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OUTLINE OF THE GEOLOGICAL AND TECTONIC EVOLUTION OF AUSTRALIA AND PAPUA NEW GUINEA

by

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Introduction

Of the several accounts of the geology of Australia that have been written, the most comprehensive is still the Geology of the Commonwealth of Australia by David (edited by W. R. Browne) issued in 1951, which recorded the state of knowledge of Australian geology up to that time. Enormous advances have been made in the postwar period due to the widespread mapping and exploration activities of governmental bodies, universities, and industry.

Important compilations recording these advances include the volumes on the geology of the States issued in the Journal of the Geological Society of Australia - Western Australia (Phanerozoic only) (McWhae et al., eds. 1956), South Australia (Glaessner & Parkin, eds. 1957), Queensland (Hill & Denmead, eds. 1960), Tasmania (Spry & Banks, eds. 1962), New South Wales (Packham, ed., 1969); 'Geological notes in explanation of the Tectonic Map' (B. P. Walpole, ed. 1963); 'Short Geological History of Australia' by R. C. Sprigg (1967); 'Handbook of South Australian Geology' (L. W. Parkin ed., 1969); and 'The Geological Evolution of Australia and New Zealand' by Brown, Campbell, and Crook (1968). In most of these, the geology is treated chronologically, except in the volumes of the GSA Journal dealing with New South Wales and South Australia where it is described by geological provinces. Important papers containing regional geological appraisals were contained in the two earlier editions of Geology of Australian Ore Deposits.

In the earlier editions of the Geology of Australian Ore Deposits, a simple geographical arrangement was adopted using states or major portions of states as subdivisions and progressing generally from west to east. The present more comprehensive publication, including as it does sections on petroleum, coal and non-metallics, as well as metalliferous deposits, has subdivisions which are necessarily very different in the different volumes, but in general the descriptions of the mineral deposits are grouped to correspond with the appropriate geological province, using that term in a very broad sense.

In recent years a great deal of study has been given to the evolving tectonic pattern of Australia, as part of the preparation of a new Tectonic Map of Australia and New Guinea by the Tectonic Map Committee of the Geological Society of Australia (GSA, 1971). Concurrently with and interdependent upon this, a Metallogenic Map (Warren 1972a) based on the Tectonic Map, has been prepared and both were issued in 1972. The Metallogenic Map is included in the Metals Volume of this publication, and the subdivision of Australia into sections dealt with in both parts of this book is based on those of the Tectonic and Metallogenic Maps. Unfortunately no notes have yet been published setting out the principles underlying the construction of the Tectonic Map but a commentary on the Metallogenic Map of Australia and Papua New Guinea gives a brief description of the principles underlying the Tectonic Map (Warren, 1972b). The following treatment of the geology of Australia is based largely on that publication.

Actually in these volumes, while the nomenclature and definition of basins and geological provinces follow in a general way those of the Tectonic Map, a certain amount of modification has been introduced to give the most logical grouping of ore deposits.

The Metals Volume follows a tectonic cum geographic pattern generally from oldest to youngest, west to east, under the main headings:

Archaean of the Western Australian Shield

Lower and Middle Proterozoic of Median and Western Australia

Upper Proterozoic-Palaeozoic Geosynclines and Basins of Median and Western Australia

The Tasman Geosyncline

Mesozoic-Tertiary Geosynclines and Basins.

The Petroleum volume on the other hand, while adhering faithfully to the Basin nomenclature of the Tectonic Map, is arranged on a purely geographic basis under seven main areas:

Southern Coastal Region
Eastern Region
Great Artesian Basin Region
Central Intracratonic Region
North Western Region
Western Coastal Region
Papua New Guinea Region

In the Coal Volume, the various coal-bearing areas are described in clockwise order around Australia, starting with Queensland.

Tectonic Concepts

The Tectonic Map of Australia is based on two central concepts - orogenic provinces and platform covers - and on the inter-relationship between these. From consideration of the distribution in time and space of these two tectonic units over the Australia-New Guinea area it seems that the continent developed in a series of tectonic cycles each of which involved a progression from unstable pre-cratonic conditions through cratonization by orogenesis into stable cratonic conditions indicated by the deposition of platform cover. A third type of unit - transitional domains - was added, mainly to contain those 'late to post-orogenic developments associated with cratonization, transitional in time, place and style between orogenic and cratonic tectonism' (GSA, 1971).

An Orogenic Province is defined as 'a group of broadly contemporaneous orogenic domains of similar tectonic history and style that, together with associated transitional domains, forms the youngest basement to an immediately overlying Platform Cover'.

Orogenic domains are the result of a cycle of tectonic activity involving the development of geosynclines (s.l.) and subsequent intense deformation, intrusion, metamorphism and rapid uplift. They are characterized by 'flysch-like sequences in extensive linear troughs, abundant and varied volcanic and plutonic rocks, intense deformation and widespread metamorphism'. The modern concepts of plate tectonics have enabled various authors to spell out detailed metallogenic evolutions for such regions which are generally areas of more intense and varied mineralization. This ranges from early manganese through the stratiform copper-lead-zinc sulphides associated with basic and intermediate volcanics to the metamorphogene vein deposits and finally to the complex zoned metallogenic provinces of the Transitional domains.

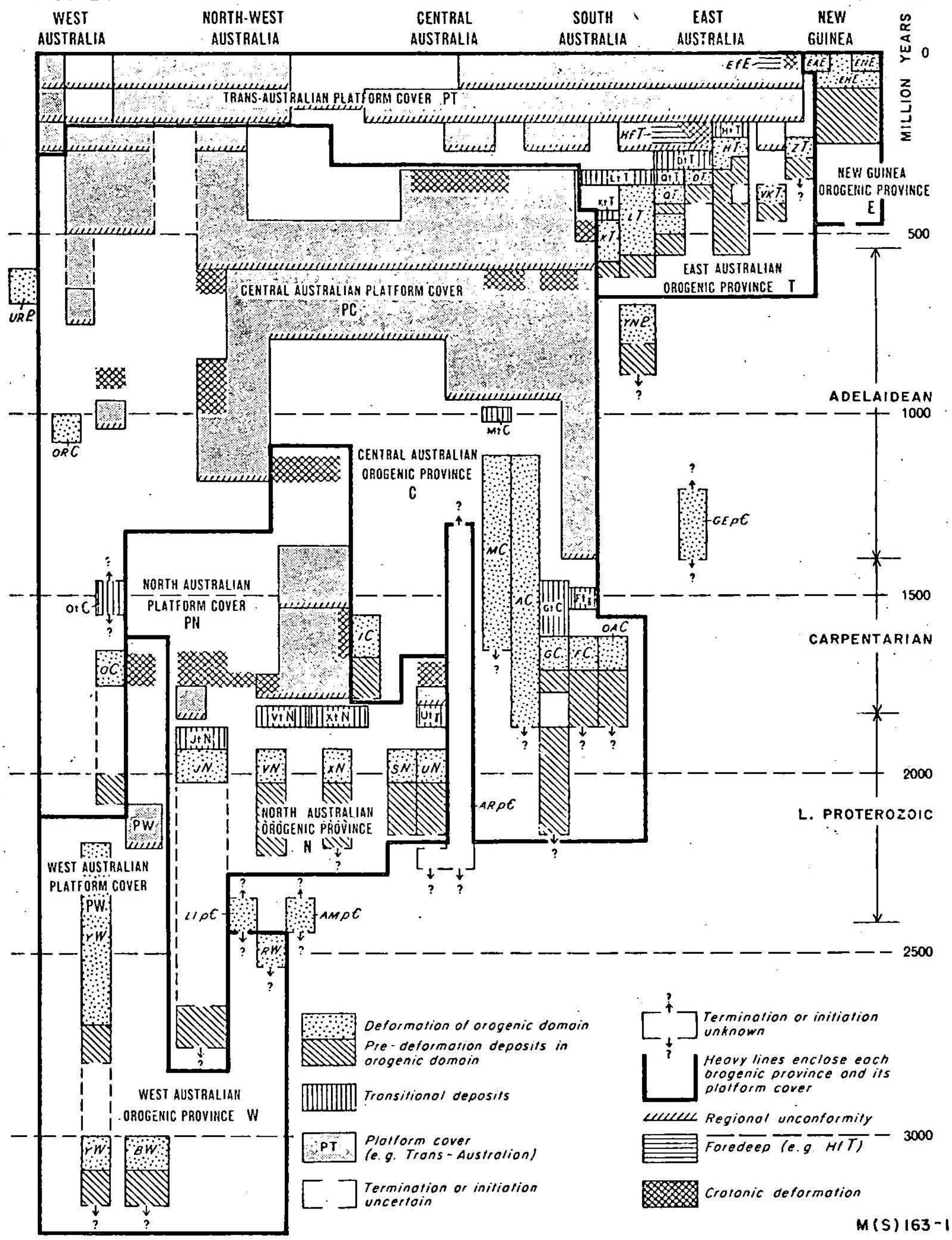
The Transitional domains are, as the name implies, associated both with the late stages of orogenesis and with cratonization, and are intermediate in time and style between the two. They are characterized by downwarping and cauldron subsidence and rifts, molasse-like sedimentation, abundant volcanic and plutonic rocks, moderate deformation and limited metamorphism.

Some domains in this category are represented only by post-orogenic granites. For the purpose of the Metallogenic Map which accompanies and illustrates this volume, the Transitional domains were included with the immediately preceding orogenic domain so that the Orogenic Provinces consist of both the orogenic and transitional domains which form youngest basement to an immediately succeeding Platform Cover. Zoned tin-tungsten-copper-lead-fluorite metallogenic provinces are formed during the period of Transitional Tectonism. Many pegmatitic lodes probably also belong to this stage.

The completion of an orogenic cycle resulting in the formation of a stable tectonic entity (a craton) is followed by erosion and mild tectonism, allowing the deposition of platform cover rocks, characterized by widespread, generally thin, shallow water to continental sediments, rare small plutons and basaltic sheets, and by generally mild deformation of basement and cover, though narrow mobile troughs and zones of deformation may develop.

"A formally named Platform Cover is a group of sedimentary basins which developed more or less at the same time and in the same way. Its deposits overlie the immediately preceding Orogenic Province and associated Transitional domains and spread across older Orogenic Provinces and Platform Covers." (GSA, 1971)

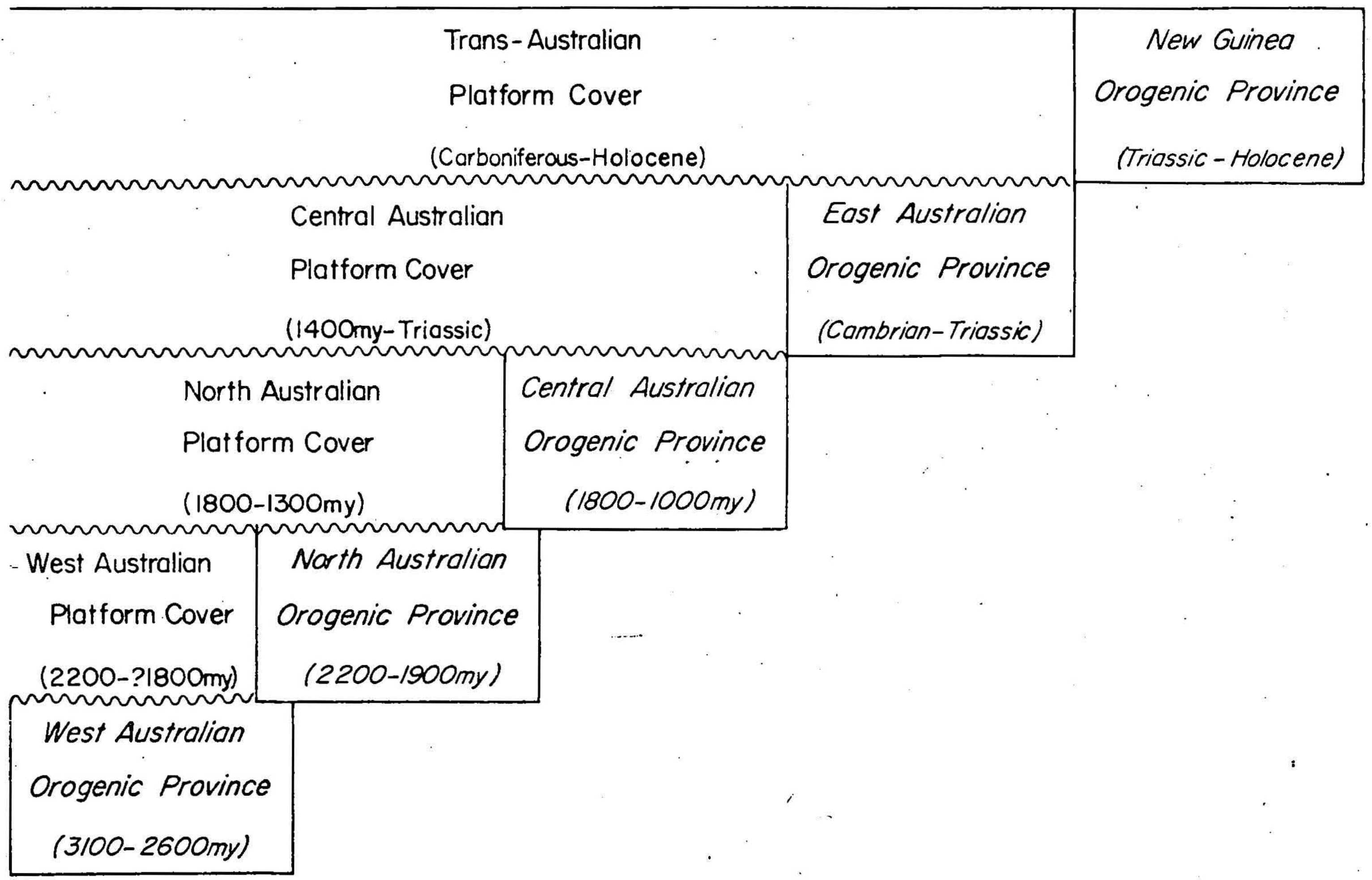
FIGURE I



Diagrammatic and geographical relationship of tectonic units (after Tectonic Map of Australia)

TABLE 1

DIAGRAMMATIC RELATIONSHIP OF TECTONIC UNITS



Reduce as required.

The Platform Covers contain syngenetically formed metal deposits and some non-metallic deposits.

Fossil fuels in Australia occur mainly in the younger Platform Covers and also in transitional domains of the East Australian Orogenic Provinces.

Tectonic Framework of Australia and New Guinea

The Tectonic Map Committee recognized and named five Orogenic Provinces and four Platform Covers as shown diagrammatically in Table 1 and illustrated in more detail in Figure 1.

Table 1 - here

Figure 1 opposite

These generalized groupings embrace most of Australia and New Guinea (Figure 2), but there are in addition four metamorphic complexes of Precambrian age which could not be assigned to any of the Orogenic Provinces; they are: the Arunta in Central Australia, Litchfield and Arnhem in the Northern part of Northern Territory, and Georgetown in North Queensland.

There are also two other isolated areas of Precambrian rocks, thought to have been deformed during the late Proterozoic, one in Western Tasmania, and the Naturaliste Block at the southwestern corner of Western Australia. The role of these in the evolutionary model was not clear.

FIGURE 2

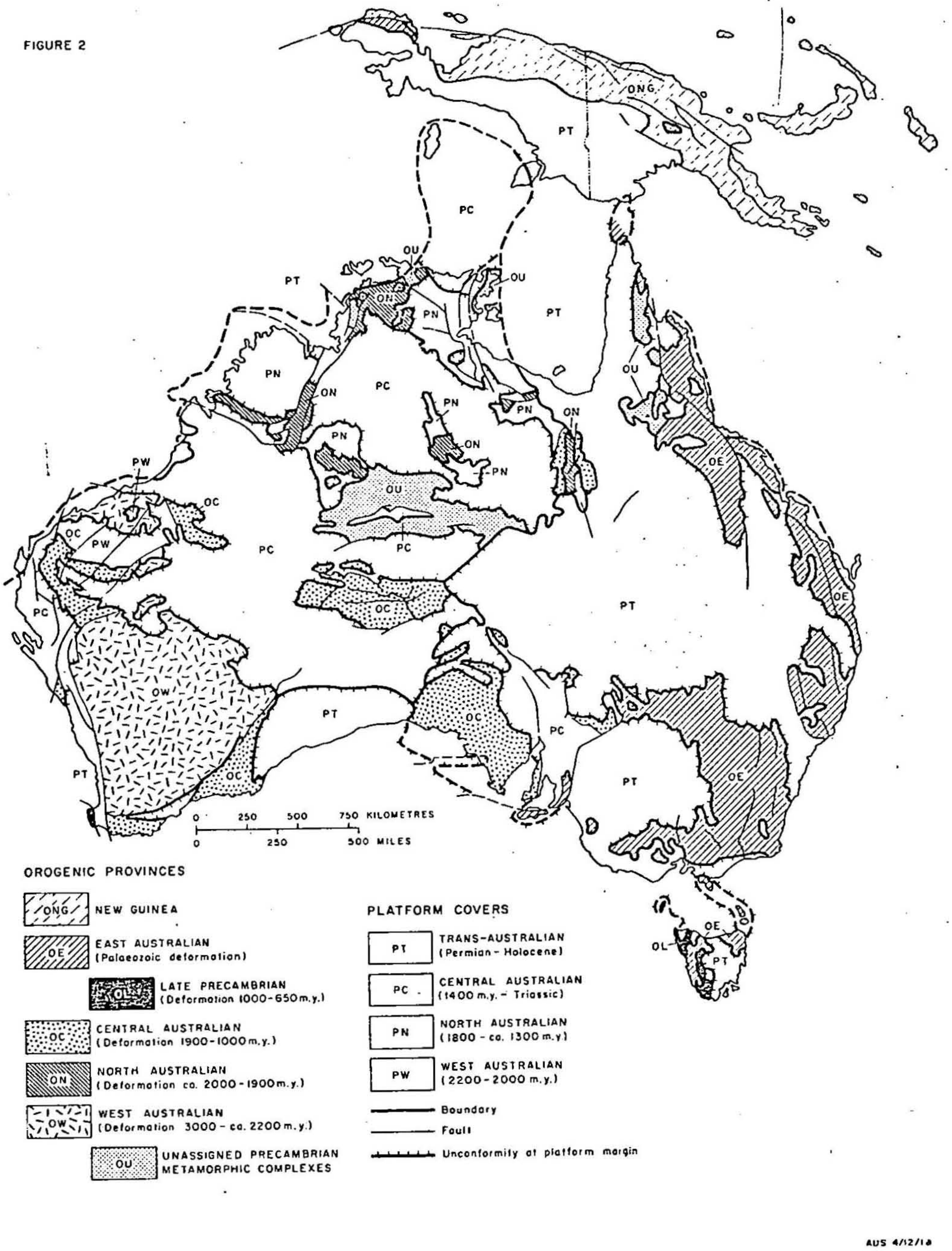


Fig. 2. Distribution of Major Tectonic Units
(After Warren 1972)

The New Guinea Orogenic Province contains areas where geosynclinal deposition is still going on, although its constituent rocks range back to the Triassic, and this is regarded as an Orogenic Province still in the process of formation. There is therefore no overlying Platform Cover.

An important group of mineral deposits, the surficial or residual type, which are related to processes acting on the present or recent surface, may occur on any of the older units, where geologic, physiographic and climatic conditions are favourable. These include the bauxite deposits, iron ore enrichments, beach sands, alluvial and eluvial gold, tin, tungsten, etc., some salt and gypsum deposits, and clays, sands and gravels, etc.

West Australian Orogenic Province

The main areas of outcrop of this province, which contains the oldest rocks in Australia, are in Western Australia: the Yilgarn Block in the southwest, the smaller Pilbara Block to the north and some lesser areas between the two. Granites in the Pilbara Block and the southwest of the Yilgarn give ages ranging up to 3050 m.y. and 3100 m.y. (Arriens, 1971) so that the intruded rocks (including metasediments) may be considerably older. They contain a distinctive lithology, not repeated in any younger terrain, consisting mainly of gneiss and granite separating belts of mildly metamorphosed basic - ultrabasic and acid volcanics and sediments. Their mineralization is dominated by gold and nickel. Tin, tantalum and beryl occur in pegmatites, mainly in the Pilbara Block. Banded iron formation forms part of the sedimentary sequence. Copper, tungsten, antimony, chromite, arsenic, palladium and plutinum are all recorded from the province. Copper-zinc deposits, common in Archaean regions elsewhere in the world have not yet been discovered, but the Mons Cupri (q.v.) and Whim Creek orebodies are said to contain copper, zinc, lead and silver.

Outside the Western Australian Archaean, rocks belonging to this Province are found only in the Rum Jungle area, where granite and metamorphic rocks form basement to the Pine Creek Geosyncline (Rhodes, 1965). These rocks are somewhat younger than the Archaean of Western Australia; they give dates ranging from 2550 to 2400 m.y. (Compston and Arriens, 1968). The granites are enriched in uranium and probably acted as the source for uranium deposits in younger rocks nearby.

Metamorphic rocks elsewhere in Northern Australia have been assigned to the Archaean by various authors in the past. However more recent work indicates that most of these units are highly deformed and metamorphosed equivalents of rocks in domains of the North Australian Orogenic Province. The Gravity Map of Australia indicates a boundary to the Archaean of Western Australia extending from Wallal on the northwest coast, southeasterly to the Talbot-Waigen area and then south-south-westerly to Esperance on the south coast.

Part 2 of the metals volume in this series is devoted entirely to descriptions of the deposits within the West Australian Orogenic Province.

<u>West Australian Platform Cover</u>

Deformation in the West Australian Orogenic Province terminated in different areas between 2900 and 2200 m.y. The only known area of platform style deposition immediately overlying the eroded surface of the rocks of the West Australian Orogenic Province is the Hamersley Basin, on the Pilbara Block. These beds were laid down under conditions of generally quiet sedimentation in a gently subsiding basin, from 2200 m.y. to sometime before 1800 m.y. ago. Deposition began with basic volcanics, and the sequence consists of pyroclastics and lavas - mostly basic but some acid-chemical sediments - chert, dolomite and banded iron formation - and shales and siltstones (MacLeod, 1966; Trendall and Blockley, 1970). Deposition appears to have been thickest and subsequent deformation strongest in the southern part of the basin, south of the west-northwest axis.

Its economic importance lies in the banded iron formations and the huge bodies of iron ore that have been derived from them. The Hamersley Province is described in this volume in Part 3, Lower and Middle Proterozoic Geosynclines and Basins, which embraces the West Australian Platform Cover, the North Australian Orogenic Province, the North Australian Platform Cover and the Central Australian Orogenic Province, as well as including the four unassigned Precambrian metamorphic complexes.

TABLE 2

Block	Sedimentation	Igneous rocks	Mineral Associations	Metamorphic grade	Tectonics
Halls Creek Province Halls Creek and King Leopold Belts	Basic volcanics, clastic sediments, some dolomite, finally turbidites and conglomerates.	Dolerite dykes gabbro anatectic granite.	Minor gold, Cu-Pb-Zn, Sn, Nb, W.	up to granulite facies.	tight folding.
Pine Creek Block	Mostly shallow water sediments - greywacke siltstone, dolomite, minor volcanics.	Updoming granites.	U., U-Cu, Cu, Pb-Zn, Fe, Au. Sn.W. Ta. Mo.	low to amphibolite.	moderate to tight folds.
Tennant Creek Block	Greywacke, shale, siltstone, hematite shale.	Granite, porphyry.	Au, Cu-Au Bi Pb, Zn, Ag	up to greenschist facies (possibly to amphibolite)	moderate folding, strong shears and faults.
Granites-Tanami Block (now Tanami Block)	Greywacke, sandstone etc. with basic and acid volcanics.	Granophyre and granite	Au. U	up to greenschist facies.	gentle folding.
Nicholson Block	Geosynclinal sediments and volcanics.	Granite.	U, Cu, Au. Sn	greenschist facies.	Isoclinal folding.

North Australian Orogenic Province

Rocks of this province are preserved or exposed in five main areas, salient features of which are tabulated below. They consist generally of low-grade metamorphic rocks, derived from early Proterozoic sediments; post-tectonic granites and acid volcanics are present in most blocks. As indicated previously, the Arnhem Block may be part of the North Australian Orogenic Province (K. A. Plumb, pers.comm). Tentative results from mapping in the Arunta Block suggest correlation with the Tennant Creek region (Shaw and Stewart, this volume).

Table 2 - here.

General descriptions of the geology of these areas are included in Part 3 of this volume, as also are articles dealing with the more important economic mineral deposits.

North Australian Platform Cover

After the stabilization of the North Australian Orogenic Province, there was widespread sedimentation during the Carpentarian (1800-1400 m.y.) over a large part of northern Australia. Much of this is preserved as gently folded and comparatively little altered areas of platform cover rocks making up the North Australian Platform Cover, which includes the Kimberley Basin, the area adjacent to the Gulf of Carpentaria from Arnhem Land down to the Mt Isa area where the Platform Cover merges with the deformed Mt Isa belt (included in the contemporaneous

Orogenic Province), and sections of the Granites-Tanami area and the Davenport "Geosyncline". The sequences are largely pelitic, with some dolomite and some volcanics.

The most important orebodies and potential ores in the North Australian Platform Cover formations are the stratiform lead-zinc-silver ores, best exemplified by the McArthur River deposits. Bedded iron ores are important, including those of Yampi Sound, Constance Range, and Roper River. Copper, at Redbank, vein-type silver-lead deposits at Lawn Hill, wolfram and associated minerals at Wauchope and Hatches Creek are other economic occurrences in the North Australian Platform Cover.

Central Australian Orogenic Province

The domains assigned to this Province are mostly metamorphic complexes, widely distributed in space, laid down and deformed between 1800 m.y. and 1200 m.y. or even later. The degree of metamorphism and deformation ranges from moderate to intense, and in general is more severe than in the rocks of the North Australian Orogenic Province. The various belts and blocks included in the Central Australian Orogenic Province are the Mt Isa Belt, Ophthalmia-Gascoyne Block, Willyama, Wonaminta, Denison and Mt Painter Blocks, Gawler Block, Albany-Fraser Belt, the Musgrave Block, the Northampton Block and probably parts of the Arunta, Georgetown and Peninsula Blocks. Metallogenically the most important units of all these are the Mt Isa Belt and the Willyama Blocks, containing huge lead-zinc-silver lodes probably similar to those of McArthur River in origin, but exhibiting different degress of subsequent tectonism and metamorphism.

The Mt Isa Belt consists of an eastern geosynclinal trough separated by a welt of older basement - highly deformed metamorphic rocks, granite and acid volcanics - from a western trough, now considered to have been deposited on continental crust. Sedimentation - shale, sandstone, dolomite - was preceded by widespread extrusion of basic volcanics. Two periods of deformation occurred, both accompanied by granite intrusion. Metamorphism is widespread. Three types have been recognized; regional metamorphism, green schist to lower amphibolite grade; sodium chlorine metasomatism resulting in widespread formation of scapolite in the eastern trough; and local thermal effects close to granite intrusions. Numerous doleritic dykes and sills, now metamorphosed and altered, have intruded the sediments, and later unaltered dykes also occur. The Mt Isa Belt contains, apart from the very large Mt Isa lodes, many copper and silver-lead-zinc deposits, and uranium mineralization including the Mary Kathleen deposit (see Derrick and Hill, this volume).

A number of blocks and inliers of rocks of the Central Australian Orogenic Province occur east of the Gawler Block in South Australia and western New South Wales, including the important Willyama Block containing the Broken Hill lead-zinc-silver lodes. The rocks of this block were originally argillaceous and arenaceous sediments which have been metamorphosed to granulite facies in the southeast near the Broken Hill orebody, with decreasing grade northwestward. Granite was intruded about 1560 m.y. ago, but earlier metamorphism (1650-1700 m.y.) had occurred and there was also a later metamorphic event at 495 m.y., which was associated with lesser lead-zinc mineralization and the intrusion of pegmatites (Vernon, 1969). Uranium mineralization is more important in the South Australian portion of these blocks. There are many small occurrences of other metals, including copper.

The Gawler Block, occupying Eyre and Yorke Peninsulas in South Australia, consists of folded high-grade metamorphics, intruded by granite and porphyry and overlain by sediments and widespread acid volcanics, all intruded by small acid stocks. More than one major episode of deformation appears to have been included in its development. The most important mineral occurrences are the hematitic iron ores of the Middleback Ranges and elsewhere, and the Wallaroo and Moonta copper deposits. Gold has been mined, and non-metallics such as talc and jade have been produced from Eyre Peninsula (B. P. Thomson, in Parkin, 1969).

The Musgrave Block of central Australia has been repeatedly metamorphosed. The oldest rocks are granulites, overlain by acid and basic volcanics and quartzose sediments, and later intruded by basic and ultrabasic rocks. The most important mineral occurrence is lateritic nickel deposits developed on the ultrabasics.

Ilmenite-vanadium deposits and minor copper are also known.

The Ophthalmia-Gascoyne Block lies between the Yilgarn Block and the Hamersley Basin. It is said to incorporate both deformed Archaean basement and thickened south-western equivalents of the sediments in the Hamersley Basin. The Block is intruded by granites with an age of 1700 m.y. (Trendall and Blockley, 1970). Mineral deposits so far reported are small.

Garnet-bearing granulites and meta-quartzites, giving a date of 1040 m.y., occur in the small Northampton Block near Geraldton, in Western Australia. Numerous cross-cutting dolerite dykes are associated with lead-zinc lodes and some small copper lodes. The area also produced a little gold (Campbell, 1965).

The Albany-Fraser Belt lies immediately east and south of the Yilgarn Block. It is cut off from the older rocks by strong fault zones, and exhibits a markedly contrasting gravity pattern. The Belt was metamorphosed several times during its development, at intervals from 1900 m.y. to 1310 m.y., and later intruded by granites, and in places gabbro and pegmatite. It has been variously interpreted as a metamorphic belt imposed on Archaean rocks (Morgan, Horwitz and Sanders, 1968) and as a complex unit consisting of a Grenville-like section in the northeast and a more normal orogenic belt in the Albany-Esperance area (Wilson, 1969). This belt is not conspicuous for mineral deposits.

Unassigned Precambrian Orogenic Domains

Some Precambrian domains have proved difficult to classify, either because they did not readily fit into the broad stratigraphical pattern adopted for the Tectonic Map, or because the information on age and geology was insufficient or inconclusive.

These are briefly summarized below:

The Arunta Block in Central Australia consists of metamorphic rocks which have been affected by at least two periods of deformation in the Precambrian and one of Devonian-Carboniferous age. It contains copper and lead-zinc lodes, gold, scheelite, fluorite, and the only carbonatite so far documented in Australia. The many pegmatites, including the Harts Range ones, are thought to be Carpentarian, and constituted the main focus of mining activity until the 1950's (Shaw and Stewart, this volume).

Two small poorly exposed blocks in the Katherine Darwin area of the Northern Territory, the Arnhem and Litchfield Blocks, may be Archaean in age but equally may be Early Proterozoic, and are intruded by Carpentarian granites and other igneous rocks. No economic deposits have been shown to occur in them yet, although the Nabarlek uranium deposits occur in a formation previously assigned to the Archaean, but now included in the Lower Proterozoic (S. Needham, BMR, pers comm). Granites were intruded about 1400 m.y. ago, but later Palaeozoic intrusions also cut the Block. Gold and copper have been the main metals found so far in the Georgetown Inlier.

To the north, in the Yambo Inlier, and farther north in the Coen Inlier, there are similar metamorphics intruded by granites. Hematite and magnetite at Iron Range, scattered gold deposits and small antimony deposits in the Peninsula Ridge are recorded as Precambrian. Much of the mineralization in these three units is Carboniferous, related to younger granites.

Late Precambrian Orogenic Domains

On the Tectonic Map, two late Precambrian areas were separated out as units which do not fit well into the general pattern. One of these, the small Naturaliste Block at the southwestern corner of Australia, consists of layered granulites and gneissic granite (Lowry, 1967) metamorphosed about 650 m.y. ago (Compston and Arriens, 1968). It contains no significant mineralization. The other, the Tyenna/Rocky Cape Block of Western Tasmania, is more important. It consists of an older sequence of schist, phyllite and amphibolite, and a younger relatively unmetamorphosed sequence of quartzite, slate, dolomite, conglomerate and volcanics. They are intruded by dykes dated at 700 m.y. The most important economic mineralization introduced in the Precambrian was iron, including the Savage River iron ore deposits. The main mineralization in this area, however, is associated with Palaeozoic intrusives (Geol. Surv. of Tasmania, this volume).

Central Australian Platform Cover

A large part of Australia west of 142°E long. is occupied by platform cover overlying and presumably masking a considerable proportion of the Central Australian Orogenic Province. Deposition extended from the Adelaidean to the end of the Palaeozoic. The Phanerozoic sections of this Platform Cover have been the subject of intensive exploration for hydrocarbons. In central Australia, the extensive, mainly gently folded, sedimentary sequences of the Amadeus and Ngalia Basins range from Precambrian up to Mid-Palaeozoic in age, and contain significant petroleum deposits and evaporites and some phosphorite (Wells, this volume).

In the south is the extensive sedimentary sequence of the Adelaide geosyncline, ranging in age from 1400 m.y. to Cambrian, with a wide range of mineral deposits associated with later intrusives, folding and metamorphism in the younger Kanmantoo Belt (Gol. Surv. of South Australia, this volume).

In Western Australia, the Central Australian Platform Cover rocks range from the exclusively Proterozoic Bangemall Basin, mainly notable for manganese deposits, and some copper, to the Canning, Carnarvon and Officer Basins which began to form in the late Proterozoic, but which contain extensive sequences of Palaeozoic sediments. Evaporites of Siluro-Devonian (?) age occur in the Canning Basin and the Carnarvon Basins. In north Australia, several Adelaidean basins are overlain by widespread flood basalts of early Cambrian (or possibly latest Adelaidean) age containing numerous uneconomic copper occurrences. These were followed by the spread of the Georgina Basin with important Cambrian phosphorites (de Keyser and Cook, 1972) and sporadic galena (Smith, 1972). The Central Australian Platform Cover extends north into New Guinea beneath the Arafura Sea (GSA, 1971).

East Australian Orogenic Province

These are the rocks of the Tasman Geosyncline, ranging in age from the Kanmantoo Belt of eo- to mid-Cambrian age, to the late Palaeozoic Belts of easternmost Australia, representing successive seaward accretions added on the margin of the pre-Phanerozoic continental plate (Scheibner, 1973).

The rocks of the Kanmantoo Belt were deposited in a trough east of the Adelaide "Geosyncline" in South Australia, and in western Victoria and western New South Wales during the early Cambrian. They were deformed and intruded by granite in the Ordovician. Rocks with similar ages of deposition and deformation also occur in western Tasmania and central-northern Queensland (Plumb, 1972). The Kanmantoo Belt (and the adjacent Adelaide "Geosyncline") contains widespread copper, lead and zinc mineralization, also gold, barite, pyrite and manganese (Geol. Surv. of South Australia, this volume).

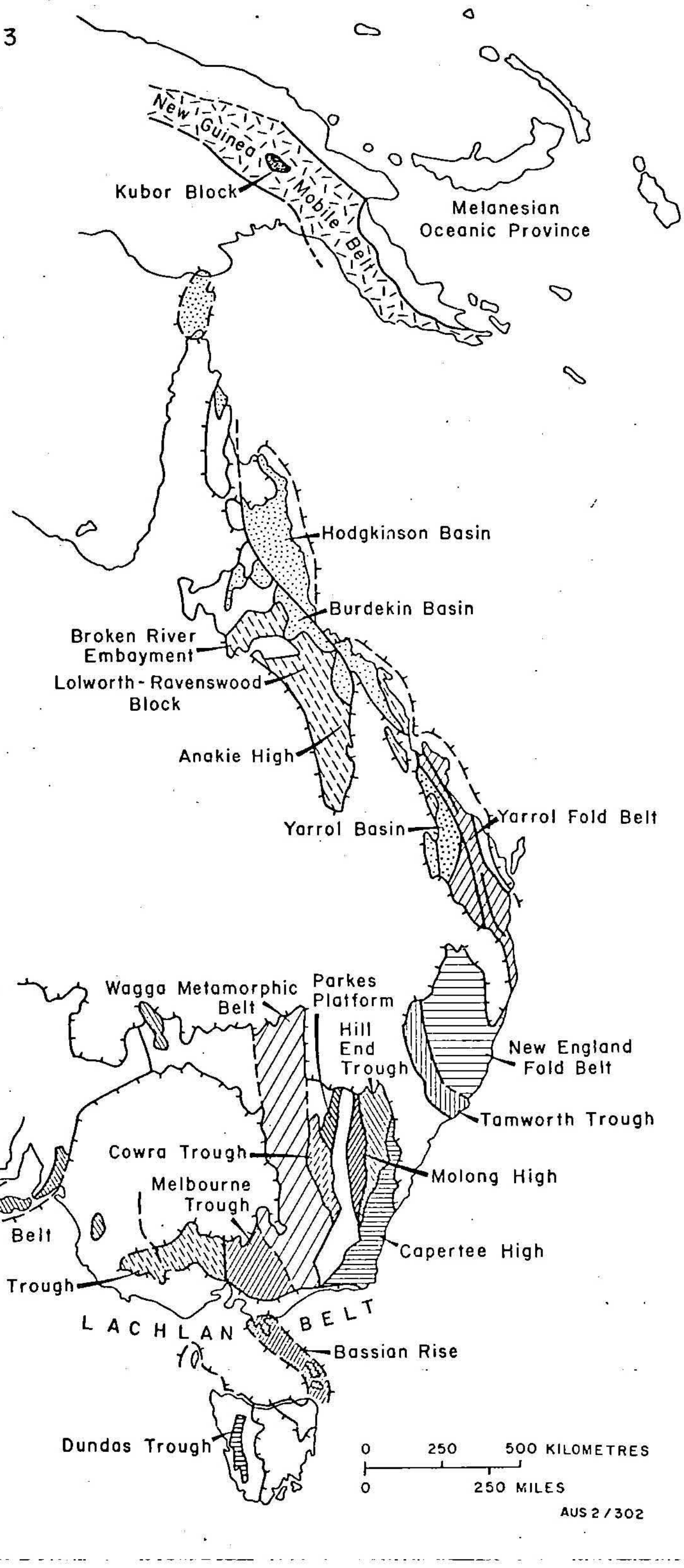
The southern part of the mainland Tasman Geosyncline is generally referred to as the Lachlan Belt or Lachlan Geosyncline and this may be divided into a number of units which generally become progressively younger towards the east (Fig. 3). Exposure is limited to the north and west by the sediments of the overlying Eromanga and Murray Basins.

(Figure 3 here)

In the most westerly unit, the Ballarat Trough, a mainly basic volcanic sequence of Cambrian age with interbedded shale and black chert is followed by a deep-sea Ordovician greywacke sequence. The main deformation probably occurred in the late Ordovician and there were several periods of granite intrusion. Gold is the principal metal, but arsenic, lead, zinc, molybdenum and bismuth are also significant (Geol. Surv. of Victoria, this volume).

East of the Melbourne Trough the Lachlan Belt has been subdivided into a number of units: the Wagga Metamorphic Belt, the Cowra Trough, Parkes Platform, Molong High, Hill End Trough and Capertee High (see Fig. 3).

FIGURE 3



Units of the East Australian and New Guinea Orogenic Provinces

Sedimentation in these areas began in the Ordovician (though questionably older rocks occur in southeastern New South Wales). The Ordovician sediments consist of quartzose greywacke, black shale and carbonate rocks with acid to andesitic volcanics. They were folded by the Benambran orogeny at the close of the Ordovician and intruded by granites. In the Silurian, sedimentation was mainly of shallow water type, except in the Cowra Trough. Widespread acid volcanics were erupted towards the close of the Silurian, followed by the intrusion of granites of the Browning Orogeny (late Silurian early Devonian). Serpentine in a narrow discontinuous belt was also emplaced at this time (Packham in Packham, 1969; Scheibner, 1973).

In the Hill End Trough, much thicker sequences, containing acid and andesitic volcanics, were laid down in the Silurian and until the Middle Devonian, where deposition was terminated by the Tabberabberan Orogeny. (Packham in Packham, 1969; Scheibner, 1973).

The mineral deposits of the Lachlan Belt are many and varied, spanning the time-range of its development and a wide spectrum of tectonic environments. Silver-lead-zinc-copper lodes along the western margin of the Hill End Trough (Captains Flat, Woodlawn, etc) developed in restricted conditions close to volcanic rocks (Oldershaw, 1965; Malone, this volume). Gold occurs close to metamorphic belts and was also extensively introduced by Kanimblan granites. The Cobar ores are in a greywacke sequence, but may have been partly mobilized during folding (BHS, this volume). Tin, tungsten, bismuth and molybdenum deposits are closely allied to high level granites in the Wagga Belt. A suite of chrome-copper and platinum mineralization follows the ultrabasic belt (Geol. Surv. of New South Wales, this volume).

In Tasmania, sediments and volcanics were laid down in the Cambrian, but deposition was restricted to a smaller area in the west after the Jukesian tectonism at the end of the Cambrian, during which granite and serpentinites were intruded. In the middle Devonian Tabberabberan orogeny, widespread folding and faulting occurred and this was followed by further granite intrusion ranging into the early Carboniferous (Geol. Surv. of Tasmania, this volume).

The tin and tungsten deposits of Tasmania are mostly associated with the granites. The Mount Lyell copper-gold and the Read-Rosebery silver-lead-zinc ores occur in the Cambrian rocks and are probably syngenetic deposits closely associated with the volcanic activity, remobilised during tectonic and intrusive events (Geol. Surv. of Tasmania (b), this volume).

Little is known of the Tasman Geosyncline beneath the Eromanga Basin, so that events in the North Queensland part can only be correlated broadly with those in the south. In the Anakie High, Devonian granite has intruded Ordovician schist and volcanics, and this was followed by acid to andesitic volcanics. A little gold and copper has been found. The Lolworth-Ravenswood

Block is a complex area of early Palaeozoic metamorphics intruded by Ordovician to Middle Devonian granites and later by Carboniferous to Permian granites. It is an important gold area (Charters Towers, etc.) and silver-lead deposits have also been mined (Wyatt, Paine, Clarke, Gregory and Harding, 1971). Farther north, the Broken River Embayment contains Silurian to mid-Devonian sediments (White, 1965). Nickel at Greenvale is derived from the weathering of ultrabasic rocks emplaced during Devonian folding movements (Metals Exploration NL, this volume). Later antimony, tin and tungsten are of minor significance.

In the Burdekin Basin, sedimentation took place in the Upper Devonian followed by folding in the mid-Carboniferous but folding was not severe and this is classified as a transitional domain.

The Hodgkinson Belt of North Queensland (Fig. 3) lying east and northeast of the Georgetown Block and separated from it by the Palmerville fault, contains sediments, strongly folded and mildly metamorphosed, of Silurian-Devonian age. Deformation probably occurred in the early Carboniferous and acid vulcanism late in the Carboniferous, accompanied by granite intrusion. Later granites were intruded in early and late Permian. Numerous ore deposits are associated with the intrusion of the late Carboniferous granites, particularly around the margin of the Hodgkinson Belt and in adjacent domains. These are chiefly of the classic zoned tin-tungsten-copper-lead-fluorite suite characteristic of high-level, late-phase granite intrusions (de Keyser and Lucas, 1968; de Keyser and Wolff, 1964; Branch, 1966; Blake, 1972).

The most easterly division of the Tasman Geosyncline is the New England-Yarrol Belt, extending from Newcastle to Broad Sound. It consists of a number of sub-units each with a different history of development. Northward from the Gogango Overthrust Zone of Central Queensland, the belt passes into platform cover overlying transitional phase volcanics of the older North Queensland Blocks; and the late phase acid volcanism and intrusions from the Hodgkinson Belt extend southwards so that there is a complex zone of overlap. South and east of the Gogango Overthrust zone, the New England/Yarrol Belt may be split into two main divisions, the Yarrol-Tamworth Trough system and a more complex eastern region, separated from each other by a series of thrust faults with some serpentinites. The oldest sediments recognized are Ordovician in the Tamworth Trough, Silurian in the Yarrol Basin, but the main sedimentation was Devonian, characterised by intermediate to acid volcanics in the upper part (which include the host rocks at Mount Morgan). The main deformation extended from latest Carboniferous in parts of New England to Triassic in the Gympie district, but seems to have taken place during the Permian over most of the belt (Geol. Surv. of New South Wales, this volume; Packham, ed. 1969; Olgers and Flood, 1973; Scheibner, 1973; Ellis; 1968; Kirkegaard, Shaw and

Murray, 1970).

In the Queensland part of the eastern region, which includes the Brisbane Metamorphics, deposition appears to have started in the Silurian, though fossiliferous evidence is generally lacking, and extended into the Permian. The older metamorphics are highly deformed and faulted, the Permian only slightly deformed except in the Gympie district where Permian and earliest Triassic sediments were deformed in the early Triassic (Runnegar and Ferguson, 1969).

The New South Wales part of the eastern region is bounded in the west by a major thrust fault passing southeasterly into a zone of arcuate faults. East of this, the geology is complex, with sediments ranging in age from Ordovician to Permian, separated by faults into a number of blocks. The most easterly Permian sediments are strongly deformed, indicating a progressively eastward migration of the main phase of deformation. Except in the Tamworth Trough which seems to be barren, the New England/Yarrol Belt contains a wide variety of mineral deposits. These include the gold-copper deposits of Mount Chalmers, minerals of the ultrabasic suite associated with the serpentinites of the Rockhampton and New England areas, gold at Gympie, Cracow and many other places, gold, antimony and scheelite at Hillgrove, and the important New England Permo-Triassic tin-tungsten-molybdenum province, as well as many deposits of mixed ores.

In New Guinea, the East Australian Orogenic zone is represented by the Vokelkop Block in the west of the island and the Kubor Block in the Eastern Highlands. The Kubor Block contains late Permian-early Triassic sediments intruded by early Triassic granite (Bain, Mackenzie and Ryburn, 1970).

Trans Australian Platform Cover

The Trans Australian Platform Cover occupies the greater part of eastern Australia, where it rests on the East Australian Orogenic Province, but it also has spread thinly and discontinuously over the western part of the continent and peripherally around the margins of the continent. In the island of New Guinea, the Trans Australian Platform cover merges into the active northern half of the island. It began to develop as early as the late Carboniferous, spread widely during the Triassic and reached maximum development in the Cretaceous. From the late Cretaceous onwards, the Australian craton has been largely emergent; apart from the Murray Basin marine sedimentation has been confined to the continental margin and New Guinea, and continental deposition has taken place on the mainland of Australia. The most notable metallic deposit in these rocks is the Groote Eylandt bedded manganese deposited in the Cretaceous (Smith and Gebert, 1970); low-grade sedimentary iron, phosphate, uranium and vanadium deposits also have formed during deposition of the Trans Australian Platform Cover. Small Cretaceous plugs in eastern Australia have introduced small gold and copper deposits.

The main economic importance of the Eastern Australian Platform cover rocks, which include large areas offshore, is that they contain most of Australia's coal and petroleum deposits. The black coals of the Bowen-Surat, Sydney and Collie Basins and Tasmania were laid down in Permian depressions, in places interbedded with marine sediments; those of the Styx, Maryborough, Ipswich (Moreton-Clarence), Leigh Creek, and Wonthaggi in the Mesozoic, and the huge brown coal deposits of Victoria in the Eocene.

All significant known petroleum occurrences, except those of the Amadeus and Bonaparte Basins, occur in these rocks: those of Roma, Moonie and Alton in the Permian of the Surat Basin, the offshore oil and gas of the Gippsland Basin in the Early Tertiary, those of the Cooper Basin in the basal Permian, Perth Basin gas in the Permian, Barrow Island oil in the Cretaceous, the Northwest Shelf gas in Triassic and Cretaceous, Scott Reef gas in Triassic and Jurassic, and Papuan petroleum, including offshore, in Tertiary and Cretaceous sediments.

The Great Artesian Basin, a hydrogeological unit, occupies a large part of the Trans Australian Platform cover in the eastern half of the continent. Underground water, which contributes significantly to the economic geology of Australia, is drawn from aquifers both in the Trans Australian Platform Cover, including its thin outliers, and in older Platform Covers.

Superficial and Detrital Deposits

An important class of mineral deposits is associated with weathering processes that have taken place during the Cainozoic and recent times on the stable Australian Craton. These can be considered as belonging to East Australian Platform cover, though some of them are formed on or from rocks of any age. These deposits include the bauxites, formed from rocks ranging from Tertiary to Precambrian; much of the secondarily constituted or enriched iron ore, the heavy mineral sands, lateritic nickel on the ultrabasics, residual manganese mainly in Western Australia, magnesite derived from magnesium-rich rocks, all the alluvial deposits of gold, tin and other heavy and/or resistant minerals, uranium in continental sediments and calcretes, the surface evaporites of the dry lakes and coastal flats, and gravel and sand deposits. The valuable supergene enrichments of many sulphide deposits are due to the slow and steady erosional conditions prevailing over long spans of geological time in the Australian Craton.

These deposits are treated in Part 7 of this volume.

New Guinea Orogenic Province

The northern margin of the Australian Craton extends north, mainly beneath Trans Australian Platform Cover, to the central backbone of New Guinea, where it meets the mobile zone of New Guinea. The area of junction is marked by major lateral faults and much overthrust faulting. To the north and east of the New Guinea

Mobile Belt lie the Oceanic Plates recently referred to as the Melanesian Oceanic Province (Dow, 1973). This includes the northern New Guinea-New Britain arc, concave to the north and abutting against the Manus-New Ireland-Solomons arc to the northeast.

In the Western Highlands, the sediments of the Mobile Belt are mainly geosynclinal, in contrast to the shelf type sediments - shale, sandstone, siltstone, limestone - of the stable Platform area to the south. The earliest dated sediments preserved are late Permian limestone, followed by Triassic shallow-water clastics and dacitic volcanics. Although this marine shelf environment persisted over the southern part of the Mobile Belt during the Jurassic and Cretaceous, to the north geosynclinal sediments derived mostly from active volcanoes to the north were deposited in deep troughs. Marine volcanism is recorded in the late Jurassic, early and late Cretaceous and Eocene (Dow, 1973).

Deformation and metamorphism to greenschist facies took place about the end of the Eocene, and further geosynclinal sedimentation and volcanism in the Oligocene and Miocene. Intrusion of andesites, diorites and ultramafics, and regional metamorphism, took place at the end of the lower Miocene followed by island-arc type volcanism and clastic sedimentation. Miocene or later porphyry - copper style deposits are the principal subject of economic interest at present, but alluvial gold has been worked at several places, and lead and zinc have been recorded.

To the southeast of the Western Highlands Belt lies the Aure Trough, a depression filled by mainly turbidites of Miocene and younger ages, now closely folded.

Northeast and east of the Aure Trough, the Highlands Belt swings more to the south and occupies most of the southeastern part of Papua, extending to Woodlark and Misima Islands. Cretaceous and Eocene metamorphosed geosynclinal sediments are intruded by granites and later porphyries and andesites, and overthrust probably during the Miocene by a large slice of basic to ultrabasic rocks. Later exposed rocks are mostly volcanogenic but limestone and other sediments are known. Mineralization, mostly gold, has been widespread, the most important producing areas being the Wau-Bulolo goldfield (largely alluvial), and Misima and Woodlark Islands. Gold and copper have been mined near Port Moresby, adjacent to gabbroic intrusives. The Frieda River porphyry copper prospect is of mid-Miocene age. Detrital gold and platinum is widespread in alluvials but much of it uneconomic, and the ultrabasic areas are mostly too deeply dissected to favour the formation of residual nickel deposits.

The Melanesian Oceanic Province includes two well-developed volcanic island arcs, one extending along the north coast of New Guinea and New Britain, the other lying east of New Island and extending down through the Solomon Islands to the New Hebrides. The area is one of interaction of moving plates. At the western end of the North New Guinea-New Britain arc, a subduction zone dips southward beneath the Torricelli mountains, which are cored by probably Early Tertiary igneous rocks and metamorphics flanked by unconformable Mio-Pliocene sediments; at the eastern end a subduction zone dips north underneath New Britain from the New Britain Trench. The boundary of the two systems is the locus of active recent faulting. The rock formations are mostly volcanogenic, with some associated limestones, and date from Lower Eocene. There are numerous granodiorite, diorite and gabbro intrusives, ranging from Eocene up to the present, but most numerous in the early Miocene. Major porphyry copper prospects are associated with some of those intrusives, e.g. Manus Island with mid-Oligocene diorite, several prospects on New Britain with granodiorites and diorites of late Oligocene-early Miocene age, Panguna on Bougainville with a Pliocene andesite-diorite series of intrusions.

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