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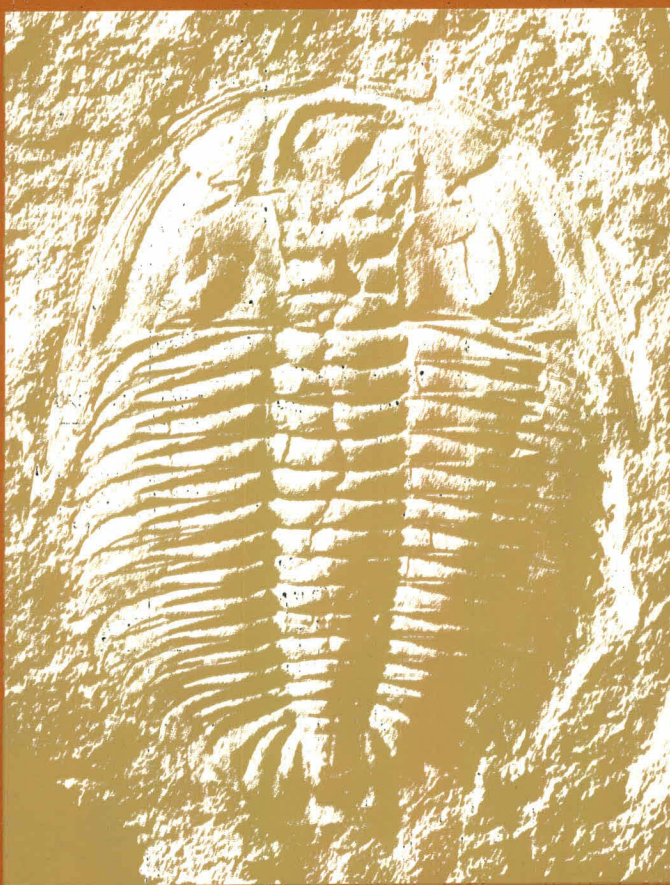
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AUSTRALIAN PHANEROZOIC TIMESCALES: PERMIAN

N.W. ARCHBOLD & J.M. DICKINS



BUREAU OF MINERAL RESOURCES  
GEOLOGY AND GEOPHYSICS

DIVISION OF CONTINENTAL GEOLOGY

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# AUSTRALIAN PHANEROZOIC TIMESCALES

## 6. PERMIAN

A STANDARD FOR THE PERMIAN SYSTEM IN AUSTRALIA

by

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**COVER ILLUSTRATION:** *Xystridura milesi* (Chapman, 1929) from the early Middle Cambrian, Beetle Creek Formation, Mount Isa district, Queensland.



# FOREWORD

A time framework is essential to an understanding of all historical 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 (palaeontology), and their stratigraphic distribution (biostratigraphy).

Early palaeontological investigations of Australian sedimentary basins were used during the nineteenth century to establish the age of major suites of sedimentary rocks. This provided a framework for the application of more detailed biostratigraphic research, an early example being the use of graptolites to subdivide Ordovician strata in the Victorian goldfields at the beginning of this century. The Victorian sequence of graptolite zones is the current standard used throughout Australasia, and is one of the most finely subdivided in the world.

The development of Australian biostratigraphy over the last 50 years has provided many 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 (such as larger invertebrates, fish, mammals, even 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. These provide a means of calibrating biostratigraphic schemes with a numerical time scale.

The current **Phanerozoic Timescales Series** makes available for immediate use a preliminary set of charts based both on recent palaeontological data from the specialist scientific literature, and unpublished information from ongoing biostratigraphic research. The charts integrate, for each geological period, 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. 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. The current series is made available to provide a set of up-to-date calibrated biostratigraphic charts specifically for use in the Australasian region.

Biostratigraphic charts were initially prepared for the AMIRA (Australian Mineral Industries Research Association) sponsored *Palaeogeographic Atlas of Australia* project. The current charts and explanatory text have been revised and updated as 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.

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## INTRODUCTION

The establishment of the Permian System of rocks by Roderick Impey Murchison in 1841, and the subsequent inclusion of older rock sequences within the system in order to define its base (and hence the top of the Carboniferous) have recently been reviewed by Archbold (1985). The provincialism often evident in Permian marine faunas and terrestrial floras has been an obstacle to reliable international correlations.

During the earliest part of the Permian, glaciation was widespread, especially in the present Southern Hemisphere, and although the tropical belt was probably restricted in geographical extent there was a strong climatic differential associated with a more distinct faunal and floral provincialism (Dickins 1985 a,b) than is found in most other geological systems. The Triassic, for example, is quite a contrast in this regard (Dickins, 1985c). During the course of the Early Permian the world became warmer and the earlier provincialism tended to break down. The tropical and subtropical zones became much wider. After the beginning of the Late Permian the world became quite warm, the relationships of the faunas are much wider and correlation becomes easier. During the course of the Late Permian, however, accompanying the development of the Hunter-Bowen (Indosinian) Orogenic Folding Phase, progressive regression of the sea occurred, and the marine basins became more and more isolated, once again hampering correlation. This regressive phase culminated in the Permian-Triassic boundary beds (Dickins, 1988, in press a). Correlation in the Triassic is potentially much easier with the development of wide-spread marine transgression and warm climate. Even though the recognition of an international standard scale for subdivision of the system is some way off, significant advances have been made in the last decade.

The Permian System is extensively developed in Australia. Large coal reserves and important oil and gas reserves have

resulted in the system receiving attention since the initial discoveries of coal in the 1790's. The occurrences of the distinctive Permian marine bivalve *Eurydesma*, the coal plant *Glossopteris*, and strata of glacial origin within the Permian sequences, has caused great international interest, and was used as evidence for the theory of continental drift during the first half of the twentieth century. However, the interpretation of the distribution of faunas and floras remains controversial (Dickins & Shah, 1981, 1987; Archbold, 1983a; Runnegar, 1984; Chatterjee & Hotton, 1986).

The first fossil species described from the Australian continent was the Tasmanian Permian brachiopod *Trigonotreta stokesii* documented by Charles König (or Koenig; see Archbold, 1985) in 1825. Despite major contributions to Australian Permian palaeontology by such nineteenth century workers as Frederick McCoy, John Morris, Alcide d'Orbigny, Laurent Guillaume de Koninck, James Dwight Dana and subsequently Robert Etheridge Junior, reliable recognition of the Permian System in Australia was not achieved until studies on Western Australian Permian ammonoids were undertaken (see Archbold, 1985 for a detailed review).

Use of the term Permian substantially in its present scope and as used in this chart followed the detailed consideration of both eastern and western Australian marine faunas by Raggatt & Fletcher (1937) - see Murray (1983). Wade (1937), Hill (1937) and others (see Clarke, 1937) had independently reached similar conclusions with respect to the Permian sequences of Western Australia. Correlation with overseas, especially of the Western Australian sequences, was placed on a firm basis by the work of Teichert (e.g. 1941), although the recognition of Upper Permian marine deposits was delayed until established first by G.A. Thomas (Thomas & Dickins, 1954). A comprehensive correlation chart based largely on the marine faunas was produced along with charts for several other systems for the 1st Gondwana Sym-

posium in Buenos Aires in 1967, subsequently brought up to date and published by the Bureau of Mineral Resources (Dickins, 1976). Correlation by spores and pollen has been subsequently undertaken (Kemp *et al.*, 1977).

The accompanying chart indicates the degree to which progress has been made. Activity has varied but critical studies have been heavily reliant on the marine groups including the Ammonoidea, Bivalvia (or Pelecypoda), Gasteropoda and Brachiopoda with important studies on the Bryozoa and Foraminifera. Terrestrial sequences have been subdivided by studies on spores and, to a lesser degree, mega-plant remains.

Permian correlation and biostratigraphy is a challenge to further development (see later). Although much has been done, radiometric dating (geochronology), is still at a rather preliminary level, and palaeomagnetic stratigraphy is poorly resolved. Pertinent comments are summarized in the following notes. The framework for the chart was designed by N.W. Archbold, the western Australian sections are the joint responsibility of the two authors, and J.M. Dickins is mainly responsible for the eastern Australian sections.

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## NOTES

### INTERNATIONAL STAGES

#### COLUMN 1

The 250 Ma age for the top of the Permian follows that of Forster & Warrington (1985). Recently, Harland *et al.* (1990), have proposed 245 Ma for the top of the system. Earlier, ages given for the top of the Permian, were considerably younger and inconsistency was shown in Upper Permian and Lower and Middle Triassic rocks with similar ages. The arguments of Forster & Warrington (1985) help to resolve this problem. It also makes the Triassic and Permian about equal in time which is more reasonable than previously with the Permian considerably longer than the

Triassic, and is more compatible with the geological and biological complexity of the two systems.

Forster & Warrington (1985) and Harland *et al.* (1990) take the base of the Permian as 290 Ma. This is modified here to take into account the data of Lippolt & Hess (1985), who give the top of the Stephanian (i.e. apparently Stephanian C), taken usually in Western Europe as the top of the Carboniferous, as 300 Ma. From palynological evidence (Bourez & Doubinger, 1977; Doubinger & Bourez, 1984) it seems likely there is a time interval between Stephanian C and Asselian, so that a compromise figure of 295 Ma seems reasonable, as in Jones (1988, in prep). Bourez & Doubinger considered that the base of the Asselian lay within the lower Autunian and referred to this part of the lower Autunian as Stephanian B. This places the base of the Permian considerably older than the 286 Ma of Harland *et al.* (1982) but close to the figure given by Carr *et al.* (1985).

Mid-Permian (i.e. the boundary between the Kungurian and Ufimian) is given as 270 Ma. This reflects the more recent work indicating that the Upper Permian represents a complex sequence from a tectonic and biological point of view, rather than a relatively thin uncomplicated sequence as had been thought from the earlier studies based largely in Western Europe. From the tectonic, sedimentary and biological development it seems more realistic to regard the Lower and Upper Permian as more or less equal in length. Some radiometric data tends to bear this out, for example 270 Ma ages for ignimbrites in the Southern Alps of Italy which appear to be mid-Permian (Dickins, 1988).

No attempt has been made to show radiometric dates for the stages of the Permian. Accurate radiometric information on their boundaries is largely lacking and dating is rather conjectural. Thus, in this respect, we do not follow Forster & Warrington (1985).

The two-fold subdivision into Lower and



Upper is followed here corresponding to the traditional scheme in the Permian type area in the Ural Mountains and Russian Platform. This scheme is the most widely used and is the most practical for most parts of the world. It is endorsed currently by the Subcommittee on Permian Stratigraphy. The term Middle Permian varies widely in scope where it is used in different parts of the world. For the present its usage is not recommended - its use in Australia is considered to hinder an understanding of both Australian and world Permian geology.

## COLUMN 2

The Lower Permian uses the four stages, and their subdivisions, recognized in the Ural-Russian Platform area (Kotlyar & Stepanov, 1984). The detailed basis for the importance of the recognition of the Kungurian Stage has been given by Dickins *et al.* (in press).

The base of the Asselian, the lowest of the four stages, regarded here as making up the Lower Permian, is taken at the base of the *vulgaris-fusiformis* zone, in conformity with Archbold (1982), Kotlyar & Stepanov (1984) and Davidov (1988).

The Upper Permian utilises a combination of the Ural-Russian Platform subdivision, and the stages from the Armenian (Transcaucasian) sequence. This has the value of combining the scheme for the traditional type area, and the utility of using the complete or more complete marine sequence in Armenia, which has the additional advantage that it is in the Tethyan Region.

The top of the Permian is taken as the top of the Changhsingian at Meishan in South China (see Zhao Jin-ke *et al.*, 1981).

The Midian has been recently defined (Kotlyar *et al.*, 1989). This usage and that of Kotlyar & Stepanov (1984), and Kotlyar *et al.* (1987) has been followed here.

The Changhsingian and the Dorashamian are taken as representing the same interval, al-

though this remains under discussion (see Zhao Jin-ke *et al.*, 1981).

Almost certainly the Tatarian does not represent all of the uppermost Permian (Gomankov, 1988) and the equivalence of its lower boundary above the Kazanian with the lower boundary of the Midian is tentative and subject to review. However, it appears to be approximately equivalent.

## WESTERN AUSTRALIA

### COLUMN 3

The biostratigraphical stages of A to F are those of Dickins (1963). The validity of Stage C has been questioned by Runnegar (1969), Waterhouse (1970) and Cockbain (1980), but work on both old and new collections is indicating the occurrence of distinctive faunal elements in the Perth Basin (Archbold, 1988a), and the Carnarvon Basin. This provides substantial support for retaining the stage.

Two faunas are now discriminated on the basis of brachiopods within Stage F, and are indicated by the subdivisions F<sub>1</sub> and F<sub>2</sub> (Archbold, 1988b).

### COLUMN 4

Ammonoids are indicated as 'spot points' rather than ranges, because many species are represented by only one or a small number of specimens from a single locality within formations.

Occurrences are based on the documentation of species provided by Glenister & Furnish (1961), Glenister, Windle & Furnish (1973), Cockbain (1980) and Glenister *et al.* (1990 a & b).

The occurrence of *Paragastrioceras wandageense* is important for understanding the age of the upper limit of Substage D1, as this species is closely related to *P. kungurensis* from the Kungurian of the Central Urals. Condon (1954) and Cockbain (1980), without giving any field evidence, conclude that F.

*wandageense* came from the Nalbia Sandstone, placed at the top of D1. At present there seems no reason not to accept Teichert's view that the species came from low in the Coolkilya Sandstone (i.e. Baker Formation in current terms).

### COLUMN 5

Selected named species are included according to stratigraphical and other interest. The bivalves from the Hardman Formation and the equivalent sequence in the Bonaparte Gulf Basin have not been described, and only a minor part of the fauna from the Wooramel and Byro Groups and the Noonkanbah Formation has been documented. This is reflected in the ranges shown.

### COLUMN 6

Important brachiopod species (with ranges as determined by examination of collections of the BMR, GSWA *et al.*) are provided in Column 6, and are based on summaries and descriptions in Archbold *et al.* (in press), a summary of data up to the end of 1986, and Archbold (1988b), Archbold & Skwarko (1988) and Archbold & Thomas (1987).

Not included in the column are reports of species by Waterhouse (in Foster & Waterhouse, 1988) many of which are doubtful or appear to be misidentified. In an attempt to force correlation between the Grant Formation of the Canning Basin and the Early Permian of Tasmania, species from the two regions were compared with each other, while closely related Western Australian species were dismissed. Of the few illustrated species described by Waterhouse, we would reassign them as follows. The *Neochonetes* remains as *N. (S.) aff. prattii* (Davidson); the *Strophalosia* cf. *subcircularis* is reidentified as juvenile *Strophalosia* cf. *irwinensis* Coleman, as redescribed by Archbold (1986), and the *Terrakea capillata* Waterhouse (in Foster & Waterhouse, 1988) is referred to *Lyonia* (Archbold, 1983b), as juvenile representatives of the genus. In view of the isolated nature of the sequence that yielded the fauna, and the lack of complete faunal description, it is not feasible to assess the biostratigraphi-

cal importance of the assemblage. A pre-Sterlitamakian (pre-Late Sakmarian) age may be possible but further study of the fauna is required.

### COLUMN 7

The palynostratigraphical units for Western Australia are based on those documented by Kemp *et al.* (1977).

### COLUMN 8

The Permian stratigraphy of the Perth Basin is based on the detailed account provided by Playford *et al.* (1976) and summarized in Skwarko (in press).

Although Playford *et al.* (1976) and other workers show the Fossil Cliff as a member presumably interbedded with the top of the Holmwood Shale, the relationships of the two units are not clear. The absence of the Fossil Cliff in some places could alternatively be due to the erosional unconformity at the base of the overlying the High Cliff Sandstone and/or lack of outcrop. No observation of interbedding has been recorded. The usage of Fossil Cliff Formation by earlier workers has considerable merit.

### COLUMN 9

The Permian stratigraphy of the Carnarvon Basin has been fully described by Condon (1967) with some revision by Hocking *et al.* (1987). The stratigraphy provided in this column is simplified from those accounts.

### COLUMN 10

The stratigraphy of the Canning Basin is summarised in Towner & Gibson (1983).

## EASTERN AUSTRALIA

### COLUMN 11

The faunal stages in this column are based on those proposed by Dickins & Malone (1973), Dickins (1984) and Runnegar (1967).

Although criticised *inter alia* by Waterhouse & Jell (1983) and Briggs (1987, 1989), the scheme shown here has proven reasonably useful, and is generally consistent with that

based on Dickins and Malone (1973), Dickins (1984) and Runnegar (1967). Reasonably well based developments or alternatives to these schemes remain to be proposed.

Foraminiferal assemblage zones have been defined for the Springsure area by Palmieri (1983). Some difficulty has been experienced in relating these zones to the present chart because it has not been possible to distinguish what part of the definitions are based on strict superpositional relationships, and what part are based on interpretative correlation.

Comments pertinent to the scheme are as follows:

- *Tomioopsis brevis* and *T. branxtonensis* are not known in the Bowen Basin, nor *T. plana* in the Sydney Basin, so that the extent of the *T. brevis* Range Zone can only be rather arbitrarily determined in the Bowen Basin. In the Bowen Basin *T. plana* overlaps the range of *T. ovata* so that *Tomioopsis plica* might be a better nominal species for this zone as suggested by Waterhouse & Jell (1983). Probably the range of *T. ovata* in the Bowen Basin overlaps that recorded for *T. ovata* and *T. branxtonensis* in the Sydney Basin.
- Ranges of the same species are known to differ considerably in the different basins, for example see Dickins (1968). The meaning of these differences are probably most satisfactorily examined in terms of Faunizones such as those used in Columns 11 and 13. Indeed, practice in Permian correlations in Australia is showing that faunizones, tied carefully into the stratigraphy, are much more reliable than zones based on a single or a few species.

- The *N. campbelli* Zone of Runnegar & McClung (1975) is replaced by *Trigonotreta* sp. nov. *Neospirifer campbelli* Maxwell (1964) from the Namurian of the Yarrol Basin, Queensland is a rather different species from that found in the basal Permian sequence in the Cranky Corner Basin containing the undescribed species referred here to *Trigonotreta* sp. nov. The Allandale fauna of Runnegar & McClung (1975) includes the *N. campbelli*, *Tomioopsis elongata* and *T. konincki* Zones. The *N. campbelli* Zone is regarded as being older than Faunizone 1 of Tasmania. The *T. elongata* Zone is regarded as being equivalent to Faunizone 1, and basal Faunizone 2 (Clarke, 1990), and the *T. konincki* Zone is regarded as equivalent to most of Faunizone 2 and Faunizone 3 of the Tasmanian succession.

## COLUMN 12

This is based on Runnegar & McClung (1975), who predominantly used spiriferid brachiopods of the family Ingelarellidae. A detailed scheme based primarily on productids has been outlined by Briggs (1987, 1989), but awaits publication of the supporting systematics.

## COLUMN 13

Detailed faunizones for Tasmania were set out by Clarke & Banks (1975) and Clarke & Farmer (1976). Modifications to details of ranges of some faunal elements have been documented in Calver *et al.* (1984) and Farmer (1985). Brachiopods from Faunizone 10 have been described by Clarke (1987), while those of Faunizones 1 to 3 are described in Clarke (1990).

## COLUMN 14

The occurrences of ammonoids in the eastern Australian Permian successions have been documented by Glenister & Furnish (1961) and Armstrong *et al.* (1967). Ammonoids are



generally extremely rare and provide 'key points' for correlation only. The species *Uraloceras lobulatum* Armstrong *et al.* 1967 is transferred to *Gobioceras* following Bogoslovskaya & Pavlova (1988).

### COLUMNS 15 AND 16

The ranges shown are based on the conclusions about the correlations shown in Runnegar (1967) and Dickins (1976) and modified in Dickins (1983, 1989). These conclusions are also used in Columns 19, 20 and 21, supplemented by information from Archbold (1982), Armstrong, Dear & Runnegar (1967) and McClung (1978). The conclusions are closely in line with those of Clarke & Banks (1975) and Clarke (1987, 1990). For alternative conclusions see Briggs (1989), McClung (1978, 1981), and Waterhouse (1983, 1987).

### COLUMN 17

Great difficulty has been experienced in relating the spore zones of the Bowen Basin, and in particular those of the Springsure area which has been the main reference area for Permian palynostratigraphy in eastern Australia, to the overall stratigraphical sequence and the macrofossils. On the left side of the column the authors have shown a generalized relationship, and on the right are shown the zones after Price (1983), together with the first occurrence of the key species on which the zones are based from Kemp *et al.* (1977) and Price (1983). Some of the spores such as the species of *Dulhuntyispora* are rare and very sporadic, to the extent that great reservation is necessary in interpreting the presence or absence of single species or combinations of species. These difficulties are referred to by Price (1983) in his account of the history of the palynological zonal scheme, and by McMinn (1987). They are also referred to later in these notes. Presumably these spores were derived from a flora which required a special environment which was not necessarily wide-spread or common in eastern Australia.

### COLUMN 18

Data on macrofloral distribution are modified

from Retallack (1981).

### COLUMNS 19 AND 20

The stratigraphy in column 19 is based on that in Mollan *et al.* (1969), Dickins & Malone (1973), and Dickins (1983, 1989). Balfe (1982) has been used for the subdivision of the Cattle Creek Formation. The stratigraphy in Column 20 follows that of Dickins (1976).

The correlations shown within the Bowen Basin have been extensively supported, inter alia, by Dickins & Malone (1968, 1973), Mollan *et al.*, (1969), Brakel (1983) and Dickins (1983, 1989). Alternative correlations have been offered (see Dear, 1972; McClung, 1978; Draper, 1983; and Briggs, 1989).

Parfrey (1988) has published information based on McClung's field work at the southern end of Reid's Dome in Dry Creek, confirming that lower Peawaddy Formation rests on the Ingelara Formation. This implies that the Catherine Sandstone and the upper part of the Ingelara Formation found to the north are missing, and that the lower sandstone of the Ingelara beds of Campbell (1953) together with its fauna belong in the Ingelara, and the upper mudstone with its fauna belong in the Peawaddy Formation. This information supports the correlations shown in Column 19.

However, the conclusions of Parfrey (1988) on the faunal relationships of the Ingelara and the lower Peawaddy Formation are puzzling, as apparently she regards the faunas from the two as so similar that they should belong in a single zone. At the same time she shows differences in the faunas which would not seem to confirm her conclusion, and that on the other hand would suggest that the Ingelara fauna can be placed in Fauna III and the lower Peawaddy fauna in Fauna IV.

Balfe (1982) shows different correlations of the Springsure area from those shown here. Although he claims to have solved this problem, examination of the details of the well logs in his report shows that apparently the

Catherine Sandstone is cross-correlated with the upper part of the Peawaddy Formation between GSQ Springsure 17 and 18 and AFO Arcturus 1. This is the same cross-correlation which caused such confusion earlier in work in the southern part of Reids Dome where, in the Dry Creek area, the Catherine was carried over non-outcrop and joined to the top part of the Peawaddy Formation (see Mollan *et al.* 1969).

Inconsistencies appear to remain between the distributions in the sequence of the spore-pollen and the macrofossils, but this may be an artefact if, as seems almost certain, the occurrence of some of the spores, such as species of *Dulhuntyispora*, are very sporadic. This seems to be the position with the identification of Lower Stage C in relation to a marine fauna reported by Briggs (1989) in the Gloucester Trough, suggesting that the occurrence of *D. parvitholus* may be older here than recorded in the Sydney Basin by McMinn (1985). Some further indication of such sporadic occurrence is tabulated by Foster (1982a) from the south-eastern part of the Bowen Basin, where *Dulhuntyispora dulhuntyi* is absent from most of the samples examined from GSQ Mundubbera 5. The same applies in the south-western part of the basin (Wood, 1984), where this species is entirely absent from above the Ingelara Formation in GSQ Springsure 19. This is equivalent to that part of the sequence in GSQ Mundubbera 5 where this species is recorded by Foster (1982a).

The claims by Waterhouse (see for example the 1987 paper) that the lower part of the marine sequence in the south-west part of the Bowen Basin are Carboniferous, or even Asselian and Sakmarian, seem without a satisfactory basis whereas, on the other hand, there is very substantial existing evidence that Fauna II is entirely younger than the Allandale and Wasp Head Formations of the Sydney Basin (Dickins, 1968; Runnegar, 1967; Dickins, Gostin & Runnegar, 1969; see also Draper *et al.* 1990). This has been borne out by subsequent work (Dear, 1972; Clarke &

Banks, 1975; Runnegar & McClung, 1975; Clarke & Baillie, 1984). The Allandale and Wasp Head Formations have been most recently regarded as of Tastubian (Lower Sakmarian) age by Archbold, Dickins & Thomas (in press) and can hardly be younger than Sakmarian.

Also in the south-west of the Bowen Basin it seems in part that the Brae and Pindari Formations (see Waterhouse, 1987) at least represent fault repetition of the Oxtrack and possibly Barfield Formations. This was the conclusion on these outcrops (later named Brae and Pindari) in earlier field work, and has been confirmed by re-examination of the aerial photographs (Mollan *et al.*, 1971) and further field examination. The fauna from the Pindari Formation seems close to or the same as that of the Oxtrack - virtually no fauna has been found in the Brae. Certainly, in the syncline slightly to the north-west of Cracow Homestead, beds of unmistakable Oxtrack fauna and lithology rest with a hiatus directly on beds with Fauna II.

A modification compared with earlier correlations of the Sirius Shale, is shown. This unit is now regarded as younger than Fauna II and equivalent to Fauna IIIA of the north-eastern part of the Basin. This correlation has been difficult because the fauna of the Sirius Shale is largely made up of brachiopods whereas in the north-east in the basal part of the Gebbie Subgroup (Fauna IIIA), bivalves and gastropods make up a more important part of the fauna. Dear (1972) had suggested the Sirius might be correlated with IIIA, and the description of the fauna in the north-east from below the Wall Sandstone by Waterhouse (1983) has provided new information. Many of the brachiopods of Fauna II appear to range into IIIA and apparently a more distinctive change occurs in the pelecypods at this level. Amongst the brachiopods, the Sirius Shale (in Reids Dome the Sirius makes up the upper part of the Cattle Creek Formation) has only *Tomioopsis plica* to distinguish it from faunas lower in the sequence. Fauna IIIA from below the Wall Sandstone in addi-

tion has *Terrakea dickinsi* and *Notospirifer extensus tweedalei* which apparently distinguish it from the underlying beds.

Both the Gebbie Subgroup (Formation), as originally proposed (Malone, Jensen, Gregory & Forbes, 1966), and the Sirius Shale (see Heywood, 1978, where in Eddystone No 1 Sirius rests with hiatus on pre-Cattle Creek) are transgressively unconformable on the underlying sequences. The reasons given by Waterhouse (1983) and Waterhouse & Jell (1983) for removing the beds underlying the Wall Sandstone from the Gebbie Subgroup, and regarding them as Tiverton, are considered unsatisfactory.

Field mapping and stratigraphical work, including section measuring and lithological considerations, indicate that the interval between the Tiverton Subgroup (or Formation), as originally defined, and the Gebbie Subgroup, marks an important change in the structure and development of the basin, and is supported by our faunal analysis. The basis for the conclusion is fully discussed in Dickins & Malone (1968; 1973). We placed the beds below the Wall Sandstone, lying above the transgressive unconformity, within the overlying Gebbie Formation, believing this solution led to the best understanding of the geology. In their proposal for placing these beds in the Tiverton, the statement by Waterhouse & Jell (1983, p. 232) that our suggested solution was seemingly based "on supposed faunal affinities" or "alleged faunal affinities" does not correspond to fact. Argument about lithological similarity or otherwise, especially of a rather crude kind, without taking into consideration other stratigraphical data, including fossil information, can be very sterile. The dogmatic philosophy espoused by Waterhouse & Jell (1983) and apparently McClung (1981), along these lines restricts the level of geological understanding which is possible. McClung (1981), like Waterhouse & Jell, also distorts the factual basis of our conclusions.

Further evidence that the Sirius Shale belongs

with the Gebbie Subgroup is indicated in GSQ Springsure 16 and 17 in the Springsure-Arcturus Downs area, where the Aldebaran rests directly on the Staircase Sandstone without the Sirius Shale (Balfe, 1982), suggesting overlap in this area at the base of the Gebbie Subgroup as in the Collinsville area in the north of the Bowen Basin.

For reasons similar to those for the Sirius Shale, it seems likely that the lower part of the Branxton Formation (Elderslie Formation) of the Sydney Basin has a IIIA fauna rather than a Fauna II, as was previously considered in Dickins (1969).

The terminology for the Cattle Creek Formation shown for the south-west Bowen Basin follows that of Balfe (1982). The Stanleigh Formation is, however, shown in addition. This is a convenient grouping for the members underlying the Sirius Shale in the Springsure Anticline, and might also be useful in Reid's Dome to the south where these members have not so far been recognised for the part of the Cattle Creek Formation below the Sirius Shale.

From new information (Dickins, 1989) it is now thought that the upper part of the Blenheim Subgroup is younger than the Mulbring Formation and its equivalents in the Sydney Basin.

The basal part of the Rewan Formation and the Narrabeen Group are taken as uppermost Permian following Helby (1973) and Foster (1982b), although the occurrence of *Dicroidium* at the base of the Munmorah Conglomerate may suggest an alternative interpretation (Dickins, in press b).

## COLUMN 21

Based on Clarke & Farmer (1976), Banks & Clarke (1987) and Clarke (1989), rocks of the Hellyerian Stage rest with marked hiatus and unconformity on Upper Devonian granites and older folded rocks. The Hellyerian Stage has been regarded as Carboniferous (see Banks & Clarke, 1987). The overlying



Tamarian, however, according to its fauna, appears likely to be equivalent to the Allandale Formation. Certainly it appears that the basal Tamarian at Maria Island, with Faunizone 1 resting unconformably on pre-Permian, is not older than Allandale and, therefore, that the Lochinvar equivalent of the Sydney Basin is missing. In this case Faunizone 1 may not be older than lower Sakmarian or slightly older and upper Asselian, if the occurrence of *Megadesmus pristinus* and *Tomioopsis elongata* in equivalent beds elsewhere in Tasmania is of significance. Thus the underlying Hellyerian could well be Asselian and therefore Permian, since no marked break in sedimentation has been found.

It is not easy to understand the meaning of *Botrychiopsis plantiana* and Microflora Stage 1, which have been taken to indicate that the Hellyerian is Carboniferous. The range of the macroplants in Australia in the uppermost Carboniferous and lowest Permian is not clear - for comment on the age of glacial beds in Queensland see Dickins (1985) and Rigby (1973). Microflora Stage 1 is a low diversity microflora apparently containing some long ranging taxa, and we are skeptical of its value in age determination. Foster, in Foster & Waterhouse (1988), has concluded this microflora is not useful biostratigraphically.

### **CENTRAL TETHYAN, NORTH AMERICAN STAGES, MAGNETOSTRATIGRAPHY**

#### **COLUMN 22**

The Murgabian is shown as equivalent to the Kazanian, the Kubergandian to the Ufimian, and the Bolorian to the Kungurian on a best fit basis. However, some greater or lesser discrepancy between the boundaries may be present. The Yakhtashian is shown to cover the whole interval between the Sakmarian and the Bolorian, although the limited complexity in the development of the fusulines might suggest this is not the case.

#### **COLUMN 23**

Only the "Upper Wolfcampian" is included within the Permian, following the correlation by Wilde (1984) of this interval in the Texas area with the Asselian and the underlying "Lower Wolfcampian" with the Gschelian of the sequence in the USSR. This is discussed further by Jones (in prep.) on the Carboniferous Chart.

#### **COLUMN 24**

The polarity shown is from Menning (1986). There is some lack of clarity in correlating to the base of the Asselian, and the information on the position of the Illawarra reversal within the Illawarra Coal Measures is a little vague.

### **CONCLUSIONS**

**(Suggestions for research to improve correlations and a more precise time-scale)**

#### **WESTERN PART OF AUSTRALIA**

On the whole, the marine faunas are much closer in their relationships with other parts of the world, especially the areas to the north, Timor, southeast Asia and southern Asia. As a consequence further work in this area is a key to more precise correlation of the Australian Permian sequences. For this reason, and also because of the more consistent and better preservation of spores and pollen resulting from lesser tectonic and magmatic activity in the western part of Australia, there is particular reason for improving palynological knowledge and integrating it with the marine sequence. Knowledge of the middle part of the Permian sequence is particularly in need of improvement, for example at the level of the Lightjack Formation of the Liveringa Group of the Canning Basin and the relationships with overlying units.

Other groups which are particularly in need of study are crinoids, especially the calcispongiids, different undescribed species of which mark many levels in the sequence. Bivalves, gastropods, bryozoans and foraminiferans, all having an important con-

tribution to make, also require additional studies, and a few key brachiopod faunas remain to be documented.

### EASTERN PART OF AUSTRALIA

Knowledge of the faunas and microfloras of the Gunnedah Basin is at present poorly developed. This is hampering understanding of the development of the geology of the basin, and its relationship with the Sydney Basin, of which it represents a northern and western extension. Similarly knowledge is poor on the New England area. This is hampering an understanding especially of its tectonic and magmatic-volcanic development, which is important for all of eastern Australia. Because of the high level of tectonic and magmatic activity the value of palynological work is, at best, likely to be sporadic. Spore and pollen preservation also in the Gunnedah may also be sporadic.

Much palaeontological work has been done in the Sydney Basin, including recent work on the crinoids (Willink, 1978, 1979a,b, 1980a,b), but much of the fauna was described many years ago, and requires review, and newly discovered faunas need description. The microfloras are known to be sporadic in their occurrence.

Much recent work has been done in Tasmania, and here research on bivalves, gastropods, bryozoans, foraminiferans and microflora would be important. For eastern Australia as a whole, study of the bryozoans is greatly lacking.

A particularly recalcitrant problem is the correlation of the upper part of the sequence in the Springsure area (from Aldebaran Sandstone upwards) with the rest of the basin. A review of information from the large number of bores available stretching from the Springsure area northward, together with an open-minded and dispassionate reassessment of the invertebrate faunas and the microfloras, might help to resolve this question. Its resolution is not only highly important for understanding the development of the Bowen

Basin, but also for the other basins of eastern Australia.

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