953 to 1955 and the South Australian Department of Mines in 1955. The BMR survey covers the northern part of the onshore Polda Basin and the SADM survey covers the southern part of the onshore basin. The data is of good quality and the interpretation is reliable. No report was written on the BMR survey. SADM also flew a detailed low-level aeromagnetic survey over the Kopi Gravity Plateau in the margin of the basin in 1960. Nine 1:63 360 total magnetic intensity maps were published by BMR in 1957 and 1958. SADM also published five 1:63 360 maps in 1957. Two 1:253 440 scale total magnetic intensity maps of the entire onshore area were published by SADM in 1960.

The offshore part of the basin was covered by a subsidized aeromagnetic survey flown by Shell Development in 1966, an unsubsidized shipborne magnetic and seismic survey conducted by Shell in 1970 and 1971, and a combined marine magnetic, seismic, and gravity survey carried out by BMR in 1972. The subsidized survey outlined an elongate trough bounded by shallow basement. The BMR survey obtained good-quality data along northerly trending traverses spaced 35 to 40 nautical km apart.

Gravity surveys

SADM measured gravity over the onshore part of the basin on a 6-km grid in 1967. 1:250 000 and 1:1 000 000 Bouguer anomaly maps are available. BMR carried out a combined marine gravity, magnetic, and seismic survey in

1972. Lines are oriented northward with a spacing of 35 to 40 nautical km. The results are not yet published. The onshore margins of the basin are located by interpretation of the Bouguer anomaly maps.

Seismic surveys

Five subsidized seismic surveys were carried out over the offshore part of the basin between 1966 and 1971 by Shell Development, Bridge Oil NL and Target Exploration NL. Record quality is poor to good. The Elliston Trough was recognized as a fault-bounded graben containing thicker sediments. Three unconformities were recognized. Target Exploration NL defined one large anticline and three small ones in the trough. Shell also carried out four unsubsidized marine seismic surveys over the offshore basin between 1969 and 1973. BMR carried out a combined regional marine seismic, gravity, and magnetic survey in 1972. High noise levels and interference from multiples resulted in poor seismic records over the continental shelf.

A small seismic refraction survey was carried out by SADM onshore near Elliston in 1966 to check a possible onshore continuation of the Elliston Trough. Poor shooting conditions seriously limit the value of the information.

Economic geology

Water: Good-quality water generally containing less than 1000 ppm of total dissolved salts is available from a Quaternary aeolianite aquifer which is underlain by sandy claystone and overlain by sheet kunkar. The aquifer varies in thickness between one and ten metres. In the lower parts of the basin the water-table is less than two metres below the surface. Water is also available from Tertiary sandstone, but is of a poor quality containing over 7000 ppm of dissolved salts.

Petroleum: The petroleum potential is untested. The most prospective area is the Elliston Trough where fold and fault traps are probably present beneath water less than 200 m deep.

Recent activities

Target Exploration has announced that it will drill a petroleum exploration well 2500 to 3000 m deep to test Tertiary and Mesozoic sediments in the Elliston Trough; its exact location has not been released. BMR carried out an extensive marine seismic, gravity, and magnetic survey in the Great Australian Bight in 1972. Data is presently being analysed. Shell Development carried out an unsubsidized marine seismic survey in 1973.

Deficiencies in geological knowledge

The major deficiency is the lack of knowledge about the lithology of the sediments, particularly in the offshore Polda Basin. Several wells are needed in the offshore part of the basin and at least one well should be drilled to basement onshore to obtain data on pre-Jurassic sediments.

A seismic survey of the onshore part of the basin would tie it to the Elliston Trough and help delineate the margins.

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ST VINCENT BASIN

The St Vincent Basin is an elongate northerly trending graben containing Cainozoic sediments that cover an area of 9500 km^2 offshore in St Vincent Gulf and 7400 km^2 onshore in South Australia.

The margins are mainly faulted and partly unconformable contacts. The Cygnet Fault, which extends across Kangaroo Island, is the southern margin. The western margin is the Ardrossan and Kulpapa Faults on Yorke Peninsula and the south end of the Torrens Lineament across St Vincent Gulf between the southern end of Yorke Peninsula and the Cygnet Fault. The Mount Lofty and Flinders Ranges flank the basin in the east and the Hummock and Barunga Ranges flank it in the northwest.

The eastern onshore area contains the Adelaide Plains, the Willunga, and the Noarlunga Sub-basins. The southeastern margin of each sub-basin is a fault forming part of an en echelon fault system.

Proterozoic and Cambrian sediments of the Adelaide Geosyncline and Permian tillite, sandstone, and claystone underlie and bound the basin.

The oldest basin sediments are middle to upper Eocene deltaic lignitic and carbonaceous sandstone, claystone, and local basal conglomerate unconformable on basement. They are 98 m thick in Croydon Bore No. 2.

Up to 340 m of upper Eocene to Miocene marine sandstone, glauconitic sandstone, limestone, marl, and claystone conformably overlie the Eocene sediments. This unit rests unconformably on basement rocks along the margins of the basin.

Pliocene and lower Pleistocene marine sandstone, limestone, and siltstone, about 230 m thick, overlie the Miocene with a slight angular unconformity. Laterally the unit passes into terrestrial sandstone and vertically into lower Pleistocene marine sandstone.

Most of the Tertiary sediments are concealed beneath a cover of Pleistocene to Recent sand, clay, silt, and marl. 700 m of Cainozoic sediments have been drilled in the Adelaide Plains Sub-basin.

Reactivation of ancient fault systems initiated the St Vincent graben early in the Tertiary and intermittent

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movement continued along these faults throughout the rest of the Tertiary. Faulting and gentle folding occurred late in the Miocene. Subsidence in the early Pliocene was followed by uplift in the late Pliocene or early Pleistocene.

Geological mapping

GSSA mapped the onshore part of the basin from 1950 to 1969. First edition maps of the western part of the basin are published at 1:253 400 scale and first edition maps of the eastern part are published at 1:250 000 scale. Eight 1:63 360 scale maps covering part of the eastern basin have been published. St Vincent Gulf is unmapped.

The mapping is of limited value except along the basin margins and the edge of St Vincent Gulf as most of the Tertiary sediments are concealed beneath a cover of Quarternary alluvium.

Drilling

Thirteen petroleum exploration wells have been drilled in the basin, mostly along Yorke Peninsula. Five of these were drilled before 1962 by Largs Bay Oil, Co-op Oil, and American Beach Oil, all bottoming in either the Tertiary or basement. Between 1962 and 1967 Beach Petroleum NL drilled six wells on Yorke Peninsula, three of which were subsidized, and two wells on the east side of the basin, one of which was subsidized. Most of the wells had pre-Tertiary targets and were drilled to either the Cambrian or Precambrian. The unsubsidized well east of St Vincent Gulf was abandoned in Tertiary sediments at a depth of 183 m.

Two wells were drilled in St Vincent Gulf by Beach Petroleum NL in 1963 and 1964. The deepest well, sited on Troubridge Island, was abandoned in the Permian at 490 m.

No hydrocarbons shows are recorded from the Tertiary sediments, although slicks of oil and traces of gaseous hydrocarbons were reported from the underlying Permian and Cambrian basement sediments on Yorke Peninsula.

Drilling on Yorke Peninsula and Troubridge Island has provided subsurface data for correlation with the better known eastern part of the basin. Petroleum exploration wells east of the Gulf contribute useful information about the basement rocks; the Cainozoic stratigraphy, however, is well documented from stratigraphic and water-bores.

Correlation

No basin-wide correlations have been published, but a good correlation can be made because most of the

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Tertiary sequence is exposed in cliffs in the Willunga Sub-basin, and over 90 bores have penetrated the Tertiary in the Adelaide Plains Sub-basin. Sediments on the Yorke Peninsula and wells drilled in the St Vincent Gulf have been correlated with those east of the Gulf.

Time correlation of the Eocene and Miocene is based on planktonic Foraminifera and to a lesser degree on benthonic species, and the Pliocene sediments are correlated on molluscs. The topmost sandstone, Pliocene to Pleistocene in age, is unfossiliferous.

Magnetic surveys

The onshore northern end of the basin was covered by two BMR aeromagnetic surveys in 1952 and 1960. 1:63 360 total magnetic intensity maps were published and a Record for the 1960 survey is available. The rest of the onshore basin was flown by SADM in 1955 and 1956. Total magnetic intensity maps of the survey area were published at 1:63 360 scale, and maps of the northern end of the basin were published at 1:250 000 scale. Beach Petroleum NL flew a subsidized aeromagnetic survey of St Vincent Gulf and the city of Adelaide in 1964. BMR carried out a shipborne magnetic, seismic, and gravity survey in the Gulf in 1972. Lines are oriented northerly with a spacing of 35 to 40 nautical km. The results are unpublished.

Magnetic data is of little value because the top of magnetic basement is deeper than the base of the Tertiary in most of the basin.

Gravity surveys

SADM measured gravity on a 6-km grid over the northern Adelaide Plains Sub-basin in 1967 and across the Willunga and Noorlunga Sub-basins in 1968. Reconnaissance and semi-detailed surveys were also carried out over Yorke Peninsula by SADM in 1956 and by Beach Petroleum NL in 1965 and 1967. The whole of St Vincent Gulf was covered by gravity surveys conducted by Beach Petroleum in 1964 and 1970, and by BMR in 1972. The 1964 survey over the northern part of the Gulf was subsidized, but the other survey by Beach Petroleum was unsubsidized. The BMR survey produced good-quality data on northerly trending traverses spaced 35-40 nautical km apart. The results are unpublished.

A 1:1 000 000 Bouguer anomaly map of the onshore part of the basin is available from SADM. The information is of little value as the Tertiary strata are too thin to significantly affect the gravity field.

Seismic surveys

Geosurveys of Australia conducted a subsidized survey in 1960 and 1961 that determined sediment thickness and structure onshore over part of the Adelaide Plains Sub-basin. Reflection seismic surveys by SADM cover both the Willunga Sub-basin and parts of the Adelaide Plains Sub-basin. Beach Petroleum NL conducted two subsidized seismic surveys in 1965 and 1966, and one subsidized combined seismic, magnetic, and gravity survey in 1969 over Yorke Peninsula. Record quality was poor to very poor, improving away from the coast, and only Palaeozoic horizons were contoured.

Two subsidized seismic surveys were completed in St Vincent Gulf by Beach Petroleum between 1967 and 1972. The surveys outlined structures within the Palaeozoic sediments. Results varied from very poor to good. BMR carried out a shipborne seismic, gravity, and magnetic survey in St Vincent Gulf in 1972. Record quality was poor owing to high noise levels and interference.

A good reflector occurs at the base of the Tertiary/Permian sequence. Where this horizon is the base of Tertiary it is most valuable.

Economic geology

Limestone, dolomite, salt, construction sand, water, and various non-metallic minerals have been exploited. Coal is present in large quantities, but has not been mined because of thick overburden and large volumes of groundwater.

Limestone: One of the most important resources in the basin is Tertiary limestone which is quarried for lime and building stone. Most of the limestone is quarried on Yorke Peninsula and some is quarried in the eastern part of the basin. St Vincent Gulf contains extensive undeveloped reserves of limestone. Shell grit, of a suitable grade for cement, occurs 11 km from shore west of Outer Harbour in water over 18 m deep. The $CaCO_3$ content improves with distance from shore.

Dolomite: Dolomite has been quarried since 1950 from Cambrian deposits below the basin at Ardrossan on Yorke Peninsula, by the Broken Hill Pty Co. Ltd. Total production is for metallurgical use. Further sources of dolomite occur in Tertiary, Pleistocene, and Recent beds deposited in lakes on Yorke Peninsula.

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Salt: Plants for harvesting salt by solar evaporation have been established at Port Price, on Yorke Peninsula, and at Dry Creek, on the eastern side of St Vincent Gulf. Over half a million tonnes of salt is harvested annually at the Dry Creek plant. Seasonal deposits are harvested regularly from salt crusts on Lake Fowler, on the southern Yorke Peninsula, and Lake Bumbunga, at the north end of the basin.

Construction sand: Well over one million tonnes of sand is quarried annually from Tertiary and Quaternary sediments in the Adelaide Plains, Willunga, and Noarlunga Sub-basins.

Water: Underground water is a major resource particularly in the Adelaide Plains Sub-basin, which supplies the city of Adelaide with water. The major aquifers are Miocene and Pliocene limestone and sandstone and Quaternary alluvium. Salinity increases, westward toward the Gulf, with distance from the intake area.

Coal: Eocene brown coal deposits have been studied in detail at Clinton, Alma, Balaklava, and Inkerman in the northern part of the basin and at Noarlunga on Fleurieu Peninsula. One hundred and eight bores were drilled to test their potential.

The Alma-Balaklava-Inkerman area contains the largest deposit of brown coal in South Australia. Reserves of 400 million tonnes were estimated in one seam 6-12 m thick. The presence of large volumes of groundwater and about 55 m of overburden have prevented development of the field. Attempts have been made to mine the lignite from shafts at Noarlunga.

Petroleum: The Tertiary sediments are probably too shallow to have generated hydrocarbons.

Possible source rocks occur in the pre-Cainozoic rocks. Grease and slicks of oil were reported in Permian and Cambrian sediments from early stratigraphic wells drilled by SADM on Yorke Peninsula. Traces of gaseous hydrocarbons were found in brines recovered from Cambrian dolomite.

Alunite: Alunite is mined on a small scale at Ardrossan, on Yorke Peninsula. It occurs as thin seams and nodules within Tertiary sediments.

Gypsum: Recent deposits of seed gypsum occur in marginal dunes and as surface encrustations on lakes. Gypsum is mined from Lake Fowler, on southern Yorke Peninsula, and Diamond Lake, north of St Vincent Gulf.

Clay and natural earth: Minor quantities of fireclay and natural earth have been mined in the eastern side of the basin.

Recent activities

Beach Petroleum NL carried out a detailed marine seismic survey over the Marsden structure in southern St Vincent Gulf in 1972. A shipborne seismic, gravity, and magnetic survey of St Vincent Gulf was conducted by BMR in 1972. Data is presently being analysed.

Deficiencies in geological knowledge

There are no major deficiencies in the geological knowledge of the basin. The maximum thickness of the Tertiary sequence may be determined by either a seismic survey or a shallow well in the eastern area of St Vincent Gulf.

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STYX BASIN

The Styx Basin contains Lower Cretaceous sediments cropping out over an area of 400 km^2 onshore and underlying an area of at least 1000 km^2 offshore from the Queensland coast.

The onshore boundary is a partly faulted unconformable contact with Permian sediments in the axis of the Strathmuir Synclinorium. The offshore boundaries are unknown.

A maximum recorded thickness of about 390 m of predominantly non-marine sandstone, shale, and coal, crops out onshore.

The sediments dip generally eastwards at about 5° towards the eastern boundary of the basin, which is probably a high angle reverse fault. They are crumpled and faulted for some distance west of the fault. Farther north interpretation of seismic data suggests a fault offshore parallel to the mainland coast with a downthrow to the east of more than 300 m. On the downthrown side of this fault there are about 500 m of sediments, presumed to lie within an offshore extension of the basin beneath Broad Sound. The sediments thin to the east and north, where basement rises to near sea bottom.

Geological mapping

The basin lies almost entirely within the St Lawrence 1:250 000 Sheet area which was mapped by BMR and GSQ between 1962 and 1964. The map has been published with explanatory notes and a report has been published with a preliminary edition of the map. The outcrop area of the basin is small and surface exposure is limited to the water courses.

Drilling

No petroleum exploration wells have been drilled, but many diamond-drill holes have been sunk onshore by GSQ and companies in the search for coal. The holes that penetrated to Permian basement demonstrate that the Cretaceous sediments were deposited on an irregular surface and that they thicken eastwards. Because of poor outcrop, knowledge of the detailed stratigraphy of the basin is based mainly on subsurface records obtained in mining and diamond drilling.

Correlation

Correlation has been achieved between the diamond-drill holes. The fossil flora, microflora, and microfauna strongly support an Albian age for the sediments.

Aeromagnetic surveys

BMR included the area in an aeromagnetic survey of the Bowen Basin in 1961 to 1963. A narrow zone of comparatively smooth magnetic profiles extends from offshore in Sheet area F55/8 (Mackay) to onshore in the St Lawrence Sheet area, where it coincides broadly with the Styx Basin. Interpreted depths to magnetic basement greater than 1200 m are indicated off Mackay, shallowing to 600 m under Broad Sound, and deepening rapidly to up to 2400 m along the Styx River. This latter figure is very much greater than the thickness of Cretaceous sediments inferred from outcrop and drilling data and presumably includes some of the Permian strata beneath the Styx Basin.

Gravity surveys

BMR included the area in a gravity survey of the north Bowen Basin in 1963, and has published 1:250 000 and 1:500 000 Bouguer anomaly maps of the relevant Sheet area. A gravity minimum broadly coincides with the Styx Basin, but must be regarded as reflecting thick Palaeozoic sediments in the Strathmuir Synclinorium in addition to those of the Styx Basin itself.

Seismic surveys

Ampol Exploration Ltd conducted a marine seismic survey over Broad Sound and the offshore Mackay area in 1966. The data are reliable only for the northern part of the sound, where a fault with a throw greater than 300 m was revealed parallel and close to the coast. About 500 m of sediments occur on the downthrown eastern side of the fault. The rest of the area appears to have little or no sediment above the basement.

Economic geology

Coal: The Styx Coal Measures were worked continuously from 1919 to 1963, production being about 1 750 000 tonnes. Reserves in the Tooloomba area are about 4 000 000 tonnes. The coal is high volatile bituminous, with ash yield of 8% to 15%, and a low sulphur content.

Petroleum: The sequence onshore appears to be too thin and with insufficient depth of burial to have generated hydrocarbons. Investigations offshore, though inconclusive, appear to rule out the prospect of any significant northward thickening of the sequence. The petroleum prospects are rated as low.

Deficiencies in geological knowledge

Very little is known of the offshore geology or of the relationship, if any, with the Hillsborough Basin.

Recent developments

Unknown.

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SURAT BASIN

The Surat Basin is a northerly trending basin containing up to 2500 m of generally flat-lying Jurassic and Cretaceous sediments. It underlies an area of about 300 000 km^2 in southeastern Queensland and northeastern New South Wales.

The northern margin is the outcropping unconformable contact between Jurassic sediments and the Permo-Triassic sediments of the Bowen Basin and the upper Palaeozoic sediments, volcanics, and plutons of the Auburn Arch. In the east the Surat Basin connects with the Mulgildie Basin, and with the Clarence-Moreton Basin over the buried Kumbarilla Ridge. Elsewhere in the east the margin is an outcropping unconformable contact between basin sediments and mainly Palaeozoic rocks in the Auburn Arch, Yarraman Block, and New England Fold Belt. In the southeast (Oxley Basin area) the margin is a disconformable contact with the underlying Permo-Triassic rocks of the Sydney Basin. In the southwest sediments within the Coonamble lobe of the Surat Basin (Coonamble Basin) rest with angular unconformity on rocks of the Lachlan Fold Belt. In the west the basin connects with the Eromanga Basin across the Nebine Ridge and its south-southwesterly extension across the Cunnamulla Shelf to the Cobar Spur.

The oldest sediments in the basin are Jurassic, mainly lacustrine and fluviatile, sandstone, siltstone, mudstone, and coal, up to 1700 m thick. The Jurassic sequence is overlain conformably by up to 1000 m of Cretaceous terrestrial and shallow marine, fine-grained sandstone, siltstone, and mudstone.

The present structural axis of the basin coincides with the depositional axis during the Jurassic. The depositional axis appears to have moved east during the Cretaceous suggesting that the New England Fold Belt was transgressed. Post-Cretaceous uplift of the eastern margin developed the present structural axis of the basin. Compressional folding and faulting are virtually absent, but there was growth of elevated areas during deposition and there was also compaction and draping over pre-depositional highs. The major faults are the Goondiwindi-Moonie Fault in the east, and the north-northwest-trending Wallumbilla Fault on the Roma Shelf. Both have maximum displacements in the Lower Jurassic of around 300 m; both are downthrown to the west.

Geological mapping

Of the nineteen 1:250 000 Sheet areas that cover the Surat Basin, twelve were mapped from 1966 to 1969 by BMR and GSQ, and seven were compiled by GSNSW. Nine Queensland sheets have been published and three have been issued as preliminary editions. Four New South Wales sheets have been published, one has been issued as a preliminary edition, and two (Walgett and Nyngan) are to be issued at 1:500 000 scale. The University of New England is preparing a series of 1:100 000 geological maps of the eastern margin of the basin in New South Wales. A 1:1 000 000 preliminary map covering the northern two-thirds of the basin has been issued by BMR, and the southern part of the basin is included in the 1:1 000 000 map of NSW published by GSNSW.

For most purposes the basin has been adequately mapped. The sediments are flat-lying and the surface mapping gives little indication of the age, lithology, and thickness of the deeper strata over large areas of the basin.

Drilling

About 1400 flowing artesian water-bores and many thousands of subartesian water-bores have been drilled. The discovery of gas in a water-bore near Roma in 1900 initiated the search for petroleum. The most active search, however, has been since 1959, and by mid-1974 about 400 petroleum exploration wells had been drilled. The petroleum exploration wells are concentrated in the Roma-Surat-Goondiwindi-Dalby region. The principal target were the Jurassic sandstone formations, especially the Precipice Sandstone.

GSQ has drilled many stratigraphic core holes, principally across the Mimosa Syncline, in the last ten years. These holes and other holes drilled by private companies were designed primarily to investigate the coal-bearing Injune Creek Group.

Under contract to BMR, wireline logs have been run in over 200 of the water bores; they have provided a considerable amount of stratigraphic information in areas where few wells have been drilled for petroleum.

Correlation

A lithological correlation over a large part of the basin, has been prepared as part of the BMR/BRGM hydrogeological study of the Great Artesian Basin. Correlation

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is best in the northern part of the basin, where it is based on abundant lithological, wireline, palaeontological, and seismic data.

Aeromagnetic surveys

Most of the basin was covered during a subsidized survey for Union Oil Development Corporation in 1962. The remainder was covered in the 1960s during subsidized surveys for Australian Oil and Gas Corp. Ltd, and Ellis Gulliver. BMR has prepared total magnetic intensity maps of the Roma district and dyeline copies are available.

Depth to magnetic basement has been interpreted from the data, but this coincides with the floor of the basin only in marginal areas such as the Roma Shelf. Interpretation is hampered by Tertiary basalt in some areas along the northern and eastern margins.

Gravity surveys

All of the basin was covered by BMR between 1964 and 1968, and 1:250 000, 1:500 000, and 1:2 534 400 Bouguer anomaly maps are available. Bouguer corrected isogals are overprinted on the preliminary 1:1 000 000 geological map of the northern Surat Basin.

The gravity data have not been fully interpreted as the gravity effects of the basement rocks are incompletely known.

Seismic surveys

The northern half of the basin has been closely surveyed by Union Oil Development Corp., Associated Australian Oilfields NL, and Philips Petroleum Co. The southern half has been less closely surveyed by a number of other companies. Reflection data is generally good. Together with stratigraphic data from the wells drilled the seismic method has provided the best method of evaluating the basin.

Economic geology

Petroleum: Both oil and gas have been found in small quantities in Jurassic sandstone on both sides of the basin. There have been six discoveries of oil, four of oil and gas, and 22 of gas. An oil pipeline from Moonie to Brisbane was completed in 1964, and a gas pipeline from Roma to Brisbane was completed in 1969. As of June 1974 oil reserves remaining were estimated to be $0.37 \times 10^6 m^3$, and gas reserves were estimated as $2.52 \times 10^9 m^3$.

Possible source rocks include marine Carboniferous sediments, Permian sediments of the Bowen Basin, early Jurassic siltstone and mudstone, and marine Cretaceous siltstone and mudstone. Recent geochemical work suggests that most oils were derived from terrestrial plant material.

The principal reservoir is a Jurassic sandstone at the base of the sequence (Precipice Sandstone), and smaller accumulations have been found in younger Jurassic sandstones. The traps are structural and combined structural and stratigraphic. The prospects for further small discoveries are moderately good.

Coal: Perhydrous coal occurs in the Middle Jurassic Injune Creek Group. It has been mined at Injune and deposits of commercial proportions occur at Brigalow (c. 160 000 000 tonnes), Buck Creek in the Chinchilla-Dalby area (c. 40 000 000 tonnes), and Millmeran (c. 90 000 000 tonnes). Some of the deposits are amenable to open-cut mining and are being investigated by private companies with a view to supplying a proposed thermal power station.

Water: About 1400 flowing artesian water-bores and many thousands of subartesian water-bores have been drilled (see Eromanga Basin). Good-quality water for domestic use and stock is obtained from Jurassic and Lower Cretaceous sandstone aquifer systems. A hydrogeological study of the Great Artesian Basin (of which the Surat Basin is a part) is being made in Canberra by BMR and BRGM.

Recent activities

Eight subsidized petroleum exploration wells were drilled and three subsidized seismic surveys were carried out in 1973. In 1974 three subsidized wells were drilled and five subsidized seismic surveys were done. In August 1974, Silver Springs No. 1 produced 8 MMcfD gas through a ½-inch choke from the interval 1867-99 m during a drill-stem test. The GSQ program of stratigraphic drilling is continuing. BMR is compiling borehole, outcrop, and geophysical data into a series of structure contour and isopach maps for publication in the Bulletin series.

Deficiencies in geological knowledge

Compared with other sedimentary areas the basin has been adequately evaluated. The major deficiency is lack of a detailed review of the large amount of data available.

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SYDNEY BASIN

The Sydney Basin contains about 5000 m of Permian and Triassic sediments covering an area of about 66 000 km^2 onshore and about 18 000 km^2 on the continental shelf in New South Wales.

The western margin is an unconformable contact between Permian sediments and basement rocks of the Lachlan Geosyncline. The northeastern boundary is a partly faulted, partly conformable, and locally unconformable contact with older rocks of the New England Geosyncline. The Sydney Basin is contiguous with the Bowen Basin in the north, the boundary being the transverse Narrabri Structural High at about latitude 30^{o}S. The offshore boundaries of the basin are not known with certainty.

The basement rocks include igneous, metamorphic, and sedimentary Ordovician to Devonian rocks of the Lachlan Geosyncline in the west and igneous, metamorphic, and sedimentary Carboniferous and lowermost Permian rocks of the New England Geosyncline in the northeast.

The Permian sediments consist of up to 3800 m of essentially conformable, predominantly marine, siltstone and sandstone with some glacigenic and volcanogenic detritus. Artinskian coal measures are intercalated with them in the north and they are overlain by extensive Tatarian coal measures.

The Lower and Middle Triassic sediments conformably and unconformably overlie the Permian. They include marginal sandstone and siltstone, up to 1200 m thick, laid down in deltas and on tidal flats.

Folding and faulting occurred on at least two separate occasions. Most of the folding and faulting in the north occurred late in the Permian during the Hunter-Bowen Orogeny, and the Mooki/Hunter Thrust formed along most of the northeastern margin at this time. Minor folding and faulting of the sediments occurred probably in the late Miocene and early Pliocene.

Permian, Triassic, Jurassic, and Cainozoic hypabyssal rocks intrude the sequence.

Geological mapping

Field mapping by GSNSW has been compiled together with that available from mining and petroleum exploration companies and from Universities at Sydney and Newcastle to provide regional coverage of the whole basin. Of the seven 1:250 000 Sheet areas, six first edition maps have been published and one has been issued as a preliminary edition. A first edition 1:500 000 map of the exposed part of the basin was published in 1969. Lithological units in the south that are mapped as Nowra Sandstone and Wandrawandian Siltstone are now identified as the Snapper Point Formation and Pebbley Beach Formation respectively, and in consequence some revisions are necessary to the Wollongong and Ulladulla 1:250 000 Sheets and the respective cross sections. Otherwise the mapping is good-quality regional.

Correlation

BMR has produced basin-wide lithological correlations that are published in Bulletin 149. There is insufficient palaeontological control to know whether or not the lithological units are diachronous.

Drilling

Three petroleum exploration wells were drilled between 1910 and 1916, ten between 1918 and 1938, and 55 between 1954 and 1970. All the wells have been drilled onshore. Some spudded in Permian sedimentary rocks, others drilled through the Triassic sequence into Permian rocks, and some tested the Triassic sequence only. Several wells reached economic basement. There are few wells in the northwest and west where the section is thinner and less prospective for petroleum. These wells together with numerous coal bores, stratigraphic holes, and measured sections provide a great deal of stratigraphic information and provide regional geological control, without which stratigraphic studies would be impossible.

Magnetic surveys

Magnetic intensity contours and interpreted depths to magnetic basement contours from all airborne and shipborne magnetic surveys carried out by private companies between 1954 and 1969 are published in BMR Bulletin 149. The results of a shipborne magnetic survey by BMR in 1971 are unpublished. The surveys give good regional coverage, although there are gaps near the northern, southern, and western edges of the basin.

Magnetic basement coincides with economic basement over large areas of the basin and the general form of the magnetic basement contours agrees with structure contours on economic basement from seismic interpretation. However,

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local intrusive and extrusive igneous rocks also give rise to anomalies that increase the uncertainty in the identification of magnetic basement. The report of the Sydney Basin survey for Australian Oil and Gas Corporation Ltd (1955), which covers a large part of the onshore area, cannot be located.

Gravity surveys

Bouguer anomaly contours of the whole onshore area, except between latitudes 33°S and 33°30'S, have been compiled from the results of five surveys carried out between 1954 and 1966 by private companies and BMR, and are published in BMR Bulletin 149. BMR measured gravity in the offshore area in 1971, but the results are not yet published.

There is broad correlation between basement structure contours, topographic contours, and the Bouguer gravity contours. Gravity interpretation will play an important part in understanding the structure and geological history of the basin, but no up-to-date quantitative interpretation has been made.

Seismic surveys

A seismic locality map is published in BMR Bulletin 149. Seismic surveying began in 1957, since when a good deal has been carried out both onshore and offshore. The terrain is unfavourable onshore and large tracts are in built-up areas but a reasonable reconnaissance coverage has been achieved in the central and northern area. Coverage in the south, west, northwest, and extreme north is sparse. Reduced sections of most surveys completed at the end of 1971 are available at BMR. Structure contour maps on several horizons are published in BMR Bulletin 149. The quality of the data is generally fair but only one of the structure contour maps is considered reliable. Marine surveys by private companies extended up to 48 km offshore, but the results are generally poor. BMR shot 1900 line-km in the offshore Sydney Basin area in 1971. However, the quality of these seismic records is also generally poor.

Economic geology

Coal, oil shale, heavy mineral sands, construction and ceramic materials, and natural gas have been exploited in the Sydney Basin. Traces of phosphate and oil have been found.

Petroleum: Potential source rocks are abundant in the Permian sequence and good structural traps exist. However, the petroleum exploration wells drilled, which give a good coverage of the onshore basin, have encountered only impermeable Permian strata and poorly permeable or impermeable Triassic strata. Continental drift reconstructions suggest a volcanic island arc existed to the east in the offshore area during the Permo-Triassic. Hence, a predicted eastward increase in volcanogenic detritus in the Permo- Triassic sediments is incompatible with the prospects of an offshore increase in permeability. Using poor quality data private companies have mapped a large anticline offshore on seismic sections, and a well, Sealion No. 1, has been proposed to test it.

Small shows of oil and slightly larger shows of gas have been encountered in drilling.

Oil shale: Between 20 and 30 deposits of oil shale in the Upper Permian coal measures in the western part of the basin have been used to produce kerosene for lighting (1865-1924), and as a source of motor fuel during World War II and for about seven years afterwards. Oil shale has also been mined from the Upper Permian coal measures at America Creek, west of Port Kembla, and in the north from the Greta Coal Measures, at Greta. Other occurrences are known in some of the coal mines near Muswellbrook and Cessnock.

Coal: Black coal occurs in the Greta, Newcastle, Tomago, Illawarra, and Clyde Coal Measures, and has been mined from all except the Clyde Coal Measures. Large reserves of good quality coal have been proved and immense reserves must exist at depths greater than 600 m in the central area of the basin.

Phosphate: Small amounts of phosphatic rock have been found in the Illawarra Coal Measures and in the Narrabeen Group. They are not of economic importance.

Building materials and ceramics: Various kinds of shale, sandstone, and igneous rock have been mined.

Heavy minerals: Rutile-bearing beach sands occur along the coast but exploitation is unlikely because of possible environmental damage.

Recent activities

GSNSW drilled a number of core holes in 1970 to 1973 to help in the appraisal of coal reserves. A petroleum exploration well was spudded onshore 64 km north of Sydney in 1973, and Bridge Oil NL unsuccessfully drilled two wells in the Triassic sediments in the Penrith-Camden area. An offshore petroleum exploration well, Sealion No. 1, has been proposed.

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Deficiencies in geological knowledge

Further palaeontological work is required. The subsurface geology is still not well known and additional drilling and seismic surveying is required. Offshore seismic surveys, particularly the earlier ones, have produced poor results, and better quality data and drilling will be required before this area can be evaluated. A gap exists in the gravity coverage and aeromagnetic coverage is incomplete. The nature and southeastern extent of the Hunter Thrust is unknown.

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TASMANIA BASIN

The Tasmania Basin is a north-trending basin covering an area of at least 36 000 km^2 mainly onshore in Tasmania. It contains upper Palaeozoic to Cainozoic sediments and Jurassic dolerite rarely thicker than 1000 m unconformably overlying a basement of lower and middle Palaeozoic sediments and granite and Precambrian metasediments.

The majority of the boundaries are unconformable contacts between basin sediments and basement rocks. The basement rocks are: upper Precambrian schist, quartzite, phyllite, slate, and minor amphibolite of the Tyenna Geanticline, mainly in the southwest and west; lower to middle Palaeozoic quartzite, slate, acid volcanics, greywacke, and granite of the Dundas Trough, in the northwest and part of the west; and Silurian and Devonian sandstone and mudstone and Devonian granite in the northeast. The eastern boundary is a north-trending fault contact with middle Palaeozoic rocks similar to those in the northeast. The northern boundary is the unconformable contact with Tertiary sediments of the Bass Basin. The extent of the basin offshore to the southeast and south is unknown.

Up to 580 m of non-marine lower Sakmarian glacial tillite and varved clays were deposited in deep valleys in the basement.

Up to 300 m of basin-wide upper Sakmarian to lower Artinskian marine and aqueoglacial mudstone, tasmanite (a marine oil shale), siltstone, and thin limestone conformably overlie the lower Sakmarian sediments. These sediments were deposited during a transgression of the sea.

Upper Artinskian deltaic conglomerate, cross-bedded sandstone, and coal, up to 120 m thick, were deposited conformably on the marine sediments. A sequence of upper Artinskian to Kazanian shallow-water marine siltstone, calcareous sandstone, and limestone, up to 350 m thick, conformably overlie the deltaic sediments. These marine sediments are conformably overlain by 100 m of Tatarian marginal sandstone, carbonaceous siltstone, and minor coal.

The Triassic consists of up to 600 m of lacustrine and fluviatile protoquartzite, lithic arenite, conglomerate, and coal. The Triassic disconformably overlies the Permian in the western margin, and elsewhere it is conformable on the Permian.

A large area of the Tasmania Basin was intruded by sills of tholeiitic dolerite, up to 450 m thick, during the Jurassic.

Extensive faulting in the early Tertiary produced a series of horsts and grabens throughout Tasmania. Three major grabens occur in the Tasmania Basin: the Midlands Graben, the Oyster Bay Graben, and the Derwent Graben. Up to 300 m of Tertiary quartzose sandstone, shale, and conglomerate occur in the Midlands Graben.

Geological mapping

Mapping was carried out by GST from 1957 to 1973. Fifty eight 1:63 360 maps cover the basin. Sixteen have been published and one of these, Hobart, is a provisional edition. Seven explanatory notes have been published.

Correlation

No lithological correlations are available for the Triassic sediments as thickness and lithology vary over short distances and no marker horizons are known. Banks (1962) has prepared a lithological correlation of the Permian and this is currently under review by M.J. Clarke of GST.

No time correlations are available for the Triassic as no marker fossils are known. Banks (1962) has prepared a time correlation of the Permian and this too is currently under review by M.J. Clarke.

Drilling

Twenty-eight wells, the deepest of which is 381 m, have been drilled. Twenty-four were drilled between 1920 and 1924, and four were drilled between 1966 and 1967. The wells are mainly concentrated in the northern part of the basin in the Mersey Valley. The wells drilled from 1920 to 1924 mostly penetrated Permian rock, and detailed information can be gained from the Geological Survey of Tasmania Mineral Resources No. 8. Information on the wells drilled from 1966 to 1967 can be obtained from the Annual Report for the Director of Mines, Tasmania, for 1967. The wells are of little value in assessing the regional geology.

Aeromagnetic surveys

One subsidized aeromagnetic survey and one BMR aeromagnetic survey cover the basin.

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Esso Exploration and Production (Australia) Incorporated carried out a subsidized reconnaissance survey that covered the offshore area of the basin to the 180 m bathymetric contour. The lines were about 3.2 km apart. Two tie lines were flown along the coast, and paralleling the coast about midway between the coast and the edge of the continental shelf. The survey was flown at 450 m, 1050 m, and 1725 m above sea level. Data quality was excellent throughout. The survey did not reveal any large areas suitable for petroleum exploration as most of the offshore area is underlain by shallow magnetic basement. Extrapolating onshore this magnetic basement proved to be Jurassic dolerites which are intruded? (stratigraphically) high in the Tasmania Basin sequence.

Gravity surveys

No subsidized gravity surveys have been carried out in the Tasmania Basin. A detailed onshore gravity survey was carried out by Johnson (1972) as part of a University of Tasmania Ph.D. thesis. The survey involved at least 5533 stations which are more densely distributed around Hobart and the northern area of the basin. A copy of the data is held in BMR, but no interpretation is available. The southern offshore part of the basin was covered by BMR in 1971 and 1972. The survey lines ran easterly and were 32 km apart. The interpretation of the survey is not available. In 1974 BMR carried out a detailed helicopter survey on a 7-km grid over the parts of Tasmania not covered in detail by Johnson.

Seismic surveys

There are no subsidized seismic surveys. The offshore part of the basin was covered by BMR in 1971 and 1972. The survey lines ran easterly and were 32 km apart. The interpretations of the survey are not available.

The basin was also covered by a BMR airborne magnetic survey which was flown in 1966 over Tasmania and the adjoining ocean to about 160 km off the coast at an altitude of 3000 m and a line spacing of 18.5 km. Again results over the Tasmania Basin were affected by the Jurassic dolerites which constituted magnetic basement. A possible dolerite feeder extending to great depths occurred at Cygnet. The Oyster Bay Graben appeared as an area of decreased total magnetic intensity extending over 64 km in length. The Midlands and Derwent Grabens did not appear as areas of low intensity. The data quality was good and the interpretation of the magnetic data was mainly qualitative onshore. The survey did not go far enough south to cover the offshore extension of the basin.

Economic geology

Petroleum: The potential for oil in the Tasmania Basin is low. The sedimentary sequence is thin and the sediments themselves are flat-lying, extensively faulted, and intruded by dolerite. Thus, although the oil shale and coal may have been suitable source rocks, the thin sequence and absence of structural traps make commercial oil accumulation unlikely within the basin.

Oil shale: 1 620 000 litres of oil were produced from 42 200 tonnes of oil shale in lower Sakmarian marine sediments between 1910 and 1934. Production came mostly from a 19-km-long area in the valley of the Mersey River, between the towns of Latrobe and Kimberley in the northern part of the basin. The shale occurs in a seam which ranges up to 1.8 m thick, is uniform, accessible, and could even be exploited in places by open pit. The shale contains between 0.11 and 0.14 litres of oil per kg. The reserves have not been adequately assessed, but limited development work suggests they are 25 000 000 tonnes.

Other lower Sakmarian deposits occur at Mount Pelion West and Barn Bluff. The reserves of the Barn Bluff deposit have been estimated at 1 625 000 tonnes yielding as high as 0.405 litres per kg.

There are also limited occurrences of oil shale in the Upper Sakmarian deltaic and marginal sediments in the northern part of the basin at Karoola, Nook, and Preolenna.

Coal: Total coal production to the end of 1961 was about 8 731 500 tonnes. Seams of Permian and Triassic age are worked, with most of the Permian coal being cannel coal and the Triassic coal being non-coking bituminous coal, anthracitic in places. The seams are thin, rarely more than 1.8 m thick, and the ash content is high. The amount of workable coal is reduced by Jurassic dolerite intrusions. Coal reserves are estimated at 143 000 000 tonnes of which 80 264 000 tonnes are recoverable. The main fields are in northeastern part of the basin in the Triassic Fingal/Mount Nicholas/Dalmayne Coal field, the Triassic Avoca coalfield, and the Permian Mersey coalfield. Other small Triassic deposits occur in the Seymour/Mount Paul, Langloh, Sandfly, Catamaran, and Longford fields and the Colebrook, Richmond, Newton, and York Plains areas. Small Permian fields exist at Cygnet and Preolenna. Tertiary brown coal occurs in the Derwent Valley. The deposits are thin, of poor quality, and have at least 6 m of overburden.

Water: The salinity of the underground water is low, usually less than 1000 mg per litre, over most of the Tas-

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mania Basin. The quality is suitable for town supplies, industry, domestic uses, most crops, livestock, and irrigation. Exceptions are: the Oatlands area and south of Launceston, where salinity is as high as 3000 mg per litre and the water is suitable only for livestock and some domestic and limited industrial use, and near the mouth of the Tamar River and the Derwent River, where salinity is between 300 and 700 mg per litre making the water suitable only for most livestock and very limited domestic and industrial use.

Limestone: Permian limestone occurs in a belt from Glenorchy, a suburb of Hobart, to Dromedary, 24 km to the northwest. The limestone is flat-lying and well bedded, with interbeds of calcareous shale. The limestone has a low magnesium content and a high silica content. The deposit was initially quarried for lime-burning and is now being used for aggregate.

Clay: Triassic clay which crops out along the banks of the Derwent River is used for making bricks at Hobart. At New Town bricks are made from the softer shale and sandstone of the Triassic coal measures. At Hamilton, clay and shale, also associated with the Triassic coal measures, are used to make firebricks.

Lacustrine clays of Tertiary age, ranging in quality from fine-grained kaolins to highly coloured sandy materials, are found throughout the basin. The most extensive deposit occurs in the Launceston area and is mainly used to make bricks, tiles, and pipes.

Clay from deeply weathered zones in Jurassic dolerite has been used for core walls in rock-fill dams.

Aluminium: Fifteen bauxite deposits occur near Ouse on an erosional surface developed on a dolerite sill. The lateritized surface was buried beneath non-marine sediments and basalt flows. Later erosion has exposed small remnants of the laterite. Most of the deposits are composed of soft to hard earthy or clayey bauxite with minor pisolitic material. Reserves are estimated at 500 000 tonnes averaging 37.2 percent available alumina.

Seven separate similar bauxite bodies also occur in the St Leonards area, near Launceston. Only two of these are economically viable deposits and their reserves are estimated at 145 000 tonnes averaging 37.4 percent available alumina.

Tin: Cassiterite in the upper Sakmarian non-marine sediments has been worked at several places including Rossarden, Rays Hill, and Brookstead.

Recent activities

There has been no oil exploration activity in the Tasmania Basin since the drilling of 4 wells in the Mersey Valley in 1967. The only activity at present is the continuation of the mapping of the basin by GST.

Deficiencies in geological knowledge

One of the major deficiencies is lack of suitable time and rock correlations for both the Permian and the Triassic sediments. The nature of the sediments may make it difficult for such a correlation to be effectively derived.

Another deficiency is the complete absence of information on the extent and type of the basin sediments in the southern offshore part of the basin.

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WARBURTON BASIN

The Warburton Basin is a northwest-trending lower and middle Palaeozoic basin in northeastern South Australia that extends into southeastern Northern Territory, southwestern Queensland, and northwestern New South Wales. The basin is concealed beneath the Eromanga, Cooper, Arckaringa, and Pedirka Basins, and its margins have not yet been determined. It contains Adelaidean to Lower Cambrian, Cambrian, Ordovician, possible Silurian, and Devonian sediments.

In the northwest the Warburton Basin connects with the Amadeus Basin; the boundary between the two is arbitrarily chosen as the northwestern limit of the unconformable contact between sediments within the Warburton Basin and the sediments within the Eromanga Basin or the Pedirka Basin. A more logical limit may be the Andado Ridge, a northeast-trending area of elevated basement (based on gravity and aeromagnetic interpretation) which occurs parallel to and slightly southeast of the other boundary. An arbitrary irregular southwestern margin, totally concealed beneath the Eromanga and Arckaringa Basins, continues from the Amadeus Basin to the east of the Musgrave Block, the Denison Block, the Muloorinna Ridge, and the northern end of the Adelaide Geosyncline. The margin swings north of the Mount Painter Block and appears to continue northeast for about 150 km before swinging southerly towards the Bancannia Trough. The relationship between the Bancannia Trough and the Warburton Basin is unknown.

The basin's eastern and northeastern margins are unknown; however, the basement of the Cooper Basin to the east is composed partly of folded lower Palaeozoic rocks. A short distance north of the northeastern corner of South Australia 1300 m of steeply dipping probable lower Palaeozoic strata intersected in Betoota No. 1 well show that the basin probably extends northeast into Queensland. In extreme southwestern Queensland Roseneath No. 1 and Tickalara No. 1 wells passed through Lower Permian strata directly into undifferentiated Precambrian 'basement' and granite respectively, but this data is too meagre to enable the eastern margin of the basin to be defined. Until the basin limits are more fully determined no estimate of the basin's areal extent can be made.

No wells have penetrated below the lower Palaeozoic sediments to basement. Metamorphic and igneous basement rocks which form the Denison Block, Muloorinna Ridge, and Mount Painter Block may continue beneath part of the Warburton Basin.

At the base, Adelaidean to early Cambrian volcanics are overlain conformably by Cambrian marine limestone, dolomite, tuff, and tuffaceous shale which in turn grade up into shale and sandstone. More than 1500 m of Cambrian sediments were encountered above the volcanics in Kalladeina No. 1 well. McDills No. 1 bottomed in Cambrian dolomite after penetrating about 500 m of Cambrian marine dolomite, limestone, and shale.

Lower Ordovician marine orthoquartzite unconformably overlies the Cambrian sediments in the northern part of the basin. It probably interfingers with fine-grained sandstone, siltstone, and shale to the southeast. Over 700 m of Lower Ordovician marine black dolomitic and graptolitic shale was intersected in the Dullingari No. 1 well in the southeastern part of the basin.

Rocks ranging in age from Upper Silurian? to Carboniferous? are known to unconformably overlie Ordovician or older rocks in the Warburton Basin. Upper Silurian? to Middle Devonian terrestrial or marginal marine sandstone and Upper Devonian to Carboniferous? terrestrial sandstone, conglomerate, and siltstone, 1300 m thick, are present in McDills No. 1. In the southwest, Cootanoorina No. 1 well passed into Devonian evaporites below the Arckaringa Basin. No rocks of Silurian age have been reliably identified in South Australia, but Upper Silurian to Devonian fluviatile deposits occur in the adjacent Bancannia Trough, and similar deposits may occur in the southeastern Warburton Basin. Devonian rocks are known to underlie the Cooper Basin in the south and the Arckaringa Basin in the west. Innamincka No. 1 intersected over 1600 m of Devonian marine to marginal marine red and green shale and siltstone beneath the Cooper Basin sediments before reaching total depth still in the Devonian. Weedina No. 1 intersected 883 m of marine to marginal marine dolomite, sandstone, siltstone, and shale unconformable on basement rocks beneath the Arckaringa Basin sediments.

The basin sediments were deformed on three separate occasions. They were first folded during the Delamerian Orogeny in the Late Cambrian. The sediments were again folded either late in the Ordovician or early in the Silurian, the most severe deformation occurring in the south. The last major diastrophism occurred in the early Carboniferous when a northeasterly trending arcuate fold belt developed in the southern part of the basin and gentle domes developed in the north.

Geological mapping

Regional mapping by BMR, GSNSW, and GSSA has been carried out since 1960 and is still in progress in South

Australia. 1:250 000 maps of all of the New South Wales, Queensland, and most of the Northern Territory part of the basin are published, and BMR has issued preliminary editions of the rest of the Northern Territory part of the basin. GSSA published six 1:250 000 maps, and dyeline prints of five 1:250 000 preliminary editions are available. BMR published two 1:1 000 000 maps of the northern and eastern parts of the basin.

Mapping provides little information because the basin is concealed beneath the Eromanga, Arckaringa, Pedirka, and Cooper Basins. Geological mapping of the Amadeus Basin and of the Bancannia Trough is valuable as it indicates the type of sedimentary sequence and structure that might extend into the Warburton Basin.

Drilling

From a total of more than 150 exploration and development wells drilled in the basin area from 1955 to 1973, most of which are in the overlying Cooper Basin in the southeast, 37 intersected pre-Permian Palaeozoic rocks.

The drilling information is vital, in that it provides the only indication of the geology of the sediments in the basin.

Correlation

No basin-wide lithological or time correlations are available. Cambrian, Ordovician, and Devonian sediments are dated by macrofossils.

Aeromagnetic surveys

The whole of the basin has been covered by surveys flown by BMR, SADM, and Delhi Australian Petroleum from 1961 to 1968. BMR and SADM published 1:250 000 total magnetic intensity maps of most of the basin. Dyelines of 1:500 000 total intensity maps of the Queensland and Northern Territory part of the basin are available from BMR. SADM compiled a 1:1 013 760 map showing the interpreted depth to magnetic basement in South Australia. The value of the maps varies across the basin.

The aeromagnetic data help to delineate the western and southern margins of the basin, but, owing to the uncertain identity of magnetic basement, the results are only a broad guide to the thickness of sediments. Where Lower Cambrian volcanics are present within the sequence, they would represent magnetic basement. However, their extent and distribution are largely unknown; where they are absent, magnetic basement may be pre-Adelaidean rocks or volcanics of Adelaidean age. Interpretation is further complicated by the varying thickness of sediments in the overlying basins.

Gravity surveys

BMR, Delhi Australian Petroleum, French Petroleum, Pexa Oil NL, Beach Petroleum, and other private companies conducted gravity surveys over the basin between 1956 and 1970. BMR has published Bouguer anomaly maps at various scales covering most of the basin, and SADM issued a four-part 1:1 000 000 map of the State of South Australia.

The Bouguer anomaly patterns arise from density contrasts between basin sediments and the underlying and overlying rocks and also from density contrasts within the underlying and overlying rocks. There is insufficient stratigraphic control available at present to enable the data to be interpreted and hence its value is not known.

Seismic surveys

Seismic surveys were carried out by BMR, SADM, and private companies, chiefly French Petroleum and Delhi Australian Petroleum, between 1957 and 1973. Many of the surveys were conducted in the northwestern and southern parts of the basin where the Warburton Basin underlies the Pedirka and Cooper Basins respectively.

The eroded top of the sequence in the Warburton Basin gives rise to a recognizable seismic reflection beneath the sediments of the Pedirka and Cooper Basins. Reflections below this unconformity are poor or absent and cannot be traced basin-wide. In general the seismic data is of limited value.

Economic geology

Petroleum: No significant hydrocarbon shows were reported from any well. Gas-cut water was recorded from Devonian-Carboniferous sediments in Cootanoorina No. 1 well in the western part of the basin, and in Cambrian dolomite in Gidgealpa No. 1 well in the southeast, beneath the Cooper Basin. Faint oil stains have also been recorded in pre-Permian (possibly Ordovician) sandstone beneath the Cooper Basin.

Petroleum potential is considered mediocre to poor. Porosity and permeability are poor to absent in most

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Devonian, Ordovician, and Cambrian sediments owing to lack of original primary porosity or weak metamorphism. Devonian sediments in the western part of the basin with acceptable reservoir characteristics were freshwater-bearing. Raised temperatures associated with the deformation of the lower Palaeozoic sediments and present depth of burial reduce the possibility of oil and indigenous gas being present.

Stratigraphic and structural traps are present and will have potential where primary accumulation is retained or hydrocarbons have moved in from an overlying Permian source.

Recent activities

Australian Aquitaine Petroleum Pty Ltd carried out two seismic surveys over the eastern end of the basin and the southeast part of the Cooper Basin in 1974; Delhi International Oil did a seismic survey in 1974 over the central part of the basin underlying the Pedirka Basin. The Aquitaine surveys investigated local structure, while the Delhi survey was of a reconnaissance nature.

Beach Petroleum has announced a 3000 m well, Colson No. 1, to be drilled on the Colson Anticline. A six-well stratigraphic drilling project was announced by the SADM. The wells will be drilled in the central part of the basin to identify reflectors and lithology, and will test hydrocarbon potential.

A study of the reservoir potential and stratigraphy of the Cambrian and Ordovician carbonate rocks is now in progress. The GSSA will study and field material for their evaluation. GSSA is also continuing regional geological mapping in the South Australian part of the basin. Various activities related to suprabasins are in progress (see Arckaringa, Cooper, Eromanga, and Pedirka Basins).

Deficiencies in geological knowledge

Little is known about the stratigraphy of the basin as relatively few wells have penetrated much of the sediment. The margins are poorly defined in South Australia and completely undefined in the Northern Territory, Queensland, and New South Wales. The major requirement is for further seismic surveying with ties to existing wells.

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WISO BASIN

The Wiso Basin occupies about 170 000 km^2 between Tennant Creek and Tanami in the Northern Territory. It contains Cambrian, Ordovician, and Devonian rocks resting unconformably on basement. The basement consists of Carpentarian sandstone and Adelaidean sediments in the west; Precambrian arenites, low-grade schists, and intrusives in the southwest; Precambrian metamorphic and igneous rocks of the Arunta Block in the south; and Proterozoic rocks in the Tennant Creek Block and the Davenport Geosyncline in the east. The northern connexion with the Daly River Basin is obscured by Cretaceous sediments. A probable southeasterly connexion with the Georgina Basin is concealed by Quaternary sand.

The northwestern area of the basin is floored by at least 15 m of Lower Cambrian? basaltic flows, agglomerate, and tuff. These are overlain conformably by sandstone and chert which form part of a conformable sequence of lower Middle Cambrian rocks (over 150 m thick) which are the youngest in most of the basin. The lower Middle Cambrian rocks include sandstone, siltstone, claystone, and chert, interbedded with and underlain by fossiliferous dolomite in some areas.

In the southern half of the basin (the Lander Trough) marine Lower to Middle Ordovician? dolomite and sandstone (estimated 150 m thick in outcrop) is overlain unconformably by continental Upper Devonian? sandstone (20 m thick in outcrop). The relationship between the Cambrian and Ordovician rocks is unknown. Seismic interpretation suggests the Palaeozoic rocks may be 2100 m thick in the eastern end of the Lander Trough.

Total measured or estimated thickness of the Palaeozoic sediments is about 350 m but depth to magnetic basement is estimated at about 1500 to 3000 m below sea level in the Lander Trough, where the Ordovician and Devonian rocks occur.

The northern part of the Wiso Basin is probably similar in structure to the northern half of the Georgina Basin, and the Lander Trough in the south is probably similar in structure to the Dulcie and Toko Ranges of the Georgina Basin. The southern margin of the basin was probably formed by faulting after deposition of the Devonian rocks.

Geological mapping

Except for a little mapping in 1956, 1961, and 1967 most of the 1:250 000 geological mapping was completed by BMR in 1965 and 1966. Of the fifteen 1:250 000 Sheets, seven have been issued as preliminary maps and seven in the north and southeast have been published with explanatory notes. The Tennant Creek 1:250 000 Sheet is being compiled.

The mapping is adequate, but its value is considerably reduced by the poor outcrop and flat-lying attitude of the sediments.

Drilling

BMR drilled ten shallow stratigraphic holes in areas of poor outcrop across the basin from Tennant Creek to Hooker Creek; all penetrated Middle Cambrian strata. The maximum depth of the holes was 200 m. Three holes yielded good supplies of water and one yielded a low supply.

Correlation

A limited lithological correlation has been achieved by mapping the poorly exposed outcrop. No fossils have been found in the Upper Devonian? sandstone. The Ordovician beds are richly fossiliferous in places and may include Lower and Middle Ordovician faunas. Lower Middle Cambrian assemblages are widely distributed. No fossils have been found in the Lower Cambrian? rocks.

Aeromagnetic surveys

BMR carried out an aeromagnetic survey over the Tanami and the Granites Sheet areas in the west in 1962. 1:26 720 total magnetic intensity maps have been published. Exoil flew about 800 flight-line-km in reconnaissance over the area bounded by 17° to 21° of latitude and 130° to 135° of longitude. The line spacing was variable. American Overseas Petroleum Ltd supplemented the coverage of this survey and extended the coverage to the east in 1966 and 1967. About 25 000 flight-line-km were flown.

The surveys indicated a number of areas of deeper magnetic basement, including the Lander Trough. The major difficulty in interpretation is differentiation of Adelaidean strata from Palaeozoic strata.

Gravity surveys

BMR has covered the whole of the basin by regional gravity surveys carried out in 1965 and 1967.

Seismic surveys

American Overseas Petroleum Ltd carried out a small seismic reflection and refraction survey using weight-dropping techniques in 1967. The reflection quality was generally poor. The survey indicated a thickness of about 2100 m of sediments in the Lander Trough, and that the southern margin of the trough is faulted (about 1000 m) and then deepens steeply before shelving gently northward. Some evidence of structure is shown in the deeper part of the trough. The only stratigraphic control on the seismic horizons comes from surface outcrop, which indicates that the sedimentary section is probably of Palaeozoic age.

Economic geology

Petroleum: Most of the area contains a thin flat-lying sequence of lower Middle Cambrian sediments and has negligible petroleum prospects. The Lander Trough may contain up to 2100 m of Palaeozoic sediments. The nature of these sediments is largely unknown but source rocks may occur in the lower Middle Cambrian carbonate sequence. Seismic surveying has given some evidence of structure in the deeper part of the trough.

One stratigraphic hole encountered a show of hydrocarbons.

Underground water: Aquifers supplying moderate to good qualities of good water are: Lower Cambrian volcanics; Middle Cambrian friable sandstone, and vuggy Middle Cambrian dolomite. Water has been obtained at shallow depths in Tertiary limestone and in Quaternary deposits.

Phosphate: Two samples of quartzose pellet dolomite from the north central Lander River Sheet area were analysed at 10.6 percent and 3.2 percent P_2O_5. The samples were collected five miles apart but the extent of the beds is unknown owing to extensive sand cover.

Copper: Copper mineralization is known in the basal volcanics.

Recent activities

There have been no recent activities.

Deficiencies in geological knowledge

Lower Palaeozoic rocks have not been differentiated on the southwest Tanami East Sheet area. The presence or absence of Upper Cambrian fossils should be determined in the Hanson River Beds on the northeast Lander River Sheet area. The Ordovician stratigraphic and fossil succession is not well known. The major deficiency is a deep well in the Lander Trough to determine the nature, age, source, and reservoir characteristics of the sedimentary rocks. Further seismic surveying should be carried out to locate a position for the well.

The sequence in the basin contains rocks of similar age and lithology to those in the Georgina Basin, and biostratigraphic zonation will be much easier after a standard has been erected in the Georgina Basin.

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YARROL BASIN

The Yarrol Basin contains up to 17 500 m of Middle Devonian to Permian rocks covering a long narrow area of about 20 000 km^2 parallel to the Queensland coast between latitudes 20° and 26°S.

In the south the eastern margin of the basin is a series of faults which separate basin sediments from pre-Devonian rocks along the coast. In the northeast the basin is unconformably overlain by and faulted against Tertiary sediments in the Hillsborough Basin and Cretaceous sediments in the Styx Basin. The western margin is complex. In places it is an igneous contact with younger batholiths and in other areas it is an unconformable contact with igneous rocks. Elsewhere along the margin the sediments continue into the Bowen Basin or are faulted against sediments within the Bowen Basin or the Mulgildie Basin. In the south, at about latitude 25°, the basin is truncated by batholiths; in the north, near Bowen, the volcanics and sediments are block-faulted and intruded where they pass out to sea.

Where the basal beds of the Yarrol Basin have been seen they rest with angular unconformity on strongly folded and slightly metamorphosed lower Middle Devonian marine sediments and volcanics.

The oldest rocks in the basin are upper Middle and Upper Devonian volcanics with minor shallow marine clastics about 1100 m thick. These are overlain disconformably by at least 5600 m of marine Carboniferous siltstone, fine-grained sandstone, and minor oolitic limestone and coarse-grained sandstone. Lower Permian volcanics interbedded with shallow -marine sandstone and minor fluvio-glacial sediments, totalling at least 7500 m in thickness, disconformably overlie the Carboniferous and are in turn disconformably overlain by about 3300 m of Upper Permian marine and deltaic sediments in the central and southern parts of the basin.

The disconformities are thought to be related to the emplacement of plutons in neighbouring areas. The strongest folding, faulting, uplift, and erosion appears to have taken place in the Late Permian. Stocks and batholiths were emplaced in the Early and Late Carboniferous, Early and Late Permian, and Early Triassic. There was further uplift and igneous intrusion in the Early Cretaceous.

Geological mapping

Of the nine 1:250 000 Sheet areas which cover the basin, eight were mapped by BMR and GSQ from 1961 to 1965.

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The Mundubberra 1:250 000 Sheet is currently being compiled by GSQ. Preliminary editions of F56/9 (Port Clinton), F56/13 (Rockhampton), and G56/1 (Monto) have been published by GSQ. First edition maps and explanatory notes for the other Sheet areas have been published.

Drilling

In 1962 Nortex Australian Oils Ltd drilled Jambin No. 1 and No. 2 on an anticline north of Biloela; they penetrated Tertiary clay, 160 m of marine Permian beds, and bottomed in andesite. The company decided that the central part of the Yarrol Basin was not worth further investigation for hydrocarbons because, although possible source rocks are present, porosity and permeability are very poor.

In 1963 Amalgamated Petroleum drilled two wells south of Monto with targets in the marine Permian beds: both were abandoned in igneous rocks after passing through sediments in the Mulgildie Basin and several hundred metres of mostly volcanic Triassic rocks. In 1968 Amalgamated Petroleum drilled a third well, northwest of Monto, in the Permian outcrop. It was sited where a geochemical survey found traces of propane and butane, but no hydrocarbons were detected in the well, which penetrated about 500 m of Permian sediments and 170 m of presumed Carboniferous sandstone. The wells showed that the Yarrol Basin sediments were much tougher and denser than formerly thought. They also provided lithological and stratigraphic data for regions where little had been known.

Correlation

A lithological correlation has been achieved by the geological mapping.

Aeromagnetic surveys

BMR surveyed some of the northern part of the basin in 1961 to 1963 and published total magnetic intensity maps of F55/16 (Duaringa), F55/12 (St Lawrence), and the western half of F55/8 (Mackay) in 1963/64. No interpretation is available. Likewise there is no interpretation of the Yarrol Basin part of a survey made by AOG in 1962 over coastal areas and the Barrier Reef. The southern part of the basin was surveyed by Amalgamated Petroleum in 1962: this survey, however, only succeeded in confirming the presence of igneous bodies and faults.

Gravity surveys

BMR included the basin in regional surveys made in 1963 and 1964 and has published 1:250 000 and 1:500 000

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Bouguer anomaly maps of all relevant Sheet areas. No detailed interpretation is available, but in general a series of positive gravity anomalies occur over the basin.

Seismic surveys

Amalgamated Petroleum surveyed a part of the southern end of the basin in 1962 and 1963. These surveys showed the disposition of major faults and the presence of folds in a thick sequence of Yarrol Basin sediments. There were, however, many reflections of doubtful origin. Two petroleum exploration wells were sited on structures indicated by the seismic surveys.

Economic geology

Although broadly suitable source and cap rocks occur together with folds and potential stratigraphic traps the petroleum potential of the basin is regarded as very low owing to a combination of generally poor permeability, severe faulting and folding, and widespread plutonic intrusions. A trace of methane was recorded in Abercorn No. 1, and Bukali No. 1 was sited on a geochemical anomaly.

Widespread base and precious metal mineralization is associated with the igneous intrusions. Copper and gold are mined at Mount Morgan.

Limestone and marble are quarried near Rockhampton. A small uneconomic deposit of high-rank bituminous non-coking coal occurs near the coast, northwest of Mackay.

The basin continues to attract a high level of interest in the search for base metals, but no exploration for petroleum is known to have been carried out since 1968.

Recent activities

Nil

Deficiencies in geological knowledge

Enough is known about the Yarrol Basin to enable most if not all of it to be dismissed from serious consideration as a petroleum exploration prospect.

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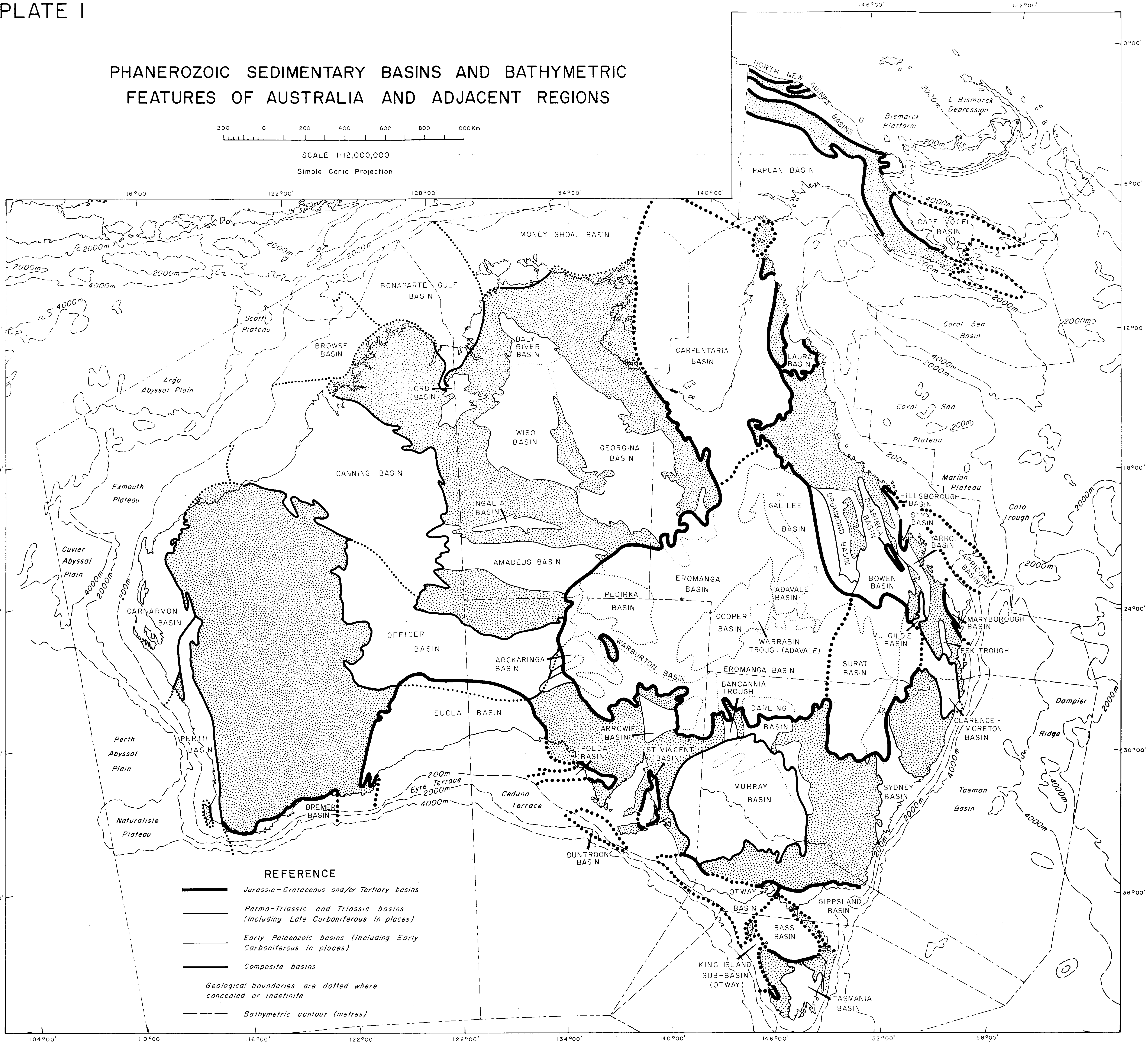
PLATE I

PHANEROZOIC SEDIMENTARY BASINS AND BATHYMETRIC FEATURES OF AUSTRALIA AND ADJACENT REGIONS

SCALE 1:12,000,000

Simple Conic Projection



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