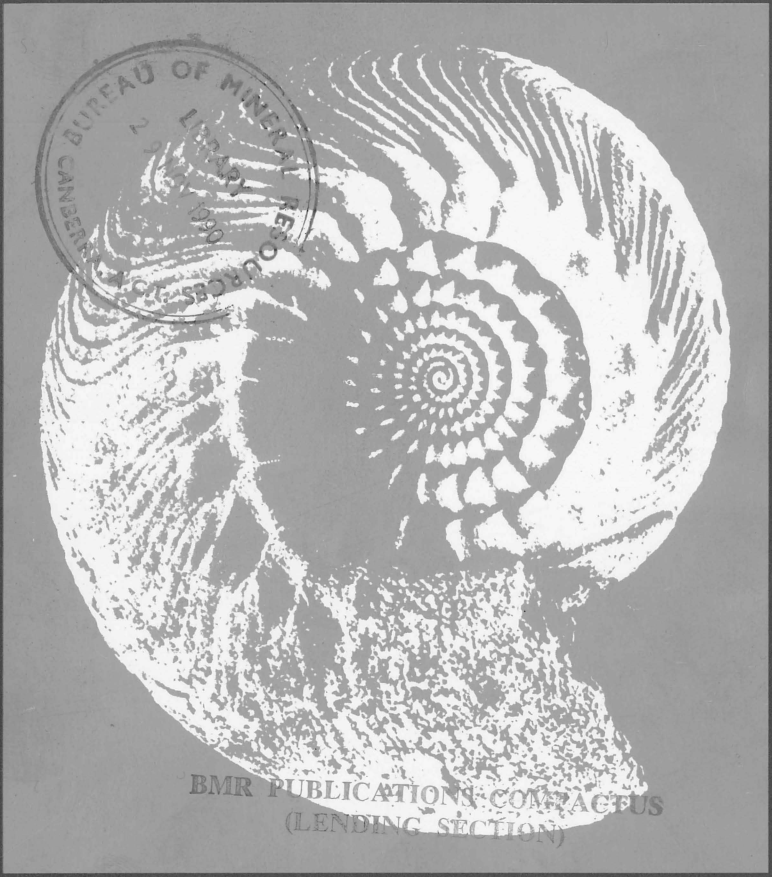
STRALIAN PHANEROZOIC TIMESCALES 7

AUSTRALIA

AUSTRALIAN PHANEROZOIC TIMESCALES: TRIASSIC

B. BALME



BUREAU OF MINERAL RESOURCES
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AUSTRALIAN PHANEROZOIC TIMESCALES

7. TRIASSIC

BIOSTRATIGRAPHIC CHARTS AND EXPLANATORY NOTES

by

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FOREWORD

A time framework is essential to understanding the history of all aspects of the geosphere. It is a prerequisite to interpreting the development and structure of the sedimentary basins which host our major petroleum, coal, and sedimentary mineral deposits, and is important when seeking patterns in the distribution of these resources through time. It is also critical to our understanding of the interactive factors which have shaped the modern Australian environment, and in determining the patterns of global change.

For the Phanerozoic (the last 570 million years, the period of 'visible life'), the most efficient way of establishing such a time framework is by the study of fossils, which represent the most concrete evidence for the evolution of life.

The palaeontological study of Australian sedimentary basins began with the first fossil descriptions in the latter part of the eighteenth century, which during the nineteenth century were used to establish the age of major suites of sedimentary rocks. An early example of the systematic use of fossils as time markers for detailed correlation was the subdivision of Ordovician rocks in Victoria using graptolites at the beginning of this century. The development of Australian biostratigraphy over the last 50 years has seen the setting up of various biostratigraphic schemes using the fossil remains of a wide range of organisms - from the microscopic, such as pollen grains and spores of land plants, to the macro- and megascopic - the remains of larger invertebrates, fish, mammals, even of human artifacts.

Recent years have also seen a rapid growth in other methods of measuring geological time, using radioactive decay of mineral elements, or reversals in the Earth's magnetic field. But no method for measuring geological time can operate in isolation, and a comprehensive time framework needs to take into account information from a variety of sources.

This preliminary series makes available for immediate use a set of charts based on recent palaeontological data from the specialist scientific literature, as well as unpublished information from ongoing biostratigraphic research. The charts integrate zonal schemes using different groups of fossils with isotopic and other data (magnetic reversal, eustasy curves), and show the relationship of the Australian zones to standard international timescales and their numerical calibration, where this information is available. The aim was not to produce a separate 'Australian time scale' in competition with already established international scales, but rather to provide a set of up-to-date calibrated biostratigraphic charts for use in the Australian region. Inevitably the detail of treatment and reliability varies for different parts of the column and for different groups of fossils, and much work still needs to be done to develop a fully integrated chronological scale comparable to those available in the Northern Hemisphere.

Biostratigraphic charts were first prepared to provide a firm chronological base for the AMIRA (Australian Mineral Industries Research Association) sponsored *Palaeogeographic Atlas of Australia.* The charts and explanatory text produced in this series are part of the second phase of that project, the *Phanerozoic History of Australia,* which is funded in part by APIRA (Australian Petroleum Industry Research Association). The charts have been compiled by palaeontologists in BMR, but incorporate contributions by other specialists working in State Geological Surveys, Universities and the exploration industry, without which such a comprehensive compilation would not have been possible.

I am confident that the charts will prove to be an essential tool for the exploration industry in Australia.

P.J. Cook,

Associate Director, BMR

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INTRODUCTION

GERMANIC TRIASSIC

The rock sequences on which the concept of the Triassic System was originally based outcrop over wide areas of the Federal and Democratic Republics of Germany (Figure 1). They overlie Palaeozoic rocks of the Variscan Fold Belt and are bounded to the west by the Rhine Graben, to the east by the Bohemian and Sudeten Massifs, to the south by the Alpine Foredeep and, in Hanover, to the north, are overlain by younger Mesozoic and Cainozoic sediments. These strata are lithologically distinctive and consist predominantly of red and yellow, continental and transitional clastics within which a sequence of shallow marine limestone is intercalated. Evaporite deposits, principally anhydrite, gypsum, halite and dolomite are extensively developed, especially in the middle and upper parts of the succession. Collectively this succession, which has a maximum thickness of about 2000m, constitutes the Germanic Facies of the Triassic. Because of its commercial significance as a source of halides and gypsum, which have been recovered from the Triassic and underlying Permian in Germany since the Middle Ages and earlier, lithological details of the sequence have been known to miners for centuries. This, together with the fact of its very complete exposures along the northern flank of the Thuringer Wald, to the south-west of Leipzig, gave the German Triassic an important position in the history of the development of stratigraphy.

In 1762 Füchsel published his account of the geological history of Thuringia, illustrated by maps and sections, in which he introduced the concept of a formation, recognised the significance of unconformities and anticipated the biostratigraphic method seven years before William Smith was born. The term Trias (subsequently Triassic) was introduced by von Alberti in 1832 and adopted in the same year by d'Omalius d'Halloy in the second edition of his text "Elemente der Geologie" and refers to the threefold lithostratigraphic sub-division of the Thuringian succession. This begins with the Bunter, consisting of variegated sediments, mainly sandstone, which is succeeded by the Muschelkalk, a shallow marine and lagoonal sequence of limestone and evaporites with invertebrate fossils, including ammonites. The uppermost unit, known as the Keuper (from the Coburg vernacular *köper*, a thread of variegated colours) is highly variable laterally but consists essentially of calcareous and gypsiferous clays with intercalated halite and dolomite beds and minor limestone. Thin coal seams occur near the base of the Keuper and it is regarded as a continental and transitional deposit, in part sub-aerial. The principal fossil remains are those of plants, amphibia and reptiles, including dinosaurs, but bivalves occur near its base and in the Täbingen Sandstone, which von Alberti regarded as the highest unit of the Keuper. The fauna of the Täbingen Sandstone includes *Avicula contorta*, a species that characterises the Kössen Beds in the Northern Calcareous Alps, which are the stratotype of the Rhaetian Stage. In 1856 Oppel & Suess proposed a correlation between the Kössen Beds and the Täbingen Sandstone and subsequently a fourth sub-division, the Rhät, has been recognised by German stratigraphers in the predominantly continental Triassic. Figure 2 summarises the broad lithostratigraphic units recognised in the Thuringian Triassic sequence.

Triassic strata are developed in Germanic Facies in Western Europe, Scandinavia, USSR, North Africa and eastern USA, that is in localities that lay, during the early Mesozoic, around the margins and in the hinterlands of the Tethys sea. These mainly continental sequences contain few invertebrate fossils and megascopic plant remains are sporadically distributed. As a result their correlation is difficult, although recent palynological studies have shown promise of resolving some of the long-standing problems.

To the south and south-east of the Thuringian stratotype areas, Triassic continental and marginal deposits grade into marine platform carbonates and deeper water sediments. These marine sequences, and, in places, Germanic-type strata, have been incorporated into the Cainozoic mountain chains of southern Europe.They make up the Alpine Triassic and are particularly favourably exposed in northern Italy and Austria (Figure 1). Since 1832 the elucidation of stratigraphic relationships within the Alpine Triassic and the correlation of these marine strata with their diverse invertebrate faunas and the sparsely fossiliferous sequences of the original German stratotypes have provided a challenge to stratigraphers, palaeontologists and structural geologists. There remain important unresolved questions at the present day.

TRIASSIC BIOCHRONOLOGY

Zittel (1901) traced the early history of the development of Triassic biostratigraphy and recently Tozer (1984) has updated the subject in a comprehensive and entertaining review, with emphasis on the role of ammonoids in Triassic biochronology. The brief summary that follows is based mainly on these accounts.

During the 19th century and until the beginning of World War I, Austrian palaeontologists and stratigraphers dominated the field of Triassic biostratigraphy. They worked mainly in two areas: the Salzkammergut, within the Northern Calcareous Alps, to the south-east of Salzburg, and the Southern Alps, especially the Val Gardena area of the Dolomites, which after World War I was incorporated into Italy (Fig. 1). The carbonate and marine clastic facies of the Alpine Triassic contain, in places, large numbers of extremely well-preserved ammonites and bivalves and these two invertebrate groups provided the principal raw materials for the early biostratigraphers. In other respects however the sections studied by the Austrian pioneers were far from ideal. In the Salzkammergut the sequence is highly tectonically disturbed and the facies developments are complex, so that, even today, stratigraphic relationships still debated. In the Dolomites the section is unmetamorphosed and the stratigraphy straightforward, but the ammonoid faunas have little in common with those from the Triassic of the Northern Alps. Although the first systematic biostratigraphic scheme for the Triassic, by Emmrich in 1844, was based on the Dolomites succession, the earliest stage nomenclature, Rhaetian of Gümbel in 1861 and Carnian and Norian of Mojsisovics in 1869, derived from localities in the Salzkammergut and nearby districts. All three were Oppelian in concept, based on faunas without clearly designated stratotypes and, at least for the Norian and Carnian, of uncertain relative stratigraphic position.

Problems concerning the relative stratigraphic position of strata containing Norian and Carnian index fossils and subsequent confusion in the application of the name Norian led Bittner, in 1892, to propose the Ladinian Stage, defined by faunas from the Dolomites section, principally characterised by trachyceratid ammonites. The remaining established Triassic Stage name based on Alpine faunal indices is Waagen and Diener's Anisian, from exposures in the valley of the Enns River, south of Linz, that contain, *inter alia* , ammonites now placed in the genus *Paraceratites*. Alpine Triassic faunas are impoverished below the base of the type Anisian, which, by definition, is also the base of the Middle Triassic, and coincides in a general way with that of the Muschelkalk. Marine stratotypes for biostratigraphic subdivision of the Lower Triassic are therefore extra-Alpine.

Triassic faunas were known to be widely distributed by the mid-19th century and fairly extensive collections had been made by Russian expeditions to Spitsbergen and northern Siberia. A few specimens had also been recovered fron the Canadian Arctic and, most importantly, by geologists of the Indian Geological Survey, from localities in the Himalayas and from the Salt Range, in what is now Pakistan. The Himalayan and Salt Range sequences provided the earliest control for the zonation of the Lower Triassic. Almost all the stratigraphers and palaeontologists who pioneered their study were Austrian or trained in Vienna and, in the main, employed by the Indian Geological Survey. They included Waagen, Diener, Stoliczka, Krafft and Griesbach, who in 1880 first described *Otoceras* and *Ophiceras* and proposed that the base of the *Otoceras woodwardi* Zone in the Kumaon Himalayas should serve as the datum plane for the base of the Triassic. Norian and Carnian faunas had also been recognised in the Karakorum Range, on the north slope of the Himalayas, and Mojsisovics, Waagen and Diener (1895) incorporated twelve zones, based on faunas from the "Indian Province", in their Triassic Time Scale. The lower seven of these zones made up the Scythian Stage (*Skythisch Serie* of the original authors) which was based principally, although not entirely or explicitly, on the sequence in the Salt Range, although the original type locality appears to have been in the Soviet Union. Mojsisovics, Waagen and Diener's monograph represented an important advance, despite the potentially confusing nomenclature, but its principal deficiency was that, except in the Salt Range, the proposed zonal succession could not be related with confidence to a stratigraphic sequence.

Even at the time of the publication by Mojsisovics and his colleagues, it was becoming clear from the work of Hyatt and Smith in California and Nevada that Triassic sections in the Cordilleran chains of North America were more complete, and more readily decipherable stratigraphically, than those of the European Alps. Triassic marine faunas are now known to occur in plate-bound successions from California, Idaho, Nevada and Oregon in the south, through to the Eastern and Western Cordilleras of British Columbia and Alaska, and also in the Canadian Arctic Islands. Ammonite faunas collected from these sequences provided the basis for the biochronological scheme proposed initially by Tozer (1967) and expanded by Silberling and Tozer (1968). The ammonoid biochronology shown in Figure 3 of the present review is taken from Tozer (1984) and is widely accepted to-day.

For about 30 years prior to the publication of Silberling and Tozer's synthesis the system of biochronological nomenclature proposed by Spath (1934) had considerable influence and was used by most Australian workers such as Dickins and McTavish (1963), Balme (1969), and Skwarko and Kummel (1974). Spath's monograph was primarily systematic and his Divisions, as their names (Otoceratan, Gyronitan etc.) imply, were biological concepts, without direct relationship to observed stratigraphic successions, although he related them implicitly to previously defined Zones and Stages. Tozer (1984) has criticised this approach, although, in fairness to Spath, it was not intended to establish a formal biostratigraphic hierarchy but rather to provide a flexible and convenient nomenclature when precise correlation was not possible.

Since the mid-1950's Triassic conodonts have been used to provide a parallel biochronological scheme to the ammonites. Sweet, in the United States, has been the protagonist in the application of conodont stratigraphy, although other American, European and Japanese workers have made important contributions. Conodonts have proved particularly effective indices for the Lower Triassic, where they may provide a more refined biochronology than ammonites, especially if the graphic correlation techniques used by Sweet (1988) achieve general acceptance. As a guide to the relationships between ammonite and conodont zonal schemes, the time scale proposed by Sweet, Mosher, Clark, Collinson and Hasenmueller (1971) has been incorporated in Figure 3.

Other fossil groups that have been widely used as Triassic indices are pectinid bivalves such as *Claraia* , *Monotis* and *Halobia*, spores and pollen and, in the Upper Triassic, dinoflagellates. A formal biochronology using plant microfossils is in use in Australia (Helby, Morgan and Partridge, 1987) and the basis of palynological biozonations has been established in, for example, the Alps (Visscher and Brugman, 1981), the North Sea (Geiger and Hopping (1968), United Kingdom (Fisher, 1972), Canadian Arctic (Fisher, 1979), U.S.S.R. (Yaroshenko, 1978) and China (Qu Lifan and others,1983). Except for local correlation purposes, palynological zonations will not, for a variety of obvious reasons, ever achieve the degree of refinement and authority possible with ammonites and probably conodonts. In the Triassic, on the other hand, palynological biochronology is far more generally applicable than that based on marine invertebrates and will almost certainly continue to be the most important biostratigraphic method for regional studies (see, for example, Scientific Shipboard Party, 1990).

BOUNDARIES OF THE TRIASSIC

Apart from minor residual debate concerning the relationship of the Rhaetian there has been general agreement since Oppel's time that the beginning of the Jurassic is defined by the base of the Zone of *Psiloceras planorbis* which occupies the lower part of d'Orbigny's Hettangian Stage. This is not, of course, to imply that it is easy to select a satisfactory boundary between the two Systems in the absence of ammonite faunas. In other faunal and floral groups a more natural break appears to lie within the Norian.

There is, on the other hand, still a spirited argument concerning the most appropriate datum to serve as the reference for the base of the Triassic. Tradition and priority, which are not principles to be lightly discarded, follow Griesbach and Waagen and Diener, and place the lower boundary at the base of the *Otoceras woodwardi* Zone in the central Himalayas. This is considered to correspond, for practical purposes, with the base of the Werfen Formation, which is usually taken to mark the base of the Triassic in the Alps. Tozer (1988 and elsewhere) strongly advocates this view and it appears to be accepted by most members of the International Sub-Committees on Permian and Triassic stratigraphy. It has also been adopted in the present review, although not with total conviction. *Otoceras* is not an ideal index. It is known only from the Himalayas, Alaska, the Canadian Arctic, Greenland, the north-eastern Soviet Union and, possibly, China, all localities that are not easily accessible. It is, in addition, difficult to identify, unless preserved three-dimensionally, and otoceratid ammonites are also known from the Late Permian. For these, and other reasons, a number of biostratigraphers (e.g. Waterhouse, 1978, Sweet, 1979, Kozur and others, 1978) have, in recent years, advocated re-defining the Permian-Triassic boundary, usually with a view to including all or part of the Griesbachian in the Permian. Some of the arguments advanced are unacceptable as they involve *a priori* assumptions as to what constitutes a Permian fauna, and ultimately the choice of any datum is an arbitrary one. The only justification for changing the boundary would be to base it on a different event, or simultaneous events, that provide greater precision and are more readily applicable.

For practical purposes, in marine Permian-Triassic sequences of low thermal maturity, palynology provides a satisfactory method of defining the base of the Triassic. Many palynologists have emphasised the highly characteristic and unusual composition of palynomorph assemblages recovered from marine basal Triassic clastic sediments throughout the world. Their most striking feature is their content of suites of small, poorly diversified, acanthomorph acritarchs. They are also unusual in that the vascular plant elements present consist predominantly of lycopsid spores and coniferalean pollen of the *Lunatisporites* -type. In the Salt Range and in Western Australia (Balme, 1970, Dolby and Balme, 1976) assemblages of this type range from the base of the Triassic section (i.e. probably lower Griesbachian) to the lower part of the Smithian. In Greenland (Balme,1979) there is evidence that the acanthomorph "spike" occurs within the Griesbachian, above the entry of *Otoceras*, and preliminary data from Alaska (Balme, 1980) and Arctic Canada (Utting,1989) suggest the same thing. In their global distribution and persistency of composition, these late Griesbachian-Nammalian plant microfossil assemblages are unlike any encountered in any other part of the geological column and must reflect some most unusual features of global coastal phytogeography during the first 2 or 3 million years of Triassic time. They thus serve an important purpose in defining a biochron within the Lower Triassic that can be no longer than about 3 million years.

AUSTRALIAN TRIASSIC

As in Europe, the Triassic System has an important association with the history of the development of Australian stratigraphy. European settlement of Australia, in 1788, was established at Sydney Cove on Triassic Hawkesbury Sandstone, which provided spectacular landscapes and excellent building materials, but extremely impoverished soils. Before the end of the eighteenth century, quarrying of sandstone and clay, the search for more tractable agricultural land and the discovery of coal at Newcastle in 1795, had brought about a crude understanding of the geology of the south-eastern Sydney Basin.

During the period 1839-1844 W.B. Clarke made palaeontological collections from various localities in the Colony of New South Wales. These included a small number of rather poorly preserved plants from the Wianamatta Group at Cobbity, about 50 km WSW of Sydney. M'Coy (1847) briefly described 4 plant species from this locality, including *Pecopteris odontopteroides* Morris (now *Dicroidium odontopteroides*), which had been first described from an unknown locality in Tasmania two years earlier (Morris in Strzelecki, 1845). Although M'Coy believed the plants he described to be Jurassic, his contribution was the first dealing with Australian Triassic fossils from a reasonably well-documented locality. Clarke (1878) was non-committal concerning the age of the "Hawkesbury Series", referring it to the Supra-Carboniferous (? Mesozoic) and Tenison-Woods (1883) who studied Palaeozoic and Mesozoic floras from New South Wales and Queensland believed, with M'Coy, that the Ipswich Coal Measures were Jurassic. Stephens (1886) appears to have been the first to suggest with any conviction that the "Hawkesbury Series" was Triassic, when he described the labyrinthodont *Platyops* (now *Blinasaurus*) *wilkinsoni* from the Narrabeen Group, and compared it to forms from the European Keuper, noting as additional evidence the abundance of *Estheria* in association with the amphibian remains. This dating was accepted with some reservation by David (1887), firmly by Feistmantel (1890) and subsequently by most workers; a conclusion resulted from consensus rather than overwhelming palaeontological evidence, although Watson (cited in David, 1932) noted that the evolutionary position of labyrinthodonts from the Hawkesbury Sandstone and Wianamatta Shale appeared to match that of those from the late Bunter and early Keuper of Europe.

Subsequent refinements of the biostratigraphy of the succession in the Sydney Basin have been based principally on palynology (Evans,1966, Helby,1974, Helby, Morgan and Partridge,1987) which has also been the principal biostratigraphic technique in the correlation of the other, mainly continental, successions of eastern Australia. These are developed in many sedimentary basins associated with the Australian eastern craton (Palfreyman, 1984) although all sequences appear to be incomplete. Triassic strata are most extensive in Queensland, but there are important successions in South Australia and Tasmania and minor occurrences in Victoria (Figure 4).

The most complete Australian Triassic sequences are now known to be present in the marginal basins of the western craton, particularly in off-shore wells on the Northwest Shelf. Lycopods (*Pleuromeia*) were collected from the Lower Triassic of the Canning Basin during the late 19th Century (Foord, 1890) but were misidentified as *Lepidodendron* and their stratigraphic significance not recognised. Antevs (1913) also recorded *Dicroidium* from the same basin, but did not make any stratigraphic inferences from the occurrence. Brunnschweiler (1954) was the first to recognise that vertebrate and invertebrate faunas from the Blina Shale, in the Canning Basin, indicated a Triassic age and shortly afterwards important Early Triassic ammonite faunas were discovered in the Perth Basin. These, together with their associated amphibians, conodonts and palynomorphs, provided the first clear evidence enabling Australian successions to be correlated directly with the standard marine Triassic. However, with the exception of two specimens referred tentatively to *Nicomedites*, of possible early Anisian age, no Triassic ammonites younger than Nammalian are known from Western Australia. The only other known Australian Triassic ammonite fauna, from the Gympie Block, Queensland, is also Nammalian. Carnian-Norian conodonts and forams, and nannofossils assigned to the Late Norian (Rhaetian) are known from the Northwest Shelf but post-Spathian faunas so far described are sparse and sometimes biochronologically equivocal. It must therefore be recognised that the practice followed in this review of applying standard stage names to these Gondwanan Middle and Upper Triassic sequences is in line with Australian precedent, but cannot always be rigorously justified.

AUSTRALIAN BIOCHRONOLOGY

Banks (1978) prepared a correlation chart for the Australian Triassic which incorporated a survey of the biostratigraphic evidence on which the correlations were based and the present review has drawn heavily on his account. He also provided a fuller bibliography than that given here and this should be consulted by anyone interested in details of the early development of Australian Triassic stratigraphy. Since Banks's paper appeared, subsequent palaeontological studies have not greatly modified his proposed correlations and the present account is mainly concerned with summarising the basis of current Australian Triassic biochronology. Most of the papers dealing with Triassic palaeontology published since 1978 have dealt with vertebrates or palynology. Important new amphibian and reptilian records have been reported from the Lower Triassic of the Tasmania and Bowen Basins, new fish have been described from the Sydney Basin and a good deal of additional palynological data have become available, principally from the sedimentary basins of Queensland. From the biochronological viewpoint the most important contribution is that of Helby, Morgan and Partridge (1987) which synthesised the available stratigraphic data on the distribution of Triassic palynomorphs in Australian sedimentary basins and proposed a comprehensive zonal scheme based on spores, pollen and dinoflagellates. This has been widely adopted and palynology is likely to remain the basic biostratigraphic technique for the intra-continental correlation of Australian Triassic sequences. Figures 5-12 summarise the available biochronological evidence relevant to the Australian Triassic and these are discussed more fully in the sections that follow.

MOLLUSCA

AMMONOIDS: [Figures 3, 5, 6] Triassic ammonoids are known from Western Australia and eastern Queensland. They are only plentiful in the Mt Minchin district in the northern Perth Basin, where they occur as limonitised moulds, near the base of the

Kockatea Shale, in its outcrop along the western flank of the Northampton Block. The earliest record of a Triassic ammonoid from the Kockatea Shale was an ophiceratid recovered from a water bore at Geraldton (Glenister & Furnish, 1961) in a core dated as Early Triassic on the basis of palynological comparison with the Blina Shale in the Canning Basin. Shortly afterwards Dickins & McTavish (1963) reported ammonoid fragments and identified three species, *Subinyoites kashmiricus*, *Ophiceras (Discophiceras) ?subkyoticum* and *Glyptophiceras* sp. from the Kockatea Shale at depths between 733.0 and 979.5m in BMR 10 (Beagle Ridge) Bore. They referred the interval to Spath's Otoceratan Substage of the Lower Scythian. Edgell (1964) was the first to recognise the Triassic age of the Mt Minchin fauna from which he listed aff. *Owenites* sp., aff. *Proptychoides* sp. and aff. *Kashmirites* sp. and assigned it to the Owenitan, noting its Timorese affinities. Edgell's tentative identifications were revised by Skwarko & Kummel (1974) who described and illustrated *Arctoceras spp. indet., Prionites* sp. indet., *Hemiprionites* sp. indet. and *Anasibirites kingianus* Waagen from Mt Minchin and several new nearby localities. In the same paper, *Proptychites* sp. indet. ?*Koninckites* sp. indet. and ?*Paranorites* sp. indet. were reported from the Kockatea Shale between depths of 1661-69m in Dongara No. 4 Well and *Gyronites* sp. cf. *G. frequens* Waagen at about 1699m in the same well. Skwarko and Kummel correlated this fauna with that from the Mittiwali Member (= Ceratite Beds) of the Salt Range and referred it to the Gyronitan-Flemingitan. The only Western Australian ammonoids so far reported from outside the Perth Basin came from Sahul Group, in the interval 3502.7-3512.5m, Sahul Shoals No.1 Well, offshore Bonaparte Basin, which were also recorded in Skwarko and Kummel's paper. They included small ribbed forms that could not be further identified and specimens attributed with some hesitation to *Nicomedites* , an index form originally described from the Turkish Anisian.

Following Skwarko and Kummel's account Dickins and McTavish (1974) revised their biochronological interpretation of the marine Lower Triassic sequence in BMR 10, Beagle Ridge Bore taking into account conodont and bivalve evidence. They also employed the Stage and Substage nomenclature for the Lower Triassic proposed by Tozer (1965) on the basis of sections in the Canadian Arctic Islands. Strata between 973-80m were referred to the early Griesbachian because of the presence of *Claraia stachei* ; those from 854-57m with *Ophiceras* were regarded as late Griesbachian and the highest ammonoid-bearing horizon with *Subinyoites kashmiricus* was correlated with the Smithian.Plant microfossils have been extracted from all the Western Australian sub-surface samples from which ammonoids have been identified and palynostratigraphy for the Lower Triassic is therefore adequately controlled, at least from the Griesbachian to Smithian. The basis for recognition of the Lower to Middle Anisian is less satisfactory and there are no younger Triassic ammonoid faunas known. This position is unlikely to change dramatically, as upper Middle to Upper Triassic marine strata occur only in offshore areas of the Northwest Shelf. Positive correlations of Australian post-Anisian sequences with standard international Triassic stages are therefore likely to depend on future evidence from conodonts and possibly dinoflagellates.

The only other Triassic ammonoid fauna known from Australia occurs in deformed strata in the vicinity of the Gympie Block, Queensland. Runnegar (1969) described and illustrated representatives of the genera *Dieneroceras*, *Paranorites*, *Pseudohedenstroemia*?, *Latisagericeras* , *Anaflemingites*, *Flemingites* and *Arctoceras* from sediments now referred to the Kin Kin Beds (Day and others, 1983). The association was correlated by Runnegar with the *Euflemingites romunderi* Zone (lower Smithian) of the Canadian Arctic and is thus more or less coeval with faunas from the upper part of the Kockatea Shale.

Attempts to recover plant microfossils from the deformed thermally mature sediments associated with the Kin Kin fauna have not been successful and it cannot, therefore, serve as a biostratigraphic reference point for the considerable volume of palynological data available from the Triassic of eastern Australia.

BIVALVES AND GASTROPODS: [Figures 5,6]. Triassic marine bivalves are known from the Perth Basin, the Northwest Shelf and the Gympie Block. The most significant faunas for biochronological purposes occur in cores from BMR 10 (Beagle Ridge) Bore in the Perth Basin. Here McTavish and Dickins (1974) recorded *Trigonucula* sp. from 760-763m, *Bakevellia* sp. between 797-800m and, most significantly, the aviculopectinids *Claraia per-*

thensis Dickins & McTavish and *C. stachei* Bittner from the interval 973-979m. Although there is some difference of opinion concerning the upper limit of the time-range of *Claraia* it is a reliable Lower Triassic index and especially characteristic of the early Griesbachian. Its occurrence about 20m above the base of the Kockatea Shale in Beagle Ridge Bore therefore suggests that, in the central part of the Perth Basin, the lower boundary of the Kockatea Shale corresponds fairly closely to the base of the *Otoceras woodwardi* Zone. Skwarko and Kummel (1974) also recorded unidentified pteriacean bivalves from the Kockatea Shale and specimens of *Nuculana* sp. and undetermined halobids in probable Early Anisian strata in the offshore Bonaparte Basin. Diverse bivalve are present in uppermost Triassic marine carbonate sequences encountered in exploration wells and Ocean Drilling Programme Sites on the Northwest Shelf (Williamson and others, 1989, Scientific Shipboard Party, 1990) but *Megalodon* is the only genus so far publically identified.

A small marine bivalve fauna from strata corresponding to part of the Brooweena Formation in the Gympie Block was first reported by Denmead (1964) and described subsequently by Fleming (1966). The genera represented are "*Ctenodonta*", *Nuculopsis* , *Bakevellia*, *Myalina* , ?*Schizodus* and *Neoschizodus*, all of which are known from the Palaeozoic. However, the species of *Myalina*, *Bakevellia* and *Neoschizodus* appear to be undoubtedly Early Triassic and their association with a poorly preserved otoceratid confirms this age. Fleming suggested that the fauna was post-Flemingitan and presumably, therefore, Smithian. Another bivalve record from the Gympie Block is that of an unidentified nuculoid bivalve from the Kin Kin Beds (Runnegar & Ferguson, 1969) which are unequivocally Smithian.

Freshwater bivalves are surprisingly rare in the Australian Triassic, considering the great range and volume of continental sediments that the system comprises in basins of the Eastern Craton. Ludbrook (1961) described unionids from the Leigh Creek and Springfield Coal Measures in South Australia. They have been reported also from the Hawkesbury Sandstone (David, 1950) and Wianamatta Shale (Etheridge Jr., 1888) in the Sydney Basin, and species of *Unio* and *Mesohydriella* from the Ipswich Coal Measures were illustrated by Hill, Playford and Woods (1965). Gastropods are even rarer. Runnegar (1964) described a new species of the bellerophontid *Stachella* from the Smithian Kin Kin Beds and an undetermined gastropod was listed by Standard (1962) from the Hawkesbury Sandstone, Sydney Basin. An older record of a bellerophontid of Lower Palaeozoic aspect from the Wianamatta Shale (Etheridge Jr., 1888) is questionable. Recently varied gastropods have been reported but not yet identified from the Brigadier Beds on the Northwest Shelf (Williamson and others, 1989).

ARTHROPODS [Figure 5]

Small arthropods, especially branchiopods and insects, are common in the Australian Triassic. They have clear palaeoecological significance but have not yet demonstrated much potential for refined biostratigraphy, although the application of modern systematics to conchostracans may enable them to be used with more confidence for this purpose.Their abundance at some localities was cited by Stephens (1886) as evidence for correlating the Narrabeen Group with the European Middle Triassic and coquinas of the same group, occurring near the base of the Blina Shale, led Brunnschweiler (1954) to assign that unit to the Keuper, the first recognition of Triassic strata from the western margin of the continent.

CONCHOSTRACANS: Conchostracans were first reported from the Sydney Basin by Cox (1880) who identified *Estheria* in a borehole sunk in the Sydney Metropolitan Area. Subsequently they were frequently recorded, mainly by authors primarily concerned with other fossil groups, and their abundance at some horizons led David (1887) to recognise a a unit that he named the "*Estheria* Shales", which is now incorporated in the Collaroy Claystone. Mitchell (1927) briefly discussed these early reports, and provided descriptions and systematic treatments of 4 species of *Estheria* from the Wianamatta Group. He dealt also with species from the Ipswich Coal Measures, from which Etheridge (in Jack & Etheridge, 1892) had previously identified *Estheria*. Tasch and Jones (1979a, b) have revised some of Mitchell's species when dealing with Triassic conchostracans from other Australian basins, but the only recent paper dealing with members of the group from the Sydney Basin was that of Webb (1978) who erected a new species of *Palaeolimnadiopsis* on the basis of specimens from the Hawkesbury Sandstone.

Recent additions to conchostracan literature have been made by Tasch (1975) who described *Palaeolimnadia* and *Cyzicus* from the Knocklofty Formation, Tasmania Basin and (Cockbain, 1974) who reported *Cyzicus minuta* (Van Zieten) from the Kockatea Shale. More detailed accounts of faunas from the Canning, Bonaparte and Bowen Basins have been presented by Tasch & Jones (1979a, b) and Tasch (1979). These came from the Blina Shale, Mount Goodwin Formation and Sagittarius Sandstone respectively, and were dominated by *Cyzicus* and *Palaeolimnadia* , although *Estheriina* was also present in the Blina Shale and Sagittarius Sandstone. Tasch (1979) assigned the Sagittarius Sandstone to the Lower Triassic on the conchostracan evidence, although palynological data suggest that at least some localities the unit is partly Permian. Possibly the base of the Rewan Group is markedly diachronous and these results may not be irreconcilable.

OSTRACODES: Lovering (1953) reported glauconitic casts of unidentifiable ostracodes from the Wianamatta Group but these are now thought to be inorganic (Byrnes & Scheibnerová, 1980) and the only undoubtedly marine species known from the Australian Triassic are from Western Australia. Jones (1970) described new species of *Paegium* and *Truncobairdia* From the lower part of the Kockatea Shale, Perth Basin, and Kristan-Tollmann (1986) listed *Cytherophyton*, *Cytherella*, *Nodobairdia* and *Hungarella* from the interval 2920-2926m in Sahul Shoals No. 1 Well, Bonaparte Basin. She assigned this association to the Upper Norian (Rhaetian) but palynological data from the same interval indicate that it cannot be younger than Carnian. Ostracodes were also reported from the uppermost Triassic Brigadier Beds at ODP Site 761 on the Wombat Plateau (Scientific Shipboard Party, 1990) but no identifications have been published.

INSECTS: Australian Triassic insect faunas, particularly those from the Ipswich Basin, are among the most diverse found in strata of that System anywhere in the World. The oldest is from the Anisian Hawkesbury Sandstone in Beacon Hill Quarry, near Brookvale, in the Sydney Basin where at least 4 Orders are represented (Tillyard, 1925; McKeown, 1937; Riek, 1950, 1954; Evans, 1963). They include Orthoptera, Hemiptera, Perlaria and the large protorthopterid *Clathrotitan scullyi*, with a wing span of nearly 25cm. A slightly younger, but probably still Anisian, assemblage occurs in the Ashfield Shale, in the lower Wianamatta Group (Tillyard, 1916). This contains 4 genera of beetles in addition to homopterids, scorpion flies and possible protorthopterids.

The most varied and best-known Australian Triassic insect remains are those from the Ipswich Coal Measures and the quality of their preservation may be judged from the illustrations of selected type specimens in Hill, Playford and Woods (1965). They occur at two stratigraphic horizons, the lower in the Mt Crosby Formation in the Kholo Sub-Group and the other in the Blackstone Formation, the uppermost unit of the Brassall Sub-Group, and the youngest in the Ipswich Coal Measures. Both occurrences are in sediments dated palynologically as Carnian (de Jersey, 1970, 1971, 1975).

Assemblages from the Mt Crosby Formation have been documented in many papers, initially by Tillyard (1937) and subsequently by, among others, Riek (1955), Evans (1956, 1961, 1971), Fleming (1966) and Dodds (1949). Over 1000 specimens have been collected (Riek, 1970) and more than 70 species, assigned to 9 orders, have been described. Cockroaches predominate, but beetles, diverse hemipterids, orthopterids, scorpion flies, hymenopterids and caddis flies are also present. Insect faunas from the Blackstone Formation have provided types for more than 100 species, referred to 10 orders, and mainly described by Tillyard in a series of monographs (e.g. Tillyard, 1916, 1920, 1922, 1923, Tillyard & Dunstan, 1924). Even allowing that this specific diversity may be partly a systematic artefact (see Riek, 1956) the association is extraordinarily heterogeneous, particularly the beetle component which contains over 50 species.

Other fossil insects are one of the oldest known zygopteran nymphs from the uppermost Triassic of the Clarence-Moreton Basin (Rozefelds, 1985) and *Triassoblattus*, a blattoid genus, and a large homopteran wing fragment from the Upper Triassic, Tasmania Basin (Riek, 1962, 1967). The record of the coleopterid genus *Mesothoris* from the Perth Basin (Riek, 1968a) is from the Early Jurassic, not as originally thought, Triassic.

MISCELLANEOUS ARTHROPODS: Some unusual freshwater crustaceans from the Sydney Basin have particular palaeozoological and palaeoecological interest. They are the syncarid *Anaspidites* [formerly *Anaspides* (?)] from the Hawkesbury Sandstone (Chilton, 1929), and the isopod *Protoamphisopus* (formerly *Phreatoicus*) from the Ashfield Shale (Chilton, 1917). Both fossil species, as their original generic identifications suggest, are morphologically very close to living forms from New South Wales and Tasmania. *Austrolimulus*, a xiphosuran, and *Synaustrus*, an anostracan branchiopod (originally interpreted as a trilobitomorph), from the Hawkesbury Sandstone at Brookvale Quarry (Riek, 1964, 1968b) are other crustaceans from the Sydney Basin that are also believed to be fresh or brackish water forms.

CONODONTS [Figures 5, 6]

Conodonts are probably much more abundant in the Triassic marine sequences in western marginal basins than published information suggests. McTavish (1970), identified 27 species, which he assigned to 13 genera, from a limestone member near the base of the Locker Shale in the Carnarvon Basin, although he acknowledged that most probably derived from multi-element genera such as *Xaniognathus* and *Ellisonia*. In this preliminary account McTavish compared the fauna with those from the Middle Triassic, although he allowed that a Lower Triassic age was possible. The appearance of the first definitive account of Triassic conodont biostratigraphy by Sweet and others (1971) enabled the Western Australian evidence to be assessed more critically and, shortly afterwards, McTavish (1973) published what is still the only comprehensive Australian paper. His specimens were obtained from cores cut in the Locker Shale in 5 hydrocarbon exploration wells in the Carnarvon Basin, and from the interval 1661-69m in Dongara No. 4 Well in the Perth Basin. The last-mentioned sample was from the same horizon that Skwarko and Kummel (1974) subsequently reported Dienerian ammonoids. McTavish dealt only with the key single element genera *Neospathodus* and *Neogondolella*, describing 9 species of the former and 4 of the latter. From the presence of many Early Triassic index species, the Western Australia conodont faunas are readily correlatable with the zones established by Sweet (1970) in the Salt Range sequence, Pakistan. They span the interval from the *Neospathodus dieneri* to the *Neospathodus timorensis* Zones of Sweet and others (1971), and thus range in age from Dienerian to late Spathian (or conceivably early Anisian). McTavish's conclusions were used by Dolby and Balme (1976), in their account of the Triassic palynology of the Carnarvon Basin, as the basis of their own palynostratigraphic zonal scheme for the Lower Triassic.

The presence of conodonts in the Blina Shale, Canning Basin was noted by Nicoll (1984) but no identifications have been published. There is, however, an important record of *Epigondolella primitia* Mosher, from Sahul Shoals No. 1 Well (1883.2-1889.6m) in the Bonaparte Basin (Jones and Nicoll, 1985) which indicates a Late Carnian to Early Norian age for the interval, and provides one of the few biostratigraphical controls for the Australian Upper Triassic.

FORAMINIFERA [Figure 5]

Foraminifera have been reported from the Narrabeen and Wianamatta Groups in the Sydney Basin (Lovering, 1973; Mayne and others, 1974) although doubt appears to surround these occurrences (Byrnes & Scheibnerová, 1980). In Western Australia, arenaceous forms are known from the Locker Shale (McTavish, 1970) and Blina Shale (Tasch & Jones, 1979a; Heath & Apthorpe, 1986) although no detailed studies of these microfaunas exist.

Calcareous Foraminifera have only been recovered from exploration wells, ODP sites and dredgings on the Northwest Shelf. Apthorpe & Heath (1981) published brief notes on faunas from Barcoo No. 1 Well, Browse Basin, in which they recognised two informal biozones in the Norian, based on species of *Nodosaria*, *Discorbis* and *Frondicularia*. The same authors (Heath & Apthorpe, 1986) provided a more complete account of Anisian foraminiferal faunas in Lawley No. 1 Well, Dampier Sub-Basin. This age determination was based on palynological rather than microfaunal evidence, although the authors compared the assemblage with those from the Early to Middle Triassic of Spiti. Thirty-four species (10 of them new) were described, and assigned to the genera *Citharinella*, *Dentalina*, *Frondicularia*, *Haplophragmoides*, *Lenticulina*, *Lingulina*, *Lunucammina*, *Nodosaria*, *Opthalmidium*, *Palmula* and *Pseudonodosaria*.

Diverse foraminiferal assemblages of Norian age are present in dredge samples taken on the northern Exmouth Plateau by the Research Vessel *Rig Seismic* (Exon and Williamson, 1988; Quilty, in press). They include the Norian species *Diplotremina subangulata* and *Oberhauserella norica*, and occur in association with bryozoans, bivalves, corals, gastropods and brachiopods. Norian forms, including benthic miliolids and species of *Eoguttulina* , *Glomospirella* and *Triasina* , were identified from carbonate/clastic sequences encountered in ODP sites on the Wombat Plateau and the Scientific Shipbord Party (1990) of ODP Leg 122 recognised a *Triasina hantkeni* Zone encompassing the Rhaetic (Upper Norian) at Site 761. The sediments in which these rich invertebrate associations occur correlate with the uppermost Triassic-basal Jurassic Brigadier Beds, which are developed in reef facies in the section encountered on the northernmost Exmouth Plateau (Williamson and others, 1989).

MISCELLANEOUS INVERTEBRATES (Figure 5)

Lingulid brachiopods and echinoids have been reported, but not further identified, from the Lower Triassic of the Canning and Carnarvon Basins and the Gympie Block (McTavish, 1973; Runnegar, 1969) and sponge spicules may be present in the Narrabeen Group (Mayne and others, 1974). Fragments of two nautiloid specimens were recovered from the Kockatea Shale in Core 2, Dongara No. 2 Well and assigned questionably to *Grypoceras* (Skwarko and Kummel, 1974). Otherwise, the only Triassic invertebrates not previously mentioned, are those in the diverse faunal associations present in cores cut in marine sequences known only from exploration wells and ODP drill-holes on the Northwest Shelf. These sediments are developed in carbonate and clastic facies in which reefal material has been recognised (Williamson and others, 1989; Scientific Shipboard Party, 1990) and are considered to range in age from Late Norian (Rhaetian) to, possibly, Early Jurassic. Apart from the Foraminifera, nannoplankton and bivalves already mentioned, the fossil assemblage contains colonial and solitary corals, echinoid and crinoid fragments, bryozoans, sponges and brachiopods, but no detailed identifications have yet been published.

VERTEBRATES [Figure 7]

Vertebrate remains are more abundant and varied in Australian Triassic sediments than in those of any other system, apart perhaps from the Devonian. They include diverse representatives of the temnospondyl labyrinthodonts, a large variety of fish, and smaller numbers of reptiles. Since Banks (1978) published his Triassic correlation chart, vertebrate specialists have been the most prolific contributors to the literature of Australian Triassic palaeontology. Recent review papers cover mammal-like reptiles (Thulborn, 1990) and tetrapods in general (Thulborn, 1986, Warren, 1984) and a checklist of Australian fossil fish species was presented by Long & Turner (1984). Molnar (1984a, 1984b) provided species lists and bibliographies of Australian fossil amphibians and reptiles to 1982, and Banks, Cosgriff & Kemp (1984) reconstructed the flora and tetrapod fauna of an Early Triassic fluviatile environment in Tasmania.

Apart from fish faunas and labyrinthodont remains from the Hawkesbury Sandstone and Wianamatta Group and a palaeoniscoid fish from Leigh Creek (Wade, 1953), all these vertebrate remains are of Early Triassic age and come from the Sydney, Bowen, Tasmania, Perth and Canning Basins. They are not critically significant for biostratigraphic purposes, although the faunas may be compared in a broad sense to those occurring in Late Permian to Early Triassic strata in other continents, especially in the Beaufort Group of southern Africa and the Indian Panchet Group.

FISH: **The record of** ***Palaeoniscus antipodeus*** Egerton from the Narrabeen Group (Egerton, 1864) was one of the earliest contributions to formal Australian palaeontology and the rich fish faunas of the Gosford Formation, shale lenses in the Hawkesbury Sandstone, and Ashfield Shale, have been described in a number of monographs (e.g. Woodward, 1890, 1908; Wade, 1935) yielding over 50 species of the Orders Ceradontida and Palaeonisciformes. Hutchinson (1973) revised the redfieldoid and perloid fish from the Sydney Basin and Rithchie (1981) described a complete dipnoan from the upper Narrabeen Group. Triassic dipnoans are also known from the Canning (Kemp, 1982), Bowen (Turner, 1982) and Tasmania Basins (Banks, Cosgriff & Kemp, 1984) and Dziewa (1980) reported an unidentified coelacanth and two acrolepid species from the Knocklofty Sandstone near Hobart.

Little attempt has been made to compare the Australian fish faunas with those from other continents and they have been dated by reference to other palaeontological evidence. At present therefore they have, in themselves, only very broad biostratigraphical significance.

AMPHIBIANS: In contrast to the other Gondwana continents, aquatic amphibians are much more common than reptiles in Australian Triassic sediments. All Mesozoic families of labyrinthodont amphibians are represented in Australia and no endemic forms have been recognised. As noted earlier, the identification of a larval brachyopid *Blinasaurus wilkinsoni* Stephens (1886) from the Gosford Formation in the Sydney Basin, was the first recognised positive evidence of Triassic strata in Australia. Subsequently further amphibian remains have been recovered from the Sydney Basin, including the capitosaurids *Parotosaurus brookvalensis* from the Hawkesbury Sandstone and *Paracyclotosaurus davidi* from the Wianamatta Group (Watson, 1958).

The only amphibian remains that can be dated by direct or indirect reference to ammonoids or conodonts occur in the Canning and Perth Basins. Four families are represented in the Blina Shale, Canning Basin: the Brachyopidae by *Blinasaurus*, the Rhytidosteidae by *Deltasaurus*, the Trematosauridae by *Erythrobatrachus* and the Capitosauridae by *Parotosaurus* (Cosgriff, 1965, 1969; Cosgriff & Garbutt,1972; Warren, 1980). Another species of *Deltasaurus* is known from a skull fragment recovered from a core cut in the Kockatea Shale in BMR No. 10, Beagle Ridge Bore, Perth Basin. It is associated with the ammonoid *Subinyoites kashmiricus* and is therefore of Smithian age.

A rich amphibian, and an associated, but much less abundant, reptilian fauna is present in the Arcadia Formation which is the highest unit of the Rewan Group in the Bowen Basin. Its principal elements were listed and discussed by Thulborn (1986) who reported representatives of 8 labyrinthodont families, including the capitosaur *Parotosaurus* and a probable species of the rhytidosteid genus *Deltasaurus*. Further labyrinthodonts have been reported from the Arcadia Formation since Thulborn's review (Jupp & Warren, 1986; Warren & Hutchinson, 1988, 1990). Although the upper part of the Arcadia Formation is unquestionably Early Triassic, it contains no palynomorphs or other fossils that enable it to be correlated more precisely with the standard system of stages. Cosgriff (1984) compared the temnospondyl assemblages of the Arcadia Formation with those of the *Lystrosaurus* Zone of the Beaufort Group in southern Africa, and recognised an Early Triassic biostratigraphic unit based on tetrapods, that he referred to as Triassic A1, believed to span the Griesbachian to Smithian Stages. The problem is, that there is no independent palaeontological control that allows the *Lystrosaurus* Zone to be precisely dated, and therefore no certainty that it is not, in part or totally, latest Permian, at least as the limits of that system are currently conceived in Australia. Because of this there is clear doubt whether tetrapod evidence alone, is at present sufficiently discriminatory to allow differentiation between uppermost Permian and Early Triassic sequences.

The richest Triassic vertebrate locality in Australia, in terms of individual specimens, is in an exposure of the Knocklofty Sandstone in the Tasmania Basin, close to Hobart (Banks, Cosgriff & Kemp, 1984). Cosgriff (1974) described species of *Blinasaurus* , *Deltasaurus*, and *Parotosaurus* from this locality, as well as the lydekkerinid *Chomatobatrachus* and *Derwentia* , the type genus of a new family the Indobrachyopidae. Vertebrates from the Knocklofty Formation, although more diverse, correspond in important respects to those from the Blina Shale and Kockatea Shale, and there is independent evidence from palynology (Banks & Naqvi, 1967) that the Tasmanian amphibian fauna is Griesbachian or Nammalian in age.

REPTILES: Skeletal remains of Triassic reptiles are known from the Arcadia Formation, at a locality known as the 'Crater' in the central Bowen Basin, an unknown locality in north-eastern Queensland (Seeley, 1891), the Knocklofty Sandstone (Tasmania Basin) in a quarry near Hobart and possibly, the Blina Shale in the Canning Basin. By far the most varied fauna is that from the Arcadia Formation and it is currently being studied by several workers. So far all the skeletal records from documented localities are Early Triassic and the only evidence of post-Spathian Triassic reptiles is a trackway in the Ipswich Coal Measures (Staines & Woods, 1964).

Warren (1984) and Molnar (1984) reviewed the distribution and affinities of these reptiles, in the general context of the evolution and palaeogeography of Australian vertebrates, and, subsequently, Thulborn (1986) attempted a more sophisticated analysis of Triassic tetrapod faunas from Gondwanaland, using a modification of Simpson's Similarity Index. Small lizard-like procolophonids and prolacertids (Bartholamai, 1979) are the most abundant elements in the Arcadia fauna and the proterosuchian thecodont *Kalisuchus* (Thulborn, 1979) is fairly common, but the most significant discovery has been that of a dicynodont (Thulborn, 1983) attributed to either *Kannermeyeria* or *Lystrosaurus*. This is the first record of a synapsid reptile from Australia and provides a clear link with the *Lystrosaurus* Zone of the Beaufort Group in southern Africa, the Panchet Group in India and the Fremouw Formation, Transantarctic Mountains. On the basis of qualitative and quantitative comparisons with these other Gondwanan tetrapod faunas, Thulborn assigned the Arcadia fauna to the basal Triassic, presumably Griesbachian, as he regarded it as older than the Smithian section of the Kockatea Shale. This may be correct, but the previously noted difficulties of relating the *Lystrosaurus* Zone to standard Triassic stages also apply to the Panchet Group which, on the basis of rather conflicting palynological evidence is, as Anderson (1981) indicated, almost certainly partly Upper Permian.

The proterosuchian *Tasmaniosaurus triassicus* Camp & Banks, from the Knocklofty Sandstone is associated with plant macrofossils, conchostracans and plant microfossils which enable it to be confidently dated as Early Triassic. Camp & Banks (1978) suggested that the closest affinities of *Tasmaniosaurus* were with primitive thecodonts from the *Cynognathus* -Zone of southern Africa which implies a Nammalian to Spathian age. If the correlation with the Kockatea Shale is correct, the lower part of the Knocklofty Sandstone is more probably Nammalian.

MEGASCOPIC PLANT FOSSILS (Figures 8, 9).

Australian Triassic fossil floras, like those of the other Gondwana continents, are dominated by fronds of the Peltaspermales, using that taxon in the sense of Meyen (1987). According to Meyen's concept, the Order Peltaspermales comprises four families of gymnosperms with platyspermic, non-cupular seeds, arranged on a laminate structure called a cladosperm. The virtue of Meyen's classification is that it stresses the relationship between the peltasperms and glossopterids, and avoids the unwarranted assumptions implicit in referring to Triassic seed-plants as Mesozoic pteridosperms. By far the most common plant remains in the Gondwanan Triassic are bifurcating peltasperm fronds, belonging to the genus *Dicroidium* (=*Thinnfeldia* of earlier Australian workers). It has therefore been designated the *Dicroidium* - Flora (Gould, 1975) and has a similar stratigraphic range to the *Falcisporites* Superzone of Helby, Morgan & Partridge, i.e from uppermost Permian to Early Jurassic.

White (1986) has provided excellent illustrations of the principal elements of the *Dicroidium* -Flora, using mainly specimens from the Narrabeen Group. Because of its variability, the genus *Dicroidium* itself is difficult to subdivide consistently, and the number of species recognised depends on how its taxonomy is approached. *Dicroidium odontopteroides* (which is frequently sub-divided into a number of varieties) and *D. zuberi* are the two species most commonly identified. *Lepidopteris*, *Johnstonia*, *Xylopteris*, *Stenopteris* and *Pachypteris*, are other genera of peltasperm foliage associated with *Dicroidium*, and the palmate seed-bearing cladosperm *Umkomasia*, together with the pollen organ *Pteruchus* (containing *Falcisporites* pollen) were also borne by peltasperms. Other gymnospermous groups are represented by the conifers *Rissikia* and *Voltziopsis*, the cycadophytes *Taeniopteris* and *Pterophyllum* and the probable ginkgoaleans *Sphenobaiera* and *Ginkgoites*. Presumed gymnosperms of uncertain affinities are *Yabiella*, *Linguifolium*, *Chiropteris* and *Phoenicopsis*. Ferns include marattialeans such as *Asterotheca*, dipteracean fronds attributed to *Dictyophyllum*, the osmundaceous genera *Cladophlebis* and *Todites* and fernlike foliage of uncertain relationships such as *Rienitsia*. Equisetalean stem casts occur throughout the Triassic and the lycopsid strobili *Cylostrobus* and *Skilliostrobus*, producing *Aratrisporites* microspores, are common in the Lower Triassic of the Sydney Basin (Helby & Martin, 1965; Ash, 1979).

Although macrofloral lists have been published for localities in many Australian sedimentary basins the only comprehensive, illustrated, systematic accounts are based on collections from the Ipswich Basin and Esk Trough (Walkom, 1915, 1917a,1917b,1924, 1928; Jones & de Jersey,1947, Rigby, 1977); the Surat Basin (Holmes, 1982) and the Sydney Basin (Walkom, 1925; Retallack, 1977, 1980), with some shorter but important contributions from the Tasmania Basin (e.g. Townrow, 1965, 1966, 1967a, 1967b).

Walkom's studies provided the earliest firm evidence for the Triassic age of sequences in the Ipswich and Sydney Basins but it is only fairly recently that attempts have been made to use plant macrofossils for biostratigraphic sub-division. Townrow (1966) recognised two zones in the section in the Tasmania Basin, the lower characterised by *Dicroidium odontopteris* and the upper by *Dicroidium obtusifolium*. However, he acknowledged that the two forms occasionally occurred together and Retallack (1977) expressed doubt that they could be reliably distinguished.

Retallack (1977, 1980) proposed a fourfold zonal sub-division of the Gondwanan Triassic following his detailed analysis and interpretation of eastern Australian plant communities, especially those represented by macrofloras from the Sydney Basin. These Triassic associations represent the remains of floras that flourished in shifting fluviatile and deltaic environments, and their compositions through the period of Triassic time are controlled by two factors; cyclical environmental patterns and irreversible 'evolutionary' changes. Generalised relationships between the climatically and edaphically controlled florules and the sequence of Oppel zones based on patterns of change in peltasperm foliage are illustrated in Figure 9. Retallack (1980) believes that this zonal scheme can also be applied to extra-Australian Triassic sequences in New Zealand, southern Africa and southern South America.

PLANT MICROFOSSILS [Figures 10-12]

NANNOFOSSILS: Coccoliths, including the oldest known representatives of the group, have been recorded from Sites 759, 760, 761 and 764 of Leg 122 of the Ocean Drilling Programme (Scientific Shipboard Party, 1990). This sites were situated on the Wombat Plateau, Northwest Shelf and the drill-holes bottomed in Late Triassic marine sediments of Norian and Carnian age. The genera identified included *Tetralithus* and *Hayococcus* from Site 760B and species of the Rhaetian (Late Norian) holococcolith *Prinsosphaera* from Sites 761 and 764.

PALYNOMORPHS: Palaeopalynology is concerned with the wide range of microscopic entities of plants, commonly referred to as palynomorphs, that are preserved in sedimentary rocks. Those that have been used most effectively for biostratigraphy are acritarchs, which are, in the main, resting cysts of algae; spores and pollen of vascular plants and dinocysts, the resistant cysts produced during periods of physiological stress by certain families of the Dinophyceae, a group of unicellular aquatic organisms. Acritarchs and dinocysts are, with a few exceptions, confined to marine sediments, but spores and pollen, although almost invariably derived from terrestrial plants, are also transported by sedimentary mechanisms into nearshore marine environments.

Palynomorphs are by far the most abundant, individually identifiable, fossils throughout the Phanerozoic and are present in virtually all unoxidised and unmetamorphosed clastic sediments. During the past 40 years they have become the most widely applied biostratigraphic instrument for the subdivision and correlation of Australian intracratonic sequences. Their advantages are obvious, but their interpretation is not without its problems. Acritarchs and dinocysts are essentially planktonic organisms and, in principle, potentially as sensitive index fossils as foraminifera, graptolites or conodonts. However, Mesozoic acritarchs are morphologically indistinctive, at least under the optical microscope, and the history of dinocyst studies is too short to judge how far their distribution is affected by provinciality.

Many vascular plants are sharply responsive to climatic shifts and this factor must always be considered when evaluating the significance of taxon ranges of spores and pollen grains. However, all datum planes based on biological events are diachronous to a greater or lesser extent and the biostratigraphic utility of any fossil organism, or groups of organisms, can only be judged in terms of the consistency of results achieved by its application. Careful synthesis of palynological data, as it becomes increasingly available, with other lines of evidence, makes it clear that certain plant groups colonised large areas of the world in very short spans of time. There are particularly good Triassic examples of this : the virtually synchronous increase in abundance, in widely separated parts of the globe, during the Early Triassic, of species of the lycopsid spore genera *Lundbladispora* and *Aratrisporites* is one, and the worldwide radiation, in the Late Norian, of the cheirolepid conifers, producing *Corollina* [=*Classopollis*] pollen another. Indeed, the palynological record suggests that the Triassic was an unusual period in the history of plant evolution, during which new peltasperm, coniferalean and other gymnosperm lineages developed rapidly, colonised wide areas of the earth's surface, and declined sharply during the Late Norian.

MIOSPORES AND POLLEN: [Figures 10,11]. Spores and pollen from Australian Triassic terrestrial plants have been comprehensively documented, especially from the intracratonic basins of the north-eastern continent, as a result of the studies of de Jersey and his collaborators. The first account published on Australian Mesozoic palynology (de Jersey, 1949) dealt with the Ipswich Coal Measures, although it was not until 13 years later (de Jersey, 1962) that formal systematic procedures were applied to Australian Triassic miospores. The history of attempts to establish a Triassic zonal scheme based on palynomorphs is summarised in Figure 10. The initial key came with the recognition of Early Triassic marine units in the Canning and Perth Basins (Brunnschweiler, 1954, McWhae and others, 1957) and the application of palynology to the elucidation of their relationships. Balme (1964) proposed a twofold division of the Triassic. The lower occurred in marine sequences and was characterised by the *Taeniaesporites* -Microflora, defined by poorly diversified assemblages, dominated by lycopsid spores (*Lundbladispora* and *Densoisporites*) and disaccate conifer pollen of the *Taeniaesporites/Lunatisporites* type.This was succeeded by the *Pteruchisporites* Microflora, in which peltasperm pollen, now referred to *Falcisporites*, was the most conspicuous and ubiquitous component. The concept of the *Pteruchipollenites* -Microflora was based principally on unpublished data from continental sequences in New South Wales, although comparable assemblages were known from strata of uncertain precise age, overlying the Kockatea Shale in the Perth Basin. Therefore, although the incoming of the *Taeniaesporites* -Microflora in Western Australian basins clearly corresponded closely with the base of the Triassic, there was no evidence to judge its time of replacement, nor was it clear where the upper limit of the *Pteruchipollenites* -Microflora should be placed.

Evans (1966) was the first to synthesise palynological data from the continental Triassic sequences of the Sydney, Bowen, Cooper and Surat Basins into a biostratigraphic zonal scheme. In these successions, because the Permian sections are more complete, the almost total palynological break that, in western marginal basins, enables marine basal Triassic assemblages to be differentiated from those of the underlying Upper Permian is not so obvious. The choice of a lower limit for the Triassic therefore becomes somewhat arbitrary and Evans placed it at the base of his Unit **Tr1a,** characterised by the presence of the non-marine acritarch *Quadrisporites horridus* Hennelly, the presence of the cavate spore *Playfordiaspora* , and the persistence of a number of characteristic Permian genera including *Dulhuntyispora* and *Marsupipollenites.* Evans regarded Unit **Tr1a** and the immediately overlying Unit **Tr1b** as older than the base of the Kockatea Shale and equated assemblages from his Unit **Tr2a,** which encompassed the upper part of the Narrabeen Group in the Sydney Basin and the higher parts of the Rewan Group in the Bowen Basin, with the *Taeniaesporites* - Microflora. In all, Evans recognised 8 units in the composite sequences that he treated, some were effectively acme zones, others taxon range and assemblage zones. The highest (**Tr 3d**) was represented in the Moolayember Formation, Bowen Basin, which is to-day regarded as Middle Triassic (Anisian).

During the 1960's Helby carried out detailed studies of the palynology of the Triassic sequence in the Sydney Basin and presented his conclusions in a number of unpublished reports and conference abstracts. His first formal zonation (Helby, 1973), although based on the Sydney Basin succession, incorporated data from Queensland basins published by previous workers, principally Evans and de Jersey. Helby's zonation is shown in Figure 10. It moved, for the first time in Australia, towards an acceptable formal zonal nomenclature, and the units were broader, but in most respects paralleled those of Evans, except for the horizon selected to mark the base of the Triassic. Helby referred his lowermost *Protohaploxypinus reticulatus* Assemblage, which he equated with **Tr1a** of Evans, to the Permian, because several of the more distinctive taxa present were known from the Chhidru Formation of the Salt Range (Balme, 1970). These included *Playfordiaspora, Duplexisporites*, *Lueckisporites*, *Limatulasporites fossulatus* (Balme), *Kraeuselisporites rallus* Balme and the peltasperm pollen genus *Falcisporites.* The *P. reticulatus* Assemblage occurs in the lower units of the Narrabeen Group, which had been customarily held to be entirely Triassic, and which shows no obvious sedimentary hiatuses within it. It is probable, therefore, that the palynological record within the Narrabeen Group represents an almost complete transitional floral sequence across the Permian- Triassic boundary.

The column in Figure 10, showing de Jersey's palynological zonation of Triassic sequences in the Ipswich and Bowen Basins and the Esk Trough, was compiled from 3 publications (de Jersey, 1975, 1976, 1979). In the first of these papers de Jersey (1975) introduced formal zonal nomenclature and recognised three broad Oppel-Zones separated by two significant hiatuses, the older believed to encompass the Ladinian and the later the Early and Middle Norian. The *Duplexisporites problematicus* Zone, which was represented in the Esk Formation, is equivalent to part of the *Aratrisporites parvispinosus* Assemblage unit of Helby but de Jersey's two higher units, designated the *Craterisporites rotundus* Zone (Carnian) and *Polycingulatus crenulatus* Zone (Middle Norian to ?Pliensbachian) are younger than any previously defined within the Australian Triassic. The absence of a clear palynological break within the *P. crenulatus* Zone emphasises the difficulty of selecting a suitable boundary between the Triassic and Jurassic in Australian Mesozoic successions. The introduction of the pollen *Corollina*, at some time in the Early Norian, marks the initiation of "Jurassic" floral ecosystems, which unfortunately appear to have anticipated by about 5 million years the extinction of the ceratitinid and prolecanitid ammonoids.

The two lower zones attributed to de Jersey in Figure 10 are interval zones which span the Permian Triassic boundary. They were based on cores taken from the lower part of the Rewan Group and upper Bandanna Formation, in drillholes in the western part of the Bowen Basin. Although de Jersey (1979) proposed them only tentatively, they can be correlated with the lower two units of the Sydney Basin sequence. Ther relationship between the boundary of the *T. playfordii* /*L. playfordii* and *L. pellucidus* /*A. wollariensis* Zones and the base of the Rewan Group needs further investigation but it is clearly diachronous to a greater or lesser extent. Subsequent to de Jersey's study Foster (1982) also considered the position of the Permian-Triassic boundary in the Bowen Basin and also drew on Balme's data from the Salt Range. Like de Jersey, he concluded that the lithostratigraphic boundary between the Bandanna Coal Measures and the Rewan Group was a diachronous one, reflecting local changes in depositional environment. He also expressed doubt concerning the chronostratigraphic significance of the *Lunatisporites pellucidus* Zone and regarded the appearance of *Aratrisporites wollariensis*, at the base of the *Protohaploxypinus samoilovitchii* Zone, as the first unequivocal evidence for a Triassic age. He accepted, however, the correlation of the *P. samoilovitchii* Zone with the Dienerian-Smithian.

Plant microfossil assemblages from the Triassic of the Sydney, Ipswich and Bowen Basins have an essential unity and strongly Gondwanan aspect. Coeval sequences in the basins of the Northwest Shelf, contain pollen and spore taxa with clear Tethyan affinities. This led Dolby & Balme (1976) to recognise two Australian Triassic floral provinces. The Onslow-Microflora, which occurs in the Carnarvon Basin, was thought to have derived from mid-latitude plant communities and contains genera such as *Ovalipollis*, *Infernopollenites*, *Aulisporites*, *Staurosaccites*, *Camerosporites* and *Enzonalasporites* which are well known from the Alpine Triassic and other Tethyan regions. Assemblages of the Ipswich-Microflora, characterising the eastern basins lack, by contrast, Tethyan elements and are dominated by peltasperm pollen grains, just as *Dicroidium* and *Stenopteris* are the most common elements in their plant macrofossil floras. They were considered to represent higher latitude regional floras.

The presence of these Tethyan taxa in the Triassic of the offshore Carnarvon Basin, together with the control provided by conodont evidence in the lower part of the sequence, allowed Dolby & Balme (1976) to relate their zonal scheme for western marginal basins to the standard international Triassic stages, with more confidence than had been possible in eastern Australia.

Since Dolby & Balme's zones were published, further palynological data from the Alpine Triassic (e.g. Visscher & Brugman, 1981, Visscher & Van der Zwan, 1981) have strengthened arguments for the general correlations that they proposed. This implies a continuous section of Triassic strata in the Carnarvon Basin, ranging at least from early Griesbachian to Early Norian.

The final two columns of Figure 10 show the current palynostratigraphic subdivision of the Australian Triassic put forward by Helby, Morgan & Partridge (1987). It represents a synthesis of the schemes suggested by Helby (1973), de Jersey (1975, 1976, 1979) and Dolby &Balme (1976) and the recognition of a new Middle Norian to (?)Hettangian unit, the *Ashmoripollis reducta* Oppel Zone, based on section in Ashmore Reef No. 1 Well, in the offshore Bonaparte Basin. Although Helby, Morgan & Partridge regard their biostratigraphic units as Oppel-zones their boundaries are more precisely defined, in terms of oldest occurrences of key species, than those of Dolby & Balme's zones. Known ranges of selected biostratigraphically important spore and pollen taxa are shown in Figure 11 on which key species used to define zonal boundaries are indicated by an asterisk (*).

Correlation between the biostratigraphic units recognised in western marginal basins and those of the eastern craton, has been facilitated to some extent by the discovery of Onslow-type associations in Triassic sediments below the Eromanga Basin (de Jersey & McKellar, 1981, McKellar, 1977). Nevertheless, the equivalences indicated in Figure 10 should be regarded as reasonable assumptions rather than as demonstrably accurate correlations.

MEGASPORES: [Figure 8] Lycopsid megaspores are common in the Australian Triassic but have not often been used for biostratigraphic purposes since the early contribution by Dettmann (1961) which treated 8 species from the Leigh Creek Coal Measures, South Australia and the Newtown Coal Measures, Tasmania. Principally because of the presence of the megaspore *Banksisporites pinguis* (Harris), a Late Norian (Rhaetian) age was ascribed to the Newtown Coal Measures, although Dettmann did not rule out the possibility that they were older. The most common species in material from Leigh Creek was *Nathorstisporites hopliticus* Jung, a species that is probably lycopodialian and was first described from the Rhaeto-Lias of Germany, and known to be widespread in broadly coeval sediments in Europe and Greenland. Its presence led Dettmann to conclude that at least the upper part of the sequence at Leigh Creek was of the same age.

Helby (1967) described a new species of *Nathorstisporites* from the Lower Triassic Wollar Sandstone, Goulburn River District, New South Wales and Scott and Playford (1985) dealt with a well-preserved Early Triassic megaspore association from the upper part of the Rewan Group, Bowen Basin. This also contained representatives of the genera *Nathorstisporites* and *Banksisporites* as well as a single species of the new genus *Bowenispora* Scott & Playford.

Other publications dealing with Australian Triassic megaspores have had a plant anatomical rather than biostratigraphic emphasis. Helby and Martin (1965) described the megaspores of 3 species of *Cylostrobus* Helby & Martin, the strobilus of a pleuromeiacean lycopod from the Narrabeen Group, which are of the *Banksisporites* -type and occur in association with the microspore *Aratrisporites*. *Skilliostrobus australis* Ash is another Early Triassic, heterosporous lycopsid cone that contains *Aratrisporites* microspores (Ash, 1979) but in this species the megaspores belong to *Horstisporites*. It is known from the Narrabeen Group, Sydney Basin and the Knocklofty Sandstone, Tasmania Basin.

ACRITARCHS AND DINOCYSTS: [Figures 10, 12]. The phenomenon of the acritarch "spike" in Griesbachian to Smithian marine strata was discussed in the introductory section of this review. Small acanthomorph acritarchs are extremely abundant, although poorly diversified, in the lower parts of the marine Triassic sequences in the Perth, Carnarvon, Canning and Bonaparte Basins (Balme & Helby, 1973, Dolby & Balme, 1976, Grenfell, unpublished data). The occur also in Early Triassic strata in the Cooper Basin (Evans, 1966) and less prominently in the Sydney Basin (Helby, 1969, 1973). Few published details exist on Australian Triassic acritarchs. Medd (1966) illustrated electron micrographs of specimens of *Micrhystridium* and *Veryhachium* from the Kockatea Shale and Sappal (1978) recognised four distinct acritarch associations in the same unit, between 659.3 -1053.4m in BMR No.10, Beagle Ridge Bore. This work has not been followed up, but it is clear that these Early Triassic acritarchs are not likely to provide the basis for refined biostratigraphy, in the absence of detailed study using scanning electron microscopy.

If a single possible record from the Silurian is neglected, the oldest undoubted dinocyst species so far established is *Sahulidinium ottii*

Stover & Helby, from probable Late Anisian strata in the Bonaparte Basin (Stover & Helby, 1987). All the Australian Triassic species so far described are from the offshore basins of the Northwest Shelf and they form the basis of the dinocyst zonal scheme proposed by Helby, Morgan & Partridge (1987). This ranges, with a discontinuity in the upper Middle to lower Upper Triassic, from Late Anisian to Early Jurassic. Helby, Morgan & Partridge recorded, from these marine Triassic sequences, 11 species of dinocyst, 6 of which do not extend higher than Norian. Their known stratigraphic ranges are shown in Figure 12, and Figure 10 illustrates the Australian dinocyst zonal nomenclature for the Triassic and suggested relationships between the microplankton biostratigraphic scheme and those based on spores and pollen of terrestrial plants.

PHYSICAL METHODS OF GEOCHRONOLOGY

RADIOMETRIC DATING (Figure 13)

A fairly large number of radiometric dates are available from volcanics and intrusives associated with Triassic strata, particularly from the region of the New England Fold Belt in northern New South Wales and south-eastern Queensland. Most published ages are based on single mineral (mainly biotite and horneblende) conventional K-Ar determinations, although the Ar-Ar neutron irradiation technique and Sr-Rb isochron analysis have also been used. The available data are of widely variable quality and at times inconsistent. In part this is because of uncertainties inherent in the techniques and the difficulty of integrating radiometric ages with palaeontologically based zonal schemes, but it is also true that many of the published dates are inadequately documented, in terms of the origin of samples and experimental precision of results. Application of the SHRIMP ion microprobe to dating biostratigraphically controlled sequences, a recently developed joint project of the Bureau of Mineral Resources and the Research School of Earth Sciences, Australian National University, is likely to introduce a new era of radiometric chronology and provide a foundation for a more rigorous Phanerozoic time-scale.

Triassic radiometric dates from eastern Australia were reviewed by Webb & McDougall (1968), Green & Webb (1974) and Webb (1981). Subsequently, Murphy and others (1983) listed, without detailed discussion, a large number of ages determined from, principally intrusive, igneous bodies, in the area of the Gympie Map Sheet, south-eastern Queensland. Six Australian radiometric ages were used by Forster & Warrington (1985) as Triassic control points on their geochronological time-scale. These are indicated on Figure 13, together with other selected dates that can be related fairly directly to biostratigraphically controlled successions. The columns of Figure 13, taken from left to right, are briefly discussed in the notes below :

Currambene Diorite: Late Permian to Early Triassic intrusive, discordant with the Nowra Sandstone in shallow bores near Wollongong in the Sydney Basin. K-Ar date of 239±6 Ma (Webb, 1981).The Nowra Sandstone is regarded as Kazanian (Dickins, Gostin & Runnegar, 1969) but the igneous body cannot be stratigraphically related with confidence to any Triassic lithostratigraphic unit.

Goomboorian Diorite: intrudes the folded and metamorphosed Smithian Kin Kin Beds in the southeastern Gympie Block. K-Ar ages 234±7, 235±7, 240±7 Ma (Green & Webb, 1974; Webb, 1981).

Neara Volcanics: andesitic volcanics and sediments in the Esk Trough. Overly upper Lower or Middle Triassic Bryden Formation (de Jersey, 1973). Overlain by Middle Triassic Esk Formation (de Jersey, 1972). K-Ar ages 236±6, 242±5, 239±5 Ma (Webb, 1981).

Station Creek Adamellite: intrudes undifferentiated Palaeozoics and Neara Volcanics, overlain by Upper Triassic or Lower Jurassic Myrtle Creek Sandstone. K-Ar dates 231±7 236±7 Ma (Webb & McDougall, 1967; Murphy and others, 1976; Webb, 1981).

Eskdale Granodiorite: intrudes Palaeozoic Sugarloaf Metamorphics overlain by Upper Triassic (Cranfield and others, 1976) K-Ar ages 238±7, 243±8, 248±7 Ma (Webb & McDougall, 1968; Webb, 1981).

Dalmally Basalt: concordant with Nymboida Coal Measures, Clarence-Moreton Basin, Anisian-Ladinian on palaeobotanical evidence (Retallack, Gould & Runnegar, 1977); K-Ar age on single sample 211±5 Ma.

Mungore Complex: granite-granodiorite-tonalite pluton, Gympie Block; intrudes Brooweena Formation overlain by (?) Lower Jurassic (Webb, 1981). K-Ar ages 212±7, 219±7 Ma, Rb-Sr 226±16 Ma (Webb & McDougall, 1967, Webb, 1981).

Djuan Tonalite : intrudes Palaeozoic Sugarloaf Metamorphics, overlain nonconformably by Carnian Tarong Beds; K-Ar age 235±8 Ma (Webb, 1981).

Sugars Basalt : flows and pyroclastics concordant with units of Kholo Subgroup of Ipswich Coal Measures underlain by Lower Palaeozoic, overlain by Upper Triassic Mount Crosby Formation; K-Ar ages 229±7, 232±7 Ma (Webb & McNaughton, 1978).

North Arm Volcanics equivalent: acid flows and pyroclastics; upper sedimentary section dated palynologically as Upper Triassic (McKellar in Webb, 1981); K-Ar whole rock age 213æ7 Ma (Green & Webb, 1974).

Parmeener Supergroup, Tasmania Basin: Basalt flow in upper part of Supergroup, palynological evidence indicates a Middle Triassic age for enclosing sediments; K-Ar whole rock determination on a single sample 233±5 Ma.

An interesting suite of intermediate volcanic rocks has been recovered in dredge samples taken on the flank of the Wombat Plateau, Northwest Shelf (von Rad & Exon, 1983). Sanidine crystals picked from these give a K-Ar age of 213±3 Ma whereas a whole rock K-Ar determination yielded an age of 206±6 Ma. These dates indicate Middle to Late Norian (Rhaetian), which is in accordance with palynological and palaeontological evidence from sediments sampled at nearby dredging sites and Triassic sequences encountered in ODP drillholes on the Wombat Plateau. Full interpretation of these results is awaiting publication but they are clearly of considerable significance in establishing a more accurate geochronology at the level of the Triassic-Jurassic boundary.

SEQUENCE STRATIGRAPHY: Figure 14 has been adapted from Haq and others (1987) and has been included principally for reference purposes. The con- cepts of sequence and seismic stratigraphy are becoming increasingly influential, particularly in the study of the Mesozoic and Cainozoic geology of the Northwest Shelf. Sophisticated depositional and tectonostratigraphic models are being developed by exploration geologists and geophysicists but, for the most part, critical data, and their interpretation, remain in proprietary hands. The most detailed relevant studies so far published are those of Kirk (1985) and Boote & Kirk (1989), which treat the Mesozoic rift domain of the Barrow Province, on the western and northwestern Australian continental margin. These papers recognise five clastic wedge sequences in the Mesozoic, that are essentially tectonically controlled. Initiation of the oldest virtually corresponds with the beginning of Triassic time and the cycle begins with a transgressive sheet sand, resting unconformably on Palaeozoic strata. The basal sand is overlain by pro-delta and fluvial-deltaic sediments which grade upwards into a thick fluvial sequence. This first cycle was terminated near the end of the Triassic and is unconformably overlain by the sediments of an Early to Middle Jurassic sedimentary cycle. The Kockatea Shale, which is the expression of the Early Triassic marine transgression in the northern Perth Basin, progressively oversteps older Permian strata and rests on Precambrian crystalline rocks, along the flanks of the Northampton Block. This appears to represent the maximum marine encroachment on to the Australian continental craton during the Triassic and to correspond to the 245.5 Ma downlap surface of Haq and others (1987).

Two Late Triassic sequence boundaries were identified in sections encountered in drillholes at sites on Leg 122 on the Wombat Plateau (Shipboard Scientific Party, 1990). The older was considered to represent the 224 Ma surface at the Carnian-Norian boundary and the younger the 211 Ma event, near the end of the Rhaetian (Late Norian).

It would be anticipated that an increase in oceanic area, resulting from a considerable eustatic rise in sea-level, would be an important factor in the modification of terrestrial floras. This should be reflected by changes in spore/pollen assemblages and some correspondence might be expected between major downlap surfaces and boundaries of palynologically based biostratigraphic units. There is a possibility of such correspondence at the boundaries of the *P. samoilovitchii* /*T.playfordii* Zones (245.5 Ma), *T.playfordii* /*S. quadrifidus* Zone [238 Ma] and *S. speciosus* / *M.crenulatus* Zones [223 Ma], but the palynostratigraphic boundaries are too imprecisely fixed to enable any firm conclusions to be drawn.

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DESCRIPTIONS OF FIGURES

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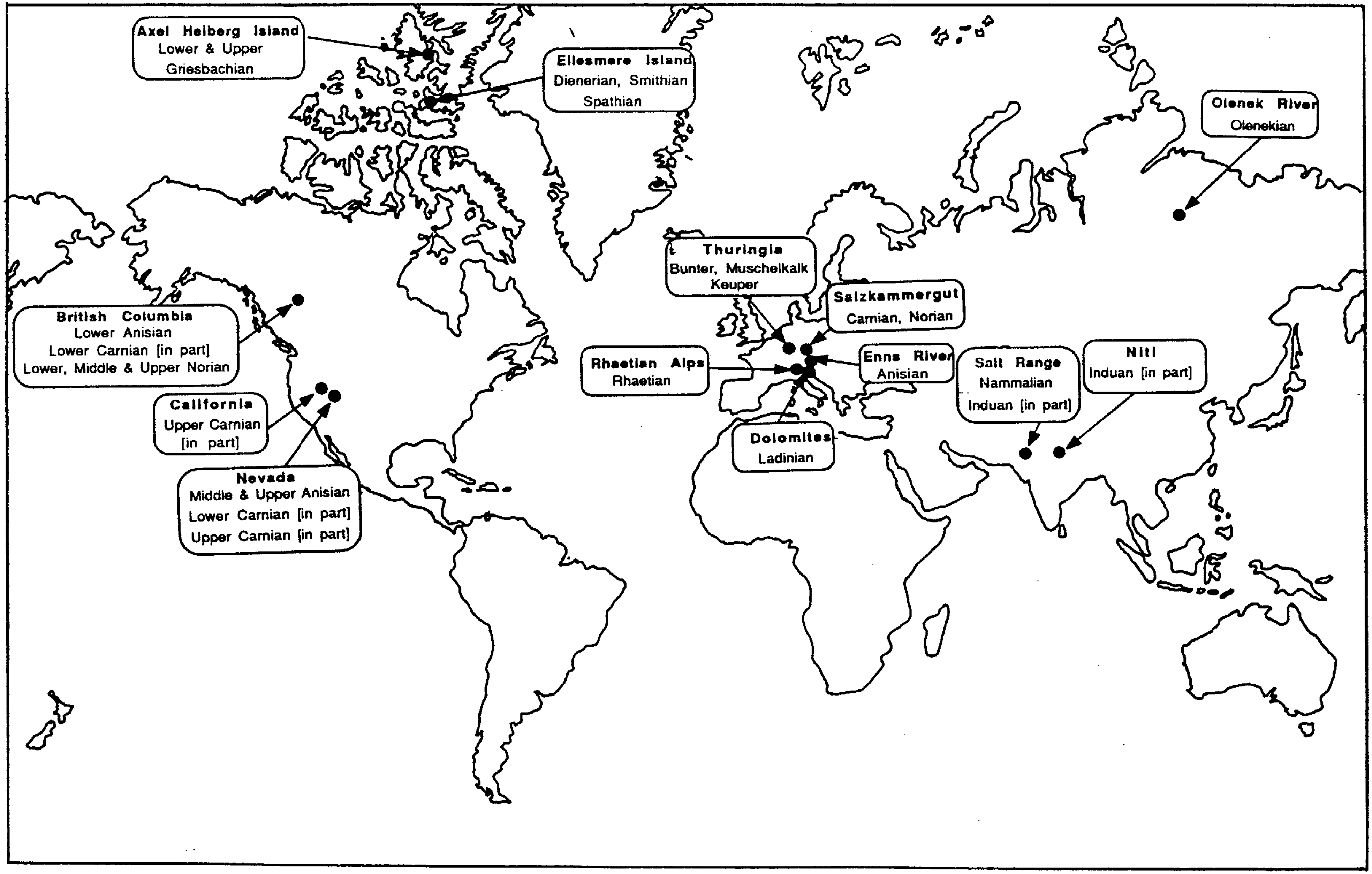

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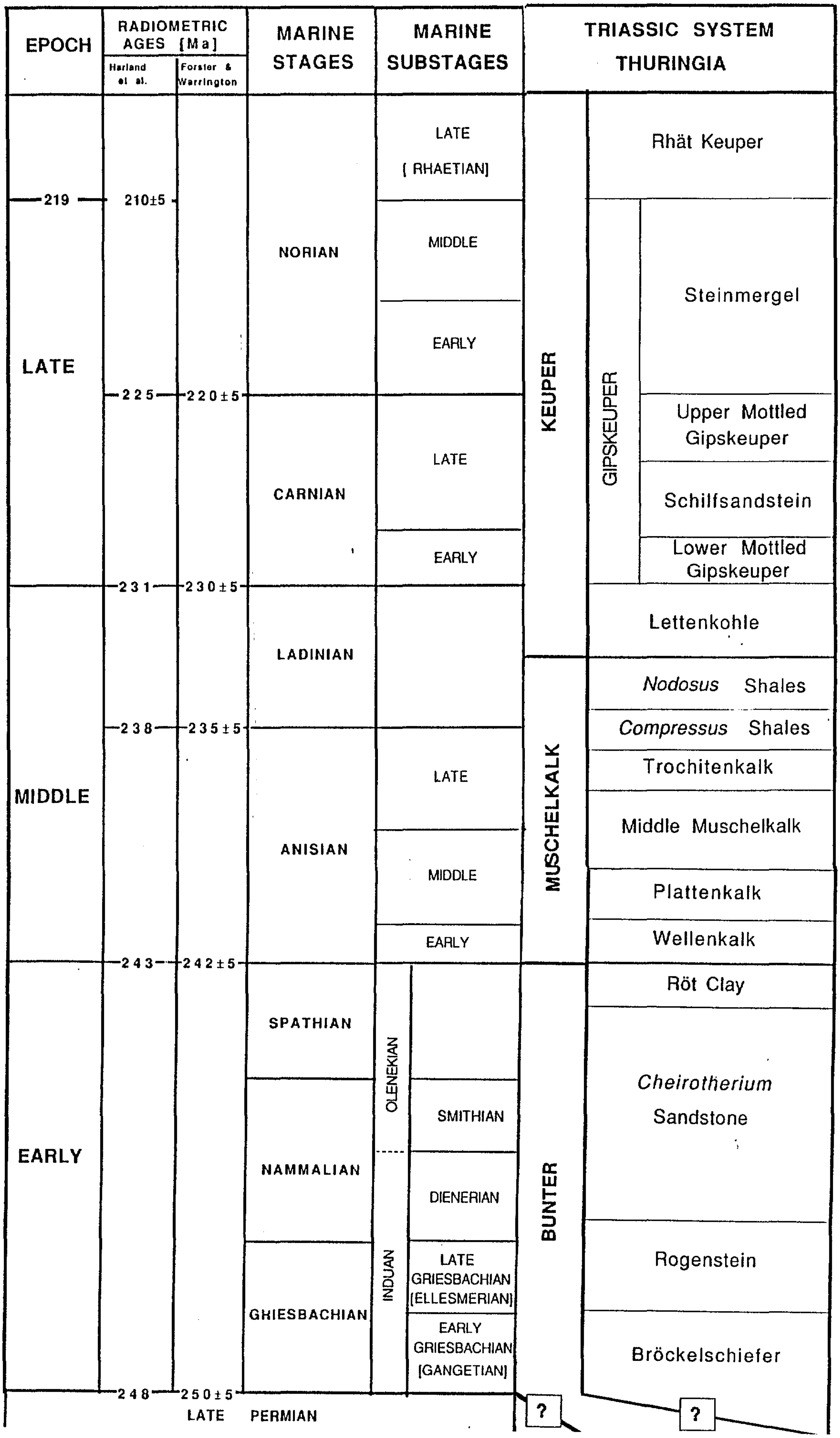

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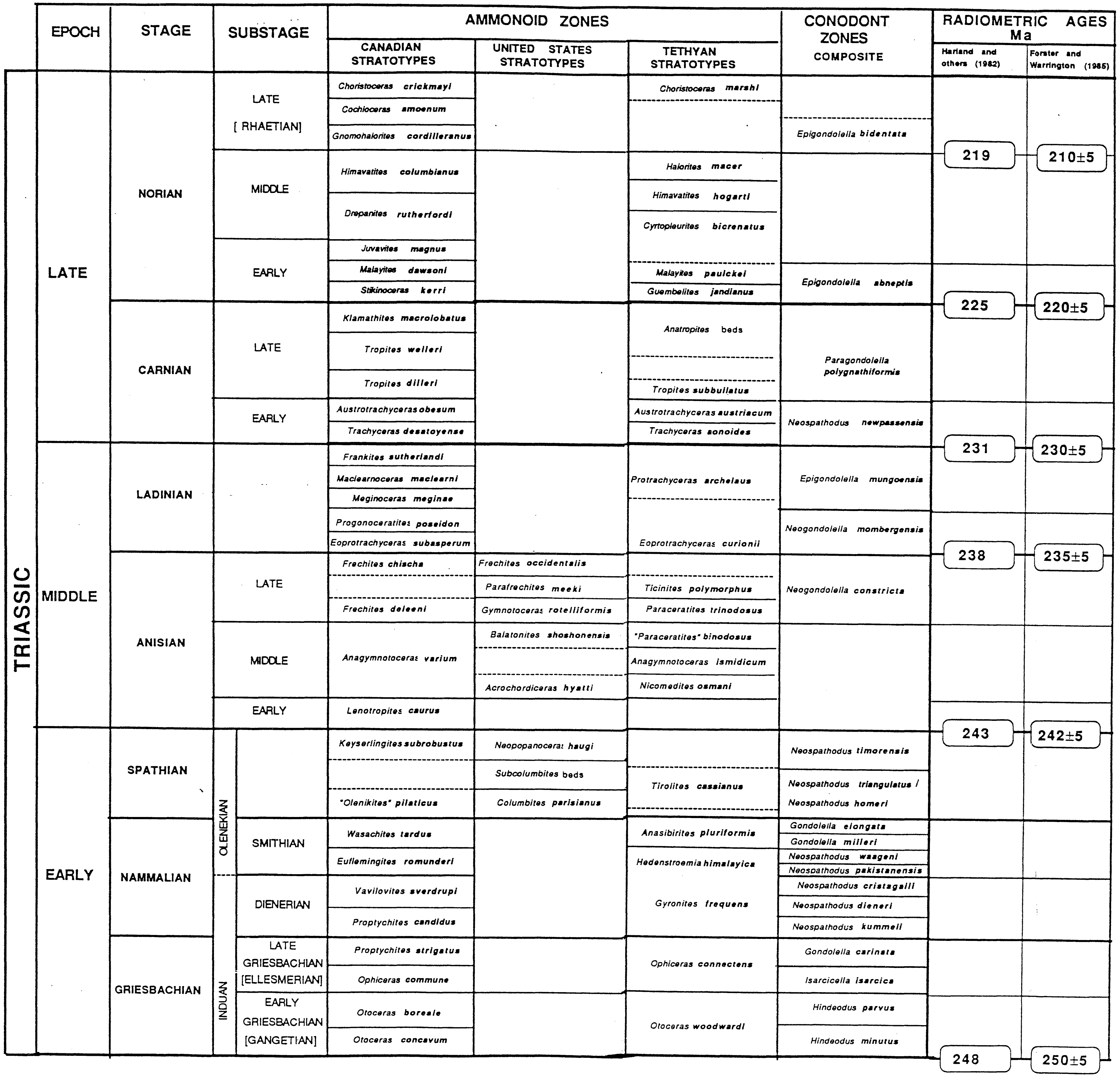

	EPOCH	STAGE		SUBSTAGE	AMMONOID ZONES			CONODONT ZONES COMPOSITE	RADIOMETRIC AGES Ma	
					CANADIAN STRATOTYPES	UNITED STATES STRATOTYPES	TETHYAN STRATOTYPES		Harland and others (1982)	Forster and Warrington (1985)
TRIASSIC	LATE	NORIAN		LATE [RHAETIAN]	*Choristoceras* ***crickmayi***		*Choristoceras* ***marshi***			
					Cochloceras ***amoenum***					
					Gnomohalorites ***cordilleranus***			*Epigondolella* ***bidentata***	219	210±5
				MIDDLE	*Himavatites* ***columbianus***		*Halorites* ***macer***			
					Drepanites ***rutherfordi***		*Himavatites* ***hogarti*** *Cyrtopleurites* ***bicrenatus***			
				EARLY	*Juvavites* ***magnus***					
					Malayites ***dawsoni***		*Malayites* ***paulckei***	*Epigondolella* ***abneptis***		
					Stikinoceras ***kerri***		*Guembelites* ***jandianus***		225	220±5
		CARNIAN		LATE	*Klamathites* ***macrolobatus***		*Anatropites* beds			
					Tropites ***welleri***			*Paragondolella* ***polygnathiformis***		
					Tropites ***dilleri***		*Tropites* ***subbullatus***			
				EARLY	*Austrotrachyceras* ***obesum***		*Austrotrachyceras* ***austriacum***	*Neospathodus* ***newpassensis***		
					Trachyceras ***desatoyense***		*Trachyceras* ***aonoides***		231	230±5
	MIDDLE	LADINIAN			*Frankites* ***sutherlandi***					
					Maclearnoceras ***maclearni***		*Protrachyceras* ***archelaus***	*Epigondolella* ***mungoensis***		
					Meginoceras ***meginae***					
					Progonoceratites ***poseidon***			*Neogondolella* ***mombergensis***		
					Eoprotrachyceras ***subasperum***		*Eoprotrachyceras* ***curionii***		238	235±5
		ANISIAN		LATE	*Frechites* ***chischa***	*Frechites* ***occidentalis***				
						Parafrechites ***meeki***	*Ticinites* ***polymorphus***	*Neogondolella* ***constricta***		
					Frechites ***deleeni***	*Gymnotoceras* ***rotelliformis***	*Paraceratites* ***trinodosus***			
				MIDDLE	*Anagymnotoceras* ***varium***	*Balatonites* ***shoshonensis***	"*Paraceratites*" ***binodosus***			
							Anagymnotoceras ***ismidicum***			
						Acrochordiceras ***hyatti***	*Nicomedites* ***osmani***			
				EARLY	*Lenotropites* ***caurus***				243	242±5
	EARLY	SPATHIAN	OLENEKIAN		*Keyserlingites* ***subrobustus***	*Neopopanoceras* ***haugi***		*Neospathodus* ***timorensis***		
						Subcolumbites beds	*Tirolites* ***cassianus***	*Neospathodus* ***triangulatus*** / *Neospathodus* ***homeri***		
					"*Olenikites*" ***pilaticus***	*Columbites* ***parisianus***				
		NAMMALIAN		SMITHIAN	*Wasachites* ***tardus***		*Anasibirites* ***pluriformis***	*Gondolella* ***elongata*** *Gondolella* ***milleri***		
					Euflemingites ***romunderi***		*Hedenstroemia* ***himalayica***	*Neospathodus* ***waageni*** *Neospathodus* ***pakistanensis***		
			INDUAN	DIENERIAN	*Vavilovites* ***sverdrupi***		*Gyronites* ***frequens***	*Neospathodus* ***cristagalli***		
					Proptychites ***candidus***			*Neospathodus* ***dieneri*** *Neospathodus* ***kummeli***		
		GRIESBACHIAN		LATE GRIESBACHIAN [ELLESMERIAN]	*Proptychites* ***strigatus***		*Ophiceras* ***connectens***	*Gondolella* ***carinata***		
					Ophiceras ***commune***			*Isarcicella* ***isarcica***		
				EARLY GRIESBACHIAN [GANGETIAN]	*Otoceras* ***boreale***		*Otoceras* ***woodwardi***	*Hindeodus* ***parvus***		
					Otoceras ***concavum***			*Hindeodus* ***minutus***	248	250±5

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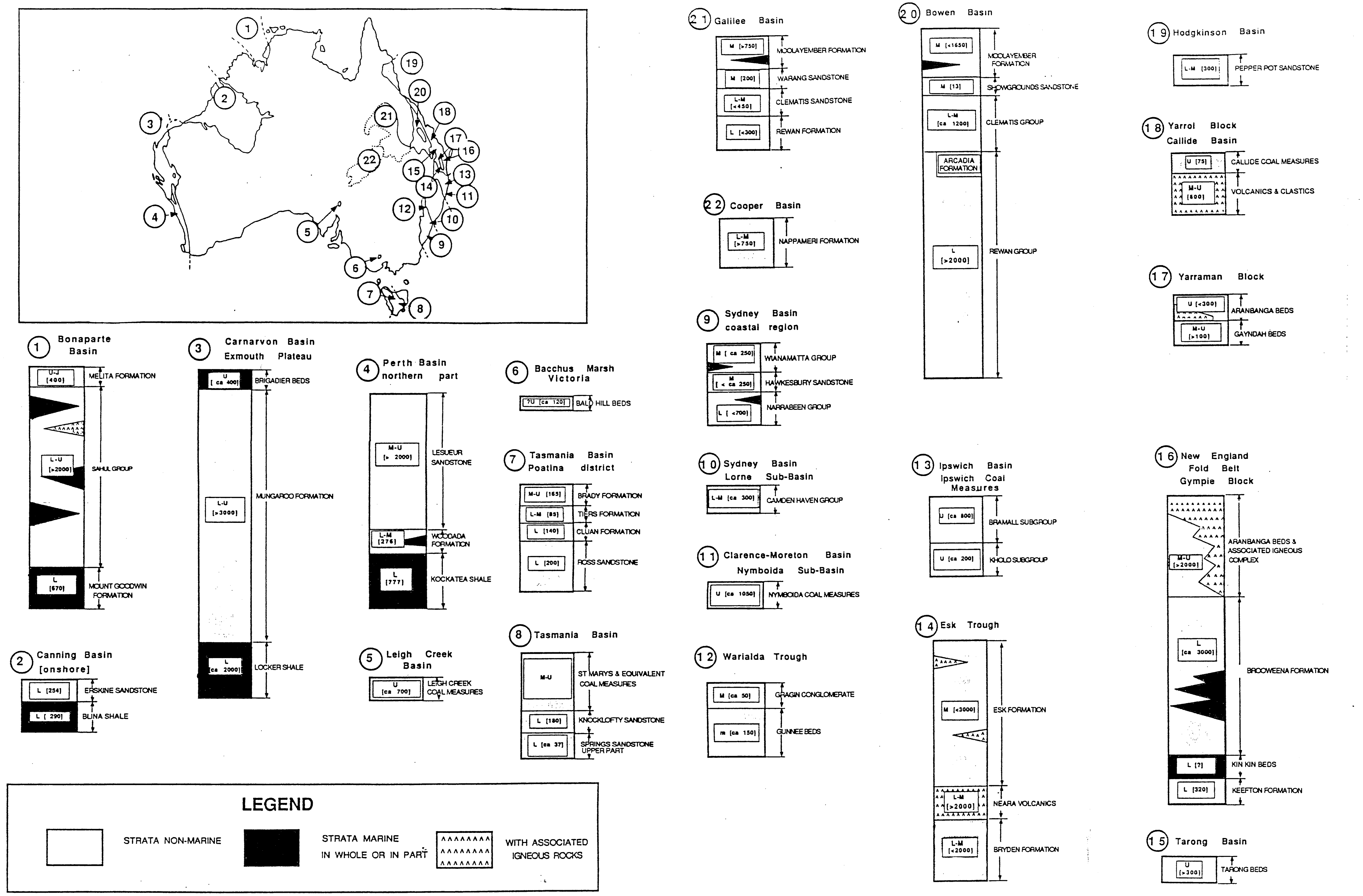

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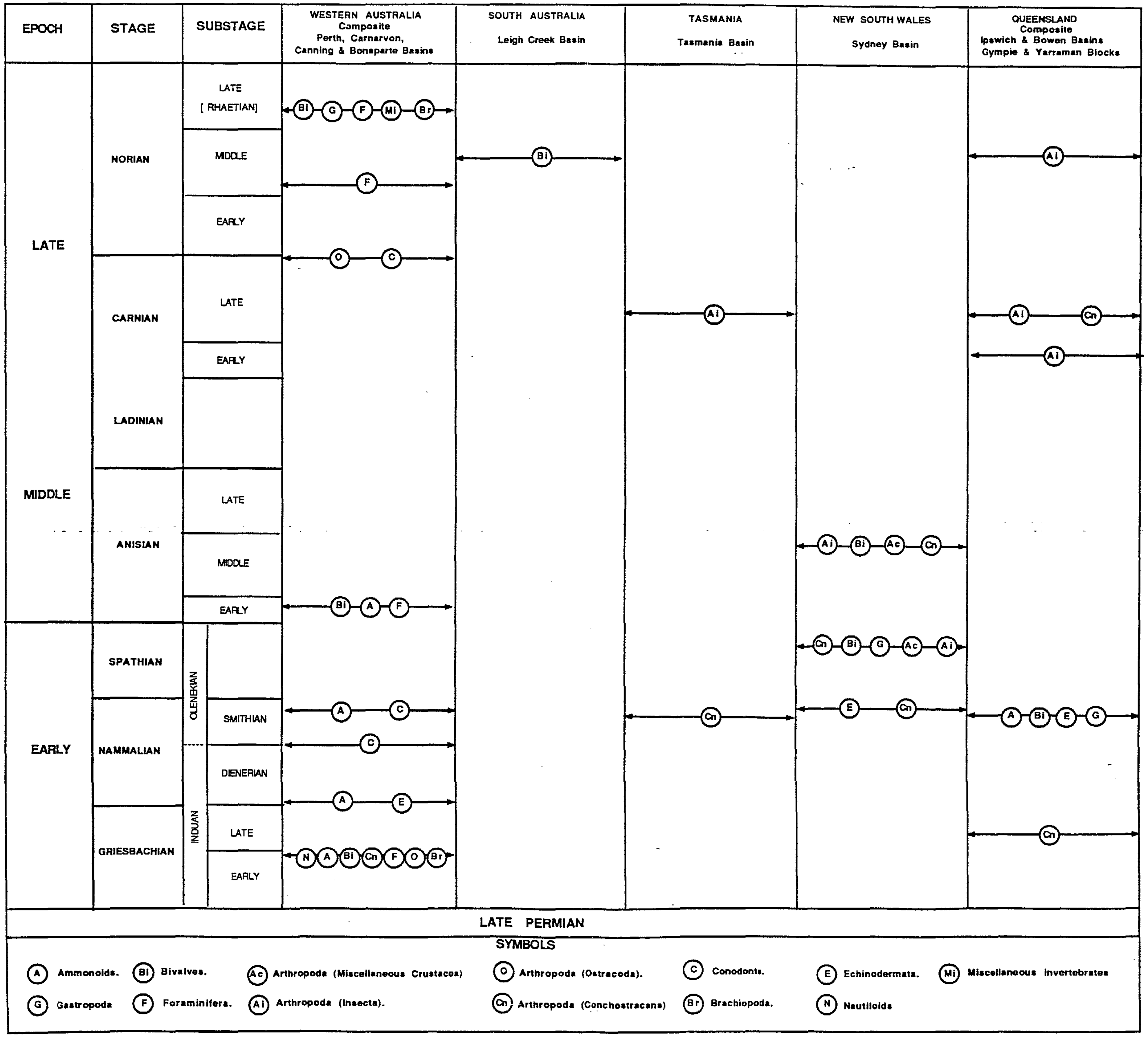

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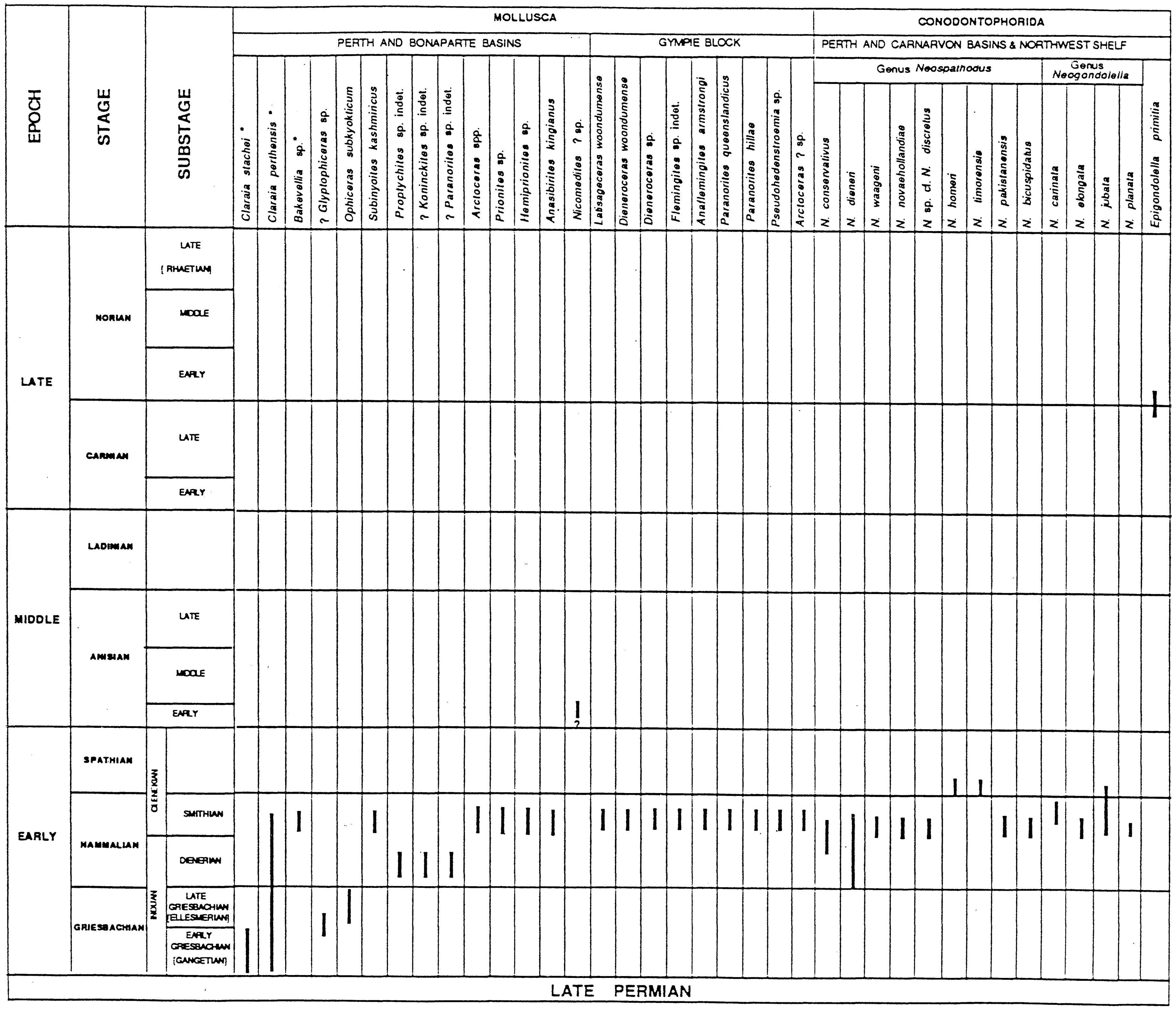

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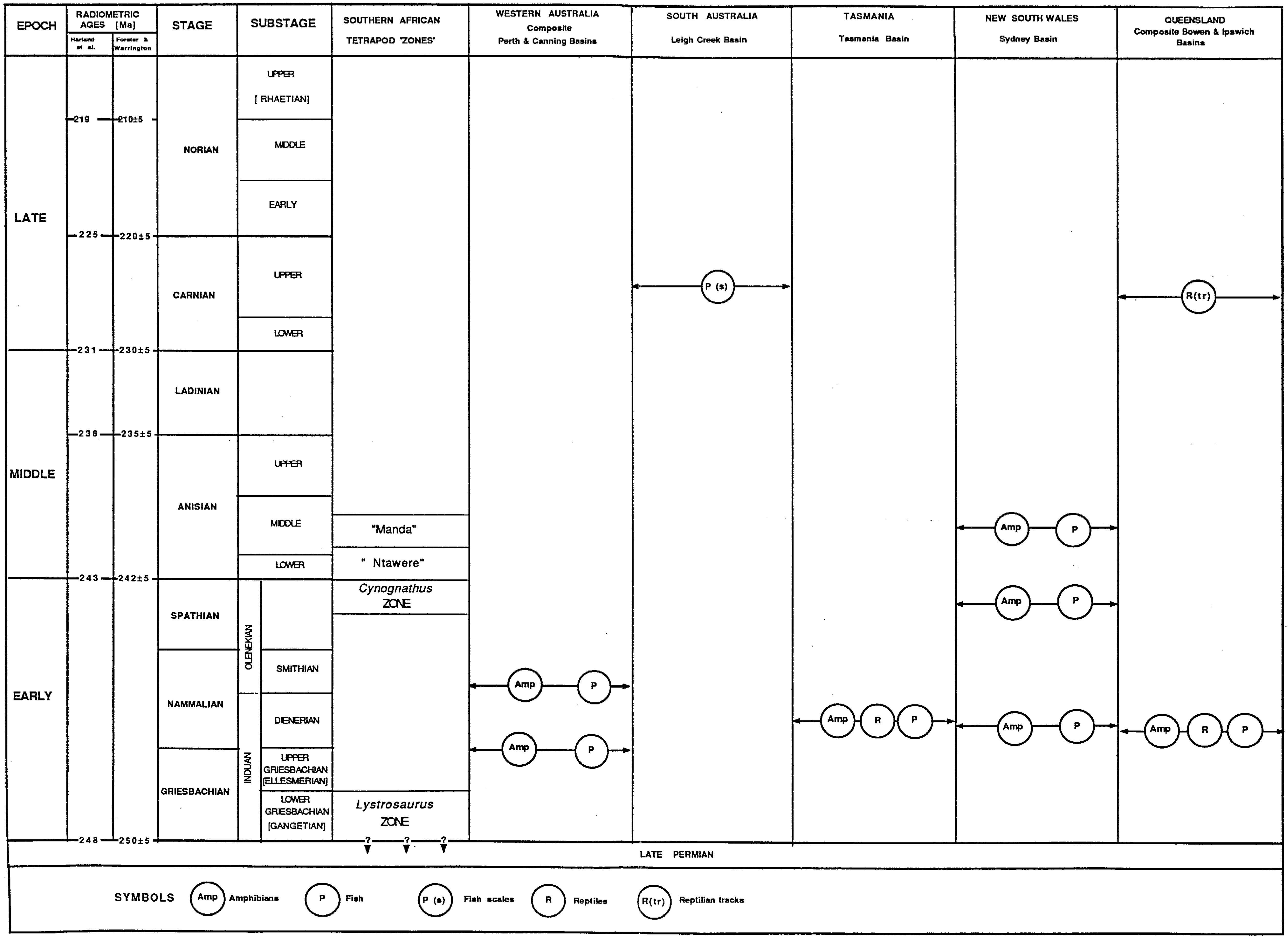

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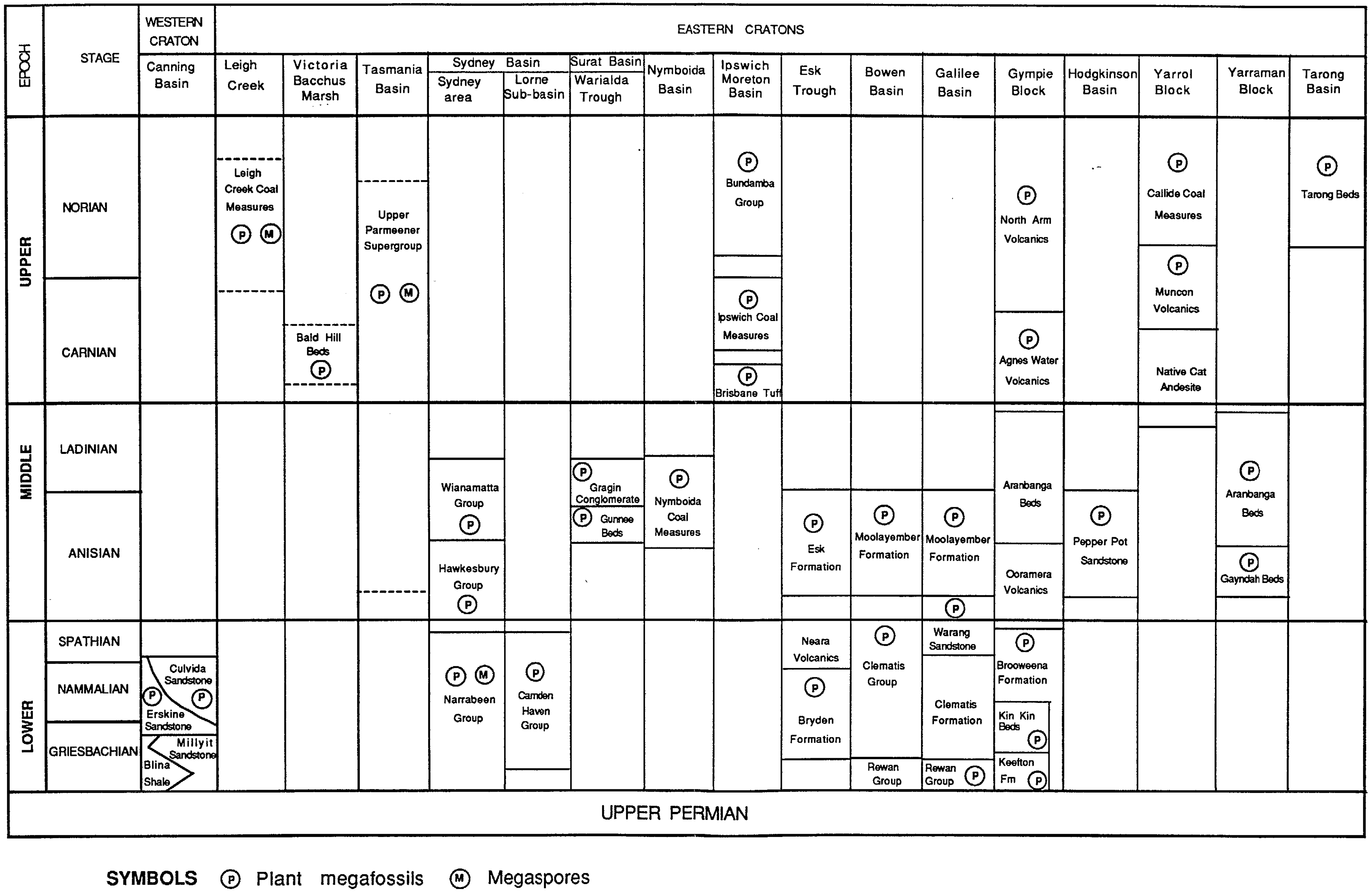

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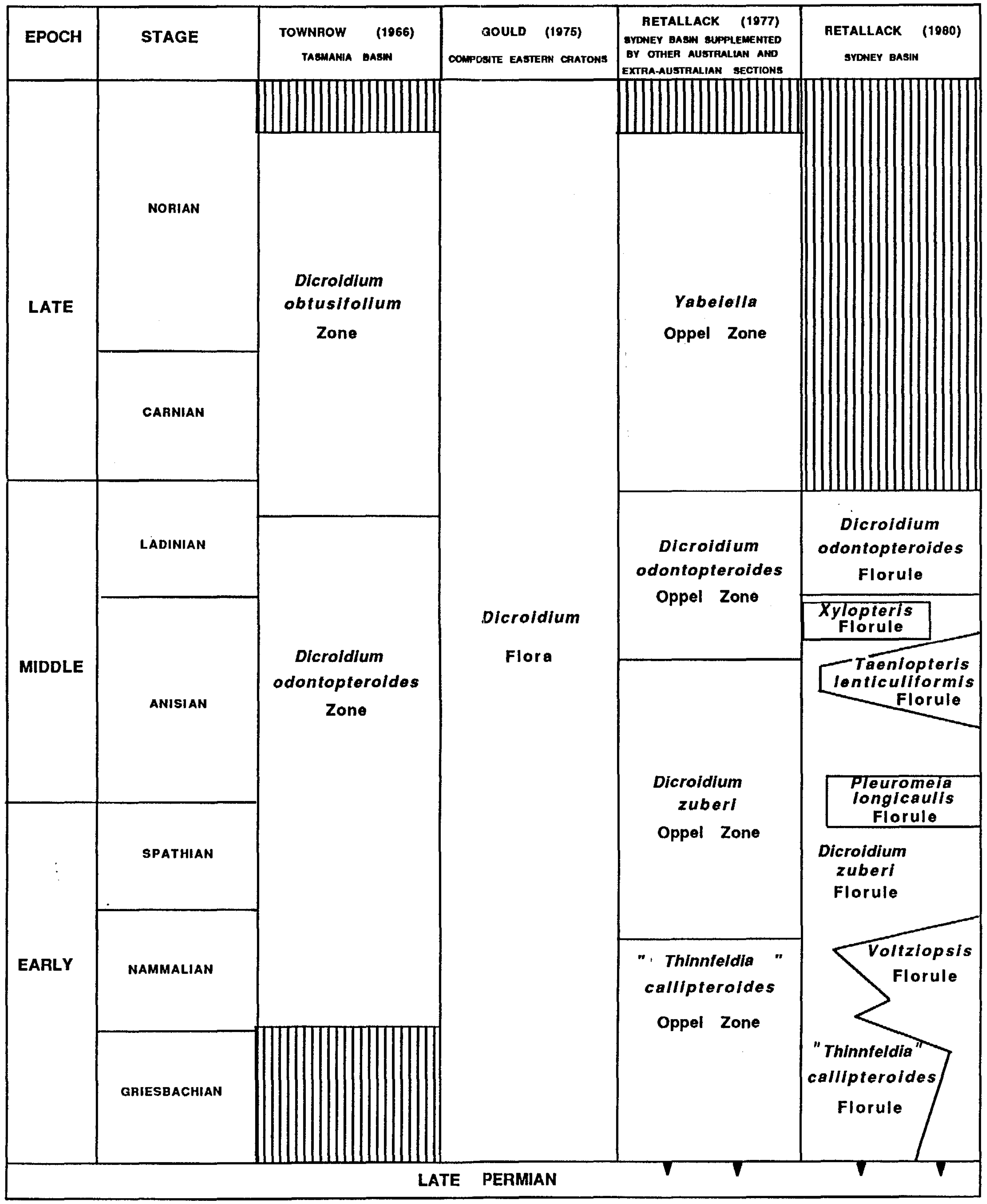

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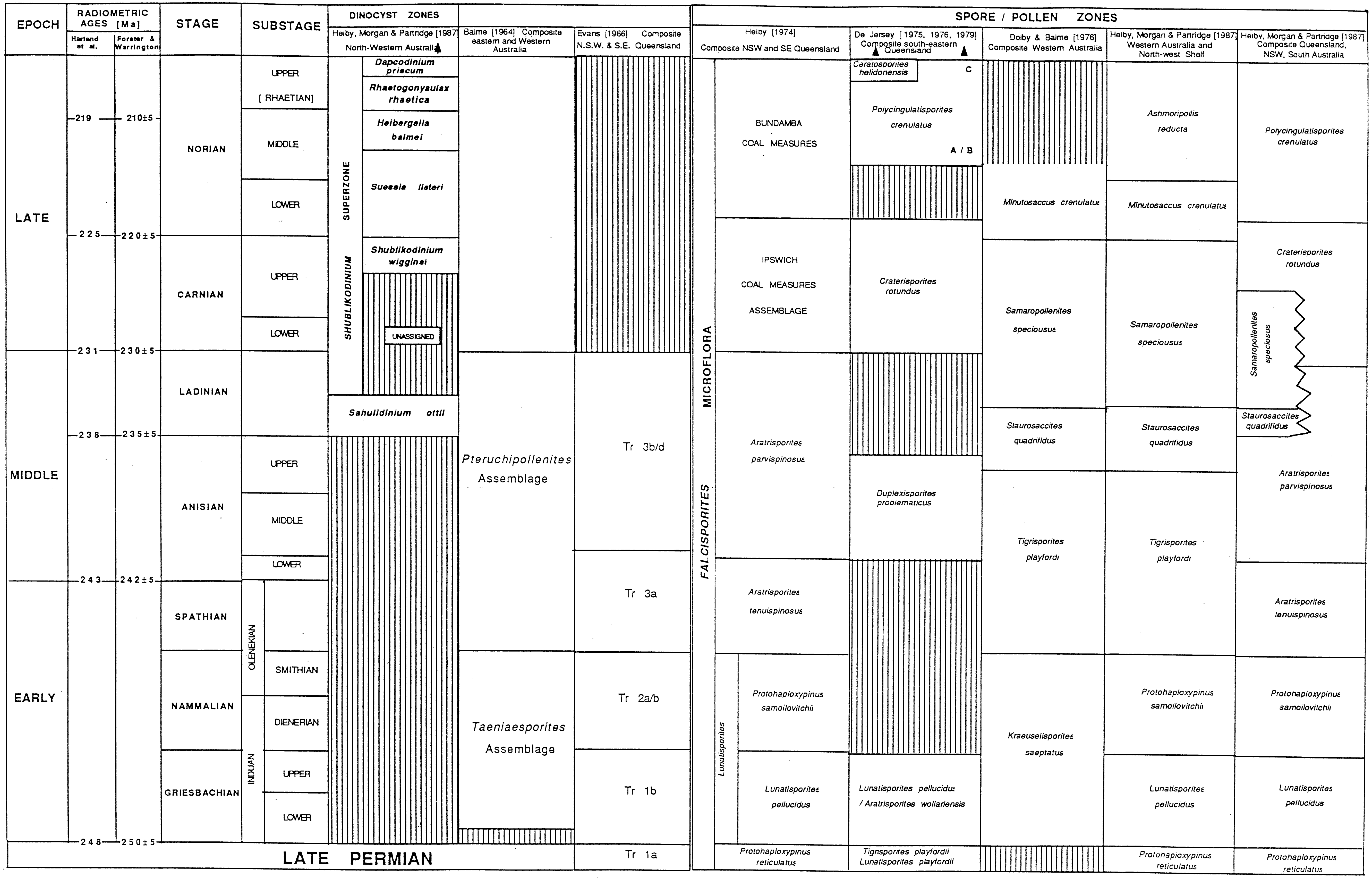

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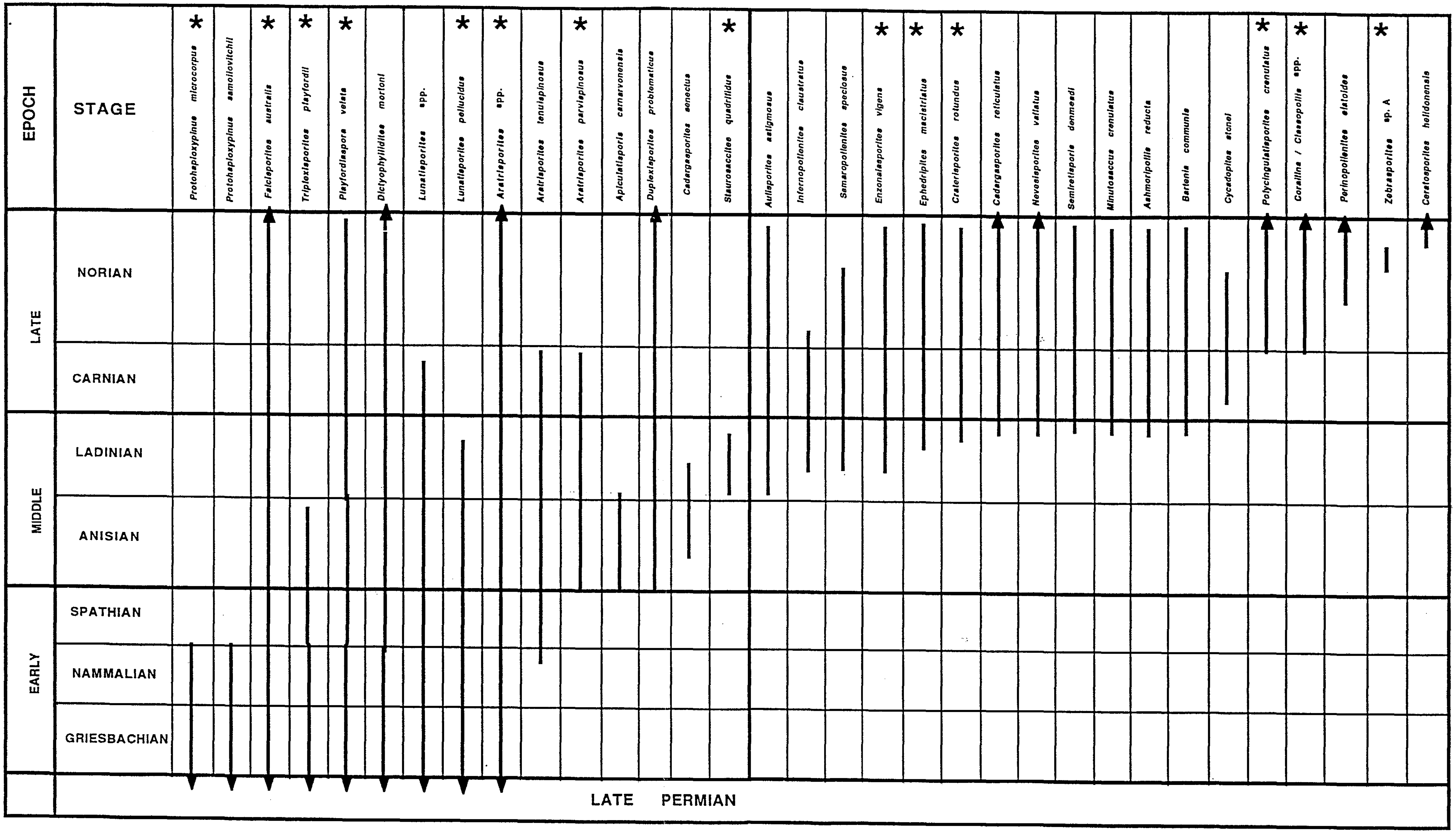

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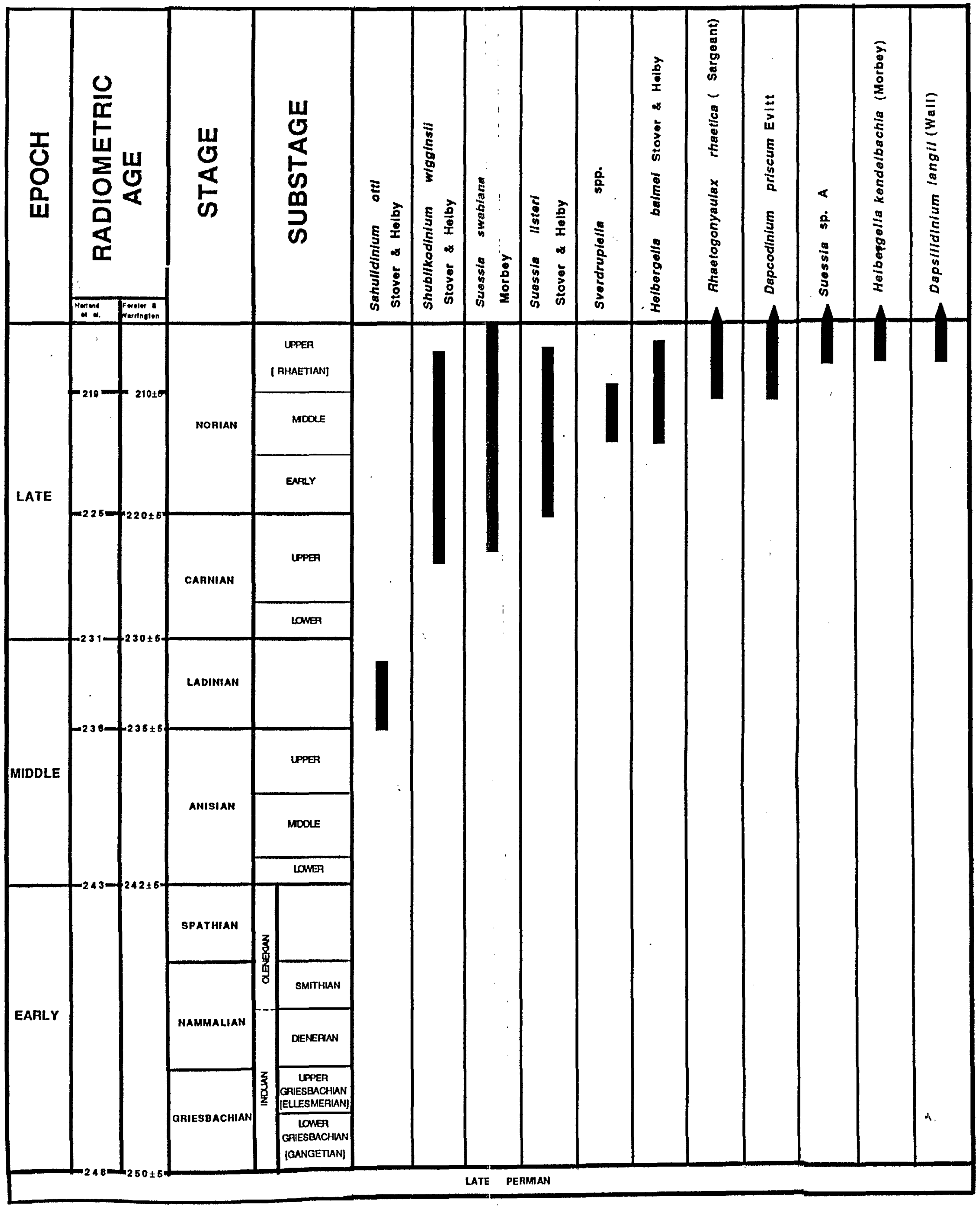

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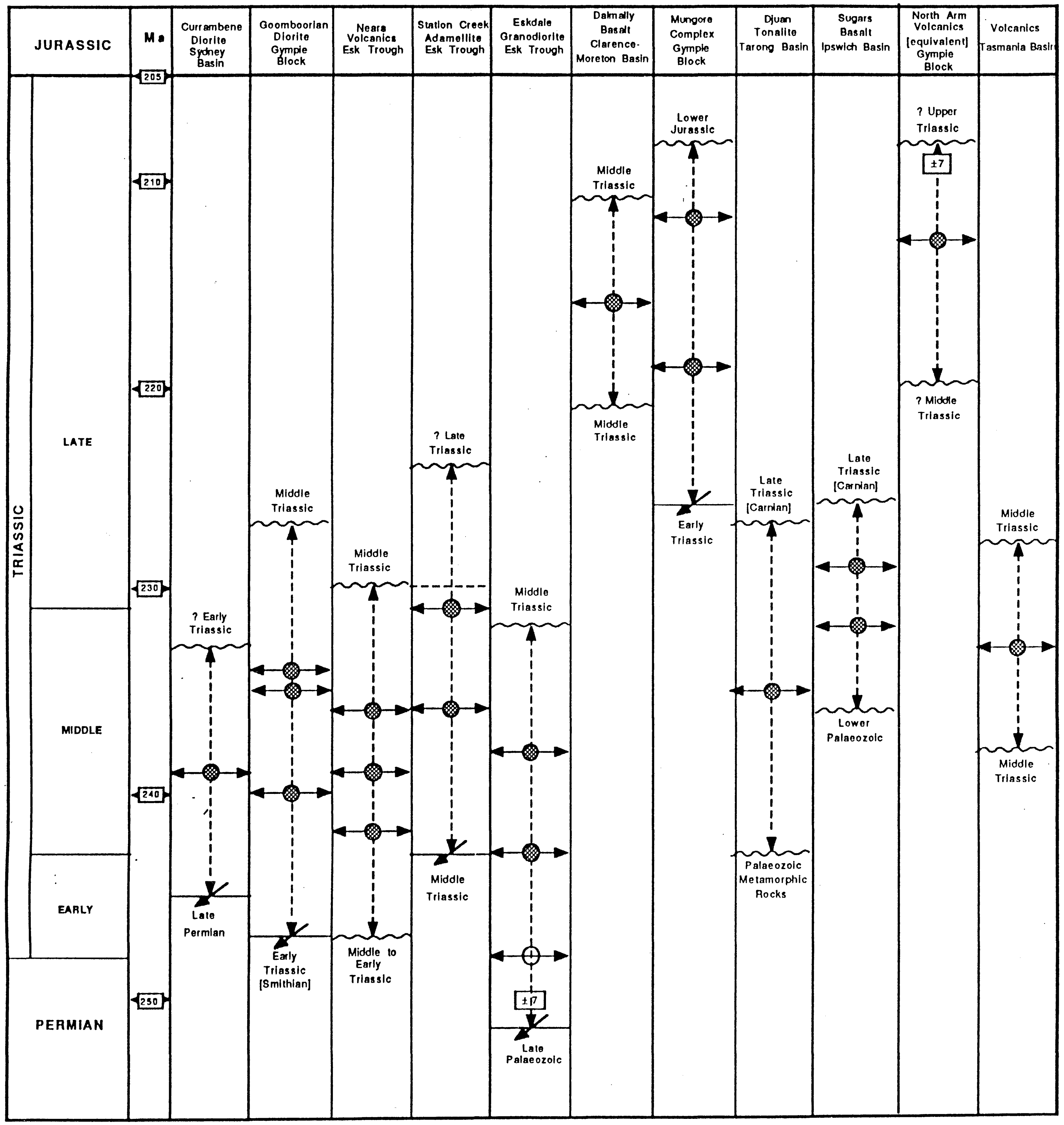

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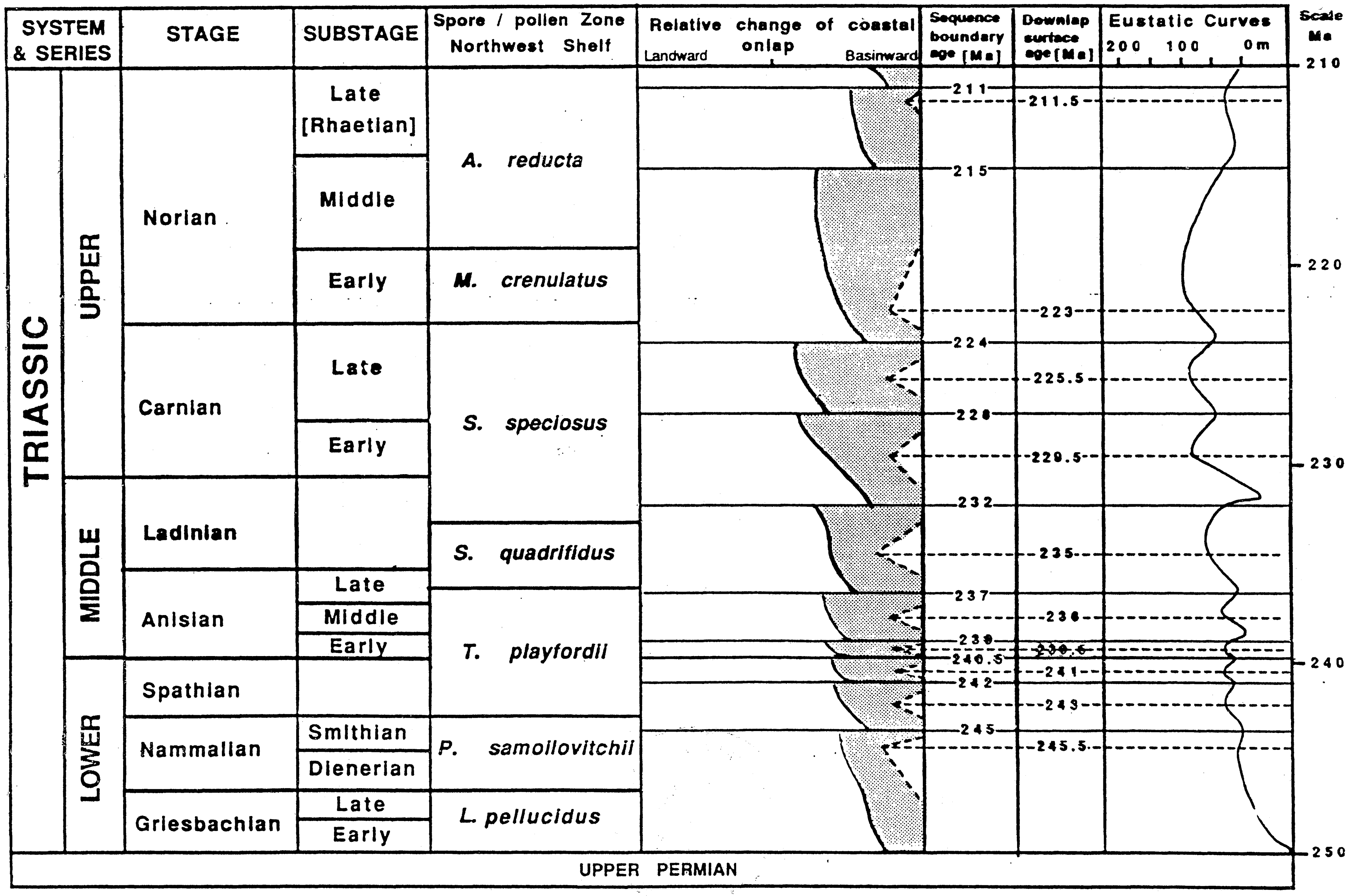

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