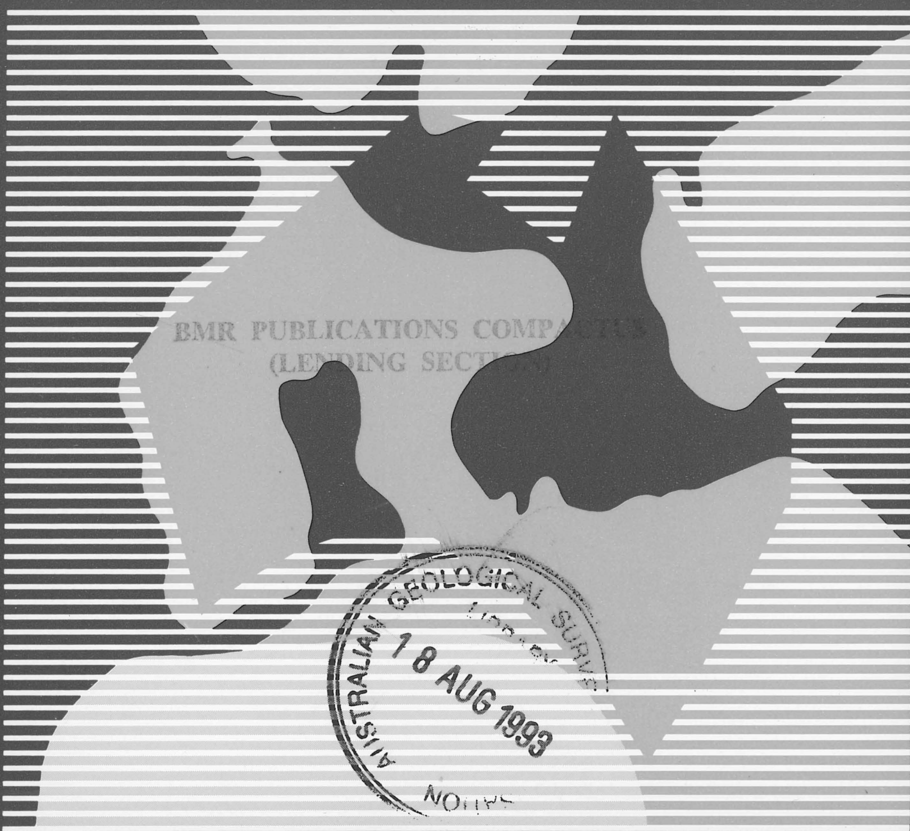
PALAEOGEOGRAPHY 32

AUSTRALIA

NOTES TO ACCOMPANY A 1: 5 000 000 – SCALE STRUCTURE AND STRUCTURAL HISTORY MAP OF THE AUSTRALIAN TRIASSIC

A. N. YEATES & S. M. MULHOLLAND



BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

ONSHORE SEDIMENTARY & PETROLEUM GEOLOGY

RECORD 1991/32

NOTES TO ACCOMPANY A 1:5,000,000-SCALE STRUCTURE AND STRUCTURAL HISTORY MAP OF THE AUSTRALIAN TRIASSIC

by

A. N. Yeates and S. M. Mulholland

Bureau of Mineral Resources, Australia Record 1991/32

CONTENTS

The consequences of Triassic movements in Australia are basins, regions of uplift, and structures. All these features are shown on an accompanying 1:5,000,000-scale Map.

The basins are subdivided into four types: epicratonic; foreland; intramontane; and marine-trough basin. Each type can be recognised by the nature of its sediments, character of associated igneous rocks (where present), its relationship to underlying pre-Triassic rocks, its deformational characteristics and its tectonic setting.

Batholith emplacement, accumulation of lava and tuff piles, doming associated with emplacement of intrusions, folding, thrusting and epeirogenic warping were all operative uplifting mechanisms during the Triassic.

The Tasman Line, some lineaments, some growth faults and strike-slip faults all influenced Triassic deposition and deformation. A sharp bend in the Tasman Line beneath the Cooper Basin may have influenced the generation of closed structures crucial for some of the trapped petroleum there. Non-diastrophic salt diapirism occurred during the Late Triassic in the eastern half of the Bonaparte Basin.

The New England Orogen (northern and southern parts) was cratonised at about the Triassic-Jurassic boundary, close to the time that the Jurassic-Cretaceous Eromanga Basin was initiated. The cratonisation followed extensive granitoid emplacement in the Orogen throughout the Triassic, and waning regional metamorphism that ceased during the earliest Triassic.

The accompanying structure and structural history map for the Australian Triassic has been compiled as part of a Palaeogeographic Maps Project (BMR Palaeogeographic Group, 1990) supported by the Australian Petroleum Industry Research Association. The Map builds on and updates information that can be deciphered from the Tectonic Map of Australia (Geological Society of Australia, 1971). Other generalised palaeotectonic maps for the Period are in the compilation edited by Clark & Cook (1983, p.443) and a sketch of Laseron (revised, Brunnschweiler, 1969).

An interpretation of Australia's Triassic tectonic history has been published by Wopfner (1985). Reviews by Evans and Roberts (1979) and Murray (1988) provide interpretations of the Triassic tectonic history of the Tasman Fold Belt in eastern Australia. Many events were a continuation of those operative in Permian times (see Totterdell, 1990).

Compared with the Permian, Triassic rocks are similarly widespread, though more terrestrial and much more restricted in extent. This is due to depositional areas onshore being smaller than in Permian times, and to widespread Mid and Late Triassic uplift and deformation which raised former depositional areas above local base levels. Consequent erosion has limited preserved deposits mainly to the larger basins and to synclinal depressions. The preserved extent of Australia's Triassic rocks is shown on the accompanying Map, which is non-palinspastic.

The Map denotes regions of subsidence and uplift as its basis, both consequences of Triassic tectonism. Triassic movements and their character are denoted with symbols. Timing of structures is shown by the lettering TR1, TR2....TR6 etc. equating to chosen "time slices" in Yeates and Mulholland (in prep.) shown on an inset in the bottom right-hand corner of the Map. The dating of these intervals follows the radiometric time scale of Harland et al. (1982). Radiometric dating of Triassic rocks in Australia is summarised by Webb (1981). Much of the timing of structures shown on the Map is inferred from the age of units and the biostratigraphic position of their palynomorph zones on the time scale (Helby et al., 1987; Balme, 1990).

Most Australian basins containing Triassic rocks are Late Carboniferous to Triassic. One group of exceptions are along or adjoin the western margin and have pre-Late Carboniferous beginnings. These basins are the Arufura, Bonaparte, Canning, Carnarvon and possibly Perth Basins. The other group of exceptions are a cluster of small Triassic basins in central and northern South Australia which apparently lies on much older rocks than Permian. These slight differences across the continent are presumably reflections of different regional tectonic characteristics.

The regions of subsidence are basins, subdivided into 4 types as follows: eipicratonic; foreland; intramontane; and marine-trough basin, based on their tectonic setting and character. These four types, as used here, have differences in the nature of their sediments, their associated igneous rocks (where present) their relationship to underlying pre-Triassic rocks, and their deformational characteristics, as summarised in Table 1. Extents shown on the Map are present-day except where exaggerated to include the smallest basins (e.g. in Victoria). Extents may have been greater during the Triassic so are shown as a colouring edge in a number of places, rather than a geological boundary.

The sites of the vast majority of Triassic deposits have mostly been inherited from the loci of Permian basins, except in central and northern South Australia and the far southeast corner of the Northern Territory. In this region depoaxes shifted during Permian and Triassic times. For instance, the western edge of the Triassic Simpson Desert Basin (Moore, 1982) has only minimal overlap with the eastern edge of the Permian Pedirka Basin due to northwest tilting of the latter in the Early Triassic (Wopfner, 1985). The Simpson Desert Basin is shown on the Map in the uncommon Configuration coallesced with the Cooper Basin as it was in the Early Upper Triassic.

Farther south, the much smaller Leigh Creek Coal, Springfield and Boolcunda Basins all lack a Permian floor and, according to Sprigg (1984, p.159) are gently infolded into bedrock hollows.

It is evident that basin development in these regions differed from that in both west and east Australia. The development of the South Australian Triassic basins was thought by Wopfner (1985) to represent a forerunner to events that initiated the Eromanga Basin in the earliest Jurassic.

Epicratonic Basins

Epicratonic basins are the most common type. Their widespread distribution is indicative of the continental nature of Australia in Triassic times. Basins considered to be epicratonic in Triassic times are listed as follows: Arafura, Bonaparte, Browse, Canning, Carnarvon, Exmouth Plateau Arch, Perth, Simpson Desert, Cooper, Leigh Creek Coal, Springfield, Boolcunda, Papuan, Galilee, Oaklands, Tasmania, and inferred pre-Bass Basin sediments.

In the west, the contiguous basins of the Westralian Superbasin underlie the North West Shelf, Exmouth Plateau and Arafura Sea (Yeates et al., 1987; Bradshaw et al., 1988; 1990). The Perth Basin (Playford et al., 1976) would have been linked to them via the Carnarvon Basin in Triassic times. Of Australia's epicratonic basins, these have the greatest extent and thickest Triassic deposits (up to 5km or more), their greater thicknesses being facilitated locally by growth faulting and graben development (Bradshaw et al., 1988; 1990) indicated on the Map. The superbasin was initiated in Late Carboniferous times following fracturing related to the eventual break up of Gondwanaland (Carey, 1976; Fairbridge, 1982).

Epicratonic basins within the present-day continent mostly have more symmetrical fills of Triassic sediments and their thicknesses are of the order of a few hundred metres or less. The occurrence of labile detritus in the Galilee Basin (Vine et al., 1965; Vine, 1976) and in the Late Triassic rocks of the Tasmania Basin (Bacon et al., 1989) are thought to reflect proximity to source areas.

This may have included a magmatic arc to the east of Tasmania (Collinson et al., 1987; 1990) with which the volcanic complex at Mt. Leinster, eastern Victoria, may have been colinear. These basins otherwise do not have the much greater thickness, asymmetric sediment thickness and thrusted margins more characteristic of foreland basins. The same may apply to the poorly known Triassic sediments of the Papuan Basin which also contain juvenile detritus at Anchor Cay-1 well (Robertson Research & Flower Doery Buchan, 1984).

The distribution of epicratonic basins shown on the accompanying Map was the most widespread in the Early Middle Triassic (Time Slice Tr.2). This extent includes numerous outliers from the major basins, including the Papuan Basin, recently discovered deposits in western Queensland (Williams & Gunther, 1989) and Mt. Mulligan (De Keyser & Lucas, 1968) all in the north, and the Oaklands Basin (Yoo, 1982) in the south.

In the far east of the continent, the contiguous Bowen, Gunnedah and Sydney Basins comprise a foreland basin or foredeep (Geological Society of Australia, 1971) the northern part of which evolved from what Murray (1990) interpreted as an Early Permian magmatic rift. Bimodal volcanics underlie Permo-Triassic sediments in the Gunnedah segment (Tadros, 1988). The foreland basin lies between the then cratonised portion of the Tasman Fold Belt System in the west affected during the Triassic only by mild epeirogenic movements, and the actively emerging highland of the adjacent New England Orogen to the east. The foreland basin merges with the epicratonic Galilee Basin above a basement high, the Nebine Ridge. Its contact with the Orogen is largely thrust faulted, (Exon, 1976; Voisey, 1959).

Dykes and plutons of alkaline mafic igneous rocks (Jaques et al., 1985) were intruded into the Sydney Basin during and after the latter stages of its depositional history. These thermal events were thought by Joplin (1968) to have accompanied the gradual stabilising of a 'mobile belt'. Late Middle Triassic teschenite sills are present in the upper Hunter region of New South Wales (Gamble et al., 1988) and indicate a continuation of the magmatism. Alkaline mafic lavas were also extruded at about the Triassic-Jurassic boundary in the Gunnedah Basin (Dulhunty, 1986; Dulhunty et al., 1987).

The larger intramontane basins are the Esk and Abercorn Troughs, and an interpreted younger trough beneath the Ipswich Basin, all in southeast Queensland. All have rift character and were initiated very soon after deposition ceased in the Gympie Block. Strike-slip faulting is thought to have triggered their development (Korsch et al., 1988; 1989) and perhaps the coeval felsic volcanism on adjacent rigid Palaeozoic basement.

The Callide, Mulgildie and Tarong Basins are smaller and younger intramontane basins within the Eastern Highlands (Day et al., 1974; 1983). All occur in a highly faulted region.

Another small unnamed basin occurs at Mt. Mulligan, north Queensland (De Keyser & Lucas, 1968). It is a Permo-Triassic basin and unrelated to the Middle to Late Triassic rifting farther south. The Lorne Basin in New South Wales is also a Triassic intramontane basin (Herbert, 1974; Leitch & Bocking, 1980).

In Queensland and northern New South Wales faulting persisted until the Norian after which volcanism waned. Thermal relaxation then induced further subsidence, and basins of sag character developed over the easternmost rifts (Korsch et al., 1988; 1989) but still in the intramontane setting which was to last until the end of the Triassic. The Clarence-Moreton, Ipswich and Maryborough Basins are the sag basins related to this Late Triassic subsidence. The Maryborough Basin farther east remained depositional after the Triassic (until the Cretaceous).

A small Permo-Triassic marine-trough basin, termed the Gympie Block (Ellis, 1968) is the youngest flysch-depositional element of the Tasman Fold Belt System. This trough-like basin ceased being depositional in the earliest Middle Triassic, after which it was intruded by granitoids before being partially overlapped by the Late Triassic to Cretaceous Maryborough Basin. The Gympie Block is possibly bound offshore to the east by a basement high termed the Bunker Ridge by Ellis (1968).

A review by Murray (1987) summarises another view that the Gympie Block may be an exotic terrane (Harrington, 1983).

Its inferred collision with the Orogen in the mid Triassic is an explanation for interpreted oroclinal bending in New England (Korsch & Harrington, 1987; Harrington & Korsch, 1987). Though most Triassic sedimentary rocks of the Gympie Block are unique within Australia, derived clasts in older (Permian) conglomerates of the Gympie Block support a local derivation and imply movement was not great (Murray & Whitaker, 1982). Also, there are uncertainties in crucial field relationships (Murray, 1987). The similarity in size, shape and facies to older Palaeozoic tectonic troughs in the Tasman Fold Belt System (eg; Hill End Trough, and Permian facies around Drake) suggest the Gympie Block could otherwise be interpreted as the basin of terminal flyschoid sedimentation in the exposed portion of the Tasman System.
If so, the block could be approximately in place. However, the 'oroclinal bending' in New England would therefore require a new explanation if this were the case.

Batholith emplacement, accumulation of lava and tuff piles, doming associated with emplacement of ultramafic intrusions on the western margin (Edel-1 well), folding, thrust faulting, and epeirogenic warping were all operative uplifting processes during the Triassic. Evidence for uplift has been reported from rock relationships (e.g. emergence of the Jones Rise, Canning Basin; Yeates et al, 1984). It can also be implied from changes in palaeocurrent direction, for example, as in the Tasmania Basin (Banks 1989) and described within the Hawkesbury Sandstone of the Sydney Basin (Conaghan et al., 1982).

The character and composition of coarse-grained facies in adjacent basins (e.g. in the Warialda Depression; Hawke & Bourke, 1984) can also be indicative of uplift nearby.

However, the Triassic uplift history of regions devoid of nearby Triassic rock is difficult to ascertain without available apatite fission-track data. It may be that many of Australia's Precambrian and Palaeozoic cratonic regions have always been high relative to their surrounds, at least since the Early Permian glaciation (Ollier, 1981). Despite the magnitude of geological time that has elapsed since the Triassic, the Precambrian and Palaeozoic cratons of Australia still underlie the continent's topographically highest regions (Harrington et al., 1982).

On the accompanying Map, uplift is indicated by presence of granites, lava and tuff piles, some intrusions, and a stipple.

Uplift is one consequence of batholith emplacement (Carey, 1976). It can be inferred throughout the Permian and Triassic history of the New England Orogen from the widespread distribution of granitic rocks (Day et al., 1983; Shaw & Flood, 1981) from granitoid clasts in conglomerates of adjacent basins, such as the Warialda Depression (Hawke & Bourke, 1984) and from the subaerial nature of coeval felsic volcanism in northern New England and Queensland (e.g. Godden, 1982; Stephens, 1986; 1987; Falkner,1987; Day et al., 1974; 1983; Barnes et al., 1991). Extensive volcanic plateaus developed as a result of these eruptions.

Doming associated with small intrusions

Alkaline ultramafic rocks in Edel-1 well (Le Maitre, 1975) thought by Hocking et al. (1987) to be shallow sills, caused doming during the Late Permian to Early Middle Triassic adjacent to the North Abrolhos Sub-basin of the Perth Basin. Absence of the transgressive Kockatea Shale in this well (Ocean Ventures, 1972) suggests that the doming associated with sill emplacement restricted the extent of this unit to the axial portion of the North Abrolhos Sub-basin until the doming waned later in the Middle Triassic allowing sandstone deposition (Lesueur Sandstone equivalent, derived from the underlying Silurian Tumblagooda Sandstone) to continue over a wider extent.

The two sandstones can be distinguished only on the sonic log of Edel-1 well (see Ocean Ventures, 1972).

Lesser doming due to probable Permian igneous activity appears to have kept the Bedout High a positive feature during the Early Triassic transgression farther north (Gorter, 1978).

Uplift associated with tectonism

Uplift in mainland eastern Australia can be inferred particularly from the time of the Middle Triassic unconformity (Yeates & Mulholland, in prep.) This may partly be due to regression of a sea to the east of the continent or to the cessation of subsidence, or both, in the Sydney, Gunnedah and Oaklands Basins. It was also a time when depoaxes shifted in the Galilee Basin (thereby implying tectonism) and depositional areas in eastern Australia became greatly restricted in extent (Yeates & Mulholland, in prep.). An exception (beyond the "mainland") however, was the Tasmania Basin which contains the most complete of Triassic sections in eastern Australia. This basin has a coincident spatial association with Jurassic dolerite sills not found in the mainland but which are widespread in Antarctica (see Barrett et al., 1986).

The central Bowen Basin is dominated by Middle to Late Triassic thrust faulting (Korsch et al., 1990) and its contact with the New England Orogen is also strongly faulted (Exon, 1976). This former sunkland emerged above base level and probably became a hogback and cuesta landscape for a time.

The eastern margin of the whole foreland basin was also thrusted from the east as uplift culminated in the adjacent Orogen.

In the Canning Basin, Western Australia, wrench movements along in the bounding faults of the Fitzroy Graben produced faulted anticlines in the Fitzroy Sub-basin and fault scarps in the Gregory Sub-basin. In the present-day landscape these exist as palaeoforms indicative of the uplift (Yeates et al., 1984). Though the timing of this event cannot be precisely dated, it can be inferred to have begun from the maximum age of fine clastics containing redbeds beneath parts of the North West Shelf (i.e. about the Late Middle Triassic) (Yeates & Mulholland, in prep.). Late Triassic uplift of the order of 1.5km, determined from apatite fission-track data, occurred in the vicinity of the Lennard Shelf, (Arne et al., 1989). In the southern Dampier Peninsula there was substantial erosion following the uplift, and the entire Permian section was removed (Yeates et al., 1984).

Offshore, the Exmouth Plateau Arch was uplifted and substantially block faulted in the latest Triassic and Jurassic (Exon & Willcox, 1980). The deformation was also a prelude to volcanism, indicated by dredged rhyolite and trachyte (von Rad & Exon, 1982) and to eventual deepening of the Indian Ocean (Bradshaw et al., 1988).

Epeirogenic Uplift

Redbeds are fairly common in Australian Triassic sediments. The pigment is generally thought to be derived initially from leached soils.

If so, then uplift would have taken place at a rate not exceeded by the rate of soil formation. Such epeirogenic upwarp could have been more widespread in the Triassic than shown on the accompanying Map; it can be inferred only from adjacent sediments, and there are large areas of the continent devoid of Triassic deposits.

An abundance of reworked Triassic and Early Jurassic spores in the Cretaceous Otway Group (Burger, 1987) is evidence of wide-spread erosion (implying uplift) so Triassic outcrops at Bacchus Marsh, Victoria, and sediments in the Oaklands Basin, southern New South Wales (Yoo, 1982) could be relicts of a formerly larger basin. Such a basin perhaps underlies the Bass Basin. An unknown pre-Bass Basin sequence there (Williamson et al; 1987, figs. 16 and 17) could possibly include Triassic (and Permian) sediments similar to those exposed in northern Tasmania.

Epeirogenic upwarp has been interpreted to account for prolonged influxes of coarse clastics into several basins. In the vicinity of the western margin of Australia, it could explain the thick sandstones and minor conglomerates of the Lesueur Sandstone in the Perth Basin (Playford et al., 1976) the thick section of Mungaroo Formation in parts of the Carnarvon Basin (Hocking et al., 1987) and its equivalent in the Exmouth Plateau Arch (Barber, 1988).

Onshore, the Warang Sandstone in the Galilee Basin (Vine et al., 1964) and conglomerates in the Moolayember Formation of the Bowen

Basin (Gray, 1984) are perhaps responses to similar, though more localised, uplift nearby. Such local uplift perhaps accounts for the more restricted extent and thinner sequences of Triassic sedimentary rocks in onshore basins when compared to the more extensive and generally thicker Permian deposits beneath them (see Totterdell, 1990).

TRIASSIC STRUCTURES

The accompanying Map shows depositional, deformational and miscellaneous structures of Triassic age and their timing where known. The chosen depositional symbols also convey an impression of the relative magnitude of subsidence.

The Tasman Line

The Tasman Line divides Australia into a western region of exposed Precambrian blocks and fold belts overlain by Phanerozoic basins, and an eastern region of exposed Phanerozoic fold belts overlain by younger basins (Veevers et al., 1984). It was a place where the differing tectonic frameworks between central and east Australia met (Harrington, 1974).

Though its influence was greatest in the Palaeozoic it appears to exert control on the shapes of Galilee, Cooper and Simpson Desert Basins and their structures.

The thinning of sediment to the south and east in the Lovelle Depression of the Galilee Basin indicate that the Cork Fault was active during deposition (Hawkins & Harrison, 1978). Its north-east orientation together with the trend and pattern of structures in, and shape of the Cooper Basin, both reveal that the Tasman Line was influential throughout the depositional and deformational history of these basins. In the first instance, the Tasman Line was probably a lineament system providing lines of weaknesses in the basement along which enough subsidence took place to enable sediments to be deposited over a wide area. Subsequent reactivation of the weaknesses deformed the sediments.

The right-angled change in direction of the Tasman Line beneath the Cooper Basin is thought here to be significant for some of this basin's petroleum occurrences. Closed interference structures crucial for future trapping of petroleum generated after Jurassic-Cretaceous subsidence suggest Late Triassic movements parallel to both directions of the Line. This possibility provides an explanation for the far greater petroleum prospectiveness of the Cooper Basin, when compared with the adjacent Galilee Basin, despite their very similar depositional histories (Yeates & Mulholland, in prep.). The Lovelle Depression is much farther distant from, and apparently beyond the region of influence of, the northwest-trending portion of the Tasman Line in the northeast of South Australia.

However, some of the basin's depoaxes did shift with time, as indicated on the Map, particularly towards the Koburra Trough.

Several large lineaments are shown on the Map (O'Driscoll, 1982; written communication, 1985; Scheibner, 1976; Wopfner, 1985; and Evans & Roberts, 1979). They reveal weaker influences seen in basin shapes, abrupt changes in basin outlines and in the orientation of a few structures (see Map).

Fractures and Mineralisation

Other smaller-scale fracture systems have been recognised from remotely-sensed data in the coastal parts of central and south-east Queensland (Nash, 1986). Some Late Triassic fracture systems have spatially-associated precious-metal mineralisation in veins and stockworks, for example at North Arm, southeast Queensland (Ashley, 1987a; 1987b; Ashley & Dickie, 1987) and farther north at the Mt Shamrock-Mt. Ophir area (Williams, 1991). A pipe-like body within the Late Triassic Aranbanga Beds in southeast Queensland contains gold and silver (Cayzer & Leckie, 1987). Tin and tungsten are also important commodities that have been mined, particularly from vein deposits sourced or hosted by Triassic granitoids in New England (Markham & Basden, 1974). The prospective granites are enriched in uranium relative to the others (Yeates, 1982).

Growth Faults

Triassic growth faulting was prominent along the basins of the western margin of Australia.

In the southern Perth Basin, one depoaxis is beside the Darling Fault.

The Flinders-Long Island Fault System facilitated deposition of Triassic sediments in the northern part of the Carnarvon Basin. At one stage (Late Lower to Early Middle Triassic) subsidence was sufficient to allow an inlet of the sea to come close to the present coast, thus influencing palaeogeography (Yeates & Mulholland, in prep.). Sub-sea canyon development followed the down-faulting (Bentley, 1988). Lesser growth faulting facilitated subsidence in depoaxes of many other basins as indicated by symbols on the Map.

Growth faulting was not restricted to the west. It has been inferred also to account for the asymmetric thickness character of Triassic deposits in parts of the east Bowen and Galilee Basins. (Yeates & Mulholland, in prep.). The thick sequence in the Gympie Block was considered by Ellis (1968) to be due to fault-controlled subsidence. The Esk Trough is also asymmetric due to uneven subsidence along its faulted margins. Subsidence there was accompanied by felsic volcanism within and along the margins of the Trough (Day et al., 1974).

Strike-slip faults

Though uplift was widespread, deformation during the Triassic was not nearly as intense as in the Palaeozoic. Though shearing, strike-slip faulting and heating occurred close to the present east coast (particularly along the northeast edge of the Bowen Basin; Day et al., 1983) there was generally little isoclinal folding or cleavage development elsewhere.

However, tight folding occurred along faults in the Esk Trough sequence during the Late Triassic (Day et al., 1974) and there was some reactivation of igneous activity associated with shearing between Cairns and Mackay in north Queensland (Stephenson & Chappell, 1987). The reactivation also continued after the Triassic.

Twenty three kilometres of dextral strike-slip movement occurred along the Demon Fault in New England during the Triassic. This is revealed by measured displacements on radiometrically dated units (McPhie & Fergusson, 1983; Korsch et al., 1978). The Fault terminates in the 227 Ma (corrected) Stanthorpe Batholith (Shaw, 1964; 1969; Korsch et al., 1978) which is not displaced thereby providing a minimum age on the movement. The Demon Fault was active at the same time as other similar strike-slip faults that bound the Esk and Abercorn Troughs in Queensland (Day et al., 1974). The mapped units of the Coombadjha Volcanic Complex adjacent to the Demon Fault (McPhie, 1982; 1986) have an elliptical outcrop pattern. As faulting began before the cessation of volcanism, this elliptical outcrop pattern may be partly due to drag along the fault.

Most workers consider the Complex to be Upper Permian, but on the timescale used here, its youngest unit the 247 Ma (corrected) Dundee Rhyodacite (Evernden & Richards, 1962) is earliest Triassic. However, more recent estimates of the age of the Permo-Triassic boundary (Haq et al., 1987; Forster & Warrington, 1985) are both younger and older than that of Harland et al. (1982).

Error factors on ages of Period and stage boundaries also should not be neglected (Webb, 1981). Volcanism should therefore perhaps be interpreted as "waning" or "almost extinct" by the earliest Triassic. The Dundee Rhyodacite is widespread in New England and occurs in and beyond the Dundee Caldera (Godden, 1982). An underlying volcanic unit there has intercalated sediments containing the definitive Permian plant *Glossopteris* (Wood, 1982). A review by Barnes et al. (1991) gives a summary of the ages of the various volcanic piles in New England.

Thrust Faults

Triassic thrust faulting has affected the Canning, Perth and Bowen Basins.

Reverse movements along the Fenton Fault (Canning Basin) have been established from field relationships of mapped units (Crowe et al., 1978). Middle Triassic to Early Jurassic redbeds occur offshore (e.g. *Bedout* and *Malita* Formations; Gorter, 1978; Mory, 1988, respectively) The Bedout Formation is thought to have been deposits of the erosion of the anticlines and fault scarps created by the Canning Basin movements (Yeates & Mulholland, in prep.).

The prolonged supply of coarse clastic sediments that comprise the Lesueur Sandstone in the Perth Basin (Playford et al., 1976) is suggestive of continual uplift along the Darling Fault in the Middle and Late Triassic. Thrust movement along the fault can be interpreted to account for the uplift.

The Hunter-Mooki and Goondiwindi-Moonie Faults separate the New England Orogen from the Permo-Triassic foreland basin to the west. Periodic uplift in the vicinity of these faults can be inferred from facies (Jensen, 1975; Gray, 1984) and is probably due to thrusting. Seismic interpretation reveals that the Bowen Basin sequence was also thrusted in the Middle to Late Triassic (Korsch et al., 1990). There is some indication that these thrusts tie to unspecified faults inferred from field relationships of mapped units (Geological Survey of Queensland, 1988). The fault pattern is currently being studied as part of a National Geoscience Mapping Accord project, and is not shown on this edition of the Map.

Normal Faults

Principal examples of Triassic normal faulting are the tilted fault blocks of the Exmouth Plateau Arch (Exon & Willcox, 1980; Barber, 1984, fig.10). In the Late Triassic, the Arch was uplifted and, in contrast to the neighbouring Carnarvon Basin, remained relatively so throughout the Jurassic. Jurassic deposits of the Arch, where present, are relatively thin or confined to fault-angle depressions.

The Rankin Platform, an element of the Carnarvon Basin, was also uplifted at this time and block-faulted (Hocking et al., 1987).

Normal faulting also occurred in Eastern Australia. It was probably associated with the formation of intramontane basins and other adjustments to the rising and cratonisation of the New England Orogen. The same faults have not affected Jurassic deposits (Bradshaw & Yeung, in press).

Salt Diapirs

Non-diastrophic salt diapirism occurred in the eastern half of the Bonaparte Basin (Edgerley and Crist, 1974) during the Mesozoic. Seismic sections examined reveal that some of the upward movement of the diapirs occurred during the Late Triassic. The positions of known diapirs (Edgerley and Crist, 1974) are shown by a symbol on the Map. The salt is probably Early to Mid Palaeozoic (Wells, 1980).

WANING METAMORPHISM

Heating sufficient to reset K-Ar ages of biotites accompanied shearing and minimal reactivation of plutonism and dyke emplacement in the Northeast Queensland Plutonic Province (Day et al., 1983; Stephenson & Chappell, 1987). This region is crossed by northwest-trending lineaments (O'Driscoll, 1982) (see Map).

The symbol denoting low grade metamorphism in the New England Fold Belt about 40 km west of Coffs Harbour, NSW, possibly denotes the waning of a mainly Permian metamorphism. Thermal metamorphism associated with Late Permian and Triassic granitoids is also widespread in New England (Graham & Korsch, 1985).

The New England Orogen became largely cratonic by about the Triassic-Jurassic boundary. The major late-stage granitoids (including those that produce Sn and W) are Middle to Late Triassic and are indicative of impending cratonisation.

The Orogen's new stability was accompanied by a great change in the composition and character of igneous intrusions, and in the architecture of subsequent sedimentary basins. Igneous rock compositions changed from calc-alkaline acidic to dominantly alkaline mafic and ultramafic. Igneous bodies were plutonic during granitoid emplacement but much smaller tabular to pipe-like during the later mafic/ultramafic magmatism. Basin shapes in Triassic times were elliptical and elongate. Subsequent basins became more amorphous in outline, except in graben.

By the end of the Triassic, granitoid emplacement had virtually ceased, and instead, much smaller ultramafic bodies were emplaced throughout eastern Australia during the remainder of the Mesozoic (Bradshaw & Yeung, in press; Bradshaw et al., in prep.). The first known of the ultramafic bodies, the Somerset Dam Igneous Complex (Mathison, 1987) was emplaced at about the Triassic-Jurassic boundary. Coinciding with this new magmatism, the Eromanga Basin was initiated along a profoundly new trend that cuts the strike of the Orogen. Jurassic sedimentation does not appear to have been influenced by topography (Bradshaw & Yeung, in press) so the Queensland portion of the Orogen had presumably become lowland by then.

Through progressive observation from place to place across the accompanying Map, and paying attention to the timing of events depicted, an impression can be gained of the nature and consequence of Triassic movements which affected Australia.

Most subsidence was inherited from Permian depositional loci, although this was not so in central Australia. The loci of depoaxes changed markedly in eastern Australia at the Triassic-Jurassic boundary when the Eromanga Basin was initiated. This change did not occur on the western margin of Australia where deposition maintained much the same character for the remainder of the Mesozoic, albeit in environments that became progressively more marine.

Uplift was probably widespread throughout Australia, especially in the Middle and Late Triassic. Many epicratonic basins ceased being depositional then, and new ones were generated in areas spatially associated with granitoid emplacement in the New England Orogen. Strike-slip faulting there facilitated sedimentation, and caused considerable deformation in older rocks. These events were a prelude to cratonisation of the Orogen at about the Triassic-Jurassic boundary.

ACKNOWLEDGEMENTS

We are grateful to many colleagues at BMR and various State Geological Surveys for discussions, advice and new information. The manuscript was read by Russell Korsch. Drafting by Janette Kovacs (Map) and Peter Brown (Map updates and Table 1) is gratefully acknowledged, as is typing of respective drafts by Robyn Leason and Lesley Jones and Lucy Smith.

The Palaeogeographic Maps Project was supported by the Australian Petroleum Industry Research Association (APIRA) and we benefitted from collaboration with geologists of the sponsoring companies. This sponsorship supported S. M. Mulholland's participation in the Project.

REFERENCES

ARNE, D.C., GREEN, P.F., DUDDY, IR., GLEADOW, A.J., LOVERING, J.F., & LAMBERT, I.B., 1989 - An apatite fission track study of Zn-Pb mineralisation on the Lennard Shelf, Western Australia. *Geological Society of Australia Abstracts 9*, p.50.

ASHLEY, P.M., 1987a - Epithermal mineralisation and alteration in the Triassic North Arm Volcanics, southeast Queensland. *Pacrim Congress 87, Queensland Australia,* 17-20. Australasian Institute of Mining & Metallurgy, Melbourne.

ASHLEY, P.M., 1987b - Sulphide-selenide-metal alloy association at North Arm epithermal precious-metal prospect, Queensland, Australia. *Transactions of the Institution of Mining and Metallurgy* (section B: Applied Earth Science)96, B221-B227.

ASHLEY, P.M. & DICKIE, G.J., 1987 - North Arm volcanics and associated epithermal gold-silver mineralisation at North Arm prospect, *in* C.G. Murray & J.B. Waterhouse (editors). *1987 Field Conference, Gympie District, 60-67.* Geological Society of Australia, Queensland Division, Brisbane.

BACON, C.A., CALVER, C.R. & EVERARD, J.L., 1989 - Volcanic Rocks *in* C.F. Burrett & E.L. Martin (Editors). *Geology and Mineral Resources of Tasmania, 309-333.* Geological Society of Australia Special Publication 15.

BALME, B.E., 1989 - Australia Phanerozoic Timescales: 7, Triassic. *Bureau of Mineral Resources, Australia, Record* 1989/37.

BANKS, M.R., 1989 - Summary and structural development *in* C.F. Burrett & E.L. Martin (editors). *Geology and Mineral Resources of Tasmania*, 293-294, Geological Society of Australia, Special Publication 15.

BARBER, P.M., 1988 - The Exmouth Plateau deep water frontier: a case history, *in* Purcell, P.G. and R.R., (Eds.). *The North West Shelf Australia: Proceedings of the Petroleum Exploration Society Australia Symposium, Perth*, 173-187.

BARNES, R.G., BROWN, R.E., BROWNLOW, J.W., & STROUD, W.J., 1991 - Late Permian Volcanics in New England - the Wandsworth Volcanic Group. *New South Wales Geological Survey Quarterly Notes*, 84,1-36.

BARRETT, P.J., ELLIOT, D.H., & LINDSAY, J.F., 1986 - The Beacon Supergroup (Devonian-Triassic) and Ferrar Group (Jurassic) in the Beardmore Glacier area, Antarctica. *American Geophysical Union: Geology of the Central Transantarctic Mountains Antarctic Research Series,* 36, 339-428.

BENTLEY, J., 1988 - The Candace Terrace - a geological perspective *in* Purcell, P.G. and R.R., (Eds.), *The North West Shelf Australia: Proceedings of the Petroelum Exploration Society Australia Symposium, Perth,* 157-171.

BMR PALAEOGEOGRAPHIC GROUP, 1990 - *Australia: Evolution of a Continent.* Bureau of Mineral Resources, Australia, 97p.

BRADSHAW, J., NICOLL, R.S., & BRADSHAW, M., 1990 - The Cambrian to Permo-Triassic Arafura Basin, northern Australia. *The APEA Journal,* 107-127.

BRADSHAW, M.T., YEATES, A.N., BEYNON, R.M., BRAKEL, A.T., LANGFORD, R.P., TOTTERDELL, J.M., & YEUNG, M., 1988 - Palaeogeographic Evolution of the North West Shelf region, *in* Purcell, P.G. and R.R., (Eds.). *The North West Shelf Australia: Proceedings of the Petroleum Exploration Society Australia Symposium, Perth,* 29-54.

BRADSHAW, M.T., & YEUNG, M., (in press) Palaeogeographic Atlas of Australia, Volume 8 Jurassic. *Bureau of Mineral Resources, Australia.*

BRADSHAW, M.T., YEUNG, M., BURGER, D., & BEYNON, R.M., (in prep.) *Palaeogeographic Atlas of Australia, Volume 9 Cretaceous.* Bureau of Mineral Resources, Australia.

BURGER, D., 1987 - Palynological examination of samples from the Otway Group in the Otway Basin, Victoria. *Bureau of Mineral Resources, Australia, Professional Opinion, Geology* 87/006.

CAREY, S.W., 1976 - *The Expanding Earth.* Developments in Geotectonics 10. Amsterdam: Elsevier.

CAYZER, R.A. & LECKIE, J.F., 1987 - Mt Rawdon: exploration of a bulk low-grade gold deposit. *Papers, Department of Geology, University of Queensland,* 12 (1): 85-99.

CLARK, I.F., & COOK, B.J., (Editors) 1983 - *Perspectives of the Earth.* Australian Academy of Science, Canberra, 651 p.

COLLINSON, J.W., KEMP, N.R., & EGGERT, J.T., 1987 - Comparison of the Triassic Gondwana sequences in the Transantarctic Mountains and Tasmania, *in* McKenzie, G.D., (Ed.). *Gondwana Six: Statigraphy, Sedimentology and Palaeontology.* American Geophysical Union, Washington, D.C., Geophysical Monograph 41, 51-61.

COLLINSON, J.W., EGGERT, J.T., & KEMP, N.R., 1990 - Triassic sandstone petrology of Tasmania: evidence for a Tasmania-transantarctic basin. *Papers and Proceedings of the Royal Society of Tasmania,* 124 (1): 61-75.

CONAGHAN, P.J., JONES, J.G., McDONNELL, K.L., & ROYCE, K., 1982 - A dynamic fluvial model for the Sydney Basin *Journal of the Geological Society of Australia,* 29, 55-70.

CROWE, R.W.A., TOWNER, R.R., & GIBSON, D.L., 1978 - Permian and Mesozoic geology of the Derby and Mount Anderson 1:250,000 Sheet areas, Western Australia. *Bureau of Mineral Resources, Australia, Record* 1978/8.

DAY, R.W., CRANFIELD, L.C. & SCHWARZBOCK, H., 1974 - Stratigraphy and structural setting of Mesozoic basins in southeastern Queensland and northeastern New South Wales; *in* Denmead, A.K., Tweedale, G.W., & Wilson, A.F., (editors), *The Tasman Geosyncline - A Symposium.* Geological Society of Australia, Queensland Division, Brisbane, 319 - 362.

DAY, R.W., WHITAKER, W.G., MURRAY, C.G., WILSON, I.H., & GRIMES, K.G., 1983 - *Queensland Geology.* Geological Survey of Queensland Publication 383, 194 p.

DE KEYSER, F. & LUCAS, K.G., 1968 - Geology of the Hodgkinson and Laura Basins, north Queensland: *Bureau of Mineral Resources, Australia, Bulletin* 84.

DULHUNTY, J.A., 1986 - Mesozoic Garawilla lavas beneath Tertiary Volcanics of the Nandewar Range. *Journal and Proceedings, Royal Society of New South Wales,* 119, 29-32.

DULHUNTY, J.A., MIDDLEMOST, E.A.K., & BECK, R.W., 1987 - Potassium-argon ages, petrology and geochemistry of some Mesozoic igneous rocks in northeastern New South Wales. *Journal and Proceedings, Royal Society of New South Wales,* 120, 71-90.

EDGERLEY, D.W., & CRIST, R.P., 1974 - Salt and diapiric anomalies in the southeast Bonaparte Gulf Basin. *The APEA Journal,* 14(1): 85-94.

ELLIS, P.L., 1968 - Geology of the Maryborough 1:250,000 Sheet area. *Geological Survey of Queensland, Report* 26.

EVANS, P.R., & ROBERTS, J., 1979 - Evolution of central eastern Australia during the Palaeozoic and early Mesozoic. *Journal of the Geological Society of Australia,* 26, 325-340.

EVERNDEN, J.F., & RICHARDS, J.R., 1962 - Potassium-argon ages in eastern Australia. *Journal of the Geological Society of Australia,* 9, 1-49.

EXON, N.F., 1976 - Geology of the Surat Basin in Queensland. *Bureau of Mineral Resources, Australia, Bulletin* 166.

EXON, N.F., & WILLCOX, J.B., 1980 - The Exmouth Plateau: stratigraphy, structure and petroleum potential. *Bureau of Mineral Resources, Australia, Bulletin,* 199, 52 p.

FAIRBRIDGE, R.W., 1982 - The fracturing of Gondwanaland, *in* R.A. Scrutton & M. Talwani (editors), *The Ocean Floor,* 229-235. New York, John Wiley & Sons.

FALKNER, A.J., 1987 - Distall air-fall tuffs: examples from the Late Triassic of southeast Queensland. *Pacific Rim Congress 87, Queensland Australia Proceedings,* The Australasian Institute of Mining & Metallurgy, 737-739.

FORSTER, S.C., & WARRINGTON, G., 1985 - Geochronology of the Carboniferous, Permian and Triassic, *in* N. J. Snelling (Editor) *The Chronology of the Geological Record,* 99-113. Geological Society (London) Memoir 10.

FORSYTH, S.M., 1989 - Upper Parmeener Supergroup, *in* C.F. Burrett & E.L. Martin (editors), *Geology and Mineral Resources of Tasmania,* 309 - 333. Geological Society of Australia Special Publication 15.

GAMBLE, J.A., WHITLA, P.A., GRAHAM, I.J., & ADAMS, C.J., 1988 - Potassium-argon and rubidium-strontium dating of a teschenitic intrusion, upper Hunter Valley, New South Wales. *Australian Journal of Earth Sciences,* 35, 403-404.

GEOLOGICAL SOCIETY OF AUSTRALIA, 1971 - *Tectonic Map of Australia and New Guinea 1:5,000,000*-scale, Sydney.

GEOLOGICAL SURVEY OF QUEENSLAND, 1988 - *Bowen Basin Solid Geology. 1:500,000-scale Geological Map.* Department of Mines, Queensland.

GODDEN, N.L., 1982 - The volcanic-plutonic association, Tenterfield region, NSW, *in* P.G. Flood & B. Runnegar (editors) *New England Geology,* 211-219. Department of Geology, University of New England, Armidale, NSW.

GORTER, J.D., 1978 - Triassic environments in the Canning Basin, Western Australia, *BMR Journal of Australian Geology and Geophysics,* 3 (1): 25-33.

GRAHAM, I.J., & KORSCH, R.J., 1985 - Rb-Sr geochronology of coarse-grained greywackes and argillites from the Coffs Harbour Block, eastern Australia. *Chemical Geology (Isotope Geoscience Section)* 58, 45-54.

GRAY, A.R.G., 1984 - Stratigraphic drilling report, GSQ Taroom 13 and GSQ Baralaba 1. *Queensland Government Mining Journal,* 85 (987) 17-27.

HAQ, B.U., HARDENBOL, J., & VAIL, P.R., 1987 - Chronology of fluctuating sea levels since the Triassic. *Science,* 235, 1156-1167.

HARRINGTON, H.J., 1974 - The Tasman Geosyncline in Australia, *in* A.K. Denmead, G.W. Tweedale, & A.F. Wilson (editors) *The Tasman Geosyncline: a symposium,* 383-407. Geological Society of Australia, Queensland Division, Brisbane.

HARRINGTON, H.J., 1983 - Correlation of the Permian and Triassic Gympie Terrane of Queensland with the Brooks Street and Maitai Terranes of New Zealand. *Permian Geology of Queensland,* 431-436. Geological Society of Australia, Queensland Division, Brisbane.

HARRINGTON, H.J., & KORSCH, R.J., 1987 - Oroclinal bending in the evolution of the New England-Yarrol Orogen and the Moreton Basin. *Pacrim Congress 87, Queensland Australia,* 797-800. Australasian Institute of Mining & Metallurgy, Melbourne.

HARRINGTON, H.J., SIMPSON, C.J., & MOORE, R.F., 1982 - Analysis of continental structures using a digital terrain model (DTM) of Australia. *BMR Journal of Australian Geology & Geophysics, 7,* 68-72.

HAWKE, J.M. & BOURKE, D.J., 1984 - Stratigraphy. *in* J.M. Hawke & J.N. Cramsie (Editors). Contributions to the geology of the Great Australian Basin in New South Wales. *Geological Survey of New South Wales, Bulletin,* 31, 23-124.

HAWKINS, P.J., & HARRISON, P.L., 1978 - Stratigraphic and seismic investigations in the Lovelle Depression, western Galilee Basin. *Queensland Government Mining Journal,* 79, 623-650.

HELBY, R., MORGAN, R., & PARTRIDGE, A.D., 1987 - A palynological zonation of the Australian Mesozoic, *in* P.A. Jell (Editor), *Studies in Australian Mesozoic palynology,* 1-94. Association of Australasian Palaeontologists, Memoir 4, Sydney.

HERBERT, C., 1974 - Lorne Basin, *in* N.L. Markman & H. Basden (Editors) *The Mineral Deposits of New South Wales,* 507 - 509, Geological Suvey of New South Wales, Sydney.

HOCKING, R.M., MOORS, H.T., & van de GRAAF, W.J.E., 1987 - The geology of the Carnarvon Basin, WA. *Geological Survey of Western Australia, Bulletin* 133.

JAQUES, A.L., CREASER, J., FERGUSON, J., & SMITH, C.B., 1985 - A review of the alkaline rocks of Australia. *Transactions of the Geological Society of South Africa,* 88, 311-334.

JENSEN, A.R., 1975 - Permo-Triassic stratigraphy and sedimentation in the Bowen Basin, Queensland. *Bureau of Mineral Resources, Australia, Bulletin* 154, 187 p.

JOPLIN, G.A., 1968 - The shoshonite association: a review. *Journal of the Geological Society of Australia,* 15, 275-294.

KORSCH, R.J., ARCHER, N.R., & McCONACHY, G.W., 1978 - The Demon Fault. *Journal and Proceedings, Royal Society of New South Wales,* 111, 101-106.

KORSCH, R.J., & HARRINGTON, H.J., 1987 - Oroclinal bending, fragmentation and deformation of terranes in the New England Orogen, eastern Australia. *American Geophysical Union, Geodynamic Series,* 19, 129-139.

KORSCH, R.J., HARRINGTON, H.J., WAKE-DYSTER, K.D., O'BRIEN, P.E., & FINLAYSON, D.M., 1988 - Sedimentary basins peripheral to the New England Orogen: their contribution to understanding New England tectonics, *in* J. D. Kleeman (Editor) *New England Orogen, Tectonics and metallogenesis*, 134-140, Department of Geology and Geophysics, University of New England, Armidale, NSW.

KORSCH, R.J., O'BRIEN, P.E., SEXTON, M.J., WAKE-DYSTER, K.D., & WELLS, A.T., 1989 - Development of Mesozoic transtensional basins in easternmost Australia. *Australian Journal of Earth Sciences,* 36, 13-28.

KORSCH, R.J., WAKE-DYSTER, K.D., & JOHNSTONE, D.W., 1990 - Deep seismic profiling in the Bowen Basin *in* J.W. Beeston (Compiler) *Bowen Basin Symposium 1990,* 10-14, Geological Society of Australia, Queensland Division.

LASERON, C.F., (revised R.O. Brunnschweiler) 1969 - *Ancient Australia: the story of its past geography and life.* Angus and Robertson, Sydney, 253 p.

LE MAITRE, R.W., 1975 - Volcanic rocks from Edel No. 1 petroleum exploration well, offshore Carnarvon Basin, Western Australia. *Journal of the Geological Society of Australia,* 22, 167-174.

LEITCH, E.C., & BOCKING, M.A., 1980 - Triassic rocks of the Grants Head district and the post-Permian deformation of the southeastern New England Fold Belt. *Journal and Proceedings, Royal Society of New South Wales,* 113,89-93.

MATHISON, C.I., 1987 - Cyclic units in the Somerset Dam layered gabbro intrusion, southeastern Queensland, Australia. *Lithos,* 20, 187-205.

MCPHIE, J., 1982 - The Coombadjha Volcanic Complex: a Late Permian cauldron, northeast New South Wales, *in* P.G. Flood & B. Runnegar (editors) *New England Geology,* 221-227. Department of Geology, University of New England, Armidale, NSW.

MCPHIE, J., 1986 - Evolution of a non-resurgent cauldron: the late Permian Coombadjha Volcanic Complex, northeastern New South Wales, Australia. *Geological Magazine,* 123(3), 257-277.

MCPHIE, J., & FERGUSSON, C.L., 1983 - Dextral movement on the Demon Fault, northeastern New South Wales: a reassessment. *Journal and Proceedings, Royal Society of New South Wales,* 116, 123-127.

MARKHAM, N.L., & BASDEN, H., 1974 (Editors) *The Mineral Deposits of New South Wales,* 682 p., Geological Survey of New South Wales, Sydney.

MOORE, P.S., 1982 - Mesozoic geology of the Simpson Desert region, northern South Australia, *in* P.S. Moore & T.J. Mount (compilers) *Eromanga Basin Symposium, Summary Papers,* 46-57. Geological Society of Australia and Petroleum Exploration Society of Australia.

MORY, A.J., 1988 - Regional geology of the offshore Bonaparte Basin, *in* P.G. and R.R. Purcell (Eds.) *The North West Shelf, Australia*, 287-309. Proceedings PESA Symposium, Perth.

MURRAY, C.G., 1987 - Review of the geology of the Gympie district, southeast Queensland, with particular reference to stratigraphic, structural and tectonic problems, *in* C.G. Murray & J.B. Waterhouse (Editors) *1987 Field Conference, Gympie District,* 1-17. Geological Society of Australia, Queensland Division, Brisbane.

MURRAY, C.G., 1990 - Tectonic evolution and metallogenesis of the Bowen Basin, *in* J.W. Beeston (Compiler) *Bowen Basin Symposium 1990 Proceedings and Field Conference, Mackay, Queensland,* 201-212. Geological Society of Australia, Queensland Division, Brisbane.

MURRAY, C.G., & WHITAKER, 1982 - A review of the stratigraphy, structure and regional tectonic setting of the Brisbane Metamorphics, *in* P.G. Flood & B.Runnegar (Editors) *New England Geology,* 79-94. Department of Geology, University of New England, Armidale, NSW.

NASH, C.R., 1986 - Permo-Triassic tectonic evolution and metallogenesis of the Rockhampton-Maryborough area, Queensland: a photogeological investigation, *in* E. Scheibner (Editor), Metallogeny and Tectonic Development of Eastern Australia. *Ore Geology Reviews,* 1, 401-412.

OCEAN VENTURES PTY LTD., 1972 - *Edel 1 Well Completion Report* Bureau of Mineral Resources, Australia, File Number 72-2074.

O'DRISCOLL, E.S.T., 1982 - Patterns of discovery - the challenge for innovative thinking. (Australian Distinguished Lecture, 1981). *The PESA Journal,* 1, 10-31.

OLLIER, C.D., 1981 - Tectonics and Landforms. Longman London.

PLAYFORD, P.E., COCKBAIN, A.E., & LOW, G.H., 1976 - Geology of the Perth Basin, Western Australia. *Geological Survey of Western Australia, Bulletin* 124, 311 p.

ROBERTSON RESEARCH (AUSTRALIA) PTY. LTD., & FLOWER, DOERY BUCHAN PTY LTD., 1984 - Petroleum potential of the Papuan Basin, Papua New Guinea, 6 Volumes. *Geological Survey of Papua New Guinea, Port Moresby* (unpublished).

SCHEIBNER, E., 1976 - *Explanatory Notes on the Tectonic Map of New South Wales.* Geological Survey of New South Wales, Sydney.

SHAW, S.E., 1964 - The petrology of portion of the New England Bathylith, *Ph.D. Thesis,* University of New England, Armidale, NSW (unpublished).

SHAW, S.E., 1969 - Granite rocks from the northern portion of the New England Batholith, *in* G.H. Packham (Editor) *The Geology of New south Wales,* 285-290. Journal of the Geological Society of Australia, 16 (1): Sydney.

SHAW, S.E., & FLOOD, R.H., 1981 - The New England Batholith, eastern Australia: geochemical variations in time and space. *Journal of Geophysical Research,* 86 (B11) 10530-10544.

SPRIGG, R.C., 1984 - *Arkaroola-Mount Painter in the Flinders Ranges, SA: The Last Billion Years.* Arkaroola, South Australia.

STEPHENS, C.J., 1986 - Late Triassic silicic volcanism near Gayndah, *in* W.F. Wilmott (Editor) *The South Burnett District Field Conference,* 32-38. Geological Society of Australia, Queensland Division, Brisbane.

STEPHENS, C.J., 1987 - The anatomy of silicic calderas: evidence from the Triassic of eastern Australia. *Pacrim Congress 87 Queensland Australia,* 701-704. Australasian Institute of Mining and Metallurgy, Melbourne.

STEPHENSON, P.J., & CHAPPELL, B.W., 1987 - A major northwest dyke swarm in north Queensland, in *Pacrim Congress 87, Queensland Australia,* 817-822. Australasian Institute of Mining and Metallugry, Melbourne.

TADROS, N.Z., 1988 - Structural subdivision of the Gunnedah Basin. *Geological Survey of New South Wales, Quarterly Notes,* 73, 1-20.

TOTTERDELL, J.M., 1990 - Notes to accompany a 1:5,000,000-scale Permian structure map of Australia. *Bureau of Mineral Resources, Australia, Record* 1990/40.

VEEVERS, J.J., (Editor) 1984 - *Phanerozoic Earth History of Australia.* Clarendon Press, Oxford.

VINE, R.R., 1976 - Galilee Basin, *in* R.B. Leslie, H.J. Evans, & C.L. Knight (Editors) *Economic Geology of Australia and Papua New Guinea 3. Petroleum,* 316-321. Australasian Institute of Mining and Metallurgy, Mongraph 7: Melbourne.

VINE, R.R., CASEY, D.J., & JOHNSON, N.E.A., 1964 - Progress report, 1963, on the geology of part of the northeastern Eromanga Basin, Queensland. *Bureau of Mineral Resources, Australia, Record* 1964/39.

VINE, R.R., JAUNCY, W., CASEY, D.J., & GALLOWAY, M.C., 1965 - Geology of the Longreach-Jericho-Lake Buchanan area, Queensland. *Bureau of Mineral Resources, Australia, Record* 1965/245.

VOISEY, A.H., 1959 - Tectonic evolution of northeastern New South Wales, Australia. *Journal and Proceedings, Royal Society New South Wales,* 92 (4): 191-203.

von RAD, V., & EXON, N.F., 1982 - Mesozoic - Cainozoic sedimentary and volcanic evolution of the starved passive continental margin off northwest Australia. *American Association of Petroleum Geologists Bulletin,* 66, 253-281.

WEBB, J.A., 1981 - A radiometric time scale of the Triassic. *Journal of the Geological Society of Australia,* 28, 107-121.

WELLS, A.T., 1980 - Evaporites in Australia, *Bureau of Mineral Resources, Australia, Bulletin* 198.

WILLIAMS, L.J., & GUNTHER, L.M., 1989 - GSQ Dobbyn 1 - Preliminary lithologic log and composite log. *Queensland Department of Mines Record* 1989/22.

WILLIAMS, P.J. 1991 - Geology, alteration and mesothermal Au-Ag mineralisation associated with a volcanic-intrusive complex at Mt Shamrock-Mr Ophir, SE Queensland. *Mineralium Deposita,* 26, 11-17.

WILLIAMSON, P.E., PIGRAM, C.J., COLWELL, J.B., SCHERL, A.S., LOCKWOOD, K.L., & BRANSOM, J.C., 1987 - Review of stratigraphy, structure and hydrocarbon potential of Bass Basin, Australia. *American Association of Petroleum Geologists Bulletin,* 71, 253-280.

WOOD, B.L., 1982 - The geology and mineralisation of the Emmaville Tin Field, NSW, *in* P.G. Flood & B. Runnegar (Editors) *New England Geology,* 335-344, Department of Geology, University of New England, Armidale, NSW.

WOPFNER, H., 1985 - Some thoughts on the post-orogenic development of northeastern South Australia and adjoining regions. *Special Publication of the South Australian Department of Mines and Energy,* 5, 365-372.

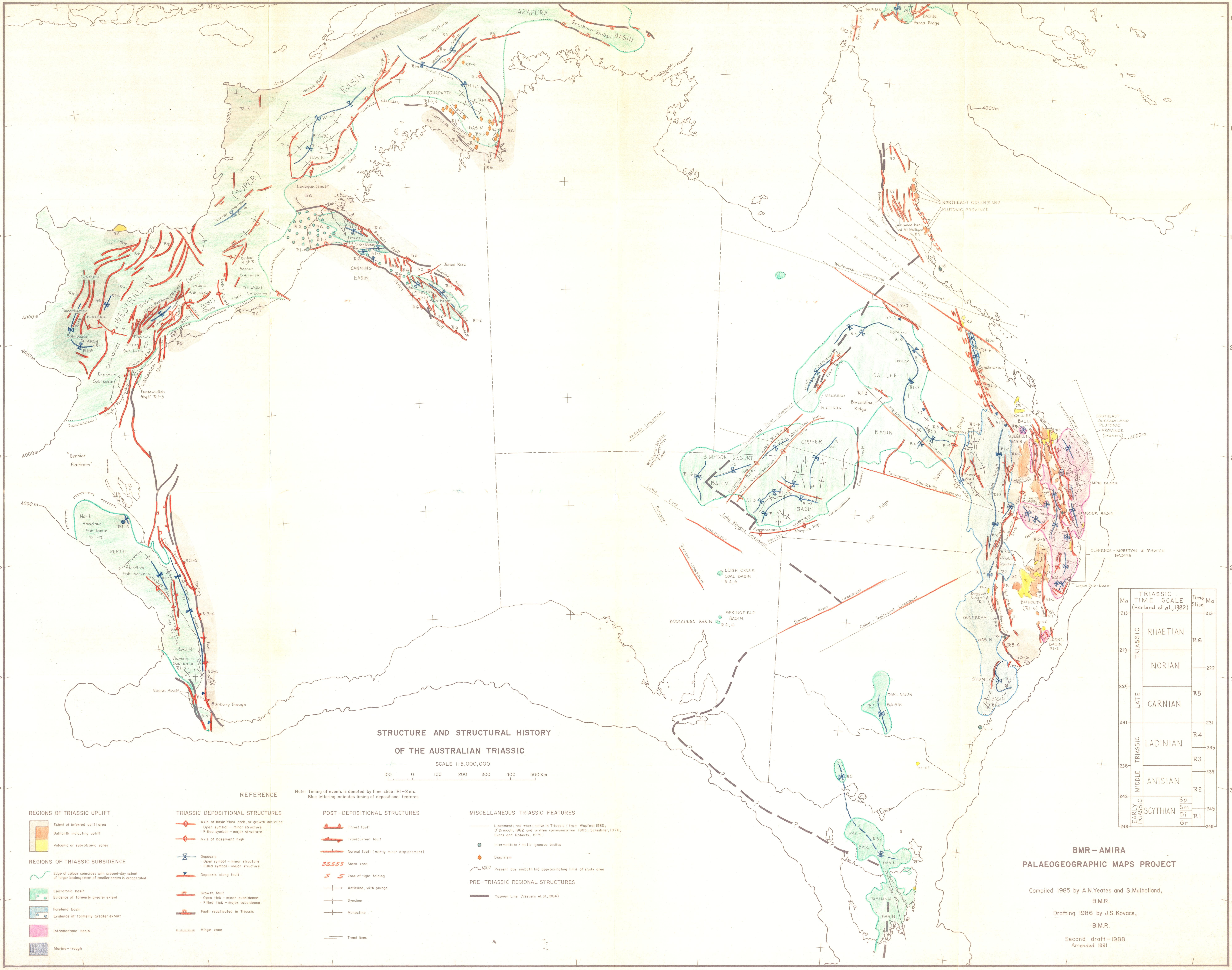
YEATES, A.N., 1982 - Radioelement characteristics of tin and tungsten granitoids in the New England Batholith, and other granitoid provinces of southeast Australia, *in* P.G. Flood & B. Runnegar (Editors) New England Geology, 301-311, Department of Geology, University of New England, Armidale, NSW.

YEATES, A.N., BRADSHAW, M.T., DICKINS, J.M., BRAKEL, A.T., EXON, N.F., LANGFORD, R.P., MULHOLLAND, S.M., TOTTERDELL, J.M., & YEUNG, M., 1987 - The Westralian Superbasin: an Australian link with Tethys, *in* K.G. McKenzie (Editor) *Shallow Tethys 2:* Proceedings of the International Symposium on Shallow Tethys 2, Wagga Wagga, NSW, 199-213. A.A. Balkema, Rotterdam.

YEATES, A.N., GIBSON, D.L., TOWNER, R.R., & CROWE, R.W.A., 1984 - Regional geology of the onshore Canning Basin, *in* P.G. Purcell (Editor) *The Canning Basin, WA,* 23-55, Geological Society of Australia and Petroleum Exploration Society of Australia, Perth.

YEATES, A.N., & MULHOLLAND, S.M., in prep., *Palaeogeographic Atlas of Australia, Volume 7 Triassic.* Bureau of Mineral Resources, Australia.

YOO, E.K., 1982 - Geology and coal resources of the northern part of the Oaklands Basin. *Geological Survey of New South Wales, Quarterly Notes,* 49, 15-26.


STRUCTURE AND STRUCTURAL HISTORY
OF THE AUSTRALIAN TRIASSIC
SCALE 1:5,000,000
100 0 100 200 300 400 500 Km
REFERENCE
Note: Timing of events is denoted by time slice: ♄1–2 etc.
Blue lettering indicates timing of depositional features
REGIONS OF TRIASSIC UPLIFT
Extent of inferred uplift area
Batholith indicating uplift
Volcanic or subvolcanic zones
REGIONS OF TRIASSIC SUBSIDENCE
Edge of colour coincides with present-day extent of larger basins; extent of smaller basins is exaggerated
Epicratonic basin
Evidence of formerly greater extent
Foreland basin
Evidence of formerly greater extent
Intramontane basin
Marine-trough
TRIASSIC DEPOSITIONAL STRUCTURES
Axis of basin floor arch, or growth anticline
· Open symbol – minor structure
· Filled symbol – major structure
Axis of basement high
Depoaxis
· Open symbol – minor structure
· Filled symbol – major structure
Depoaxis along fault
Growth fault
· Open tick – minor subsidence
· Filled tick – major subsidence
Fault reactivated in Triassic
Hinge zone
POST-DEPOSITIONAL STRUCTURES
Thrust fault
Transcurrent fault
Normal fault (mostly minor displacement)
Shear zone
Zone of tight folding
Anticline, with plunge
Syncline
Monocline
Trend lines
MISCELLANEOUS TRIASSIC FEATURES
Lineament; red where active in Triassic (from Wopfner, 1985; O'Driscoll, 1982 and written communication 1985; Scheibner, 1976; Evans and Roberts, 1979)
Intermediate / mafic igneous bodies
Diapirism
Present day isobath (m) approximating limit of study area
PRE-TRIASSIC REGIONAL STRUCTURES
Tasman Line (Veevers et al., 1984)
TRIASSIC TIME SCALE (Harland et al., 1982)
Ma
Time Slice
RHAETIAN
NORIAN
CARNIAN
LADINIAN
ANISIAN
SCYTHIAN
LATE TRIASSIC
MIDDLE TRIASSIC
EARLY TRIASSIC
BMR-AMIRA
PALAEOGEOGRAPHIC MAPS PROJECT
Compiled 1985 by A.N. Yeates and S. Mulholland, B.M.R.
Drafting 1986 by J.S. Kovacs, B.M.R.
Second draft–1988
Amended 1991
WESTRALIAN (SUPER) BASIN
CANNING BASIN
BONAPARTE BASIN
BROWSE BASIN
PERTH BASIN
ARAFURA
GALILEE
COOPER BASIN
SIMPSON DESERT BASIN
GUNNEDAH BASIN
SYDNEY BASIN
OAKLANDS BASIN
TASMANIA BASIN
NORTHEAST QUEENSLAND PLUTONIC PROVINCE
SOUTHEAST QUEENSLAND PLUTONIC PROVINCE
CLARENCE-MORETON & IPSWICH BASINS
LEIGH CREEK COAL BASIN
SPRINGFIELD BASIN
BOOLCUNDA BASIN