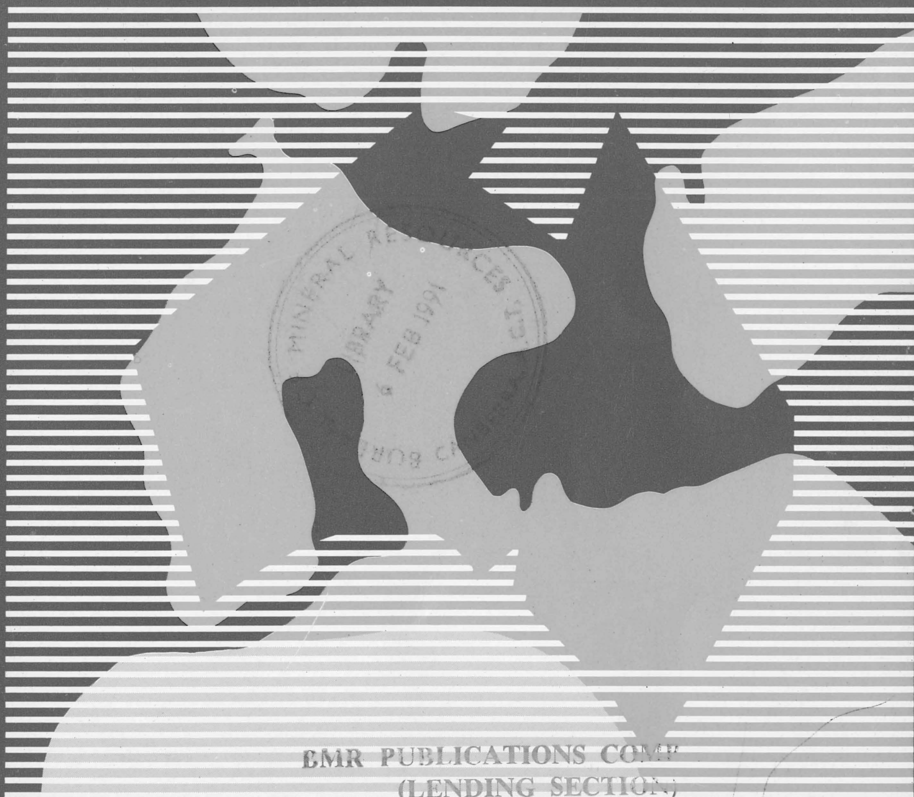
PALAEOGEOGRAPHY 26

THE JURASSIC PALEOGEOGRAPHY OF AUSTRALIA

MARITA BRADSHAW & MONICA YEUNG



BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

ONSHORE SEDIMENTARY & PETROLEUM GEOLOGY

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BY

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Bureau of Mineral Resources, Geology and Geophysics
Australian Petroleum Industries Research Association

PALAEOGEOGRAPHIC MAPS PROJECT

1990

P R E F A C E

This Record contains early drafts of material to be edited for eventual publication as part of the Palaeogeographic Atlas of Australia, and is issued to make it publically available at an early date. Copies of the data maps, on which the interpretation maps are based, are available separately (1: 5 000 000 scale) from BMR Copy Service (Tel: 062-45 1374; fax: 062-472728) at a cost of $5.00 each plus postage.

CONTENTS

SUMMARY

As part of the joint Bureau of Mineral Resources and Australian Petroleum Industry Research Association Palaeogeographic Maps Project environmental reconstructions have been prepared for Australia for ten Jurassic time slices. The maps were compiled from well and outcrop information for both on and offshore Australia. Correlation was based on the palynological zonation of Helby et al.,(1987) and the time scale used was that of Harland et al. (1982).

Jurassic rocks are distributed as a thin but extensive platform cover spread across the continent through the Eromanga and adjacent basins, while the thickest depocentres were along the western margin (Barrow-Dampier Sub-basin and Perth Basin) and to the east (Clarence-Moreton Basin) and north (Papuan Basin). Marine to fluvio-deltaic deposition occurred along the western and northern margins of the continent that bordered Tethys and non-marine sequences were deposited in eastern Australia. Deposition was initiated in a terrestrial rift valley system along the southern margin between Australia and Antarctica. The widespread fluvio-lacustrine facies attest to a temperate and humid climatic regime. Redbeds are restricted to the Early Jurassic along the western margin and marine sequences are dominated by clastics with only rare carbonates.

Australia's Jurassic tectonic regime was dominated by the break-up of Gondwana. At the beginning of the Jurassic, Greater India and possibly other parts of Asia lay to the west and Antarctica filled the curve of the southern margin. Tensional rift environments encircled the continent from the northwest to the southeast. In contrast to this divergent stress regime, a Chilean-type magmatic arc, present off the eastern margin, was indicative of a convergent plate boundary in the northeast quadrant of the continent. In response to rifting along the southern margin, large volumes of dolerite were intruded into the Permo-Triassic sediments of Tasmania and there are many small basic to intermediate intrusives of Jurassic age throughout southeastern Australia.

The shifting pattern of environments across Australia during the Jurassic was controlled by global climate and sea level, tectonic regime and the continent's palaeogeographic position in high southerly latitudes, on the eastern margin of Gondwana facing north and west into Tethys. Eastern Australia was partially enclosed from the "palaeo-Pacific" by the Lord Howe Rise, the Bunker Ridge, Queensland Plateau, New Caledonia, and other possible land areas to the east of the present continent. Through the Jurassic there was a gradual expansion of the area of deposition in onshore Australia and an increasing marine influence on sedimentation along the northwestern margin.

INTRODUCTION

Despite the importance of Jurassic sediments as major hydrocarbon reservoirs and source rocks, there have been few attempts to produce Australia-wide palaeogeographies for this period. The only Jurassic reconstructions in the literature are parts of general syntheses of the Mesozoic (Ludbrook, 1978), or of the entire geological column in Australia (Laseron, 1969; Brown et al., 1968; Veevers, 1984), or summaries of the geology of particular states (Queensland: Day et al., 1983; New South Wales: Packham, 1969; South Australia: Ludbrook, 1980; Victoria: Douglas & Ferguson, 1976; Tasmania: Spry & Banks, 1962; Western Australia: Playford et al., 1975). Sequences of detailed palaeogeographies are available for the Jurassic of individual basins (Bonaparte: Mory, 1988; Browse: Allen et al., 1978 and Passmore, 1980; Barter et al., 1984; Canning: Forman & Wales, 1981; Dampier and Barrow Sub-basins: Kopsen & McGann, 1985; Exmouth Plateau: Exon & Willcox, 1980; Perth Basin: Playford et al., 1976; Eromanga: Senior et al., 1978; and Surat: Exon, 1976). But this is the first attempt to reconstruct a detailed and comprehensive view of the Jurassic in Australia, both on and offshore, with a high resolution of time slices.

Palaeogeographic maps of the Jurassic are especially relevant to resource exploration as the distribution of significant amounts of Australia's oil and gas has been controlled by the pattern of Jurassic sedimentation and tectonics. The most prolific area of onshore production is from the Jurassic sediments of the Eromanga Basin and many of the major hydrocarbon accumulations on the North West Shelf are believed to be largely sourced from Jurassic marine shales (Alexander et al., 1980).

Oil shale, coal, gold, possibly diamonds, bentonite and other minor industrial minerals are resources to which Jurassic palaeogeography is also relevant. Palaeogeographic maps are well suited to providing the framework for understanding the distribution of these commodities and for predicting the occurrence of other potential deposits. For example, the trend of an ancient shoreline may indicate the location of porous sandstone reservoirs for hydrocarbons; former deep restricted marine embayments and fault-controlled lakes may be source rock kitchens; palaeodrainage networks can point to the occurrence of alluvial gold and diamonds; and downwind of past volcanoes bentonite deposits may be found.

ACKNOWLEDGMENTS

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Special thanks are due to Alan Partridge, Murray Johnstone (ESSO Australia Ltd.), Peter Price, John Filatoff (CSR Petroleum Ltd), Robin Helby (consultant) Mike Hall, Cathy Sharpe, Greg Smith (BHP), Marcus Haring (Shell), Tony Cockbain, Roger Hocking, Arthur Mory, John Backhouse (Geological Survey of Western Australia), Neville Alley, Murray Lindsay, John Morton, Barry Cooper, Wolfgang Preiss (South Australian Department of Mines and Energy) Andrew McMinn (New South Wales Department of Minerals and Energy), Bob Day, John McKellar, Ces Murray, A. R.G. Gray (Queensland Geological Survey), S.M. Forsyth, P.W. Baillie (Tasmanian Department of Mines), Jack Douglas (Victorian Geological Survey), Dick Evans (University of New South Wales), Mary Dettmann (University of Queensland), Denis Burger, Fred Doutch, Peter Wellman, Liz Truswell, Tony Yeates, Virginia Passmore, Ian Lavering, Alan Wells, Phil O'Brien, Neville Exon, Phil Symonds and Larry Harrington.

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CORRELATIONS

Biostratigraphy, supplemented by lithostratigraphy and radiometric dates from igneous rocks, was the main correlation tool used in this study. Due to the scarcity of marine macrofossils, palynology provides the most precise and widely applicable biostratigraphic control for the Australian Jurassic. The integrated dinoflagellate and spore-pollen zonation of the Australian Mesozoic developed by Helby et al.(1987) is the keystone of the Jurassic Correlation Chart presented here.

Other published palynological zonations have been based predominantly on spore-pollen, and have dealt only with the Jurassic sequence or parts of it, within restricted regions:- Backhouse (1978, 1988) (Late Jurassic/Early Cretaceous of the Perth Basin); de Jersey (1959, 1971 & 1976) and de Jersey and Paten (1964) (Early Jurassic of the Surat and Clarence-Moreton basins); Filatoff (1975) (Early and Middle Jurassic of the Perth Basin); and Reiser and Williams (1969) (Early Jurassic of the Surat Basin). Evans (1966a) was a pioneering attempt at an Australia- wide scheme but it was largely based on eastern Australian data, as were the later modified versions of this scheme (Burger, 1976 & 1986; and Price et al. 1985). The Helby

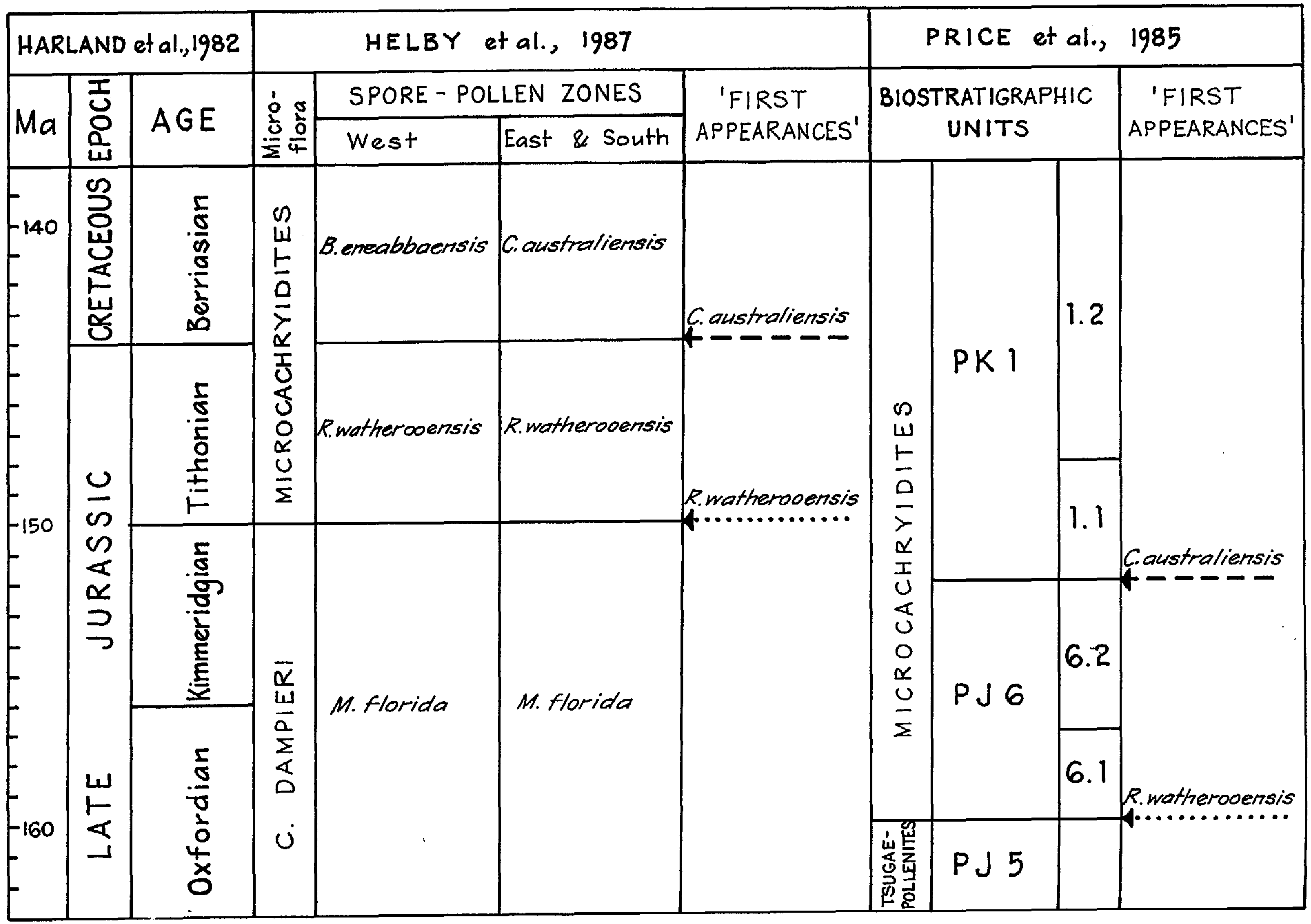

FIGURE 1. Jurassic biostratigraphic zonations, Helby et al. (1987) and Price et al. (1985), showing alternate ages of palynological datums.

et al. (1987) zonation establishes a correlation between the dichotomy of the continental sediments of eastern Australia, controlled by spore-pollen and the marine influenced sequences of western Australia dated by dinoflagellates. Dinoflagellates and sporadic occurrences of marine macrofossils link the Helby et al. (1987) zonation to the European Jurassic stages which are defined by ammonites (Arkell, 1956; Cope, 1980a & 1980b).

The inherent character of the Australian Jurassic:- high latitude location on the distant fringes of Tethys and predominantly non-marine sediments, except for the western margin, creates biostratigraphic problems. Controversy exists concerning the correlation of spore-pollen zones and dinoflagellate zones to the European stages, presented in Helby et al.(1987). Discrepancies are largest in the Late Jurassic where the Microcachryidites Microflora shows marked provincialism between eastern and western Australia and latitudinal differentiation (Burger, in press). An alternative assignment of spore-pollen zones to the European stages by Price et al. (1985) is older by more than a full stage, or ten million years (Fig. 1). This study accepts the Helby et al.(1987) zonation, though noting that difficulties in correlation internationally and within Australia exist, and that Helby et al., state that their "scheme must be viewed as preliminary rather than comprehensive".

Other supplementary palynological schemes shown on the correlation chart are Price et al. (1985) which is used extensively by the petroleum industry in the Eromanga Basin; and modified versions of Evans (1966a) which is applicable to older well and outcrop data. These zonations are internally consistent but have been modified to agree with datums of the Helby et al. (1987) scheme. The reader is referred to Burger (1989) for a fuller discussion of Australian Jurassic biostratigraphy.

The time scale used in the study, and by Helby et al. (1987) is Harland et al. (1982). A more recent geochronology, Hallam et al. (1985) has significantly younger dates for the beginning (205 /213Ma) and end (135/144Ma) of the Jurassic. But this time scale is based on the dating of glauconitic sands and intrusive igneous rocks, and should be regarded as providing minimum ages. Both time scales derive a similar time, of around 70Ma, for the duration of the Jurassic. The Jurassic time scale proposed by Kent and Gradstein (1985) has a shorter period of 64Ma, ranging from 208 to 144Ma; while Kennedy and Odin (1982), who re-evaluated radiometric (glauconite) data, dated the Jurassic as 74 million years long, from 204 to 130Ma.

The numerous Jurassic igneous rocks have been correlated using published radiometric ages, standardised using new constants where necessary from the conversion tables in Harland et al. (1982). It is noteworthy that the few igneous rocks that occur within sedimentary sequences give reasonable agreement between radiometric age and biostratigraphic age as indicated by

Helby et al. (1987), (see Column 18 and 23).

Where biostratigraphic control is absent or only poorly defined, lithostratigraphy has been used for correlation. In the Eromanga Basin, log correlation has been employed in conjunction with biostratigraphy, as log analysis permits finer division of units than the broad spore-pollen zonation allows. Many of the log picks used are those of B.R. Senior recorded in PEDIN, the BMR's Petroleum Exploration Data Index.

Ten time slices have been selected from the Jurassic Correlation Chart. From the discussion above, the exact correlation of units and the duration and absolute ages of the time slices cannot be regarded as hard and fast at this stage; but they are the best compromise reached after lengthy consultations with the industry sponsors of the project, the State Geological Surveys and many biostratigraphers. The time slice boundaries occur at natural breaks in sedimentation or changes in facies that are common to several basins. In some cases they are representative of events that have continent-wide implications. The Jurassic time slices have an average length of seven million years, though they range from thirteen million years to under three million years long. Longer time slices cover intervals with less precise biostratigraphic zonation, e.g. Time Slice 1; and the short time slices have been chosen to capture specific events, such as a marine transgressions, e.g. Time Slice 5.

Difficulties arise in selecting time slices that are applicable to both the eastern and western halves of Australia, which have contrasting depositional and tectonic regimes throughout the Jurassic. Differences in biostratigraphy also cause problems. Ideally time slices should be easily identified by fossil content, but few spore-pollen zones correspond directly with dinoflagellate zones, and much greater subdivision is possible in the marine sequences of the North West Shelf, than in the continental sediments of eastern Australia.

As a result the time slices chosen are a compromise between the demands of the varying histories across the continent and the need to have rough correspondence with biostratigraphic zones. Despite these limitations, the time slices show ten successive aspects of Australia throughout the Jurassic, capturing the major events in its geological evolution, and revealing a remarkable coincidence between changes in the depositional regime from east to west. In several instances, marine transgression on the North West Shelf equates with a switch from sandy, high energy fluvial deposition to shale-prone, lower energy, fluvio-lacustrine deposition in eastern Australia.

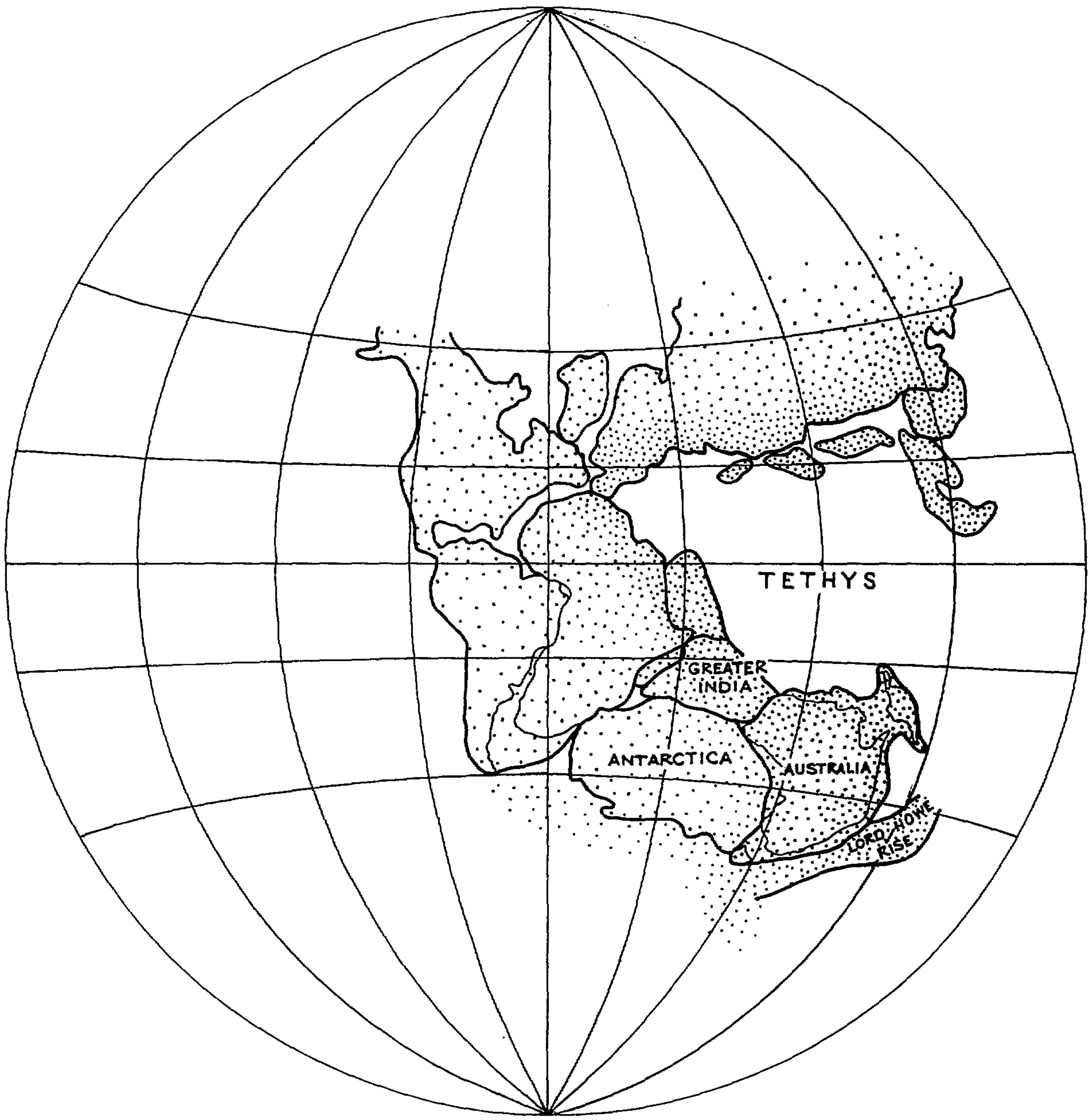

Figure 2. Global reconstruction for the Late Jurassic from Scotese (1986).

TECTONICS

Australia's Jurassic tectonic regime was dominated by the break-up of Gondwana. At the beginning of the Jurassic, Greater India and possibly other parts of Asia lay to the west and northwest, while Antarctica filled the curve of the southern margin (Fig. 2). Tensional rift environments encircled the continent from the northwest to the southeast (see Structure Map), as a prelude to seafloor spreading which commenced with the formation of the Argo Abyssal Plain in the Late Jurassic and progressed southwards throughout the Cretaceous. In contrast to this divergent stress regime, a Chilean-type magmatic arc (Veevers, 1984) present offshore of the Maryborough Basin, was indicative of a convergent plate boundary in the northeast quadrant of the continent.

The thickest depocentres were in marginal rifts (Barrow-Dampier Sub-basin, Perth Basin) and back arc troughs (Clarence-Moreton Basin). There was a thin but extensive platform cover spread across the continent through the Eromanga and adjacent basins.

Along the northwest margin, deposition (over 10km thick in places) was controlled by a series of fault-bounded depressions that trended southwest to northeast, perpendicular to the Palaeozoic Canning and Bonaparte Basin trends (Bradshaw et al. 1988). This rift system commenced in the Permo-Triassic (Yeates et al., 1987) but fault movements, such as on the Flinders Fault System and the Sholl Island Fault, continued throughout the Jurassic and were especially active in the Callovian (Veenstra, 1985).

The fault pattern was complicated in the Bonaparte Basin where the Mesozoic and Palaeozoic trends interfered to produce depocentres that were aligned both southwest-northeast e.g. Vulcan Sub-basin, Malita Graben; and northwest-southeast e.g. Sahul Syncline, Petrel Sub-basin.

The igneous rocks on the northwest margin reflect the extensional tectonic regime, evolving from a rift environment to the creation of new seafloor by the Late Jurassic. Alkali intermediate rocks dredged from the Scott Plateau, Browse Basin and Exmouth Plateau (Von Stackleberg et al. 1980, Von Rad & Exon, 1982) have been attributed to early rift subcrustal melting associated with continental break-up (Exon et al, 1982, Veevers & Hansen, 1981). Those from Exmouth Plateau are of Early Jurassic age. Jurassic volcanics have also been intersected in several wells in the Browse and Bonaparte basins including Buffon 1, Yampie 1 and Ashmore Reef 1. Dolerite sills intrude the Jurassic sediments of the Exmouth Sub-basin (Yardie East 1) and ocean floor basalt, variously interpreted as Late Jurassic (Shipboard Party Site 261, 1974) or Early Cretaceous (Leg 123 Shipboard Party, 1989), lies beneath the Argo Abyssal Plain.

Not all tectonic and igneous activity was confined to the continental margin in the northwest quadrant. Jurassic kimberlitic intrusions are located near the Wandagee Fault in the Carnarvon Basin (Hocking et al., 1987); and a series of large en echelon anticlines were formed by wrench movements during the Late Triassic to Early Jurassic in the Fitzroy Trough (Rattigan, 1967; Forman & Wales, 1981; Towner & Gibson, 1983). These features reflect some intra-plate stress in the Jurassic, perhaps related to the opposing vectors of extension on the west and southern margins, and convergence to the east.

Deposition in the Perth Basin was controlled by the north/south Darling Fault, an ancient dislocation bounding the eastern edge of a rift valley that formed in the Permo-Carboniferous (Playford et al., 1975). Movements occurred on this and other faults during the Jurassic, and over six kilometres of sediment accumulated on the downthrown side of the Darling Fault. However, the major tectonic and igneous activity associated with the break-up of Gondwana on Australia's southwest margin occurred in the Neocomian, when sea floor spreading commenced in the Perth Abyssal Plain, the Bunbury Basalt was extruded and a major angular unconformity was produced within the Perth Basin sediments (Playford et al., 1975).

A rift valley environment existed along the southern margin between Australia and Antarctica. Extensional faulting produced narrow half grabens that accumulated a few kilometres of sediment during the Jurassic, as a prelude to the major phase of rift sedimentation in the Cretaceous. The east-west trend of the rift valley system from the Eyre Sub-basin to the Polda Trough, may reflect a Palaeozoic structural grain seen in the orientation of the Officer, Amadeus and Ngalia Basins. Nelson et al. 1986) proposed that the Polda Trough is a Palaeozoic feature as indicated by the Permian glacials, and older Palaeozoic evaporites that underlie the Jurassic.

Hegarty (1988) and Stagg & Willcox (1987) have described an early phase of oblique extension along the southern margin, directed on a northwest/southeasterly trend, prior to more orthogonal north/south extension and eventual sea floor spreading in the mid-Cretaceous. Blake, (1980) described in Megallaa (1986) suggested an initial phase of wrench faulting as indicated by a series of en-echelon east-west faults in the Otway Basin.

Under the extensional regime along the southern margin large volumes of tholeiitic magma were intruded into the Permo-Triassic sediments of Tasmania and Antarctica (Compston et al, 1968; Schmidt & McDougall, 1977). The Wisanger Basalt on Kangaroo Island (Milnes et al., 1982) is also part of this suite. Slightly younger Jurassic dolerites intersected in Casterton 1, Robertson 1 and outcropping at Coleraine (Bowen, 1975; Douglas et al., 1976; see Structure Map) are more trachytic in composition.

There are also other basic to intermediate Jurassic igneous rocks (Douglas & Ferguson, 1976; Evernden & Richards,1962; Facer & Carr, 1979; Bean,1974; Dulhunty, 1976; McDougall & Wellman, 1976), many of kimberlitic affinities (Ferguson, 1980; Ferguson et al., 1979), scattered throughout southeastern Australia from Port Augusta (Strake et al,. 1979) to Towallum (McElroy, 1969) in the Clarence-Moreton Basin (see Structure map). Some intrusions can be related to structural features such as faults. This igneous activity may represent the presence of a Mesozoic hotspot (Ferguson et al. 1979; Wellman, 1983).

In contrast to the basic to intermediate rocks that characterise the Jurassic igneous suite throughout most of Australia, acid igneous activity occurred in the northeastern quadrant of the continent. Late Jurassic hornblende porphyrite crops out at Noosa Head (Evernden & Richards, 1962) and there are tuffs, bentonites and other sediments indicating a high volcanic input throughout the Jurassic basins of eastern Australia (Holmes, 1981 and Exon, 1976) and into the Papuan Basin. Volcanic derived sediments of Jurassic age also occur in New Zealand and New Caledonia (Paris, 1981). These occurrences are evidence of a Chilean-type magmatic arc located somewhere east of the Queensland coast, active in the Jurassic. Convergent plate activity along Australia's eastern margin was established by the Devonian and continued throughout the remainder of the Palaeozoic and into the Mesozoic, moving progressively eastwards (Veevers, 1984).

The thickest Jurassic sediment accumulations in eastern Australia occur in troughs rimming the edge of the continent - the Clarence-Moreton, Maryborough and the Papuan basins. In excess of 2km of Jurassic sediments accumulated in these basins. The Clarence-Moreton and Maryborough basins could be viewed as back arc basins behind the convergent margin (Veevers, 1984), while the Papuan Basin has been interpreted as a passive margin sequence accumulated after rifting and sea floor spreading in the Triassic (Pigram & Panggabean, 1984).

An extensive sheet of Jurassic sediments is spread across the Eromanga and adjacent basins, blanketing older intracratonic rifts, such as the Cooper Basin. The platform cover is relatively thin (a few hundred metres thick) and influenced by only minor movements on older structural features during the Jurassic, such as the Canaway Fault (Pinchin & Anfiloff, 1982). Formation of the interior sag of the Eromanga Basin is proposed to be in response to deep crustal metamorphism due to crustal heating (Middleton, 1980, Zhou, 1989).

PALAEOGEOGRAPHY

The shifting pattern of environments across Australia during the Jurassic was controlled by global climate and sea level, tectonic regime and the continent's palaeogeographic position. Australia was located in high southerly latitudes,on the eastern margin of Gondwana (Fig.2). The continent was rotated clockwise around 45 degrees relative to its present position, with the region of today's North West Shelf facing north onto the Tethyean Ocean and the Australia-Antarctic rift system aligned nearly north/south. Eastern Australia was partially enclosed from the "palaeo-Pacific" by the Lord Howe Rise, the Bunker Ridge, Queensland Plateau, New Caledonia and other possible land areas to the east of the present continent.

Though the Jurassic sediments of eastern Australia are predominantly non-marine, some marine influence is apparent to the north and east, as indicated by the paralic Helby Beds of the Carpentaria Basin; and more ambiguously further south by ironstone oolites in the Maryborough, Nambour, Surat and Clarence-Moreton basins. The southern margin deposits are entirely non-marine throughout the Jurassic as befits a location landlocked deep within Gondwana. On the southwest margin, the Perth Basin, had only a brief connection with Tethys during high sea level phases, as it was hemmed in by Greater India (Veevers, 1984). Despite a thin continental sliver (possibly Mount Victoria Land, Veevers, 1988, and Sengor, 1987) lying along the northwest margin until the Late Jurassic, the North West Shelf sediments show strong marine influence throughout the Jurassic.

Global Jurassic climates were mild, lacking or having only minor polar ice caps; and though most of southeastern Australia was south of sixty degrees south, conditions were temperate rather than frigid (Frakes, 1979), and humid rather than arid. The mild, humid climatic regime was reflected in widespread fluvio-lacustrine deposition, characterised by coal swamps. Redbed lithologies have been found in the Lower Jurassic sediments of the western margin. They include multi-coloured shales and sandstones, but unlike the Jurassic of China, no evaporites. Climatic modelling (Parrish et al., 1982) suggests that the maximum influence of the Pangaean Monsoon on Australia was in the Late Triassic to Early Jurassic, an interpretation supported by the redbed facies in this part of the sedimentary sequence. The southeast and centre of the continent were always well watered during the Jurassic. In the marine realm, there was minor carbonate deposition within a predominantly clastic sequence. There are no known examples of tropical carbonate reef or marine evaporite environments from the Australian Jurassic, though those facies characterise the period in other parts of the world. Recent drilling by ODP (Williamson et al., 1989) has intersected Rhaetian reefal facies on the Exmouth Plateau. This is more evidence to suggest that the late Triassic/early Jurassic was a time of slightly warmer conditions on the western margin in comparison to the remainder of the Jurassic.

Eustatic sea level rose gradually through the Jurassic, with distinct peaks in the Toarcian, Bajocian and Kimmeridgian (Haq et al., 1987). The impact of specific transgressions was recorded in the changing distributions of marine facies on the western margin. The record in eastern Australia is more ambiguous. Periods of marine transgression on the western margin correspond to changes from high energy, sandy fluvial regimes to lower energy, shaly fluvio-lacustrine conditions in the Eromanga Basin, that may reflect rising base levels tied to rising sea level.

Also the general sea level rise throughout the Jurassic was mirrored by a gradual extension of the depositional area on the continent, though largely of non-marine sediments.

Outcrop and well data, supplemented by some seismic information was used to construct the interpretation maps. The maps were compiled at 1:5 million. The 4000m water depth contour, the Timor Trough and approximately eight degrees south are the boundaries of the maps. Beyond these limits in the Jurassic, were other land masses bordering the Australian continent, which have not been included in the map area.

Difficulties with the data base include the lack of Jurassic outcrop, poor biostratigraphic control and the scarcity of information from some offshore areas. In almost all Australian basins the Cretaceous sequence overlaps the Jurassic. Jurassic outcrop is restricted to eroded basin margins and scattered outliers. An interpretation problem is whether these discontinuous outcrops once formed a continuous sheet of sediments or were only deposited in restricted areas. Exploration wells are the major data source , both on and offshore. Though it must be remembered that well locations are usually anomalous high points within the basin, and that few deep basin sections have been intersected. Interpretation of these areas relies on seismic data and palaeogeographic interpolation. A common difficulty with well data is the interpretation of missing section:- it can represent a time of no deposition, or there may have been sediments deposited which have since been eroded, or poor biostratigraphy may have failed to resolve a condensed sequence.

Biostratigraphic control in the Jurassic sequence is variable, dinoflagellates in the marine sediments of the North West Shelf provide the most detailed zonation. The spore-pollen zones used in the non-marine sections are much longer in duration, and for the Eromanga and surrounding basins lithostratigraphy provides a finer division of the stratigraphic column. But inherent in this approach is the problem of diachronous facies changes, where there is biostratigraphic control the facies are shown to be diachronous (see Ma Ma Creek Member, Column 17, Burger pers. comm., and Birkhead Formation, Column 8).

Over much of the Australian interior the desert flatness is relieved by mesas of sandstone, termed "Desert Sandstone" by the geological pioneers (Daintree, 1872), and now defined variously as the Longsight Sandstone, Callawa Sandstone, Gilbert River Formation and other units. This highly weathered sediment overlies Palaeozoic or older basement and is overlain in places by marine Cretaceous strata of Aptian age. The age of the sandstone is commonly recorded as late Jurassic to early Cretaceous, though little fossil material has been recovered save for some macroflora which support a general Jurassic/Cretaceous age. The poor age resolution of such a widespread unit allows some interpretative license in the latter time slices.

Table 1

Code on map	Environment	Working definition
Land environments		
LEU	unclassified	Areas with no preserved sediments of time-slice age, interpreted as land, for example the Ashmore Platform. Also areas that are largely unknown that may have Jurassic sediments, such as the Queensland Plateau.
LEE	erosional	Highland areas of sediment erosion, indicated by palaeocurrents, provenance studies, tectonic setting and the presence of igneous intrusions, for example the Arburn Arch.
LDF	depositional, fluvial	River deposits such as alluvial fans, braided and meandering channel deposits and coarser overbank sediments, and sand-dominated continental sequences with no evidence of aeolian or lacustrine deposition.
LDFL	depositional, fluvio-lacustrine	Sediments deposited in low-energy river environments such as channels, overbanks, backswamps and shallow lakes on low-gradient flood plains; typically sequences dominated by fine-grained sediments and coal, with sheet geometry.
LDFL	depositional, lacustrine	Deposits of deep, persistent lakes, usually in tectonically controlled basins. Distinguished from LDFL by thicker shales and more restricted distribution.
Coastal Environments		
CDP	paralic	Deposits of coastal or marginal-marine environments. Includes the range of environments situtated at the land/sea boundary such as lagoonal, beach, intertidal, deltaic, etc., and is recognised by a variety of depositional facies ranging from coarse cross-bedded beach sand, to sand deposited in tidal deltas, to finely laminated organic sediment deposited in lagoons and estuaries (includes deltaic and intertidal--supratidal environments).
CDIS	intertidal--supratidal	Sediments deposited in the tidal zone, indicated by the presence of finely interlaminated fine and coarse detritus, herring-bone cross-bedding, flaser bedding, evidence of periodic exposure, etc.
CDD	deltaic	Deltaic deposits indicated by isopach patterns, upward-coarsening sequences and the map pattern of adjacent environments. Cuspate or lobate form of deltas on maps in some cases follows isopach pattern.
Marine environments		
MVS	very shallow (0--20 m water depth)	Marine sediments with evidence of deposition above wave base and/or occasional emergence, e.g. oolites, cross-bedding.
MS	shallow (0--200 m water depth)	Marine sediments deposited on the continental shelf or on flanks of volcanic islands, e.g. sand, mud and limestone containing fossils that typically lived in shallow water; also includes areas along young, active spreading ridges (includes MVS).
MBA	bathyal to abyssal (> 200 m water depth)	Marine sediments with indicators of deep-water deposition, e.g. condensed sequences, turbidites, monotonous shale, and the presence of deeper-water organisms (includes abyssal environments).

There are some minor problems with Jurassic stratigraphic nomenclature that have been identified in the course of the Palaeogeographic Maps Project. They include the changes in the names of formations as they cross State borders within the Eromanga Basin. In the past the detailed stratigraphic divisions of the Surat Basin have been carried westward into the sandier Eromanga Basin beyond their practical limits. The correlation chart shows the compromise nomenclature reached in consultation with the State surveys.

The naming of offshore formations has also been a problem, with the informal use of names coined by the exploration industry outpacing the careful establishment of clearly defined formation names. The recent Memoir on the Carnarvon Basin (Hocking et al., 1987) has stabilised the stratigraphy in this area, and Mory (1988) has proposed a new system of formation names for the Bonaparte Basin. The region between the Bonaparte and Carnarvon basins - Browse Basin, Rowley and Bedout Sub-basins - is also in need of defined stratigraphic units.

New stratigraphy has been erected in the Clarence-Moreton Basin (Wells et al., in press) and palynology suggests that several of these units may be older than shown on the correlation chart (Burger pers. comm.). However part of this difference in age assignment relates to the problems discussed above between the Helby et al., (1987) zonation and other schemes.

In some areas there is no hard data on the Jurassic section. Offshore Queensland is the biggest blank on the map. No Jurassic has been intersected in wells. Seismic records indicate a thick pre-Eocene section in places (Taylor & Falvey, 1977; Pinchin & Hudspeth, 1975; Mutter & Karner, 1980; and Symonds et al., 1988), that may be Cretaceous clastics and volcanics as intersected in the Capricorn Basin. However part of the sequence may be Jurassic as facies patterns onshore suggest early Jurassic rivers flowed eastwards and deposited sediment out in the present offshore.

There is little data from the southern margin as the Jurassic is mostly beyond drillable depths. The Abrolhos Sub-basin is another area lacking well information. One well in the basin, Wittecarra 1, intersected the feather edge of a thick Jurassic sequence observed on seismic records to the west (Smith, 1987). The Jurassic history of the Naturaliste Plateau is also a mystery.

Table 1 lists the definitions of the environments used on the interpretive palaeogeography maps. Some of the problems of interpretation include the difficulty of determining "palaeo-topography". Tectonic environment and the sedimentary record in adjacent basins gives some indication of the areas of highlands in the Jurassic. Fission track analysis is a technique that may provide more detailed information on timing of uplift when more basins have been analysed. The drainage patterns on the interpretive maps are diagrammatic. The present day courses of rivers have been used where they are known to be ancient streams; for example, the Finke, whose course is superimposed on Late

Palaeozoic folds (Wells et al., 1970). In other cases the drainage pattern has been determined from palaeocurrent, provenance and isopach information. The location of drainage channels through the fluvio-lacustrine and fluvial depositional areas of the Eromanga Basin has been left largely undefined. A future refinement to the maps would be the delineation of the Eromanga fluvial system from seismic and well information, such as has been achieved for parts of the Patchawarra Trough in the Permian Cooper Basin (Stanmore & Johnstone, 1987; Taylor & Thomas, 1989).

TIME SLICE 1: Hettangian to Sinemurian (213 - 200 Ma)

The Jurassic/Triassic boundary, the base of Time Slice 1, is not marked biostratigraphically in Australia. It occurs within the A. reducta and P. crenulatus spore-pollen zones, and close to the base of the D. priscum dinoflagellate zone (Helby et al. 1987). The real disjunction in the biostratigraphy and break in the stratigraphy occurred within the Hettangian, with the change from the Falcisporities to the C. dampieri Superzones (see chart). The mid-Hettangian boundary according to Helby et al. (1987) is "usually distinct representing a substantial extinction horizon and commonly coinciding with a major regression". Sedimentation commenced or recommenced in many basins in the latter part of Time Slice 1, following this break. On the north western margin (columns 36 to 43, 52 & 55) and in some east coast basins (columns 18,19 & 20) deposition was continuous across the Jurassic/Triassic boundary, and the "mid-Hettangian break" is absent. However some hiatuses may be present that are not apparent due to poor biostratigraphic control, especially in the sparsely fossiliferous redbed facies of the Malita Formation from the Bonaparte Basin.

Jurassic Time Slice 1 was a continuation of the Triassic regime, which was typified by a high-riding continent with restricted depositional areas, little marine influence, and granitic intrusions in eastern Australia (Lorne Basin). The Jurassic 1b map, shows isolated patches of continental deposition in eastern Australia and in the Perth Basin; and a broad fringe of paralic environments on the northwestern margin, facing onto Tethys. There was igneous activity in eastern Australia and on Exmouth Plateau that produced some acid rocks, which were reminiscent of the Triassic rather than the basic suite which characterised the Jurassic extensional regime.

During the early Jurassic, in eastern Australia, fluvial networks developed over and around the irregular topography of the Palaeozoic to Triassic Tasmanides fold belt. Arkosic sandstones and conglomerates of the basal Balimbu Formation, were shed from the granitic Cape York-Oriomo Ridge into the Papuan Basin. Deposition was confined to restricted depocentres, such as the isolated lake basin interpreted at Anchor Cay 1.

To the south, fluvial sands were deposited in eastern Queensland, the Precipice Sandstone and its equivalents. Isolated outcrops have been interpreted as erosional remnants of a once continuous cover, and thus the areal extent of the fluvial system may have been more restricted than shown on Jurassic 1b. Palynological evidence (Playford & Cornelius, 1967) indicates that the quartzose Razorback Beds (outcrops on Jurassic 1a around 24 degrees south) are "J1" (Evans, 1966a) in age. The Collopy Formation (Wyatt et al., 1970), outcropping farther north around twenty degrees south, is also interpreted as an age equivalent of the Precipice Sandstone. It is undated, but like the Razorback Beds, is a cross-bedded, fluvial sandstone, around 100m thick, overlying Palaeozoic igneous rocks. Wyatt et al. (1968) suggested that the Collopy Formation resembled the Lower Triassic Warang Sandstone, however the Triassic typically occurs in grabens and overlies Permian sediments rather than the older Palaeozoic (Yeates, pers. comm.).

This extensive fluvial system was composed of high energy, fast flowing streams that traversed a landscape forested with conifers and Dicroidium (White, 1986). Plesiosaurs hunted in the quieter backwaters and cut-off lakes (Molnar, 1982). The broken topography was controlled by the underlying Tasmanides. The New England Fold Belt, the Auburn Arch and Yarraman Block were highland source areas that provided sediment to the streams and deflected their courses. Palaeocurrent measurements, and variations in sediment thicknesses and facies, indicate that the general palaeoslope was to the east. East flowing streams may have deposited earliest Jurassic sediments on the Queensland Plateau, where areas of Mesozoic sediments are interpreted from seismic records (Symonds et al., 1988).

The influence of a convergent plate regime, on the northeastern margin is recorded in the tuffs intercalated in the Mrytle Creek Sandstone in the Maryborough Basin and the Garrawilla Volcanics extruded to the southwest of the New England highland area. Farther south isolated uplifts represent areas of igneous intrusion.

An area of fluvial deposition is interpreted in the Bass Basin during Time Slice 1. Evidence for sediments of this age underlying the Cretaceous and younger sequence of the Bass Basin includes reworked palynomorphs indicative of the "J1" zone (Evans 1966a) found in the outcropping Cretaceous of the Otway Ranges (Burger, 1987). Another possible source of reworked earliest Jurassic palynomorphs is the Leigh Creek area, 1000km to the northwest. A nearby origin from erosion of tilted fault blocks observed on seismic records from the Bass Basin (Williamson et al., 1987) is preferred. The fault blocks are believed to contain a conformable sequence of Triassic and earliest Jurassic sediments, as suggested by reworked palynomorphs and Triassic outcrop either side of Bass Strait, in Tasmania and at Bacchus Marsh in Victoria (Yeates & Mullholland, in prep.).

An isolated pocket of fluvio-lacustrine sediments was deposited in the Poolowanna Trough. The clastic material was derived from highland areas of central Australia, uplifted and folded in the Late Palaeozoic Alice Springs Orogeny (Bradshaw and Evans, 1988). The depocentre was active in the Triassic, though there is a hiatus between the Upper Triassic/Early Jurassic Peera Peera Formation and the Lower Jurassic Poolowanna Formation (Moore, 1982). To the south, at Leigh Creek, Lower Jurassic fluvio-lacustrine sediments overlie Triassic coal measures (Hos, 1978). Here, deposition was restricted to a small intermontane basin within folded pre-Mesozoic rocks.

The Upper Triassic to Lower Jurassic sequence of the Perth Basin is composed of barren quartz sandstones and redbeds and as a consequence is poorly dated. An unconformity, approximating the "mid-Hettangian break" (Helby et al., 1987) is believed to separate the Triassic Lesueur Sandstone from the overlying Eneabba Member of the Cockleshell Gully Formation (Playford et al., 1976). The Eneabba Member was shed from highlands on the Yilgarn Block and accumulated in alluvial fan to flood plain environments, within a rift valley setting.

The Woodleigh Beds are a small pocket of Lower Jurassic sediments located mid-way between the major Jurassic depocentres of the Perth and Carnarvon basins. Shale, coarser clastics and minor coal were deposited in a shallow fault controlled lake basin, lying within the stable Gascoyne Platform. Palynological material indicates (Balme, 1964) that deposition occurred within a range from Time Slice 1 to 4.

Along the northwest margin, the distribution of environments followed the pattern established in the late Triassic - marine conditions on the Exmouth Plateau, a broad arc of paralic facies trending northeast/southwest and alluvial environments in the cross trending embayment of the Petrel Sub-basin. Sediments derived from the highland areas of the Pilbara and Kimberley blocks were deposited in a variety of marginal marine to marine environments. Time Slice 1 sediments intersected in the Rankin Platform area (columns 40 & 41) are the Brigadier and North Rankin formations (Crostella & Chaney, 1978; Hocking et al., 1987). The interbedded sandstones and claystones of the Brigadier Formation represents deposition in lagoonal to deltaic environments. The overlying sandier North Rankin Formation indicates barrier bar and beach facies and has been related to a mid-Hettangian regression (Crostella & Chaney, 1978).

Interpreted land areas, standing as higher ground, amid a maze of lagoons, sand bars and marshy delta lowlands, are the Hilda Arch, a string of islands along the Rankin and Ashmore platforms. This interpretation is based on Triassic/late Jurassic or early Cretaceous unconformities in these locations; and supported by secondary porosity in the Triassic Mungaroo Formation in the North Rankin gas field which indicates subaerial weathering during the Jurassic (Beston, 1986). Another land area is interpreted on the northern margin of the Exmouth Plateau where acid igneous rocks of late Triassic/early Jurassic age have been dredged (von Rad & Exon, 1982), and further land may have existed to the north which was later rifted off (Bradshaw et al., 1988).

As in the Perth Basin, the alluvial facies deposited in the more landward parts of the northwestern margin were redbeds - the Malita Formation and its equivalents (columns 43, 46, 52 & 55). Thus the western margin, during Time Slice 1 may have experienced monsoonal climates with seasonal aridity that lowered water tables and reddened sediments.

TIME SLICE 2: Pliensbachian to early Toarcian (200 - 191Ma)

The base of Time Slice 2 corresponds to the Sinemurian/Pliensbachian boundary at 200Ma (Harland et al., 1982) and the N. vallatus datum (Price et al., 1985). It is marked by a facies change in many basins and commencement of deposition in several areas. In eastern Australia, during Time Slice 2 there was a change from sand deposition to more shale prone facies, which is best exemplified by the Precipice Sandstone/Evergreen Formation succession in the Surat Basin (columns 13, 14, 15 & 21). On the northwest margin there was a facies change from marginal marine clastic sediments to shallow water limestone (columns 37, 40 & 41), and in central Australia deposition commenced in the Eromanga Basin (columns 7 & 8) at the base of Time Slice 2.

In comparison to Time Slice 1, Time Slice 2 was a phase of relatively higher sea level. There was a marine transgression across part of the northwest margin, and in the continental regime of eastern Australia there was a corresponding rise in base level that produced a change to low energy fluvio-lacustrine deposition. During Time Slice 2 a distinctive Jurassic cast to the continent developed. There was expansion and coalescence of fluvial systems, the underlying fold belt basement topography had less control on depositional patterns, and facies became increasingly marine on the northwestern margin.

In eastern Australia, the fold belt topography was partially buried by the alluvial fan and fluvial deposits of Time Slice 1. This subduing of basement relief, coupled with a relative rise in base level produced low energy fluvial systems meandering through broad flood plains, studded with shallow lakes. In the southern Papuan Basin, the basal conglomerates intersected in Anchor Cay 1 were gradually overlain by arkosic sandstones with minor shaley interbeds, as the distal ends of alluvial fans were reworked into lacustrine deltas. However, despite the lower gradients and energy of the depositional environment, the sediments remained coarse grained due to the proximity of the Cape York-Oriomo Ridge.

The fullest development of the fluvio-lacustrine regime was seen to the south, where a drainage network of Amazonian proportions threaded its way 2000km, from the central Australian highlands to the present day east coast and farther. Deposition of the Basal Jurassic Unit in the Eromanga Basin linked the Poolowanna Trough with the Surat and other east coast basins. Though some basement highs, such as the Birdsville Track Ridge and the Canaway Ridge, were overlapped by this blanket of sediment, the underlying structure still exerted an influence on depositional patterns. There was an extension of the Eromanga Basin in a narrow trough north along the Lovelle Depression and a necking of the extensive flood plain around 144 degrees east, related to the Canaway Fault and the Eulo Ridge. Other basement features such as the Auburn Arch and the New England Fold Belt remained as highlands. Rivers flowing north down the western side of the New England highland joined the Coonamble Embayment (column 16) into the giant fluvial network. The Leigh Creek area remained an isolated lake basin.

The landscape of eastern Australia was a shifting mosaic of sandy fluvial channels, coal swamps and lakes. Individual lakes that have been interpreted within the maze of water and forest were at Bodalla South oil field (Watts, 1987), the Evergreen lake occupying a large area of southeastern Queensland and a lake in the Maryborough Basin. Amphibians and reptiles such as plesiosaurs (Molnar, 1982) lived in the densely vegetated and well-watered lowlands. The Cockatoo Creek Flora (White, 1986) is representative of the forest that covered eastern Australia during Time Slice 2, and contributed to the accumulation of the Tiaro Coal Measures in the Maryborough Basin (column 20).

In the Surat Basin the clean quartz sands of the Precipice Sandstone are overlain by the muddier sediments of the Evergreen Formation, recording the change from the fast flowing rivers of Time Slice 1 to the lower energy fluvio-lacustrine regime of Time Slice 2. This stratigraphic pattern is repeated in the Maryborough Basin with the succession, Myrtle Creek Sandstone overlain by Tiaro Coal Measures; and in the Clarence-Moreton Basin by the Ripley Road Formation and the overlying Marburg Sub-group (column 18). The Marburg Sub-group has a component of volcanic detritus (Wells et al., in press) indicating the presence of a volcanic arc to the east (Korsch & Harrington, 1981). Growth of the arc during the early Jurassic may have partially dammed the drainage network and contributed to the change to a lower energy fluvio-lacustrine regime (Watts, 1987).

Other evidence of igneous activity in eastern Australia during Time Slice 2 includes the Garrawilla Volcanics (data point 197, Appendix 1) which contributed kaolinite to the sediments of the Coonamble Embayment (Dixon, 1974); the Murrumburrah Monchiquite (data point 216) and diatremes in the Sydney Basin (Mt Jellore, 211, Bong Bong, 212, Moss Vale, 215 & Dapto, 230). Sediments preserved within the diatremes are interpreted as maar deposits (Crawford et al., 1980), restricted to volcanic crater lakes and not remnants of an extensive sheet of early Jurassic sediment since removed from the Sydney Basin as suggested by Middleton & Bennett (1980) from vitrinite reflectance studies. The former view is portrayed on these maps, see Branagan (1983) for a full discussion of this controversy. The areas of igneous intrusion are annotated as uplifted highlands on the interpretation maps.

In the Perth Basin deposition of the redbed Eneabba Member of the Cockleshell Gully Formation continued and expanded in area to cover the Beagle Ridge. Deposition of a similar conglomeratic sandstone, the Greenough Sandstone (column 32) may have commenced during Time Slice 2 in the Geraldton area, though dating of the Chapman Group is only controlled by the overlying Champion Bay Group. The Woodleigh Beds continued to accumulate in an isolated lake basin on the Gascoyne Platform.

There was a marine transgression across the northwestern margin. The shoreline advanced landward of the Rankin Platform and the Cape Range area was inundated. Initially limestone was deposited over the marginal marine clastics of Time Slice 1. This transgressive deposit was then overlain by fine grained marine clastics of the Dingo Claystone. A condensed sequence, less than ten metres thick, of marls and claystone accumulated in deep water on the outer parts of the Exmouth Plateau. Sufficient sediment was derived from the highlands to the east for a delta system to prograde into the Barrow Sub-basin. The Rankin Platform was emergent as an island and there was another patch of land along the northern margin of the Exmouth Plateau where igneous activity occurred during Time Slice 2.

To the north, in the Bedout Sub-basin and the Browse Basin, the sea advanced across the outer third of the area, but inshore the broad band of paralic and deltaic deposition continued from Time Slice 1 through Time Slice 2.

TIME SLICE 3: Early to middle Toarcian (191 -189Ma)

Time Slice 3 is a narrow interval of two million years, contained within the Toarcian. On the chart its base in placed slightly above the C. torosa/C. turbatus boundary of Helby et al.(1987), within the "J2" zone of Evans (1966a). It is recognised by a distinct change in lithology and depositional environment in Surat and other eastern basins that corresponds to the incoming of Applanopsis spp. palynomorphs (Evans, 1966a). The stratigraphic record of Time Slice 3 is the development of ironstone oolite beds within the Evergreeen Formation and its equivalents (columns 14, 15, 17, 18, 19, 20, & 21).

Time Slice 3 has been selected as a "snapshot" to capture the depositional interval of the ironstone oolites in eastern Australia, but it also corresponds to the end of redbed deposition on the northwestern margin and the further advance of paralic conditions into the Bonaparte Basin. The cycle chart of Haq et al (1987) places the peak high sea level of the early Jurassic in the mid Toarcian, corresponding to the interval chosen for Time Slice 3. Ironstone oolite beds also record this high stand in Europe (Hallam, 1975).

The environment of deposition of the ironstone (chamositic) oolite facies has been variously interpreted as lacustrine (Wiltshire, 1982) lagoonal or shallow marine (Exon, 1976). At the present day chamositic ooids occur in shallow marine environments, usually under reducing conditions, such as at the base of modern deltas (Hallam, 1975). They are also forming in the shallow, brackish waters of Lake Chad (Lemoalle & Dupont, 1973) far from any connection with the sea. The Toarcian ironstone oolites from eastern Australia are associated with acritarchs, which indicate marine or at least brackish conditions (Evans, 1964), and shelly fossils interpreted as an estuarine or coastal lagoon fauna (Mollan et al. 1972). The area of oolite deposition which extends through the Maryborough, Nambour, Clarence-Moreton and Surat basins into the Eromanga Basin is depicted as a paralic environment on the Time Slice 3 interpretation map.

By Time Slice 3 the continued rise of sea level had caused the encroachment of brackish water into the lake systems of eastern Australia. In the shallow, mildly salty waters of this large lagoon chamositic ooids formed. The inflow of freshwater from the surrounding hinterland of fluvial channels, lakes and coal swamps was sufficient to prevent fully marine conditions from developing. The location of the actual shoreline was probably east of the present coast. Basement highs, such as the Auburn Arch and the Yarraman Block, which had been emergent during the earlier time slices, were drowned beneath the waters of the lagoon.

In the Coonamble Embayment of the Surat Basin (column 16) there was a change in facies from the braided stream, channel fill and flood plain sandstones, shales and coals of the Ukebung

Formation to the shales and ironstones lenses of the Digilah Formation, deposited in backswamp environments (Loughnan & Evans, 1978). This reflected the elevated base levels and mirrored the change from Time Slice 1 to 2 experienced earlier farther downstream in the fluvial network. The Talbragar fish beds, located in the eastern part of the outcrop area, preserve a microcosm of the world of Time Slice 3 in eastern Australia, fish sheltered in pools hidden in a dense forest of podocarp conifers while cicadas sang overhead (White, 1986).

Being a time slice of short duration few igneous bodies have an age falling within the narrow limits of Time Slice 3. However the Mt Jellore trachyte (data point 211) and the Tong Bong teschenite sill (data point 206), which is interpreted as an uplifted area to the south of the Coonamble Embayment, both occur within Time Slice 3.

No significant changes are recognised from Time Slice 2 to 3 in the southern Papuan Basin, central Australia or the Perth Basin. On the northwest margin the shoreline prograded out to the Rankin Platform. A broad fringe of paralic environments - sand bars, lagoons and barriers stretched from south of Cape Range to the Sahul Platform. Areas of fluvial to deltaic deposition occurred where supplies of sediment were greatest, such as along the Rough Range Fault scarp and at the mouth of the ancestral De Grey River which drained the Pilbara. Marginal marine environments advanced farther into the Browse and Bonaparte basins than in earlier time slices.

More humid climatic conditions may have coincided with the Toarcian high sea level phase of Time Slice 3. The redbed facies characteristic of the terrestrial deposits of the northwest margin in the early Jurassic ceased to be deposited, indicating high water tables throughout the year.

TIME SLICE 4: Late Toarcian to earliest Bajocian (189 - 180Ma)

Time Slice 4 occupies the nine million year interval between two short duration time slices chosen to capture high sea level episodes. It encompasses the latest Toarcian, all of the Aalenian and the earliest Bajocian. The base of Time Slice 4 is loosely defined biostratigraphically as occurring within the lower part of the C. turbatus zone (Helby et al., 1987). The stratigraphic definition of Time Slice 4 is provided by the commencement of deposition of the Hutton Sandstone in the Eromanga and Surat basins (columns 7, 8, 13, 14, 15, 16 & 21), the Algebuckina Sandstone in the Poolowanna Trough (column 9), and the Cattamarra Coal Measures in the Perth Basin (column 31). Time Slice 4 also corresponds to a major expansion of the depositional area of the Papuan Basin (columns 1 & 2).

In contrast to the generally rising sea level throughout the early Jurassic since the mid-Hettangian, Time Slice 4 was a period of lowered sea level, following a sharp regression in the early Aalenian (Haq et al., 1987). This regression is most evident in eastern Australia where there was a lowering of effective base level to the fluvial system and fast flowing braided stream deposition replaced the lower energy fluvio-lacustrine regime of Time Slices 2 and 3. A broad sand sheet spread out and overlapped the depositional edge of the shale-prone overbank, coal swamp, and lacustrine facies of the underlying Evergreen Formation and the Basal Jurassic Unit. Areas of fluvio-lacustrine environment remained in the downstream easterly parts of the drainage network, in the Maryborough Basin, where the Tiaro Coal Measures accumulated in well-watered forested lowlands. Similar pockets of shaley, coal-bearing sediments were deposited either side of the New England Highland, in the Coonamble Lobe (Purlawaugh Formation) and the Clarence-Moreton Basin, and deposition continued in the isolated lake basin at Leigh Creek.

A fall in base level reflecting a global fall in sea level is interpreted as the cause of the start of the Hutton deposition. However, other factors may have been influential such as a change in climate disturbing the vegetation cover and altering infiltration and runoff rates, and tectonic uplift in the hinterland. Whatever the cause there was a radical change from Time Slice 3 to 4 in eastern Australia, the forest cover was broken, quiet lakes were breached and stagnant coal swamps were dissected by swift streams. A shifting sheet of sand cris-crossed by braided channels stretched in a wide band across the eastern half of the continent. Wiltshire (1989) has proposed that aeolian processes were significant in the transport and deposition of sand dominated units in the Eromanga Basin.

Igneous activity continued in southeastern Australia. Dates on the Garrawilla Volcanics (data points 196 to 200), the Towallum Basalt (195), the Umbiella Creek breccia pipe (202), the Mt Stormy laccolith (205), the Tong Bong sill (206), the Mt Gibraltar microsyenite (213) and the Sutton Forest basanite (214) place them within Time Slice 4. There is good agreement between the radiometric date from the Towallum Basalt and the palynological age of the adjacent Clarence-Moreton basin sediments (Wells et al., in press). Oldest dates on the Tasmanian dolerites (Schmidt & McDougall, 1977) are of Time Slice 4 age, indicating that extension between Australia and Antarctica was commencing. A large highland area across Tasmania on the 4b map represents the zone of dolerite intrusion and uplift. Rift valley sediments along the southern margin may also date from Time Slice 4. However, only upper Jurassic sediments have been intersected in offshore wells, though there is an older section interpreted on seismic sections in down-dip locations in the Eyre Sub-basin (Bein & Taylor, 1981).

In the Perth Basin the redbed alluvial fan and floodplain facies of the Eneabba Member of the Cockleshell Gully Formation were overlain by the Cattamarra Coal Measures. The Yilgarn highland continued to supply coarse sediment, but a more humid climate supported coal swamps in the broad rift valley floor (Filatoff, 1975). A similar facies change occurred in the Chapman Group sediments (column 32) where conglomeratic redbed sandstones were overlain by felspathic sandstone. Deposition of the Woodleigh Beds continued in the isolated lake basin on the Gascoyne Platform.

The pattern of environments on the northwest margin during Time Slice 4 has been described by Bradshaw et al.(1988). "In the Exmouth Sub-basin (column 35 & 36) alluvial fans of Learmonth Formation built out from the Rough Range Fault scarp, and fell steeply into the offshore, where they interfingered with the monotonous siltstones of the Dingo Claystone. Out under the deeper waters of Exmouth Plateau, thin marls and claystones accumulated. In the lee of the Rankin Platform there was a more gradual transition to the marine regime via paralic environments. In the Bedout Sub-basin the marginal marine fringe expanded to several hundred kilometres. Westward flowing rivers deposited the Wallal Sandstone onshore (column 44) and carried sediment from the Canning Basin, Pilbara and Kimberley blocks to build an extensive deltaic crescent. Alongshore and seaward, the delta lobes passed into a complex of lagoons, interdistributary bays and sand shoals. A thin paralic zone bordered the Leveque Shelf, with marine environments in the Browse Basin. The Ashmore Platform was isolated as an emergent island separated from the uplifted Londonderry High by a shallow seaway through the Vulcan Sub-basin. Paralic environments occupied the Sahul Platform, and alluvial plain facies filled the embayments of the Bonaparte" and the Money Shoals basins.

TIME SLICE 5: Early to middle Bajocian (180 -177Ma)

Time Slice 5, like Time Slice 3, is another interval of short duration designed to capture a specific depositional episode; in this case a marine transgression in the Perth Basin. Time Slice 5 occupies three million years (180 - 177Ma) within the early and middle Bajocian (Harland et al., 1982). It is biostratigraphically defined by the D. caddaense dinoflagellate zone (Helby et al., 1987). It is the one of the rare instances in the Jurassic stratigraphy of Australia with good correlation to the international time scale. Ammonites contained within the sediments of Time Slice 5, in the Perth Basin, allow direct correlation with the European stages. The original correlation reported in Playford et al., (1976) of the S. sowerbyi ammonite zone to the middle Bajocian with reference to Arkell (1956), has been modified to early Bajocian by Cope (1980b).

Despite the marine transgression which was evident in the Perth Basin, there was little change in the pattern of environments from Time Slice 4 to Time Slice 5 in eastern Australia. The sand sheet deposition of the Hutton regime continued, with some extension of the fluvial system to the northwest and the south. In the Coonamble Lobe of the Surat Basin there was a shift from fluvio-lacustrine to high energy fluvial environments.

However, in the Papuan Basin, a rise in sea level during Time Slice 5 was recorded by a change in the Torres Strait area from fluvio-lacustrine to paralic facies. Bajocian ammonites reported from the Bol Arkose (Davies & Norvick, 1974; column 1) also indicate that the transgression was not confined to the southwest part of the continent.

The effects of the Bajocian transgression were most pronounced in the Perth Basin. The shales and limestones of the Cadda Formation (columns 31 & 33) are a wedge of marine sediments in a continental rift valley sequence. The equivalent Champion Bay Group (column 32) overlapped the edges of the basin to be deposited on the Precambrian North Hampton Block in the Geraldton area. The intricate arrangement of environments shown on map 5b is interpretative, based on isopach and facies data. Basement structure continued to control sedimentation - the rampart of the Darling Fault scarp formed the eastern shore of the marine embayment, and there was a restricted lagoon behind the Beagle Ridge island. A sand spit prograded northwards from the tip of the island and a large cuspate foreland grew from the shore in its lee. At the southern end of the rift valley estuarine and paralic environments gave way to an uninterrupted sequence of continental sediments (column 30).

Connection to the ocean was to the north and west, the sea may have flooded across the Gascoyne Platform though there is no evidence that it took this path. The Cretaceous directly overlies the Palaeozoic over most of the platform, and in the shallow lake basin that accumulated the Woodleigh Beds no Jurassic sediments younger than Time Slice 4 are preserved. A seaway farther west, beyond the present continent/ocean boundary is preferred. The invasion of the sea into the Perth Basin in Time Slice 5 was preceded by marine transgression in the Permian and Triassic. This suggests that the basin was not a totally landlocked rift valley between Australia and India as shown in some palaeogeographic reconstructions (King 1973), but rather was partially barred by fragments of "Greater India" that rifted off in the early Cretaceous (Veevers, 1984).

In comparison to the Perth Basin, the Bajocian transgression was recorded more subtly on the northwestern margin. The mosaic of marine through marginal marine to terrestrial environments was much as it was described in Time Slice 4, except for a farther invasion of paralic conditions into the Bonaparte Basin. The links to Tethys established during the transgression are revealed in the fossil content of the sediments, which show an influx of more cosmopolitan species at this time (Yeates et al., 1987).

TIME SLICE 6: Late Bajocian to early Callovian (177 - 167Ma)

Time Slice 6 is ten million years long (177 - 167Ma), encompassing the latter part of the Bajocian, all of the Bathonian and the early part of the Callovian (Harland et al. 1982). The base of Time Slice 6 is well controlled biostratigraphically. It lies between the C. turbatus/D. complex spore-pollen zone boundary (Helby et al., 1987) and the R. circolumenus datum (Price et al., 1985), and equates with the top of the D. caddaense dinoflagellate zone.

The stratigraphy of the western margin has controlled the selection of Time Slice 6. Its base coincides with the end of the Cadda transgression in the Perth Basin, and its top is the regional "Callovian Main Unconformity" (Hocking, 1988) seen in several basins on the North West Shelf. Time slice 6 is notable in eastern Australia by the commencement of deposition in the Laura and Carpentaria basins. There was no marked stratigraphic change in most Australian basins from Time Slice 5 to 6. The exception was the Perth Basin, where continental sedimentation was re-established after the retreat of the Cadda transgression.

The paralic environments established in the Torres Strait area during Time Slice 5 expanded southward into the Carpentaria Basin and perhaps into the offshore extension of the Laura Basin. With the advance of the shoreline, the basal parts of the Helby Beds were deposited across the top of Cape York Peninsula in a complex of marginal marine environments, including deltas and estuaries (Smart & Rasidi, 1979; Powell et al., 1976). Tuff beds and tuffaceous sandstones at the base of the Helby Beds (Smart & Rasidi, 1979) indicate the proximity of a volcanic source somewhere to the east at the convergent plate boundary (Veevers, 1984).

Deposition was initiated in the Laura Basin (DeKeyser & Lucas, 1968) - rivers spilled out of small montane lakes and flowed north, gradually building up flood plain deposits that prograded across older paralic facies (Hardy, 1970). Sediment was derived from the Coen Block and the ring of highlands to the south that define the semi-circle of the basin margin (Smart et al., 1980).

Hutton sand sheet deposition continued in the Eromanga and Surat basins, with some expansion of the depositional area northwards. Fluvio-lacustrine conditions persisted in the most easterly parts of the drainage network, in the Maryborough Basin. In contrast to the blanket of quartz sand spread across the interior basins; thicker pockets of sediment, including lithic and felspathic sandstones and tuffs, accumulated in the Clarence Moreton Basin, reflecting the proximity of volcanic sources in the New England Highland (Garrawilla Volcanics, Dulhunty, 1967, 1973; Bean, 1974; McDougall & Wellman, 1976) and the input of volcanic material from the east (Veevers, 1984). Towards the end of Time Slice 6 there was a westward encroachment of lithic sands (Eurombah Formation) and more shale prone facies (Birkhead

Formation) into the Hutton depositional area (Exon, 1976).

Deposition continued in the isolated lake basin at Leigh Creek during Time Slice 6. There was also significant igneous activity throughout eastern Australia. The broad geographic compositional zonation, ranging from acid rocks in Queensland (Mt Esk Rhyolite, West, 1975) through alkaline basic rocks in New South Wales (Garrawilla Volcanics, Dulhunty, 1967; Sydney Basin, Facer & Carr, 1979;) to basic rocks in the south (dolerite intrusions in Tasmania, Ferguson, 1980; Wisanger Basalt in South Australia, Daily et. al., 1975; data point 229) reflects a plate tectonic setting of convergence on the northeast margin and extension along the southern margin. There are also a number of igneous bodies with kimberlitic affinity which have dates falling within Time Slice 6 (Delegate, McDougall & Wellman, 1976; Terowie, Walloway and Euralia, Ferguson, 1980, Ferguson et al., 1979; data points 219, 233, 231 & 232).

The change from Time Slice 5 to 6 was most marked in the Perth Basin, where the complex mosaic of marine and paralic environments produced by the Cadda transgression was replaced by a terrestrial rift valley regime of alluvial fans and high energy fluvial systems. Wedges of coarse sediment were shed from the Yilgarn Block as movement occurred along the Darling Fault. In some places over a thousand metres of Yarragadee Formation accumulated during Time Slice 6 (Filatoff, 1975).

Along the northwestern margin the pattern of environments established in earlier time slices persisted. The fluvial facies of the Canning Basin passed westwards into a band of paralic and deltaic environments trending northwesterly along the entire length of the margin. Variations to this simple regional picture occurred where there was a relative rise in sea level from Time Slice 5 to 6. The Rankin Platform was almost isolated as an island as marine environments were established in the subsiding Dampier Sub-basin. Similar structural control determined the shape of the marine embayment in the Bonaparte Basin.

TIME SLICE 7: Mid Callovian to earliest Oxfordian (167 - 162Ma)

Time Slice 7 covers five million years (167 - 162Ma) from the mid-Callovian to the earliest Oxfordian (Harland et al. 1982). The base of Time Slice 7 is well defined by both spore-pollen and dinoflagellate zonations. It equates with the coincident bases of the M. florida and W. digitata zones (Helby et al. 1987). The top of time slice 7 however, is only defined by the dinoflagellate zonation, the base of the W. spectabilis zone (Helby et al. 1987).

Time Slice 7 has been chosen to capture the environmental distribution on the North West Shelf during an episode of uplift and erosion, prior to the commencement of sea floor spreading. The reasonably short duration of this time slice approximately brackets the so called "break-up unconformity" (Falvey, 1974) as seen in columns 37, 39, 41, and 43 through to 52. In the eastern Australian context, the boundary between Time Slice 6 and 7 roughly equates with an important transition, from sandy Hutton deposition to a lower energy, shale prone Birkhead/Walloon fluvio-lacustrine regime.

By Time Slice 7 deposition in the Carpentaria Basin had been extended southwards into the gulf. Sandstones were deposited in basement lows by streams flowing north into the coastal lowlands across Cape York (Burgess, 1984; Smart & Senior, 1980; Powell et al., 1976). Shallow lakes and flood plains lay within a ring of hills in the Laura Basin area.

Across hundreds of thousands of square kilometres of eastern Australia stretched a vast wet lowland of sluggish meandering streams, shallow lakes and coal swamps. This regime is mapped as a broad area of fluvio-lacustrine deposition, though an area of more precisely defined lacustrine environment has been recognised around the Bodalla field (Watts, 1987). The change from Hutton Sandstone to Birkhead Formation and Walloon Coal Measures (Exon, 1976; Senior et al., 1978) was not only a change in facies, but also in composition with the introduction of a significant volcanic contribution. There was an expansion westward of the volcanic component that was already well represented in the easterly basins (Watts, 1987).

At its northern margins, this vast fluvio-lacustrine system graded into an area of higher energy fluvial deposition (Longsight Sandstone, Blantyre Formation and Ronlow Beds - Senior et al., 1978) that linked one of the major upland source areas to the lowland swamps and lakes. Coal measure deposition continued in the Maryborough Basin and became more widely established in the Clarence Moreton Basin, as high water tables enhanced the preservation of fallen vegetation beneath the Walloon forests of Kauri pine (Agathis sp.) interspersed with podocarp conifers and tree like cycadophytes (Pentoxylon australica), (White, 1986). However, deposition ceased in the isolated Leigh Creek coal basin.

Various mechanisms have been proposed for this partly diachronous but relatively rapid reversal of the depositional regime over a vast area. Exon & Burger, (1981) have associated the transition with a rise in sea level, and thus base level, causing aggradation and ponding of the Hutton fluvial system and a shift to a lower energy depositional regime. A more recent proposal (Watts, 1987) suggests that growth of the eastern volcanic arc resulted in damming of the fluvial system and the observed input of lithic material. This model predicts that drainage patterns during Birkhead deposition may have trended to the west and northwest across the Eromanga, reversing the earlier easterly directed fluvial system. An alternative view (Wiltshire, 1989) maintains that drainage was largely internal throughout the Jurassic history of the Eromanga Basin.

Fewer igneous rocks date within Time Slice 7 than Time Slice 6, which was twice as long, but a similar pattern of activity occurred; - dolerites in Tasmania, kimberlitic rocks in South Australia (Terowie, data point 233) and basic to intermediate rocks in New South Wales (Cooma Syenite, McDougall & Wellman, 1976; Wollar Sill, Dulhunty, 1976; data points 218 & 203).

The oldest Jurassic sediments as yet intersected on the southern margin are of Time Slice 7 age from Jerboa 1 in the Eyre Sub-basin. Fluvial sands were deposited over crystalline basement in a subsidiary valley of the rift between Australia and Antarctica (Bein & Taylor, 1981).

In the Perth Basin, Yarragadee deposition continued with the development of more diverse facies within the rift fill sequence. Coarse alluvial fan and channel sediments were interbedded with siltstones, shales and coals that accumulated in shallow lakes and floodplain environments. A central area of coastal lowlands is interpreted along the western edge of the basin.

Time Slice 7 on the North West Shelf was characterised by tectonic and igneous activity. In the Dampier and Barrow Sub-basins depositional relief was increased by fault movements (Veenstra, 1985). Marine troughs were deepened and expanded at the expense of paralic environments and other areas were uplifted and became partially emergent. Turbidite fans spilled down off these high blocks into the troughs introducing sands into the predominantly fine grained basin sediments (Biggada sandstone Member, Hocking et al. 1987). In the Browse Basin and on the Scott Plateau there was widespread extrusion of basalt, in some cases subaerially and in others subsea (Von Rad & Exon, 1982; Stagg & Exon, 1981; Veevers & Cotterill, 1978;). To the north in the Bonaparte Basin, the sea flooded into the subsiding Vulcan Sub-basin, isolating the Ashmore Platform as an island; and invaded farther down into the trough of the Petrel Sub-basin.

The commencement of seafloor spreading in the Argo Abyssal Plain has been accepted as the cause of Callovian tectonism on the North West Shelf. Current information (Shipboard Party Site 261, 1974) indicates that the oldest sea floor in the Argo Abyssal Plain is Callovian in age, neatly coinciding with the regional unconformity in Time Slice 7. However recent ODP drilling (Leg 123 Shipboard Party, 1989) may result in a revision of the age of the sea floor to early Cretaceous. In this case the Callovian tectonism would be a prelude to eventual breakup and new seafloor creation 20 million years later.

Regardless of the timing of actual breakup, the question remains as to what landmass was rifted off. A thin continental sliver of similar size, shape and stratigraphy to the Seringapatam Rise and the Ashmore Platform has been suggested as a candidate (Bradshaw et al. 1988). Veevers (1988) suggested that the "Argo Landmass" rifted off, without indicating its present whereabouts. Audley-Charles (1989) suggested that present day South Tibet and Burma (as well as Malaysia and Sumatra) rifted off from the North West Shelf in the Late Jurassic.

TIME SLICE 8: Early Oxfordian to Kimmeridgian (162 - 150Ma)

At twelve million years long Time Slice 8 is one of the longest time slices in the Jurassic. It covers most of the Oxfordian and all of the Kimmeridgian (Harland et al. 1982). The base of the time slice is the base of the W. spectablis dinoflagellate zone and the top corresponds to major zonation boundaries in both the dinoflagellate and spore-pollen schemes of Helby et al. (1987).

Time Slice 8 encompasses the time of maximum transgression in the Jurassic. The top boundary coincides with an unconformity on the North West Shelf, the Papuan and Laura basins. It also coincides with a facies change in many other basins.

The pattern of depositional environments in northeastern Australia remained much the same as in the previous time slice. In the latter part of Time Slice 8, there was some contraction in the area of paralic environments as fluvial deposits of the Garraway Beds were deposited on Cape York.

The fluvio-lacustrine environments of the Birkhead and Walloon formations still held sway over most of eastern Australia, though there was an expansion of fluvial environments at the western (Algebuckina Sandstone - Wopfner, 1969; Wopfner et al., 1970;) and southeastern (Pilliga Sandstone - Exon, 1976) fringes. Towards the end of Time Slice 8, the Springbok Sandstone was deposited by meandering streams in the Surat Basin (Exon, 1976). The Birkhead, Walloon and Springbok formations all show the input of volcanic material derived from an arc of probable andesitic composition located somewhere to the east (Veevers, 1984).

In this study the correlations of Price et al. (1985) are followed, such that the Springbok and Adori sandstones are not exact age equivalents. The Adori Sandstone in the Eromanga Basin is considered to be slightly younger than the Springbok Sandstone of the Surat Basin (see columns 13, 14 & 15). Though Adori Sandstone deposition probably commenced in Time Slice 8, on the palaeogeographic maps it is illustrated as a depositional episode confined to Time Slice 9.

Characteristic basic to intermediate igneous activity continued in the southeast quadrant. There are basic sills, basalt flows and other igneous bodies of Time Slice 8 age in New South Wales, Victoria and Tasmania (Douglas & Ferguson, 1976; McDougall & Wellman, 1976).

A significant feature of Time Slice 8 is the recognition of the onset of deposition along the southern margin. Sediments of this age have been intersected in half a dozen wells from the western Otway Basin (Robertson 1), the Polda Trough (Harris, 1964; Gatehouse & Cooper, 1982) and the Eyre Sub-basin (Bein & Taylor, 1981). Deposition occurred in a series of fault bounded valleys along the general Australian/Antarctic rift zone, within the interior of Gondwana. A generalised area of fluvio-lacustrine environments is interpreted as occupying the rift zone, with well information (Jerboa 1) indicating that a lake filled part of the Eyre Sub-basin. The facies intersected in wells are predominantly carbonaceous shales indicative of a low energy, low sediment input, humid regime within the rift at this stage in its history (Powell & Bradshaw, 1987).

The facies distribution in the Perth Basin remained similar to that for the earlier time slice. There was development of an area of lower energy, fine grained fluvio-lacustrine deposition between the Harvey Ridge and the Darling Fault.

A reshaping of the pattern of environments took place on the north western margin from Time Slice 7 to 8. The sea transgressed significantly across the present-day coastline into the Canning Basin, where shallow water sediments of the Alexander Formation and Jarlemai Siltstone were deposited with a fringe of fluvial sand (Barbwire and Meda Sandstones - Gorter et al., 1979; Yeates et al., 1984, see Column 44) to the east . Seaward, deep marine environments extended into the fault-controlled troughs of the Barrow-Dampier Sub-basin, the Vulcan Sub-basin and the Malita Graben and Sahul Syncline. Rising seas submerged some areas that were uplifted in Time Slice 7, though the Rankin and Ashmore platforms remained high, and an area in the Browse Basin was emergent owing to uplift related to igneous activity (Barter et al., 1984).

Sedimentological features indicative of the suite of facies associated with elevated sea level (Loutit et al., 1988) include phosphate in the Jarlemai Siltstone (column 44, Yeates et al., 1984), condensed intervals in offshore areas (see column 43,) and accumulation of organic matter in the restricted, deep water troughs (Powell & Bradshaw, 1987). Time slice 8 corresponds to a phase of eustatic high sea level, with a peak in the Kimmeridgian (Haq et al., 1987). There is a component of tectonic subsidence as shown by fault displacements (Veenstra, 1985) perhaps due to the developing ocean in the Argo Abyssal Plain. During Time Slice 8 the Wandagee Kimberlite was intruded in the Carnarvon Basin (Hocking et al., 1987).

TIME SLICE 9: Early Tithonian (150 - 147.5Ma)

Time Slice 9 covers an interval of only 2 to 3 million years, from 150Ma to approximately 147.5Ma in the Early Tithonian (Harland et al., 1982). It is defined biostratigraphically by the C. perforans and O. montgomeryi dinoflagellate zones and is within the lower part of the R. watherooensis spore-pollen zone (Helby et al. 1987).

The base of the time slice is well marked in northern Australia by a regional unconformity observed in the Papuan and Bonaparte basins (see columns 1, 2, 51 to 57). The occurrence of the dinoflagellate, Omati montgomeryi, is generally restricted to a few locations in the deeper parts of basins, e.g. in Madeleine 1 (data point 303). Time Slice 9 was a phase of relative regression on the North West Shelf that corresponded to a shift in the Eromanga Basin from low energy Birkhead deposition to the higher energy sandsheet regime of the Adori Sandstone (see columns 7 & 8, Senior et al., 1978).

In the Papuan Basin, Toro Sandstone deposition commenced as sea level rose following a sharp regression after the peak in the Kimmeridgian (Burns & Bein, 1980). A broad floodplain and delta system prograded to the east and north, with sediments partly derived from the Oriomo High (Skwarko et al., 1983). In the Laura Basin, sketchy palynological data (Evans, 1966b) indicates that the Dalrymple Sandstone was overlain, sometimes unconformably (Smart & Rasidi, 1979; DeKeyser & Lucas, 1968), by the Battle Camp and Gilbert River formations. There was little change in the pattern of depositional environments though the Gilbert River and Battle Camp formations had a more marginal marine aspect than the strictly terrestrial Dalrymple Sandstone (Burgess, 1984,; DeKeyser & Lucas, 1968). There was expansion of the area of fluvial deposition in the Carpentaria Basin across Cape York Peninsula (Garraway Beds, column 5, Smart & Senior, 1980).

Time Slice 9 in the central Eromanga Basin was characterised by the deposition of the Adori Sandstone, a thin sand sheet spread across the shales, siltstones and lithic sands of the Birkhead Formation. In the southwest there was further expansion of the area of deposition of the Algebuckina Sandstone. Conglomeratic beds indicate that alluvial fans mantled the edges of highland source areas in the Gawler Block (Moore, 1982).

The Adori Sandstone has been interpreted as a fluvial deposit (Senior et al., 1978), indicative of a reversion to a higher energy regime similar to the Hutton depositional cycle in Time Slices 4 to 6. The well vegetated floodplains, quite backwaters, swamps and lakes of Time Slice 8 were destabilised and replaced by a shifting sheet of sand, spread widely by migrating braided channels. Though another interpretation (Wiltshire, 1989) suggests that the Hutton Sandstone and the Adori Sandstone are lake deposits. The sand sheet is interpreted as having been dispersed across the basin by wind generated currents and waves; and in some instances having been windblown sediments redistributed across the dry lake floor.

The apparently synchronous change from Hutton Sandstone to Birkhead Formation deposition during Time Slice 6 has been attributed to several causes (see Time Slice 7), and the reversion back to sand sheet deposition (the Adori Sandstone) is perhaps even more perplexing. Some form of long period cyclic change in sea level (Exon & Burger, 1981) and/or climate is a potential forcing mechanism causing the alternation of high energy sandy facies with low energy shale prone facies. The base of the Adori Sandstone as determined by the Helby et al., (1987) scheme, correlates with a significant eustatic regression (Haq et al., 1987).

Clean quartz sands (Pilliga and Kangaroo Creek sandstones) carried by braided streams accumulated in the Coonamble Embayment of the Surat Basin (Exon, 1976) and in the Clarence Moreton Basin (Wells et al., in prep.). While in the lowlands of the central Surat Basin the siltstones, lithic sandstones and tuffs of the Westbourne Formation were deposited by meandering streams and in backswamp environments (Exon, 1976). There are no preserved sediments of Time Slice 9 age in the Mulgildie Basin or Maryborough Basin.

Being a time slice of short duration, few dates from igneous rocks fall within Time Slice 9. The exceptions are the Noosa Head quartz diorite (Evernden & Richards, 1962; data point 194) and the Bendigo Monchiquite (McDougall & Wellman, 1976; data point 223).

Along the southern margin the pattern of fluvio-lacustrine environments occupying the rift zone altered little from the earlier time slice. There are no preserved sediments of Time Slice 9 age within the Polda Trough but deposition is interpreted to have continued along this part of the margin. Sediments were removed later, sometime prior to deposition of the overlying Tertiary sequence.

In the Perth Basin there was also little change from Time Slice 8 to 9, the regression which was evident on the North West Shelf and perhaps influenced deposition in the Eromanga Basin had no obvious impact in the terrestrial rift environments of the southern and southwestern margins.

From Time Slice 8 to 9 regression occurred on the northwestern margin. It is most dramatically seen by the retreat of the sea from the Canning Basin. Broad zones of paralic environments (Broome Sandstone - Yeates et al., 1984) fringed the new shoreline now displaced over 300km to the west. At the northern end of this coastal plain a small delta is interpreted as having built out into the Browse Basin. The fingers of deep marine environments that characterised the offshore zone in Time Slice 8 were less pronounced by Time Slice 9 due to sediment in-filling of the structural troughs and falling sea level. They had been largely obliterated in the Bonaparte Basin, but the Barrow-

Dampier Sub-basin remained as a deep water embayment tucked in behind the Rankin Platform (Kopsen & McGann, 1985). Turbidite fans spilled into the embayment, producing a sandy top (Dupuy Sandstone, Column 39) to the Dingo Claystone (Tait, 1985).

Following the highest stand of eustatic sea level of the Jurassic in the late Kimmeridgian, the Haq et al. (1987) chart shows a sudden fall in the early Tithonian. The contrasting palaeogeography of the equivalent Time Slices 8 and 9 shows a similar pattern across the North West Shelf, with retreat of the shoreline, erosion and unconformity and "low stand" (Van Wagoner et al., 1988) features such as turbidite fans (Kopsen & McGann, 1985).

TIME SLICE 10: Late Tithonian (147.5 - 144Ma)

Time Slice 10 is the final Jurassic time slice, covering a short time interval in the latter half of the Tithonian (147.5 to 144 Ma, Harland et al., 1982). The base of Time Slice 10 corresponds to the base of the D. jurassicum dinoflagellate zone. The top of the time slice is the Jurassic/Cretaceous boundary which lies within the narrow P. iehiensis dinoflagellate zone, and coincides with the R. watherooensis/ C. australiensis boundary in the Helby et al. (1987) spore-pollen zonation.

The first appearance of C. australiensis pollen has been used as a pragmatic biostratigraphic definition of the base of the Cretaceous in Australia since the concept was introduced by Evans (1966a). This definition is followed by Helby et al. (1987) and used in this study, however other palynologists believe that the range of C. australiensis can be extended into the Kimmeridgian (Dettmann & Playford, 1969; Burger, 1989).

Time Slice 10 corresponds to a transgressive phase following the regression of Time Slice 9. The palaeogeography of Time Slice 10 shows an expansion of the fluvial network in eastern Australia and marine transgression in northern Australia. The Jurassic/Cretaceous boundary has little stratigraphic definition. Most units trail across it and the natural break in the stratigraphy is higher up within the Cretaceous, in the Valanginian, corresponding to a major regression on the Haq et al. (1987) chart.

Marine influences persisted in the paralic environments of the northern Carpentaria Basin and the adjacent parts of the Papuan Basin. In the southern Carpentaria Basin there was a significant expansion of the area of fluvial deposition to link with the northern Eromanga Basin and the Laura Basin. This interpretation is based on placing the poorly dated Loth Formation (Smart & Senior, 1980) within Time Slice 10 based on log correlation with the Westbourne Formation and attributing outcrops annotated as "JKg" on the Queensland Geology map (Day et al., 1983) in part to the latest Jurassic.

The specific arrangement of drainage within this broad area of fluvial deposition is speculative. A drainage divide may have persisted between the Carpentaria and Eromanga basins, with drainage being directed northward in the Carpentaria Basin and perhaps internal in the Eromanga Basin into the Westbourne Formation lake system. The fluvio-lacustrine environments of the Laura Basin suggest that drainage may have also been centripetal, before turning to flow north.

Coinciding with the transgression on the northwest margin there was a shift in depositional regime in the Eromanga Basin during Time Slice 10. The high energy sandsheet deposits of the Adori Sandstone were replaced by the lithic sandstones, silts, clays and coaly sediments of the Westbourne Formation. Fluvio-lacustrine environments were once again established in the central and eastern Eromanga Basin and in the Surat Basin. Meandering streams, swampy flood plains and scattered shallow lakes occurred in a pattern of environments similar to those in which the Birkhead Formation had been deposited during Time Slices 7 and 8, though their extent was more limited. The western and southern Eromanga remained a region of sand dominated fluvial deposition.

Once again the cause of the change in depositional environment could be attributed to either a eustatic rise in base level or to a damming of the drainage system by increasing volcanic activity on the eastern margin, or a combination of both factors. The Westbourne Formation does have a significant component of volcanic material, especially in the Surat Basin where bentonitic tuff beds occur within the section (Exon, 1976). An easterly source for the volcanic material is supported by the occurrence of the Noosa Heads hornblende porphyrite (Evernden & Richards, 1962) within Time Slice 10, one of the few igneous rocks to date within its narrow limits.

The rapid cycle of regression and transgression recorded in Time Slices 9 and 10 on the North West Shelf and mirrored by facies changes in eastern and central Australia, had no discernible impact in the terrestrial rift valley system along the southern margin. The environmental pattern remained constant from Time Slice 8 to 10, as far as the limited well data allows interpretation.

In the Perth Basin there was an increase in marine influence. A variety of paralic and deltaic environments is interpreted seaward of the present shoreline, while fluvial environments occupied the valley floor along the base of the Darling Fault scarp. On the correlation chart, based on Helby et al. (1987), the top of Time Slice 10 represents the top of the Yarragadee Formation, however Backhouse (1988) suggests that the overlying Otowiri member of the Parmelia Formation (column 31) is in fact late Tithonian in age. If this age scheme were followed the Perth Basin in Time Slice 10 would look little different to that shown, as the Otowiri was deposited in paralic to lacustrine environments.

The palaeogeography of Time Slice 10 on the North West Shelf presents a more simple picture than the convoluted mosaic of environments seen in previous time slices. Broad, straight facies belts were aligned along the northeast/southwest structural trend of the Westralian Superbasin (Bradshaw et al., 1988) from paralic through shallow marine to deep marine in the northwest. The deep marine troughs established in Time Slice 8 have been obliterated beneath the sandy deposits of the Dupuy Sandstone and Angel Formation (Hocking et al., 1987). A small segment of the Rankin Platform and the Ashmore and Sahul platforms remained emergent and the De Grey Nose projected out to break the northeasterly trend of the shoreline.

In the Canning Basin an extensive fluvial system flowed northwest, feeding into the broad tidal flats of the Broome

Sandstone. The distribution of the fluvial system is based on the occurrence of the Callawa Sandstone, a poorly dated sandstone that probably extends into the latest Jurassic (Yeates et al., 1984).

From Time Slice 9 to 10 in the Bonaparte Basin the shoreline shifted landward and the depositional area expanded as sedimentation was resumed over the unconformity seen in columns 51, 52, 53, 55, 56, & 57. Shales (Frigate Formation and undifferentiated Flamingo Group, formerly Petrel "B", - Mory, 1988) were deposited in the basinal areas and their sandy equivalents, including the Tinganoo Bay Beds on the Bathurst Terrace (Burger, 1978), accumulated under paralic to fluvial environments on the basin margins.

Time Slice 10 is a prelude to the Cretaceous. The sea is lapping at the edges of the Carpentaria Basin, prior to its Aptian invasion into the heart of the continent. Australia has commenced its separation from Gondwana:- fully marine conditions have been established on the northwest margin, to be followed by sea floor spreading along the western, southern and southeastern margins in the Cretaceous. Australia is on its way to becoming the island continent.

JURASSIC MINERAL & ENERGY RESOURCES

The Jurassic is a key interval in controlling the distribution of hydrocarbons in Australia. Many producing oil and gas fields in the Eromanga, Surat (Passmore, 1989), Carnarvon, and Bonaparte basins (Bradshaw et al., 1988, Passmore, 1989 & Lavering & Ozimic, 1989) have Jurassic reservoirs and/or source rocks. In the Browse Basin gas fields that are currently undeveloped have Jurassic reservoirs (Bradshaw et al., 1988, Passmore, 1989), there have been significant oil shows in the Jurassic sediments of the Perth Basin and the Jurassic sequence along the southern margin may be prospective for hydrocarbons (Powell & Bradshaw, 1987). In many cases a close association is revealed between environment of deposition and petroleum distribution, which then permits predictions to be made about the occurrence of new resources.

The Jurassic palaeogeography of the Eromanga and Surat basins was a shifting mosaic of fluvial channels, coal swamps and lakes that has controlled the distribution of reservoir, seal and source facies. Fluvial channel sands provide the best reservoirs and the carbonaceous shales of fluvio-lacustrine and lacustrine facies act as seals, and as source rocks in areas with suitable thermal maturation. The patchy distribution of these shales allows hydrocarbons to escape from the major reservoirs up the section into poorer quality sands.

The oil produced from the Eromanga Basin is from stacked reservoirs of Jurassic to Early Cretaceous age (Passmore, 1989). The Hutton Sandstone is the major reservoir in the basin and is supplemented by other Jurassic units:- the Poolowanna Formation or "Basal Jurassic", the Birkhead Formation, the Adori Sandstone and the Westbourne Formation. The hydrocarbon occurrences cluster over the Permian Cooper Basin with some Adori shows being further north. The Poolowanna accumulation is located in the Poolowanna Trough well to the west of the Cooper-Eromanga fairway.

The fluvial channel facies of the Hutton Sandstone provides the best reservoir characteristics (commonly up to 20% porosity and 1 darcy permeability - Passmore, 1989). The fluvio-lacustrine Birkhead and basal Jurassic formations are source rocks though much of the oil in the Eromanga Basin is currently believed to have been derived from the underlying Permian of the Cooper Basin (Jenkins, 1989). Intraformational seals are provided by shales within the Birkhead and Westbourne formations.

In the adjacent Surat Basin gas and oil are produced from the channel sands of the Precipice Sandstone and sands within the lacustrine Evergreen Formation. The source of the hydrocarbons is the underlying Permian and Triassic sequence of the Bowen Basin (Thomas et al., 1982; Philp & Gilbert, 1986).

Other onshore occurrences of hydrocarbons in non-marine Jurassic sediments include oil and gas shows from the Cockleshell

Gully Formation in the Perth Basin. There is a reported oil show in the Eneabba Member. But most hydrocarbon occurrences have been in the younger member of the formation, the Cattamarra Coal Measures, these include oil in Mt Horner No.7 and gas in Gin Gin No. 1 . Offshore in the Abrolhos Sub-basin Houtman No.1 had gas shows over the same interval. The rift valley sediments of the Perth Basin had initial high porosities but these have been decreased by diagenetic alteration of feldspars derived from the nearby Yilgarn highland. Consideration of the palaeogeographic maps suggests that improved reservoir characteristics may occur further north where sands were partly derived from the erosion of the Palaeozoic Tumblagooda Sandstone.

There is limited information about the petroleum potential of the Jurassic sequence along the southern margin but many lines of evidence point to the existence of source rocks. Seismic sections from the Eyre Sub-basin (Bein & Taylor, 1981) show thick wedges of Jurassic sediments in fault-controlled half-grabens. Only a handful of wells penetrate the Jurassic in the 3000km extent of the ancient rift valley system, but where intersected it consists predominantly of dark carbonaceous clays and lignites deposited in lacustrine and fluvio-lacustrine environments.

As discussed above, similar facies are proven source rocks in the Eromanga Basin showing that the Jurassic climate and vegetation was suitable for the formation of continental oil-prone source rocks (Powell & Bradshaw, 1987). However, along the rift valley system of the southern margin it is expected that lakes would be deeper and more persistent and capable of accumulating greater thickness of source rocks, than the shifting lakes of the Eromanga floodplain (Powell & Bradshaw, 1987). The composition of offshore oil seeps in South Australia in the Otway Basin are consistent with a lacustrine source facies in the area (McKirdy & Horvath, 1976). Certainly there are candidates for Lower Cretaceous source rocks in the Otway Basin (Struckmeyer, 1988) but generally there was less chance of dilution of organic matter during the Jurassic than in the Cretaceous, when there was increased tectonic activity and the influx of large volumes of volcanic detritus into the Otway Basin.

Seasonal freezing and overturn of lakes causing oxygenation of bottom waters and disruption of the optimum conditions for accumulation of organic matter would have been a minor risk during the mild climatic regime of the Jurassic. Figure 2 shows that during the Jurassic, the Australia-Antarctica rift was aligned nearly north-south indicating that the present-day western end of the southern margin would have been in warmer latitudes and perhaps thus have an enhanced source potential. Only further drilling can prove up the potential of the Jurassic as an oil source rock along the southern margin.

The North West Shelf is Australia's second major hydrocarbon province, and probably in the future its main petroleum source, and the Jurassic sequence is the key to the petroleum potential of this region (Bradshaw et al., 1988). The combination of tectonically controlled depressions and elevated sea levels in the Late Jurassic produced a favourable palaeogeographic configuration for the accumulation of source rocks on the North West Shelf. Organic rich sediments deposited in these restricted deep marine environments are the source of the major hydrocarbon accumulations, whether they are reservoired in Triassic, Jurassic or Cretaceous rocks.

Jurassic sediments in the Barrow-Dampier Sub-basin are the major source for the Rankin Platform gas contained in Triassic Mungaroo Formation sands and the oil in Cretaceous reservoirs at Barrow Island and other nearby, smaller fields (Alexander et al., 1980). To the north, equivalent Late Jurassic source rocks in the Vulcan Sub-basin are believed to have sourced the oil in the Jabiru, Challis, Skua and Puffin discoveries (MacDaniel, 1988). Using the correlation established between palaeoenvironment and petroleum potential other deep water troughs such as the Sahul Syncline and Malita Graben may also have Late Jurassic source rocks as suggested by the gas discoveries in Sunrise 1 and Troubadour 1, and the oil show in Flamingo 1.

The largest known hydrocarbon fields on the North West Shelf are in the Triassic and Cretaceous reservoirs rather than in the more shale prone Jurassic sequence. However there are a number of significant accumulations in sandy facies at the base, top and in the middle of the Jurassic, at the "break-up unconformity".

Porous sandstones deposited in fluvial to deltaic and strandline environments during the Lower and Middle Jurassic contain gas in the Browse Basin (Scott Reef 1 and 2A, Brecknock 1, Brewster 1A and North Scott Reef 1; Barter et al., 1982) and on the Rankin Platform (North Rankin 4); and oil in the Vulcan Sub-basin, including the major producing oil field at Jabiru (MacDaniel, 1988), the Skua discovery and shows in East Swan 1, Dillon Shoals and Avocet (Lavering & Ozimic, 1989).

In the Barrow-Dampier Sub-basin hydrocarbons occur in the Biggada Formation (Barrow Deep 1 and Bambra 1) which is a sandy turbidite facies within the Dingo Claystone (see correlation chart, column 39) related to erosion on the Callovian unconformity (Hocking et al., 1987, Woodside Offshore Petroleum, 1988).

Hydrocarbon accumulations in Upper Jurassic sands include oil in the Tithonian turbidites of the Dupuy Formation (the Barrow Island field) and in the coeval Angel Formation (Hocking et al., 1987) in the Egret and Legendre accumulations and possibly at Talisman 1 (Forrest & Horstman, 1986) and Wanaea 1. Gas occurs in the Angel field in the Dampier Sub-basin and at Sunrise 1 and Troubadore 1 on the Sahul Platform (Forrest & Horstman, 1986). There is also a significant oil leg in Upper Jurassic sands of the Jabiru field and an oil show in the same age sands in Eclipse 1 also in the Bonaparte Basin (Lavering & Ozimic, 1989).

In comparison to the wealth of petroleum resources described above, Australia's Jurassic sequences are less well endowed with mineral deposits. Significant metallic ore occurrences are more common in the Precambrian, Palaeozoic and Triassic rocks partly due to more active tectonics related to convergent regimes and the associated volcanism and plutonism. Most of Australia's major coal deposits are Permian in age, while Cretaceous and Cainozoic sediments host major manganese and bauxite deposits. However, there are Jurassic age deposits of gold, diamonds, bentonite and coal.

The widespread fluvial systems of the Jurassic in eastern and central Australia provided many opportunities for gold to be reworked from Palaeozoic and older crystalline rocks into alluvial sediments. Several placer deposits of Jurassic age have been found but none are actively worked at present. De Keyser and Lucas (1968) report deep leads in basal conglomerates of the Dalrymple Sandstone at the southern edge of the Laura Basin derived from late Palaeozoic granites of the Hodgkinson Basin. Auriferous conglomerate is also found within the Algebuckina Sandstone in the Peake and Denison Ranges area in the southwestern Eromanga Basin (Wopfner et al., 1970).

Several of the numerous Jurassic igneous intrusions throughout southeastern Australia have kimberlitic affinities, though Ferguson (1980) states that it is unlikely that any will be found to be diamondiferous due to shallow depths of formation (60-70km). The exception is the Eurelia kimberlite in South Australia (Column 24, Data Point 231) which has a composition suggestive of a depth of formation in excess of 125km (Ferguson, 1980). Diamonds were recovered from samples of Eurelia kimberlite by Scott-Smith et al. (1984). However there are some other occurrences that may also have a Jurassic source, though the unambiguous evidence of diamonds found within the kimberlite matrix is absent. It is possible that diamonds in Tertiary gravels in the Mittagong area may have been derived from Sydney Basin diatremes and the Umbiella Creek breccia pipe (Data Point 202, Column 23) is postulated to be the source of diamonds found in early Tertiary gravels at Mt Airly west of Sydney (MacNevin, 1977).

Bentonite and Fullers earth are other resources derived from Jurassic igneous activity in eastern Australia. Holmes (1983) reports a bentonite deposit of possible ceramic clay quality associated with the Cooma Syenite (Data Point 219, Column 23). Fullers earth from a thin clay horizon, probably originally a tuff, within the Pilliga Sandstone (Column 16) near Dubbo has been mined intermittently since 1941 (Holmes, 1983).

Inspection of the correlation chart shows that coal measures are common in the Jurassic of eastern Australia, however the major coal production is from Permian age sediments. The Walloon Coal Measures of the Clarence-Moreton Basin are mined in Queensland. The West Moreton District, as termed by the Queensland Coal Board (1989), produced 2.3 million tonnes of coal in 1987-88, that is 3.5% of the total production for Queensland in that period. Reserves are also identified in the Surat, Mulgildie and Laura basins (Queensland Coal Board, 1989).

DISCUSSION

The palaeogeographic history of Australia during the Jurassic presented here shows the controlling influence of a predominantly extensional tectonic regime, mild humid climate and cycles of sea level change. In turn, the pattern of environments has determined the location of key resources, in particular petroleum source rocks.

In the global context, Jurassic sediments are prolific producers of petroleum, second only to Cretaceous age reservoirs. Reasons proposed for enhanced petroleum occurrence in Jurassic and Cretaceous strata include the effects of continental fragmentation and the occurrence of wide shallow warm transgressive epicontinental seas (Green, 1985). In the Australian Jurassic these factors have also been influential. Graben features formed in response to the break up of Gondwana have provided the locus for source rock deposition on the North West Shelf and along the southern margin. The sea level high of the Kimmeridgian has been implicated in creating conditions for the accumulation of organic rich sediments on the North West Shelf, in the North Sea and along the Atlantic margin of Canada (Powell & Bradshaw, 1987). The Jurassic history of the Eromanga and Surat basins shows the response of non-marine depositional systems to these changes in base level.

The maps presented here are a starting point for further study of the Jurassic in Australia. As more information is gathered it is expected to see the face of the maps change, especially in offshore Queensland and along the southern margin. There will be an increasing need for the delineation of the pattern of past environments as some areas reach a more mature phase of petroleum exploration and stratigraphic traps become important targets. Detailed Jurassic palaeogeographic maps of fluvial networks across the Eromanga Basin or of shelf morphology on the northwest margin, pin-pointing the location of turbidite fans, will be key exploration tools in the future.

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APPENDIX I

IGNEOUS ROCKS

The following table lists the occurrences of dated igneous rocks of Jurassic age in Australia. It includes occurrences which are not mentioned in the list of data points and shows rock type and radiometric age in addition to location and bibliographic references.

Location:

placename, general geographic location as well as latitude and longitude are shown. Where seconds are not shown, latitude and longitude have been estimated from maps and figures.

Radiometric ages:

All ages are K-Ar unless shown otherwise.
Ages based on pre-1979 decay constants (shown in brackets where applicable) were adjusted to new constants using the list provided in Harland & others (1982).
Symbols:

- *A Depicts an average age derived from a number of ages given in the relevant reference.
- *P Represents a preferred age from a number of ages given in the reference.
- *O Represents an age which may reflect later overprinting.
- *S Represents an age which disagrees with the rock's stratigraphic position.

References:

as a rule only one or at the most two representative references are given.

Rock type:

only a very general description is presented.

Some additional igneous rocks which are likely to be Jurassic in age, but which have not been radiometrically dated:

* Igneous rocks intercepted in wells (age is based on stratigraphic position):
  - Yardie East 1 (Data point 280) in the Carnarvon Basin (dolerite), (Tomlin et al., 1983).
  - Lombardino 1 (Data point 354) in the Browse Basin (basic to intermediate volcanics), (Allen et al., 1982).
  - Scott Reef 1 (Data point 357) in the Browse Basin (basic volcanics), (Allen et al., 1982, Stagg & Exon, 1981).
  - Buffon 1 (Data point 358) in the Browse Basin (basic to intermediate volcanics).
  - Yampie 1 (Data point 356) in the Browse Basin (intermediate volcanics, olivine basalt), (Allen et al., 1982).
  - DSDP 261 (Data point 352) western edge of Scott Plateau (basalts), (Allen et al., 1982).
  - Ashmore Reef 1 (Data point 366) on the Ashmore Platform (basalt), (Allen et al., 1982).
  - Robertson 1 (Data point 226) in the Otway Basin (trachyte).

* A breccia pipe at Ruby Hill in NSW is believed to be of similar age as the Umbiella Creek breccia pipe (Lovering & White, 1964).
* Kimberlitic sills at Port Augusta are believed to be of similar age as the other kimberlitic occurrences in South Australia (Ferguson and Sheraton, 1979).

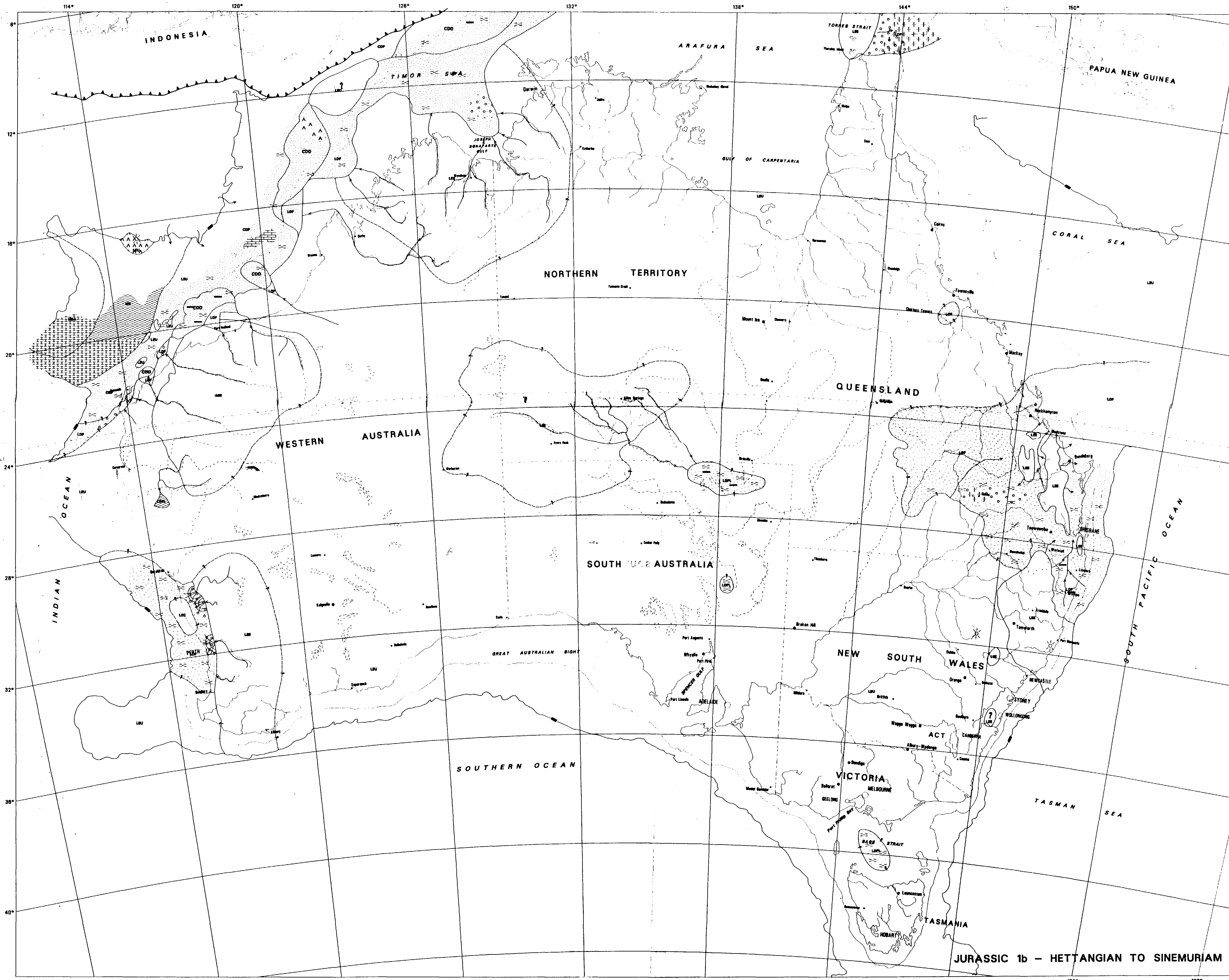
DATA PT.NO.	NAME/LOCATION	GENERAL AREA	LATITUDE (S)	LONGITUDE (E)	REFERENCE/AGE (10^6yrs)
194	NOOSA HEAD (hornblende porphyrite)	S.E. QUEENSLAND	26°23′	153°06′	EVERNDEN & RICHARDS, 1962 145 (142) ± 3
195	TOWALLUM BASALT	CLARENCE-MORETON	30°04′	152°53′	FLINT ET AL., 1976 187 (183) ± 5
196	BORAH CREEK (alkali basalt)	GARRAWILLA VOLCS.	31°02′00"	149°32′30"	DULHUNTY & McDOUGALL, 1966 185 (181) ± 5
197	MULLALLY (alkali basalt)	"	31°07′	149°44′	DULHUNTY & McDOUGALL, 1966 197 (193) ± 10
198	ULAMAMBRI (alkali basalt)	"	31°19′	149°21′	DULHUNTY, 1972 176 (172)
199	ULINDA CREEK (alkali basalt)	"	31°35′	149°22′	DULHUNTY, 1972 202 (197)
200	DANDALOO (alkali basalt)	"	31°36′	149°21′	DULHUNTY, 1972 206 (202)
201	MIDDLE BROTHER INTRUSION (microgranodiorite)	LORNE BASIN	31°41′30" 31°42′24" 31°42′24"	152°43′00" 152°40′48" 152°40′48"	McDOUGALL & WELLMAN, 1976 194 (190) ± 2 191 (187) ± 2 209 (205) ± 3 THOMPSON, 1974 198 (194) ± 6 *O
202	UMBIELLA CREEK (massive nephelinite)	EASTERN NSW	33°00′	150°24′	LOVERING & WHITE, 1964 ~ 180
203	WOLLAR SILL (microsyenite)	"	32°21′	149°58′	DULHUNTY, 1976 167 (163) ± 6
205	MOUNT STORMY LACCOLITH (phonolite)	"	32°33′	150°03′	DULHUNTY, 1976 183 (179) ± 7

DATA PT.NO.	NAME/LOCATION	GENERAL AREA	LATITUDE (S)	LONGITUDE (E)	REFERENCE/AGE (10^6yrs)
206	TONG BONG MOUNTAIN SILL (teschenite)	E. NSW	32°42′	149°54′	DULHUNTY, 1976 189 (195) ± 8
			32°43′24"	149°55′36"	EMBLETON ET AL., 1985 181 ± 2
207	DRY CREEK INTRUSION (teschenite)	"	32°24′	150°10′	DULHUNTY, 1976 202 (198) ± 8
-	PINNACLE MT LACCOLITH (phonolite)	"	32°36′	149°59′	DULHUNTY, 1976 182 (178) ± 7
-	DAIRY MT FLOW (phonolite)	"	32°48′	150°08′	DULHUNTY, 1976 203 (199) ± 7
208	PROSPECT HILL (dolerite)	SYDNEY BASIN	34°35′	150°25′	EVERNDEN & RICHARDS,1962 172 (168)
209	MOUNT MISERY (trachyte)	"	34°27′36"	150°19′18"	McDOUGALL & WELLMAN,1976 175 (171) ± 10
210	MOUNT GINGENBULLEN (quartz dolerite)	"	34°32′06"	150°19′12"	McDOUGALL & WELLMAN,1976 176 (172) ± 4 *A
211	MOUNT JELLORE (quartz riebeckite, trachyte)	"	34°22′06"	150°22′18"	McDOUGALL & WELLMAN, 1976 192 (188) ± 3 191(187) ± 3,
230	DAPTO (latite)	"	34°29′	150°54′	EVERNDEN & RICHARDS, 1962 193 (189) *S
212	BONG BONG (basalt)	"	34°41′54"	150°47′42"	CARR & FACER, 1980 190 ± 8
213	MOUNT GIBRALTAR (microsyenite) (tholeiitic dolerite)	"	34°37′42"	150°24′12"	EVERNDEN & RICHARDS, 1962 182 (178) McDOUGALL & WELLMAN, 1976 201 (197) ± 5
214	SUTTON FORREST (basanite dolerite)	"	34°34′54"	150°17′48"	McDOUGALL & WELLMAN, 1976 188 (184) ± 5 CARR & FACER, 1980 202 ± 8

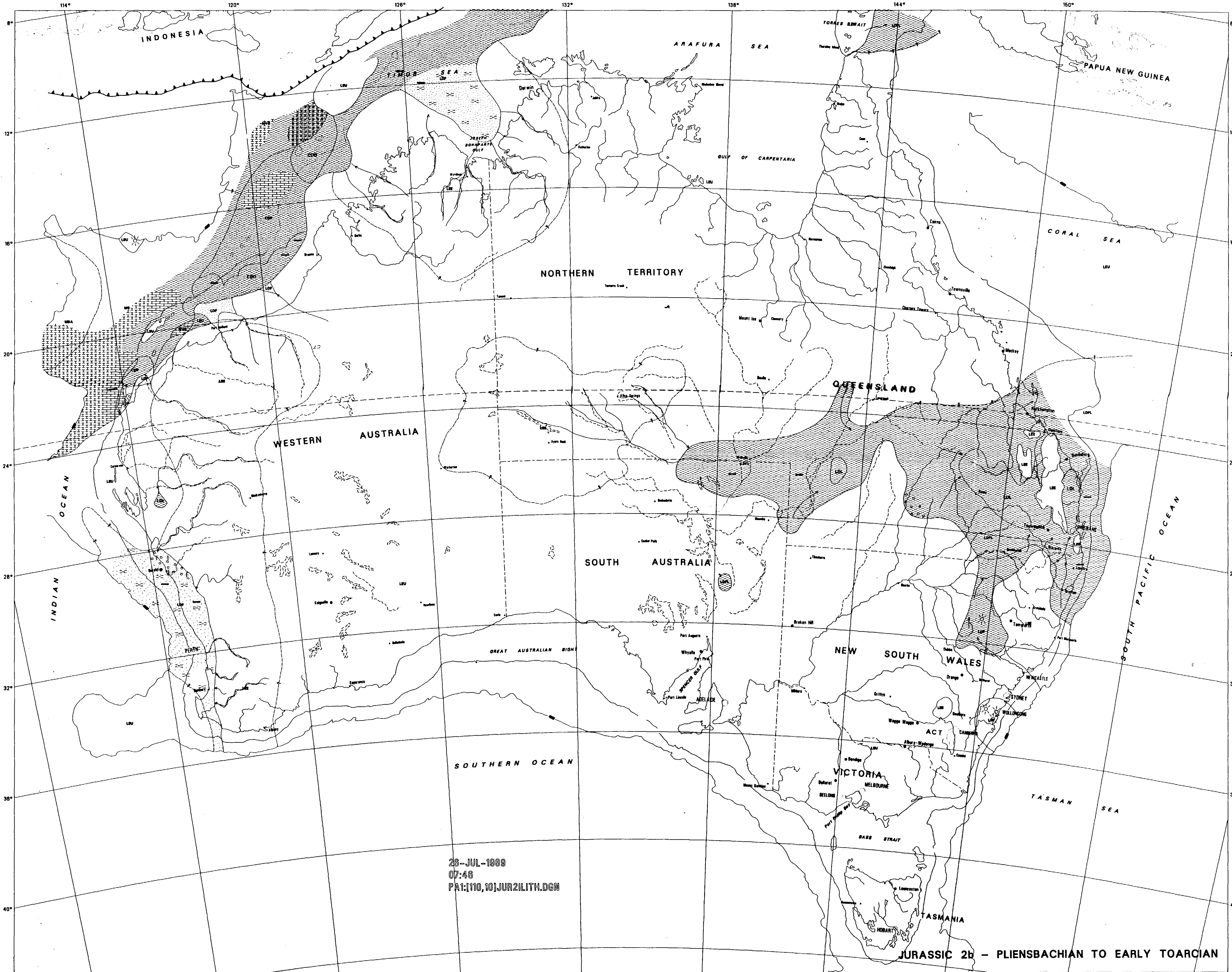
DATA PT.NO.	NAME/LOCATION	GENERAL AREA	LATITUDE (S)	LONGITUDE (E)	REFERENCE/AGE (10^6yrs)
215	MOSS VALE (tholeiitic dolertie)	SYDNEY BASIN	$34^o33'30"$	$150^o23'48"$	McDOUGALL & WELLMAN, 1976 198 (194) ± 9
-	NORTH BONDI (basalt)	"	$33^o53'30"$	$151^o16'54"$	EMBLETON et al., 1985 151 ± 3
-	HIGH RANGE (basalt)	"	$34^o07'18"$	$150^o36'12"$	EMBLETON et al., 1985 152 ± 3
-	GLENORIE (basalt)	"	$33^o37'12"$	$151^o00'54"$	EMBLETON et al., 1985 168 ± 2
-	BARRENJOEY HEAD (basalt) (nephelinite)	"	$33^o34'48"$	$151^o20'00"$	EMBLETON et al., 1985 171 ± 3 173 ± 3
-	KIAMA (dyke with xenoliths)	"	$34^o39'06"$	$151^o51'36"$	EMBLETON et al., 1985 200 ± 3
216	MURRUMBURRAH (leucite monchiquite)	EASTERN NSW	$24^o35'$	$148^o20'$	WELLMAN, 1970 198 (194) ± 3 WELLMAN, 1983 199
217	EUCUMBENE (basaltic dyke)	S.E. NSW	$36^o03'$	$148^o32'$	McDOUGALL & WELLMAN, 1976 172 (168) ± 7
218	COOMA (syenite, quartz monzonite)	"	$36^o18'$	$149^o08'$	McDOUGALL & WELLMAN, 1976 167 (163) ± 6 *A WILLIAMS et al., 1982 172 ± 4 *A
219	DELEGATE (breccia Pipe)	"	$36^o54'$	$148^o46'$	LOVERING & RICHARDS,1964 171 (167) *P, *A

DATA PT.NO.	NAME/LOCATION	GENERAL AREA	LATITUDE (S)	LONGITUDE (E)	REFERENCE/AGE (10^6yrs)
220	BENAMBRA (quartz syenite) (quartz monzonite)	VICTORIA	36°51'	147°50'	McDOUGALL & WELLMAN, 1976 211 (207) ± 4 *A
221	GALLOWS HILL, TOOMBULLUP (nepheline phonolite)	"	36°55'00"	146°10'42"	McDOUGALL & WELLMAN, 1976 156 (153) ± 20
222	MOORABOOL RIVER, MELBOURNE (volcanic plug)	MELBOURNE	37°51'07"	144°07'40"	McKENZIE et al., 1984 167 ± 4
223	BENDIGO (monchiquite)	VICTORIA	36°47'12" 36°47'42"	144°16'18" 144°15'42"	McDOUGALL & WELLMAN, 1976 149 (146) ± 4 158 (155) ± 4
224	HARROW (?hawaiite)	OTWAY BASIN	37°12'54"	141°30'00"	McDOUGALL & WELLMAN, 1976 195 (191) ± 10
225	CASTERTON 1 (basalt)	"	37°36'54"	141°20'06"	HARDING, 1969 156 (153) ± 5
227	COLERAINE (trachyte)	"	37°35'40"	141°41'00"	BOWEN, 1975 166 (163) ± 3
229	WISANGER BASALT	KANGAROO ISLAND	35°39'18"	137°38'42"	McDOUGALL & WELLMAN, 1971 173 (169) ± 6 *A

DATA PT.NO.	NAME/LOCATION	GENERAL AREA	LATITUDE (S)	LONGITUDE (E)	REFERENCE/AGE (10^6yrs)
231	EURALIA (Kimberlite)	STH. AUST.	32°37′	138°33′	SCOTT-SMITH et al., 1984 170 (Pb-U)
232	WALLOWAY (Kimberlite)	"	32°37′	138°35′	STRAKE et al., 1979 172 (Rb-Sr) 173 ± 4 (K-Ar)
233	TEROWIE (Kimberlite)	"	33°15′	139°00′	STRAKE et al., 1979 164 to 174 (Rb-Sr)
-	TASMANIA (dolerites)	Widespread throughout central and eastern Tasmania			SCHMIDT & McDOUGALL, 1977 175 (171) ± 8 *A
-	WANDAGEE (kimberlitic intrusions)	WESTERN AUST.	25°50"	114°25′	HOCKING et al., 1988 160 ± 10
-	EXMOUTH PLATEAU (trachyte, alk.rhyolite)	"	16°33′24"	115°14′18"	VON STACKELBERG et al.,1980 192 ± 4
331	BARLEE 1	"	17°48′25"	122°42′40"	VEEVERS & EVANS, 1975 200 (196)



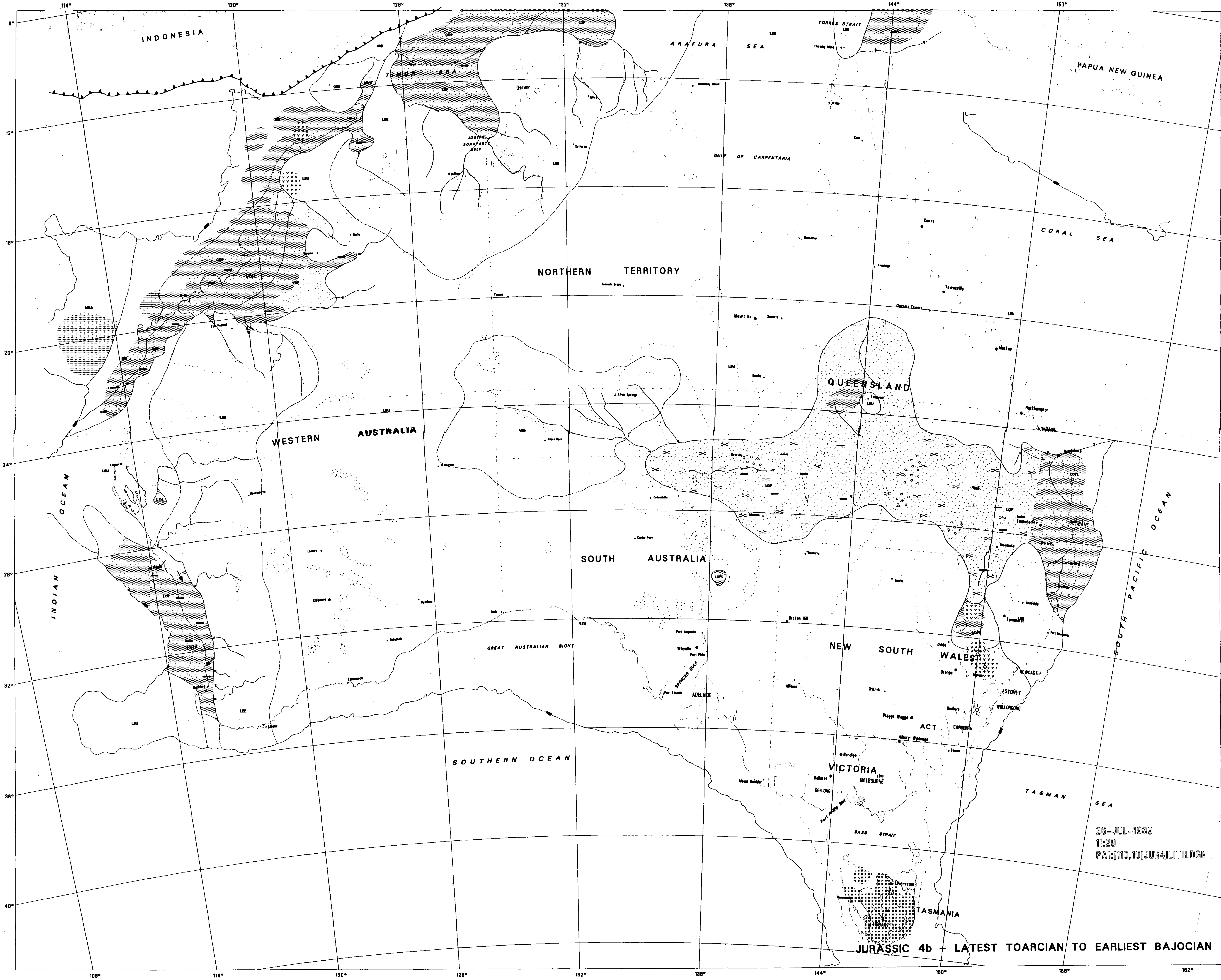
JURASSIC 1b – HETTANGIAN TO SINEMURIAM



JURASSIC 2b - PLIENSBACHIAN TO EARLY TOARCIAN

R9007617

JURASSIC 3b – LATE TOARCIAN



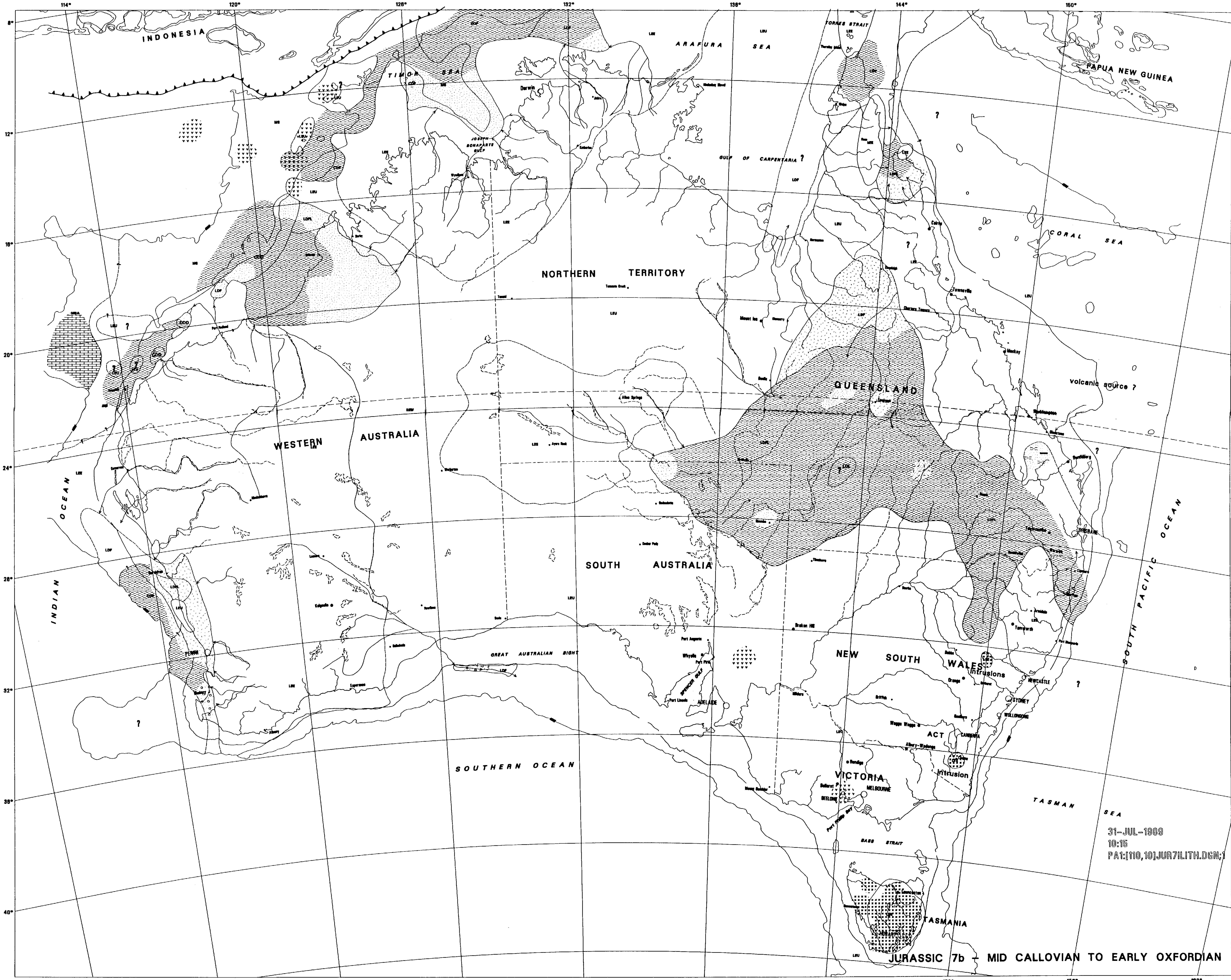
JURASSIC 4b - LATEST TOARCIAN TO EARLIEST BAJOCIAN

R9007615

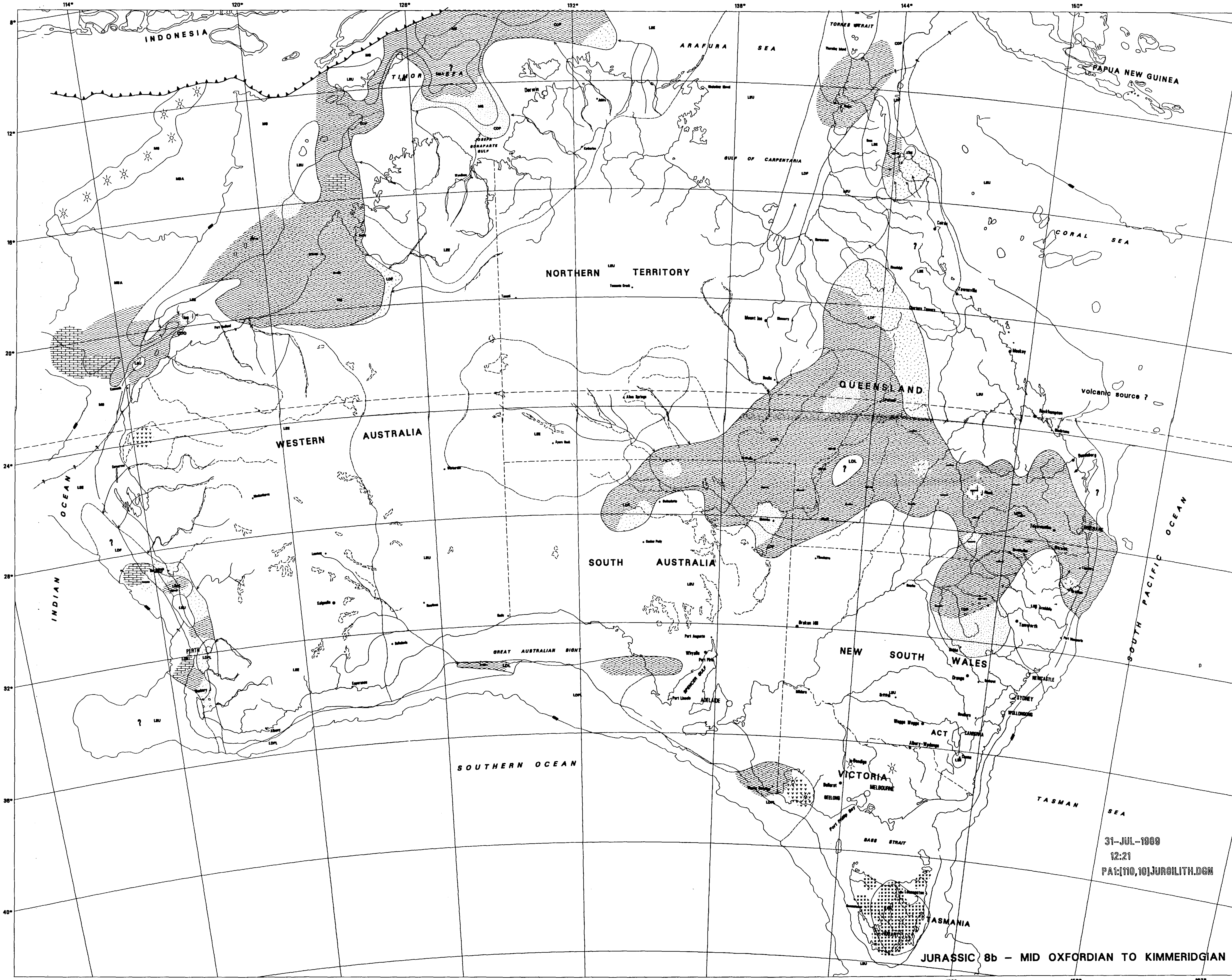
JURASSIC 5b – EARLY BAJOCIAN

JURASSIC 6b - LATE BAJOCIAN TO EARLY CALLOVIAN

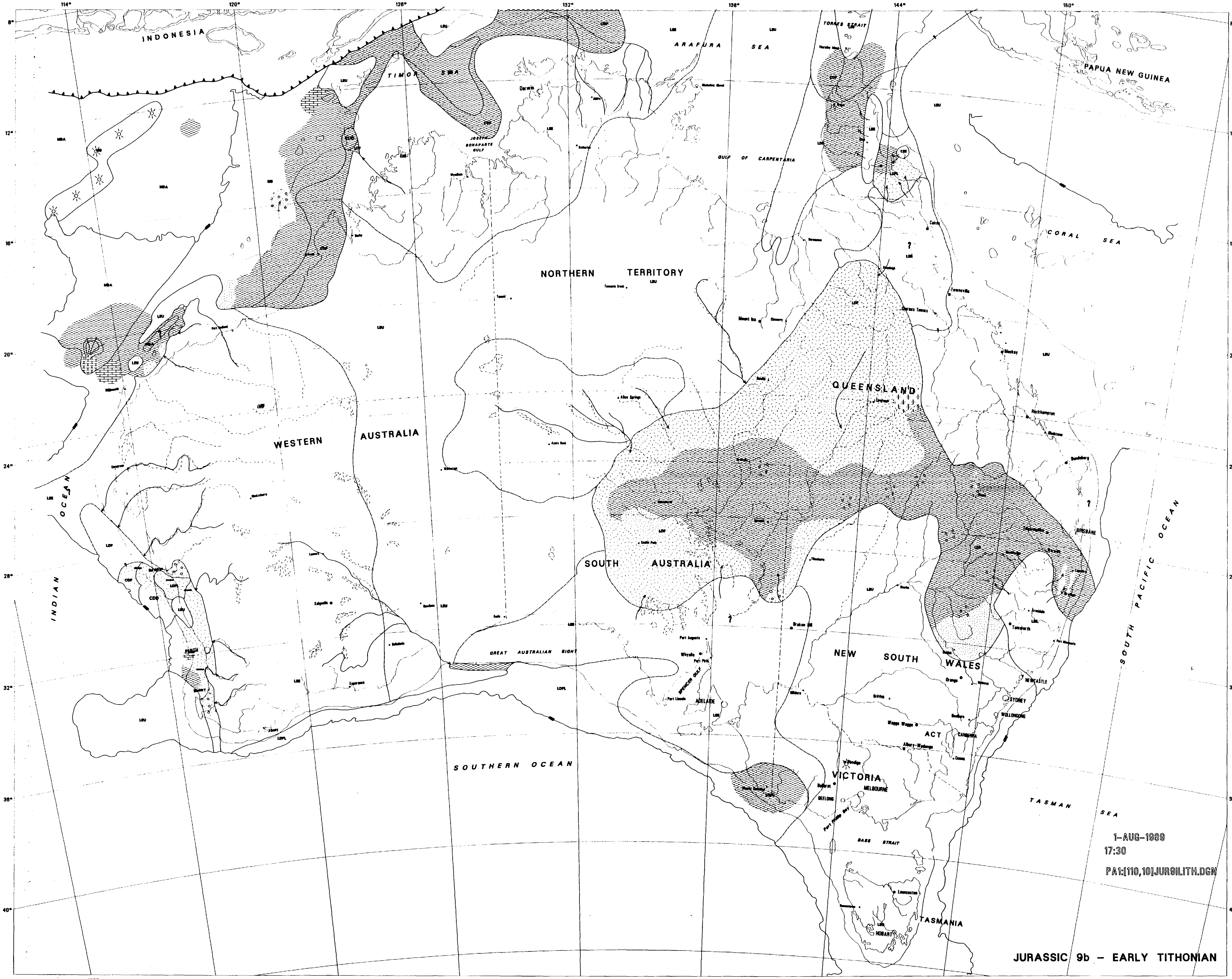
R9007613



JURASSIC 7b - MID CALLOVIAN TO EARLY OXFORDIAN



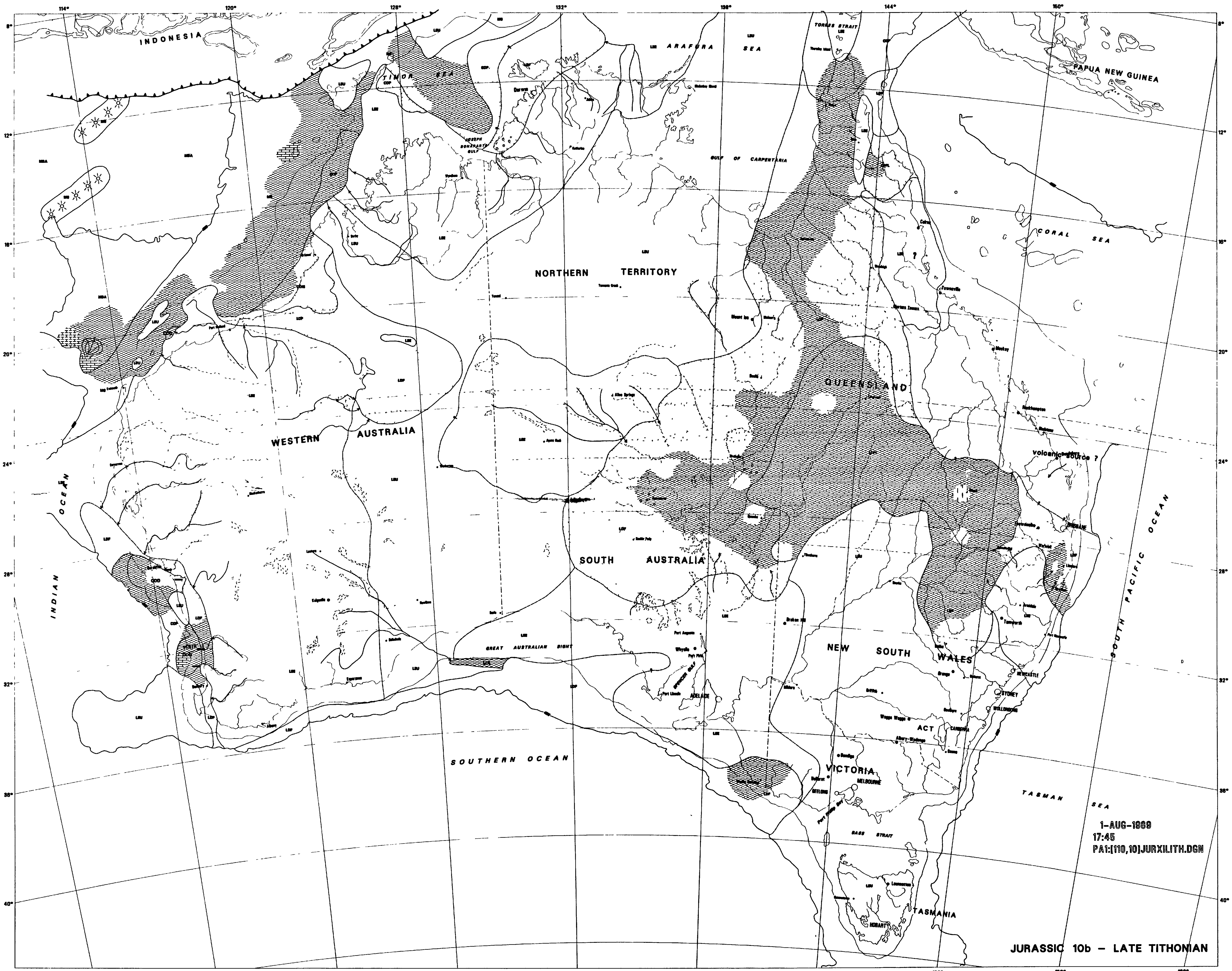
JURASSIC 8b – MID OXFORDIAN TO KIMMERIDGIAN

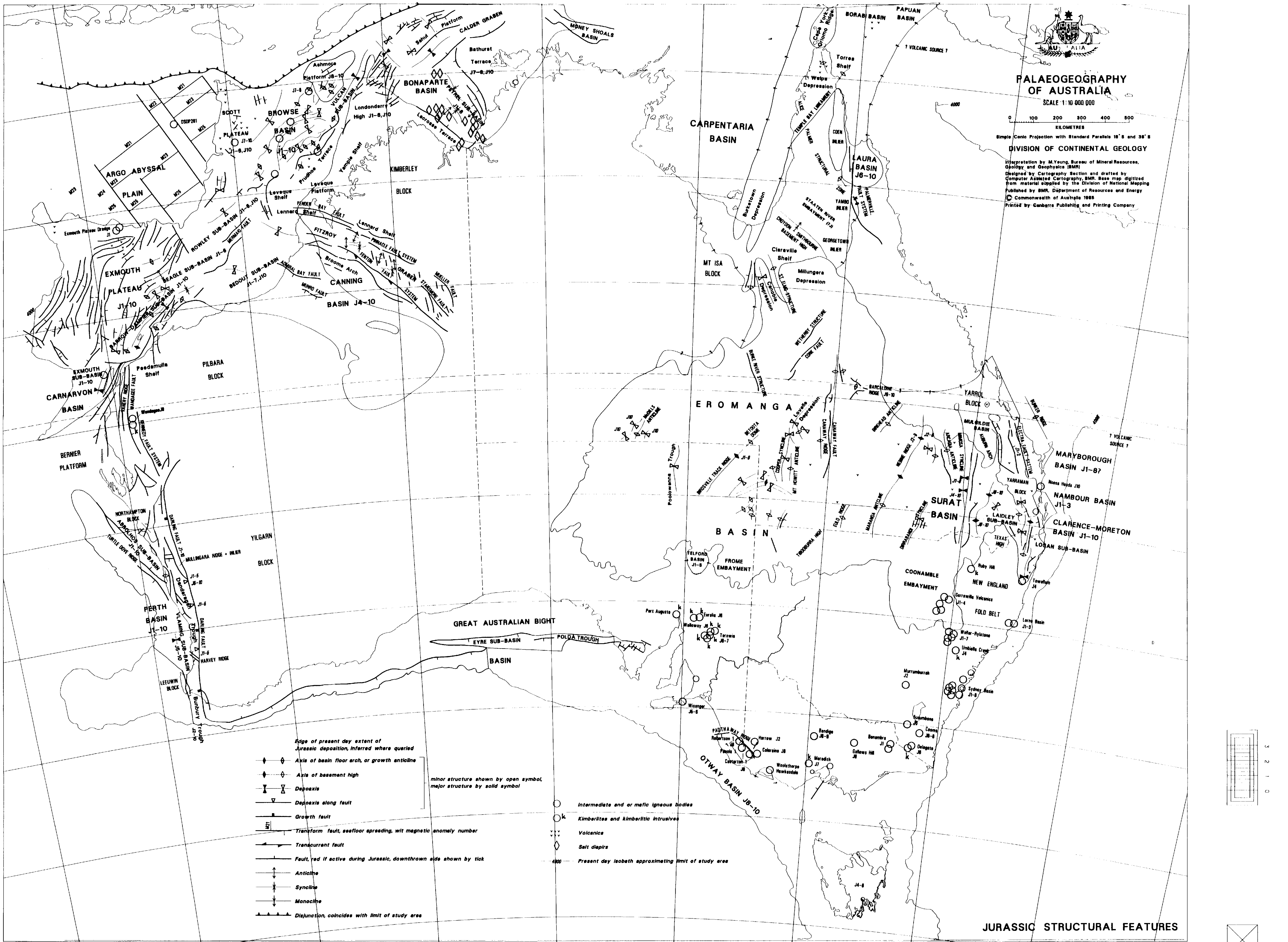


JURASSIC 9b - EARLY TITHONIAN

1-AUG-1989
17:30
PA1:[110,10]JUR9ILITH.DGN

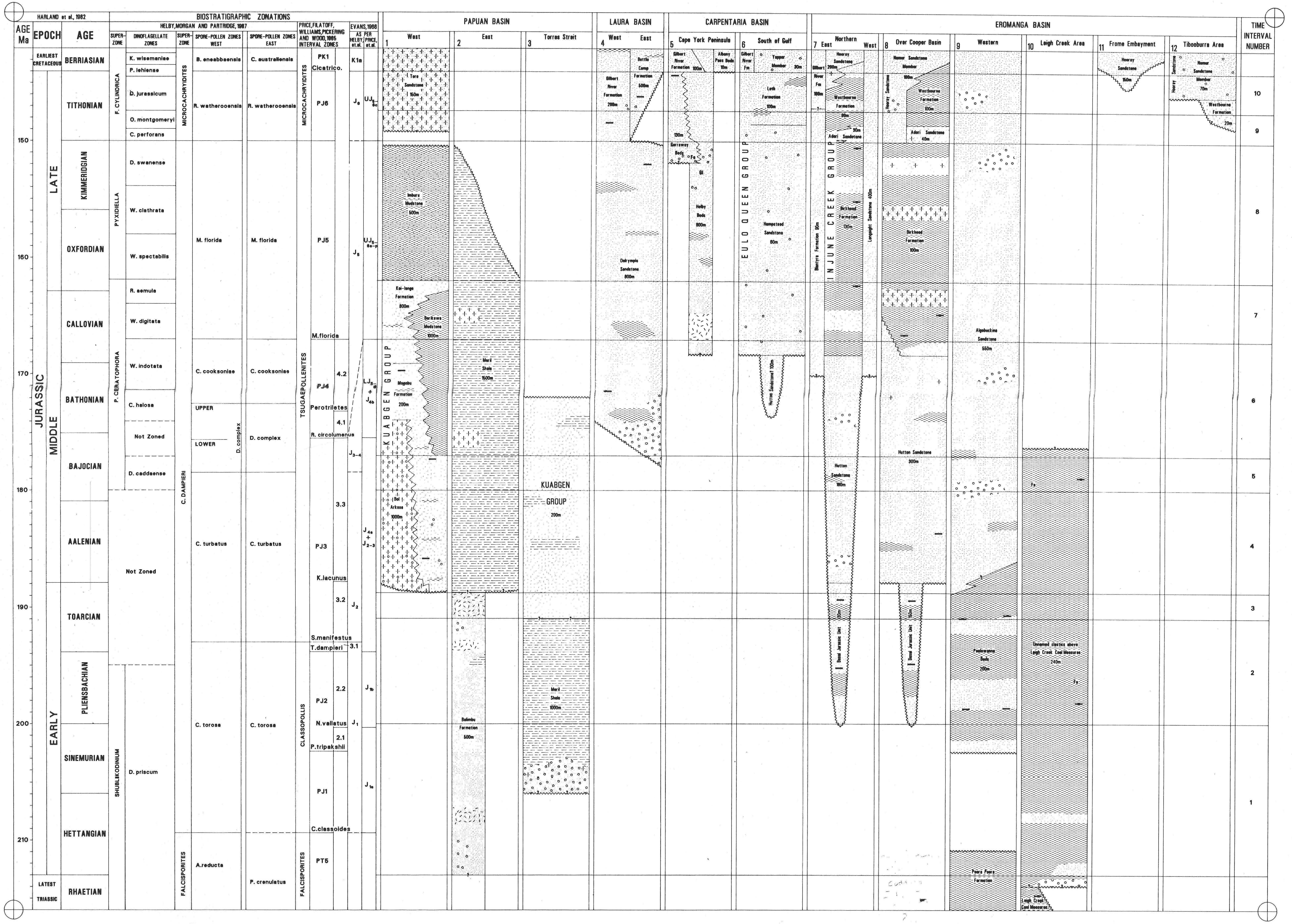
R9007610


INDONESIA
TIMOR SEA
ARAFURA SEA
TORRES STRAIT
PAPUA NEW GUINEA
GULF OF CARPENTARIA
JOSEPH BONAPARTE GULF
CORAL SEA
NORTHERN TERRITORY
QUEENSLAND
WESTERN AUSTRALIA
SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
TASMANIA
ACT
INDIAN OCEAN
SOUTH PACIFIC OCEAN
SOUTHERN OCEAN
GREAT AUSTRALIAN BIGHT
TASMAN SEA
BASS STRAIT
volcanic source ?
SYDNEY
MELBOURNE
ADELAIDE
BRISBANE
HOBART
NEWCASTLE
CANBERRA
GEELONG
1-AUG-1999
17:45
PA1:[110,10]JURXILITH.DGN
JURASSIC 10b – LATE TITHONIAN

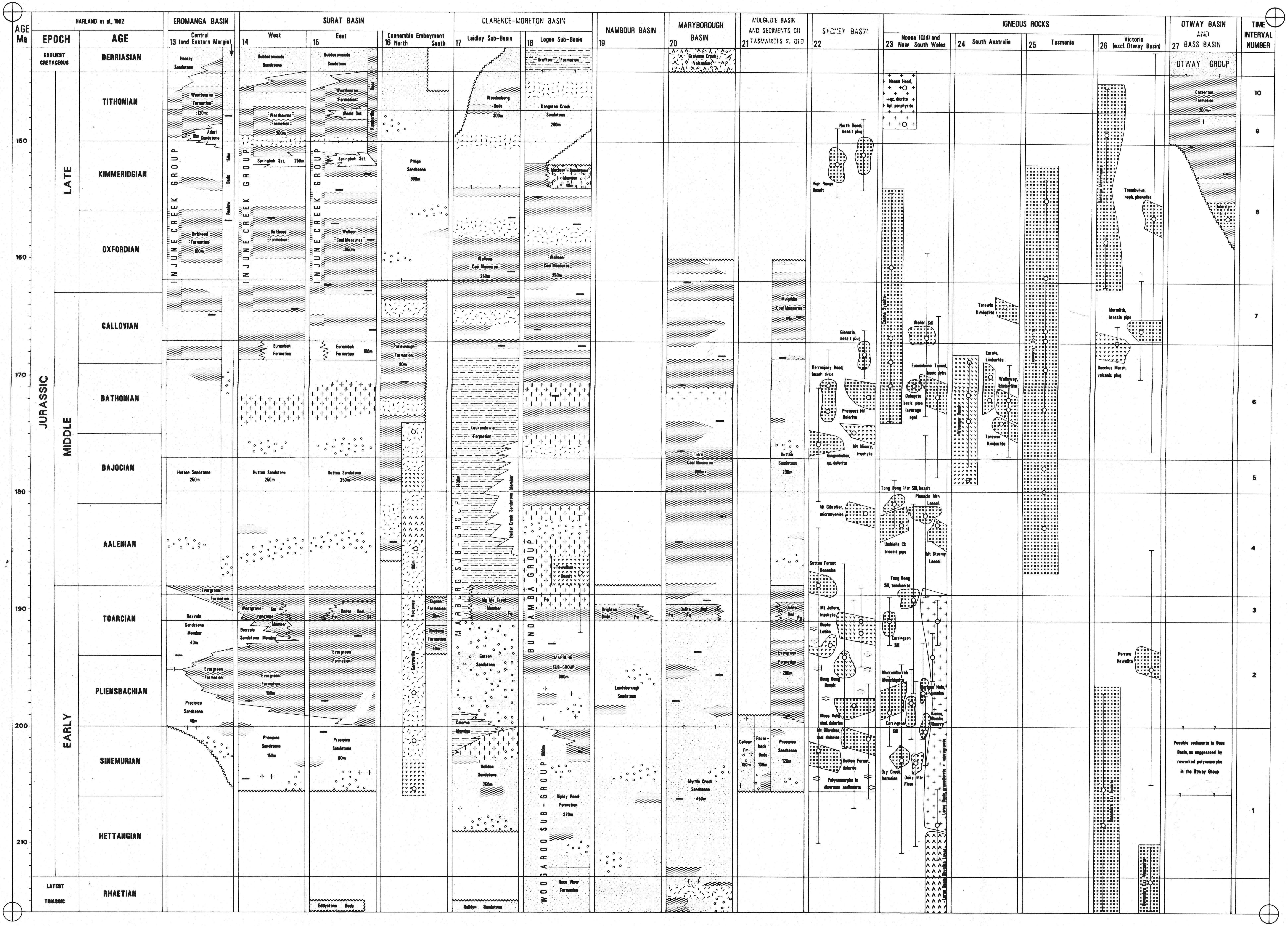


PALAEOGEOGRAPHY
OF AUSTRALIA
SCALE 1:10 000 000
0 100 200 300 400 500
KILOMETRES
Simple Conic Projection with Standard Parallels 18° S and 36° S
DIVISION OF CONTINENTAL GEOLOGY
Interpretation by M.Yeung, Bureau of Mineral Resources, Geology and Geophysics (BMR)
Designed by Cartography Section and drafted by Computer Assisted Cartography, BMR. Base map digitized from material supplied by the Division of National Mapping
Published by BMR, Department of Resources and Energy
© Commonwealth of Australia 1985
Printed by Canberra Publishing and Printing Company
Edge of present day extent of Jurassic deposition, inferred where queried
Axis of basin floor arch, or growth anticline
Axis of basement high
Depoaxis
Depoaxis along fault
minor structure shown by open symbol, major structure by solid symbol
Growth fault
Transform fault, seafloor spreading, wit magnetic anomaly number
Transcurrent fault
Fault, red if active during Jurassic, downthrown side shown by tick
Anticline
Syncline
Monocline
Disjunction, coincides with limit of study area
Intermediate and or mafic igneous bodies
Kimberlites and kimberlitic intrusives
Volcanics
Salt diapirs
Present day isobath approximating limit of study area
ARGO ABYSSAL PLAIN
SCOTT PLATEAU
BROWSE BASIN
BONAPARTE BASIN
KIMBERLEY BLOCK
FITZROY
CANNING BASIN J4-10
EXMOUTH PLATEAU J1-10
PILBARA BLOCK
CARNARVON BASIN
BERNIER PLATFORM
YILGARN BLOCK
PERTH BASIN J1-10
GREAT AUSTRALIAN BIGHT
EYRE SUB-BASIN
POLDA TROUGH
BASIN
CARPENTARIA BASIN
LAURA BASIN J6-10
MT ISA BLOCK
EROMANGA BASIN
SURAT BASIN
MARYBOROUGH BASIN J1-8?
NAMBOUR BASIN J1-3
CLARENCE-MORETON BASIN J1-10
LOGAN SUB-BASIN
COONAMBLE EMBAYMENT
NEW ENGLAND FOLD BELT
FROME EMBAYMENT
TELFORD BASIN J1-8
OTWAY BASIN J8-10
PAPUAN BASIN
BORAB BASIN
MONEY SHOALS BASIN
? VOLCANIC SOURCE ?
JURASSIC STRUCTURAL FEATURES

R9007607

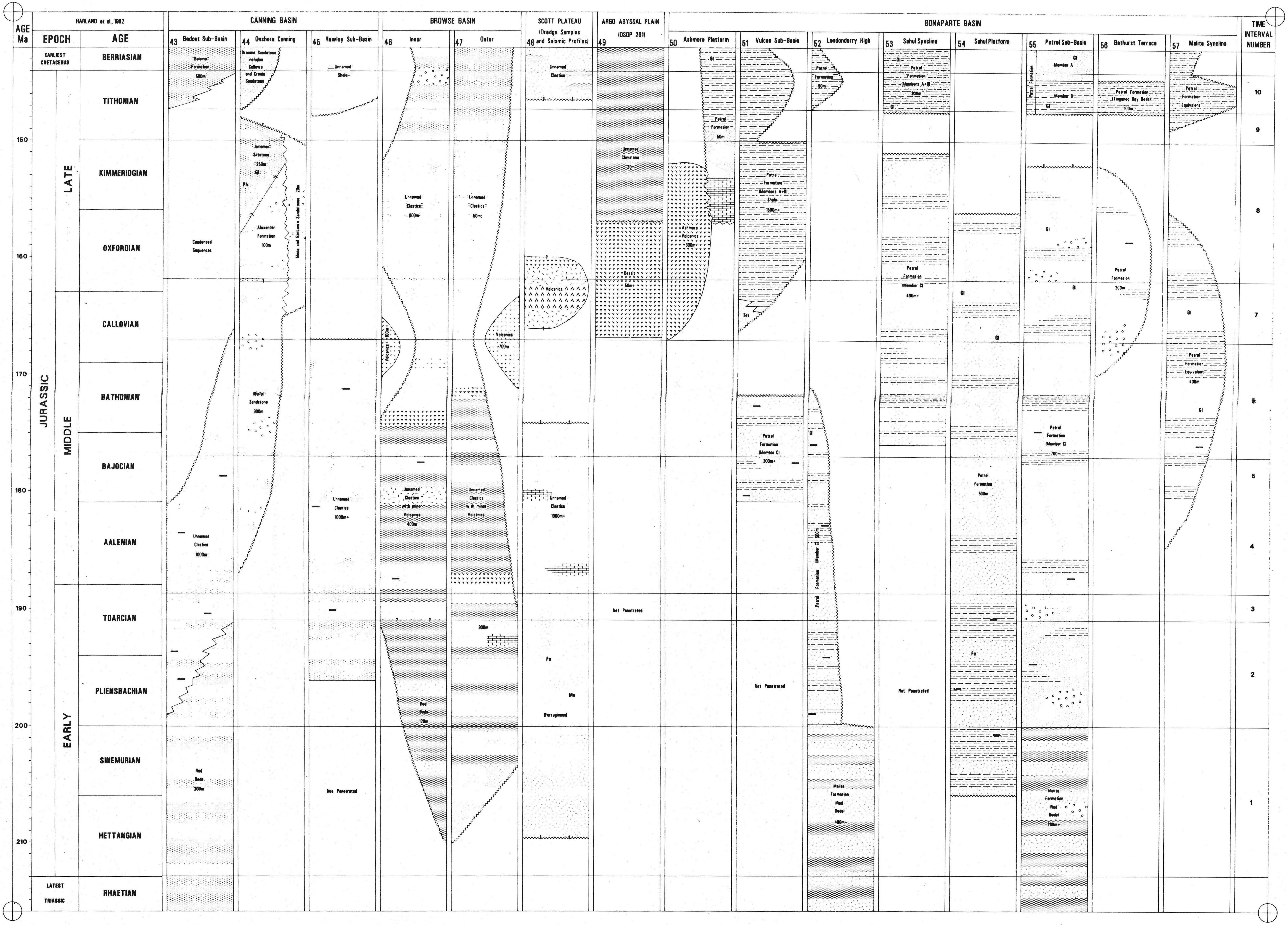


HARLAND et al., 1982
AGE Ma
EPOCH
AGE
BIOSTRATIGRAPHIC ZONATIONS
HELBY, MORGAN AND PARTRIDGE, 1987
SUPER-ZONE
DINOFLAGELLATE ZONES
SUPER-ZONE
SPORE-POLLEN ZONES WEST
SPORE-POLLEN ZONES EAST
PRICE, FILATOFF, WILLIAMS, PICKERING AND WOOD, 1985 INTERVAL ZONES
EVANS, 1966
AS PER HELBY, et al.
PRICE, et al.
EARLIEST CRETACEOUS
BERRIASIAN
TITHONIAN
KIMMERIDGIAN
OXFORDIAN
CALLOVIAN
BATHONIAN
BAJOCIAN
AALENIAN
TOARCIAN
PLIENSBACHIAN
SINEMURIAN
HETTANGIAN
LATEST TRIASSIC
RHAETIAN
JURASSIC
LATE
MIDDLE
EARLY
150
160
170
180
190
200
210
F. CYLINDRICA
PYXIDIELLA
P. CERATOPHORA
SHUBLIKODINIUM
K. wisemaniae
P. lehiense
D. jurassicum
O. montgomeryi
C. perforans
D. swanense
W. clathrata
W. spectabilis
R. aemula
W. digitata
W. indotata
C. halosa
Not Zoned
D. caddaense
Not Zoned
D. priscum
MICROCACHRYDITES
C. DAMPIERI
FALCISPORITES
B. eneabbaensis
R. watherooensis
M. florida
C. cooksoniae
UPPER
LOWER
D. complex
C. turbatus
C. torosa
A. reducta
C. australiensis
R. watherooensis
M. florida
C. cooksoniae
D. complex
C. turbatus
C. torosa
P. crenulatus
MICROCACHRYDITES
TSUGAEPOLLENITES
CLASSOPOLLIS
FALCISPORITES
PK1
Cicatrico.
PJ6
PJ5
M. florida
PJ4
4.2
Perotriletes
4.1
R. circolumenus
3.3
PJ3
K. lacunus
3.2
S. manifestus
T. dampieri
3.1
2.2
PJ2
N. vallatus
2.1
P. tripakshii
PJ1
C. classoides
PT5
K1a
J6
UJ5c
J5
UJ5a-b
LJ5 + J4b
J3-4
J4a + J2-3
J2
J1b
J1
J1a
PAPUAN BASIN
1 West
2 East
3 Torres Strait
Toro Sandstone 150m
Imburu Mudstone 500m
Koi-iange Formation 800m
Barikewa Mudstone 1000m
KUABGEN GROUP
Magobu Formation 200m
Bol Arkose 1000m
Maril Shale 1500m
Balimbu Formation 500m
KUABGEN GROUP 200m
Maril Shale 1000m
LAURA BASIN
4 West
East
Gilbert River Formation 200m
Battle Camp Formation 500m
Dalrymple Sandstone 800m
CARPENTARIA BASIN
5 Cape York Peninsula
Gilbert River Formation 100m
Albany Pass Beds 10m
130m
Garraway Beds
Helby Beds 800m
6 South of Gulf
Gilbert River Fm
Yappar Member 30m
Loth Formation 100m
EULO QUEEN GROUP
Hampstead Sandstone 80m
Hutton Sandstone? 100m
EROMANGA BASIN
7 East
Northern
West
Hooray Sandstone
Gilbert River Fm 100m
200m
Westbourne Formation
80m
30m
Adori Sandstone
INJUNE CREEK GROUP
Birkhead Formation 130m
Eurombah Formation 90m
Longsight Sandstone 400m
Hutton Sandstone 180m
Basal Jurassic Unit 150m
8 Over Cooper Basin
Namur Sandstone Member
Hooray Sandstone
100m
Westbourne Formation 80m
Adori Sandstone 40m
Birkhead Formation 100m
Hutton Sandstone 300m
Basal Jurassic Unit 150m
9 Western
Algebuckina Sandstone 550m
Poolowanna Beds 200m
Peera Peera Formation
10 Leigh Creek Area
Unnamed clastics above Leigh Creek Coal Measures 240m
Leigh Creek Coal Measures
11 Frome Embayment
Hooray Sandstone 150m
12 Tibooburra Area
Hooray Sandstone
Namur Sandstone Member 70m
Westbourne Formation 20m
TIME INTERVAL NUMBER
10
9
8
7
6
5
4
3
2
1



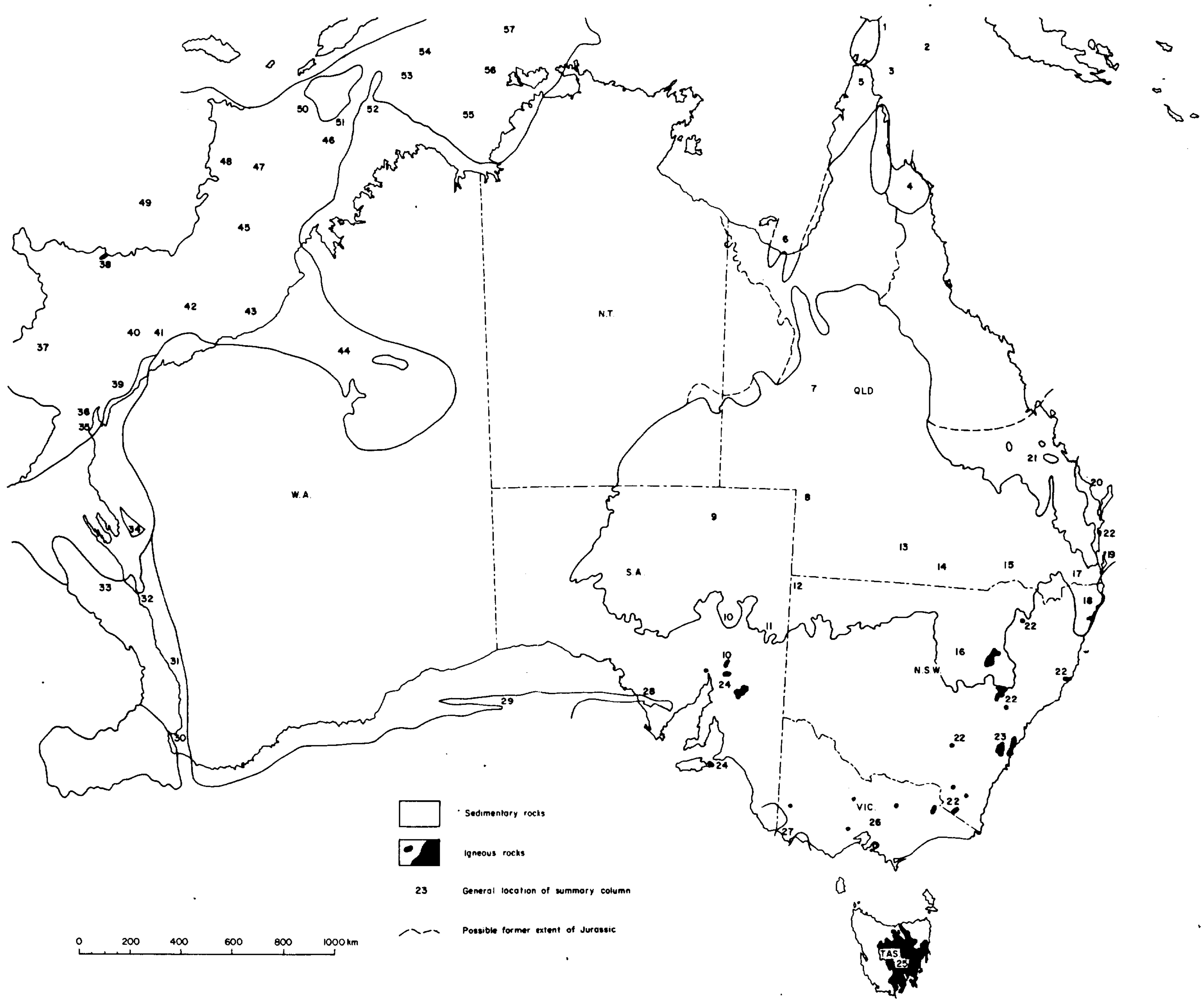
AGE Ma
HARLAND et al., 1982
EPOCH
AGE
EROMANGA BASIN
13 Central (and Eastern Margin)
SURAT BASIN
14 West
15 East
16 Coonamble Embayment North South
CLARENCE-MORETON BASIN
17 Laidley Sub-Basin
18 Logan Sub-Basin
19 NAMBOUR BASIN
20 MARYBOROUGH BASIN
21 MULGILDIE BASIN AND SEDIMENTS ON TASMANIDES IN QLD
22 SYDNEY BASIN
IGNEOUS ROCKS
23 Noosa (Qld) and New South Wales
24 South Australia
25 Tasmania
26 Victoria (excl. Otway Basin)
27 OTWAY BASIN AND BASS BASIN
TIME INTERVAL NUMBER
EARLIEST CRETACEOUS
BERRIASIAN
JURASSIC
LATE
TITHONIAN
KIMMERIDGIAN
OXFORDIAN
CALLOVIAN
MIDDLE
BATHONIAN
BAJOCIAN
AALENIAN
EARLY
TOARCIAN
PLIENSBACHIAN
SINEMURIAN
HETTANGIAN
LATEST TRIASSIC
RHAETIAN
150
160
170
180
190
200
210
Hooray Sandstone
Westbourne Formation 120m
Adori Sandstone
INJUNE CREEK GROUP
Birkhead Formation 100m
Hutton Sandstone 250m
Evergreen Formation
Boxvale Sandstone Member 40m
Precipice Sandstone 40m
Gubberamunda Sandstone
Westbourne Formation 200m
Springbok Sst. 250m
Birkhead Formation
Eurombah Formation
Hutton Sandstone 250m
Westgrove Ironstone Member
Boxvale Sandstone Member
Evergreen Formation 100m
Precipice Sandstone 150m
Gubberamunda Sandstone
Westbourne Formation
Springbok Sst.
Walloon Coal Measures 860m
Eurombah Formation 100m
Hutton Sandstone 250m
Evergreen Formation
Precipice Sandstone 80m
Eddystone Beds
Pilliga Sandstone 300m
Purlawaugh Formation 80m
Garrawilla Volcanics
Woodenbong Beds 300m
Walloon Coal Measures 250m
Koukandowie Formation
Heifer Creek Sandstone Member
Ma Ma Creek Member
MARBURG SUB-GROUP
Gatton Sandstone
Calamia Member
Helidon Sandstone 250m
Helidon Sandstone
Grafton Formation
Kangaroo Creek Sandstone 200m
Walloon Coal Measures 250m
Towallum Basalt
BUNDAMBA GROUP
MARBURG SUB-GROUP 800m
WOOGAROO SUB-GROUP
Ripley Road Formation 370m
Raven View Formation
Brighton Beds
Landsborough Sandstone
Grahams Creek Volcanics
Tiaro Coal Measures 800m+
Myrtle Creek Sandstone 450m
Mulgildie Coal Measures
Hutton Sandstone 230m
Evergreen Formation 200m
Precipice Sandstone 120m
Callope Fm 150m
Razorback Beds 100m
North Bondi, basalt plug
High Range Basalt
Glenoris, basalt plug
Barrenjoey Head, basalt dyke
Prospect Hill Dolerite
Mt Minery, trachyte
Gingenbullen, qz. dolerite
Mt Gibraltar, microsyenite
Sutton Forest Basanite
Mt Jellore, trachyte
Bong Bong Basalt
Mt Gibraltar, thol. dolerite
Sutton Forest, dolerite
Polymorphs in diatreme sediments
Noosa Head, qz diorite, hbl. porphyrite
Weller Sill
Eucumbene Tunnel, basic dyke
Delegate basic pipe
Tong Bong Mtn Sill, basalt
Pinnacle Mtn Laccol.
Umbiella Ck breccia pipe
Mt Stormy Laccol.
Tong Bong Sill, teschenite
Carrington Sill
Murrumburrah Monchiquite
Dry Creek Intrusion
Dairy Mtn Flow
Terowie Kimberlite
Euralia, kimberlite
Walloway, kimberlite
Meredith, breccia pipe
Bacchus Marsh, volcanic plug
Toombullup, neph. phonolite
Harrow Hawaiite
OTWAY GROUP
Casterton Formation
Possible sediments in Bass Basin, as suggested by reworked polymorphs in the Otway Group
1
2
3
4
5
6
7
8
9
10

AGE Ma
EPOCH
AGE
HARLAND et al., 1982
POLDA BASIN
GREAT AUSTRALIAN BIGHT BASIN EYRE SUB-BASIN
PERTH BASIN
CARNARVON BASIN
TIME INTERVAL NUMBER
28
29
30 Bunbury Trough
31 Dandaragan Trough and Vlaming Sub-Basin
32 Geraldton Area
33 Abrolhos Sub-Basin
34 Gascoyne Platform
35 Exmouth Sub-Basin (Rough Range)
36 Exmouth Sub-Basin
37 Exmouth Plateau
38 Exmouth Plateau (Igneous)
39 Barrow Sub-Basin
40 Brigadier Trend + Rankin Platform
41 Dampier Sub-Basin
42 Beagle Sub-Basin and De Grey Nose
EARLIEST CRETACEOUS
BERRIASIAN
TITHONIAN
KIMMERIDGIAN
OXFORDIAN
CALLOVIAN
BATHONIAN
BAJOCIAN
AALENIAN
TOARCIAN
PLIENSBACHIAN
SINEMURIAN
HETTANGIAN
LATEST TRIASSIC
RHAETIAN
JURASSIC
LATE
MIDDLE
EARLY
150
160
170
180
190
200
210
1
2
3
4
5
6
7
8
9
10
Polda Formation 800m
Unnamed clastic sequence in JERBOA 1 200m+
Yarragadee Formation 400m
Yarragadee Formation 8000m+
Yarragadee Formation 500m+
Otorowiri Member
Parmelia Formation
Cadda Formation 300m
CHAMPION BAY GROUP 300m
Cadda Formation 300m
Moonyoonooka Sandstone 30m
Cattamarra Coal Measures 500m
Cattamarra Coal Measures 500m
CHAPMAN GROUP 2500m
Cockleshell Gully Formation
Cockleshell Gully Formation 1300m
Greenough Sandstone 300m
Eneabba Member 700m
Eneabba Member 800m
Lesueur Sandstone
Lesueur Sandstone
Lesueur Sandstone
Woodleigh Formation 100m+
Wandagee Kimberlite
Learmonth Formation 700m
Wogatti Sandstone
BARROW GROUP
Dupuy Sandstone 100m
Dingo Claystone 50m
Dingo Claystone 2000m+
Dingo Claystone 200m
Unnamed Siltstone 800m
Brigadier Formation 800m
Basal Transgressive Limestone 45m
Mafic Volcanics
Acid-Intermediate Volcanics
BARROW GP
Dupuy Sandstone 500m
Dingo Claystone 4000m+
Biggada Sandstone Member 250m
Unnamed Siltstone 300m+
"Mungaroo Formation" in HERMITE 1
Unnamed Sandstone
Dingo Claystone 500m
Basal Limestone
North Rankin Formation 60m
Brigadier Formation 350m
Unnamed Shale
Angel Formation 450m
Dingo Claystone 1200m+
Legendre Formation 300m
Basal Limestone
North Rankin Formation 100m
Brigadier Formation 130m
800m
Unnamed Clastics
1200m
Not Penetrated
Gl



AGE Ma
EPOCH
AGE
HARLAND et al., 1982
EARLIEST CRETACEOUS
BERRIASIAN
TITHONIAN
KIMMERIDGIAN
OXFORDIAN
CALLOVIAN
BATHONIAN
BAJOCIAN
AALENIAN
TOARCIAN
PLIENSBACHIAN
SINEMURIAN
HETTANGIAN
RHAETIAN
LATEST TRIASSIC
JURASSIC
LATE
MIDDLE
EARLY
150
160
170
180
190
200
210
CANNING BASIN
43 Bedout Sub-Basin
44 Onshore Canning
45 Rowley Sub-Basin
BROWSE BASIN
46 Inner
47 Outer
SCOTT PLATEAU
48 (Dredge Samples and Seismic Profiles)
ARGO ABYSSAL PLAIN
49 (DSDP 261)
BONAPARTE BASIN
50 Ashmore Platform
51 Vulcan Sub-Basin
52 Londonderry High
53 Sahul Syncline
54 Sahul Platform
55 Petrel Sub-Basin
56 Bathurst Terrace
57 Malita Syncline
TIME INTERVAL NUMBER
10
9
8
7
6
5
4
3
2
1
Baleine Formation 500m
Condensed Sequences
Unnamed Clastics 1000m
Red Beds 200m
Broome Sandstone includes Callawa and Cronin Sandstone
Jarlemai Siltstone 250m
Gl
Ph
Alexander Formation 100m
Meda and Barbwire Sandstones 20m
Wallal Sandstone 300m
Unnamed Shale
Unnamed Clastics 1000m+
Not Penetrated
Unnamed Clastics 800m
Volcanics 100m
Unnamed Clastics with minor Volcanics 400m
Red Beds 120m
Unnamed Clastics 50m
Volcanics 700m
Unnamed Clastics with minor Volcanics
300m
Unnamed Clastics
Volcanics
Unnamed Clastics 1000m+
Fe
Mn
(Ferruginous)
Unnamed Claystone 20m
Basalt 50m+
Not Penetrated
Gl
Petrel Formation 50m
Ashmore Volcanics 300m
Petrel Formation (Members A+B) Shale 1500m+
Sst
Petrel Formation (Member C) 300m+
Not Penetrated
Petrel Formation 50m
Petrel Formation (Member C) 500m
Malita Formation (Red Beds) 400m+
Petrel Formation (Members A+B) 300m
Petrel Formation (Member C) 400m+
Not Penetrated
Petrel Formation 600m
Fe
Petrel Formation
Member A
Member B
Petrel Formation (Member C) 700m
Malita Formation (Red Beds) 200m+
Petrel Formation (Tingana Bay Beds) 100m
Petrel Formation 200m
Petrel Formation Equivalent
Petrel Formation Equivalent 400m

MAP SHOWING JURASSIC SEDIMENTARY AND IGNEOUS ROCKS, AND LOCATION OF SUMMARY COLUMNS IN CORRELATION CHART



LITHOLOGY SYMBOLS ON DATA MAPS

(Where symbols are mixed, the time slice comprises more than one dominant or characteristic rock type)

- Conglomerate
- Sedimentary breccia
- Quartzose sandstone
- Lithic sandstone
- Feldspathic sandstone
- Undifferentiated sandstone
- Mudstone, siltstone
- Marl
- Black coal
- Limestone
- Dolomite
- Pyroclastics
- Felsic extrusives (including ignimbrites, 62% SiO_2 or greater)
- Mafic extrusives, less than 62% SiO_2
- Felsic intrusives 62% SiO_2 or greater
- Mafic intrusives, less than 62% SiO_2

ENVIRONMENT SYMBOLS ON INTERPRETATION MAPS

LAND

- LEU Land, unclassified
- LEE Land, erosional

DEPOSITIONAL ENVIRONMENT

- LDF Fluvial
- LDFL Fluviolacustrine
- LDL Lacustrine

COASTAL

DEPOSITIONAL ENVIRONMENT

- CDP Paralic
- CDIS Intertidal
- CDD Deltaic
- LDA Aeolian

SEA

MARINE ENVIRONMENT

- MVS Very shallow (0 - 20 m)
- MS Shallow (0 - 200 m)
- MBA Bathyal - abyssal (>200 m)

- Palaeocurrent direction
- Fan
- Diagrammatic drainage
- Igneous centre
- Disjunction, coincides with limit of study area
- Environment boundary
- Environment boundary approximate, or guessed where queried

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