

# BIOSTRATIGRAPHY and CORRELATION

D.I. Gravestock,  
with contributions from  
J.G.G. Morton and W-L. Zang

## Chapter 7

### INTRODUCTION

In a basin with an area of 100 000 km<sup>2</sup> and a stratigraphic succession up to 6 km thick, the problem of having too little biostratigraphic data means that there will inevitably be a range of plausible depositional models. With hindsight, some of these prove to be widely off target, as was the case in the eastern Officer Basin when Munyarai 1 was drilled by Continental Oil Company of Australia (Conoco, 1969). Prior to the drilling of Ungoolya 1 in 1986, and despite radiometric age evidence to the contrary (see below), the Munyarai Trough was thought to contain Devonian strata to at least 2399 m, the total depth of Munyarai 1. However, this interpretation did not sit comfortably with outcrops on the eastern and southern margins of the Munyarai Trough which were interpreted to be mainly Neoproterozoic to Ordovician (Krieg, 1973; Krieg *et al.*, 1976). In fact, certain isolated outcrops mapped as Mintabie beds were thought to be Devonian because of the evidence from Munyarai 1 (Krieg, 1969, 1973).

A seismic tie from Ungoolya 1 to Munyarai 1 finally settled the order of succession in the Munyarai Trough — Devonian on Cambro-Ordovician on Neoproterozoic — even though conflicting interpretations were still emerging from careful palynological processing of core samples (Womer *et al.*, 1987).

Since 1980, there have been several macrofossil discoveries in the Palaeozoic and major advances in acritarch biostratigraphy in the Neoproterozoic, leading to a more detailed understanding of the Officer Basin's depositional sequences. This chapter is concerned chiefly with the biostratigraphic scheme as currently understood, but also reviews radiometric, lithologic and other data that assist correlation in the eastern Officer Basin.

### NEOPROTEROZOIC STRATIGRAPHY AND AGE

The Neoproterozoic has been defined globally as beginning at 1000 Ma. In the sense used here, early Neoproterozoic refers to the first three stages of the local Adelaidean succession, namely the Willouran, Torrensian and Sturtian stages. The age of the base of the Willouran stage is ~850 Ma, which corresponds to the late Riphean in Russian terminology.

Lack of macrofossils has caused emphasis to be placed on lithostratigraphic comparisons with better known regions such as the Adelaide Fold Belt (Krieg, 1973; Preiss, 1993), the Officer Basin in Western Australia (Townson, 1985) and

the Amadeus Basin (Stainton *et al.*, 1988). Now, however, biostratigraphic correlation is possible using acritarchs.

Recently, Zang and Walter (1992) demonstrated the utility of acritarch studies in parts of the Neoproterozoic and Cambrian of the Amadeus Basin. The biostratigraphy of acritarch assemblages, though still at a preliminary stage, has also greatly improved correlation within the Officer Basin. The preservation of microflora in deeply weathered exposures of the Adelaide Fold Belt is too poor to permit interpretation but samples from cored drillholes on the Stuart Shelf have been tied to a biostratigraphic scheme proposed by Zang (1994).

Recent work by Zang (much of it unpublished), based on 207 samples from Officer Basin wells, has added greatly to understanding the composition of acritarch assemblages in the eastern Officer Basin. In his scheme, Zang (1994; Zang and Preiss, in prep.) distinguished eight informal Neoproterozoic acritarch assemblages based on the first appearance of key species. The number has now been reduced to six, as listed in Table 7.1 which also allows for a possible new assemblage (AAC 1) from Cambrian strata. Two Ordovician assemblages (AAO 1, AAO 2) known in the Warburton Basin (Zang, 1994) have been added, based on the likelihood that acritarchs will be recovered from rocks of this age in the Officer Basin.

Key elements of the Neoproterozoic microfloral assemblages can also be recognised on the Stuart Shelf. From there, lithostratigraphic correlation provides the only tie to the Neoproterozoic of the Adelaide Fold Belt. The Officer Basin correlations reviewed below are based on a variety of attributes. These include acritarchs and stromatolites in the Neoproterozoic, Cambrian invertebrates, Devonian vertebrates and palynomorphs, and magneto-, chemo- and event stratigraphy, all of which have been applied by different workers to obtain a clearer history of the Officer Basin.

### Stromatolites

Stromatolites occur in the Coominaree Dolomite of the Peake and Denison Ranges, and two species — *Acaciella* cf. *australiana* and *Gymnosolen* cf. *ramsayi* — were described by Preiss (1973); these were later amended to *Acaciella* f. indet and *Gymnosolen* f. indet (Preiss, 1987). *Acaciella* also occurs in the Coominaree Dolomite in Manya 5 (Preiss, 1993). This form is very similar to *A. australiana* which occurs in the Skates Hill Formation of the Savory Basin (=Savory Sub-basin of the WA Officer Basin (Perincek, 1996)), and in the Bitter Springs Formation of the Amadeus

Basin. *A. australica* appears to be restricted to the Callanna Group at the base of the Adelaidean succession, although its full stratigraphic range is not known (Grey, 1995).

### Early Neoproterozoic acritarchs

Acritarchs from the Alinya Formation in Giles 1 are interpreted by Zang (1995a; Zang and Preiss, in prep.) to be Torrensian in age. His species (Zang, 1995a, fig. 22) correlate with those from the Bitter Springs Formation (Zang and Walter, 1992), thus Zang places both units and their correlatives in the Torrensian. Zang (1995a; Zang and Preiss, in prep.) reserved a Willouran age for the Cadlareena Volcanics–Coominaree Dolomite–Youngusband Conglomerate suite, and has extracted acritarchs from Manya 5 core which he interpreted to be Youngusband Conglomerate. Zang considered this suite to be representative of a graben system beneath the widespread Alinya Formation–Pindyin Sandstone stratal package. The Cadlareena–Youngusband suite crops out in the Peake and Denison Ranges and was fully cored in Manya 5. These strata were not deposited in a graben, and they are considered more or less coeval with the Alinya–Pindyin suite (Fig. 5.6), though they may be slightly older (Arkaroola Subgroup *versus* Curdimurka Subgroup).

This work follows the more widely held view that the Alinya–Pindyin of the eastern Officer Basin, the Browne–Lefroy–Townsend [≡Skates hill–Munjdajini–Spearhole] of the Savory Basin and western Officer Basin, and the Bitter Springs–Heavitree of the Amadeus Basin, are all Willouran in age. The Manya 5 acritarch assemblage is designated AAW 1b in Table 7.1. It may be older than, or the same age as, the Giles 1 acritarch assemblage, designated AAW 1a in Table 7.1. The two assemblages contain a number of species in common, but six species occur only in Manya 5 (Zang and Preiss, in prep.). Zang’s (1995a) correlation raises the question as to what does constitute the fill of the channel or ‘graben’-like features evident on seismic beneath the Alinya–Pindyin stratal package. As discussed in Chapter 5, this underlying sedimentary pile is thought to be older than the Adelaidean.

In the eastern Officer Basin there is a major hiatus between the Alinya Formation and the late Neoproterozoic (Marinoan) Tarlina Sandstone. A Sturtian tillite does intervene but this is restricted to the northeast near Chambers Bluff and to Nicholson 2. There remains uncertainty as to the existence of a disconformity in the Chambers Bluff Tillite, with upper beds being possibly Marinoan in age (Preiss, 1993). No diagnostic acritarchs have been recovered from this part of the succession, although Zang (1994) reported *Favosphaeridium* and *Comasphaeridium* in an inter-tillitic shale. However, both genera are long ranging, which emphasises the need to identify assemblages to species level for more reliable correlation.

### Late Neoproterozoic acritarchs

Acritarchs from late Neoproterozoic strata were first documented in Munyarai 1 (Narana–Dey Dey) by van Neil (1984). He recognised a large (~350 µm) form possibly referable to *Micrhystridium*, but this genus ranges through the Neoproterozoic and Phanerozoic and is of no value for correlation. Van Neil also recognised algal filaments and sphaeromorphs in the Tanana Formation and Dey Dey Mudstone in Murnaroo 1; again, these are long-ranging forms.

Possible *Trachysphaeridium laufeldi* was noted by Eames (*in Womer et al.*, 1987) from 1251.3 m in Birksgate 1, suggesting a likeness to forms known to be of Neoproterozoic age. With regard to Munyarai 1 however, Womer (*in Womer et al.*, 1987) stated ‘The persistent reports of Middle Devonian *Ancryospora* below 1550 metres tends to support the interpretation that this interval is an Indulkana Shale equivalent, although...this conclusion is very tenuous’.

It was not until 1992 that Jenkins *et al.* (1992) and Zang (unpublished report to Comalco) began to carefully extract and systematically document the fragile late Neoproterozoic acritarchs from Officer Basin wells. Jenkins *et al.* recovered two acritarch assemblages, an older assemblage mainly from the lower Karlaya Limestone in Murnaroo 1 (AAM 3, Table 7.1), and a younger one from the Narana Formation in Ungoolya 1 (AAM 4, Table 7.1). Seismic data (e.g. Sukanta

**Table 7.1** Officer Basin acritarch assemblages (after Zang, 1994, 1995a,b).

Zang (1994, 1995a,b assemblages)	'Giles'	'Manya'	1,2,3	4	5	6				
New assemblage names	AAW1a	AAW1b	AAM1	AAM2	AAM3	AAM4	AAC1	AAC2	AAO1	AAO2
<b>Genus/species</b>										
<i>Amadeusphaeridium cyathospora</i>		k								
<i>Ambiguaspora parvula</i>						k				
<i>Comasphaeridium magnum</i>				k						
<i>Comasphaeridium strigosum</i>							k			
<i>Cymatiosphaeridium kullingii</i>	k									
<i>Goniosphaeridium cebrum</i>					k					
<i>Unispinosphaeridium</i> n.sp.			k							
<i>Hocosphaeridium scaberfacium</i>					k					
<i>Leiofusa squama</i>									k	
<i>Petaloferidium</i> sp.									k	
<i>Skiagia</i> spp.							k			
<i>Tongzia meitana</i>										k
<i>Trachystrictosphaera aimika</i>	k									
<i>Trachystrictosphaera vidalii</i>	k									
<i>Unispinosphaeridium willouranum</i> gen et sp nov.		k								

k=Key first appearance species

*et al.*, 1991) indicate that the beds yielding these assemblages are separated by a canyon-cutting unconformity. Jenkins *et al.* (1992) noted that the older assemblage consisted of diverse spinose acritarchs and few filamentous forms. The younger assemblage was dominated by filamentous types with 8–10 species of very large, unsculptured spheroidal forms. Jenkins *et al.* (1992, p.405) noted that the differences between the two microfloral assemblages ‘may be due to chronological or biofacies differences, or both’.

Zang (1994, p.204) noted that both abundance and diversity of species increased during marine transgressions which he interpreted as ‘a transfer of phytoplankton from relatively calm offshore environments to turbulent shelf environments with rising sea level’ necessitating adaptation. The schematic curve on Figure 7.1 (right hand column) illustrates the change in species diversity which reached a maximum of more than 80 species in the upper Dey Dey Mudstone, representing the *Hocosphaeridium scaberfacium*–*Goniosphaeridium crebrum* Assemblage (Zang 1994). Many of the species in this assemblage (AAM 3, Table 7.1) had not previously been found in strata older than Palaeozoic although several, including the nominate species, have been recorded from the Pertatataka Formation in the Amadeus Basin by Zang and Walter (1992). Another significant discovery by Zang (1994) is the oldest occurrence of the trilete spore *Ambiguaspora parvula* in chert from the Punkerri Sandstone in the Birksgate Sub-basin (AAM 4, Table 7.1), the first record of a higher plant anywhere in the world.

### Late Neoproterozoic invertebrates

Specimens of the soft-bodied Ediacara fauna have been recorded from loose blocks in the Punkerri Sandstone. Daily (*in* Major, 1974) recorded *Charnia*, *?Charniodiscus*, *Tribrachidium*, *Rangea* and a ‘double spiral’, presumably a

trace fossil. The fauna permits correlation from the Ediacara Member of the Adelaide Fold Belt to at least part of the Punkerri Sandstone. Impressions resembling the attachment stalk of *Charniodiscus* have been found near Albany more than 1500 km distant (Cruse *et al.*, 1993), attesting to the wide distribution of this fauna. Jenkins (1992) suggested that acritarchs may have constituted the food supply for some of the Ediacara metazoans, and Zang (1993) regarded the oldest ‘semi-aquatic’ plant (parent of the trilete spores in the Punkerri Sandstone) as another food source.

### Geochronology

As mentioned above, Compston (*in* Conoco, 1969) obtained an isochron of 650 Ma from the Munyarai Formation in Munyarai 1. However, Webb (*in* Preiss, 1993) calculated a considerably younger Rb–Sr age of  $588 \pm 35$  Ma from the Yarloo Shale of the Stuart Shelf which correlates with the Dey Dey Mudstone. Since the Dey Dey underlies the Munyarai Formation, an age discrepancy of at least 70 million years is evident. Greater Rb–Sr ages have been obtained:  $731 \pm 54$  Ma from the Rodda beds east of Chambers Bluff and  $715 \pm 210$  Ma for the Dey Dey Mudstone in Murnaroo 1 (Webb *in* Womer *et al.*, 1987), demonstrating that geochronology has not assisted Neoproterozoic correlation in the Officer Basin. Nevertheless, the age difference between the Devonian Mimili Formation and Neoproterozoic Munyarai Formation, shown on Figure 7.2, should have been evident shortly after Munyarai 1 was drilled.

### Chemo- and magnetostratigraphy

Patterns of secular change in isotopes of carbon, sulphur and strontium can indicate rates of burial of organic carbon as well as biological events such as major extinctions, and erosional cycles. It may be possible to track parallel

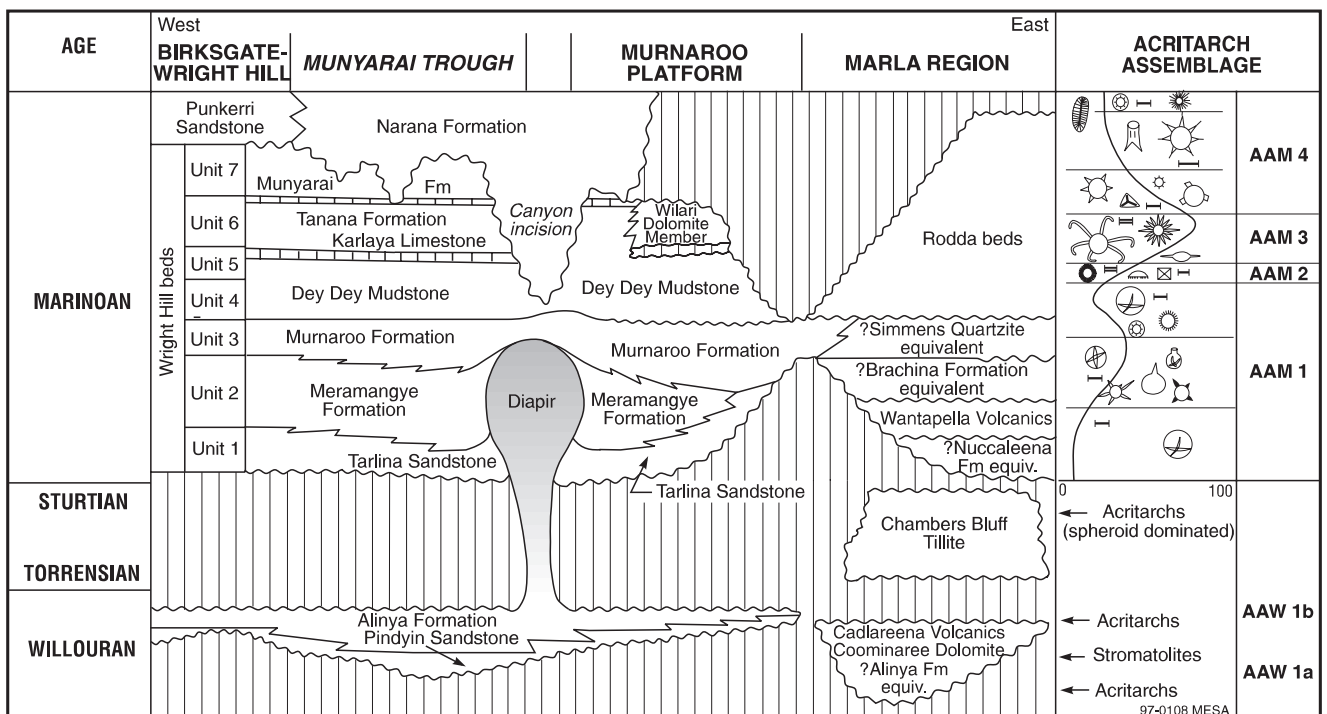
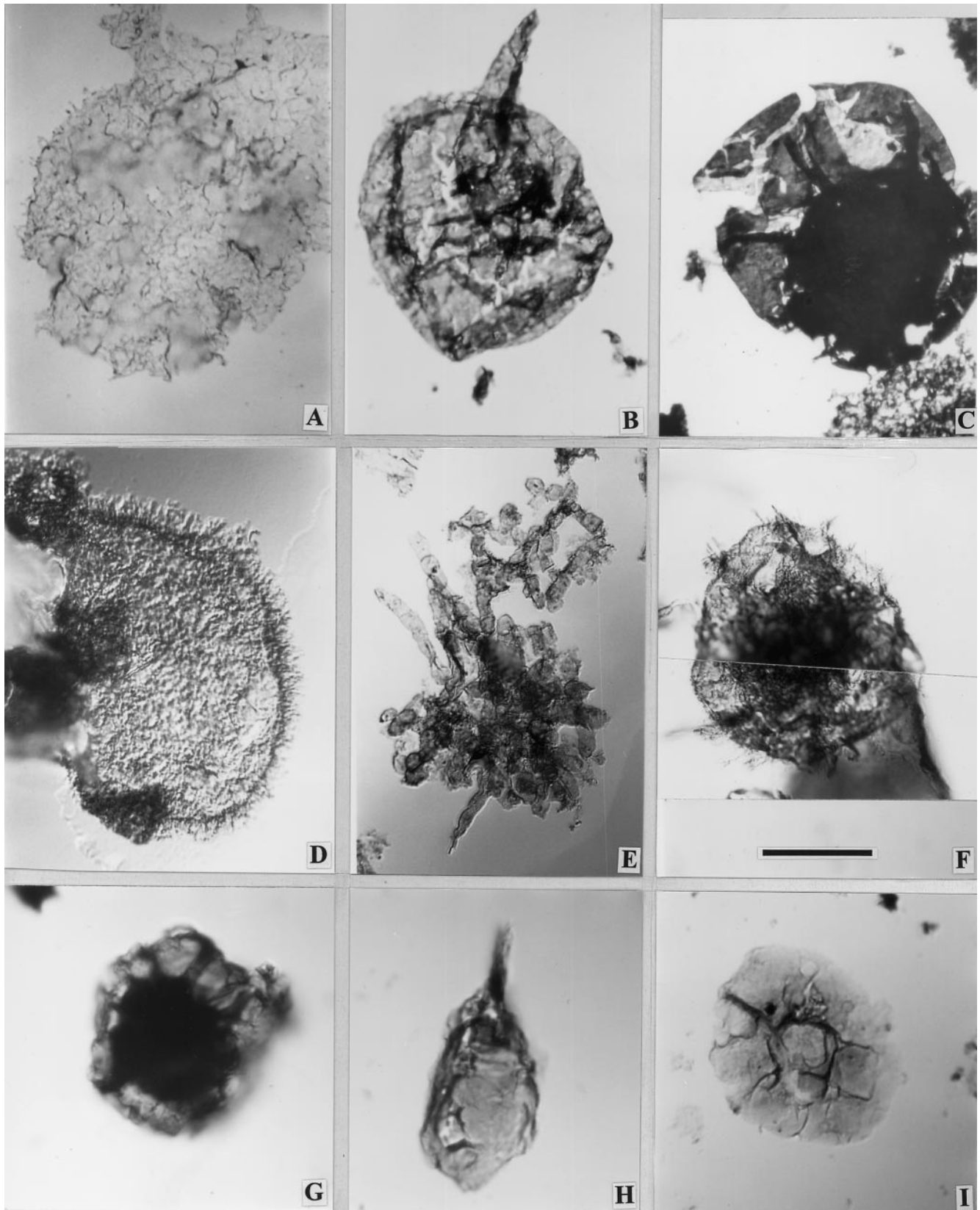


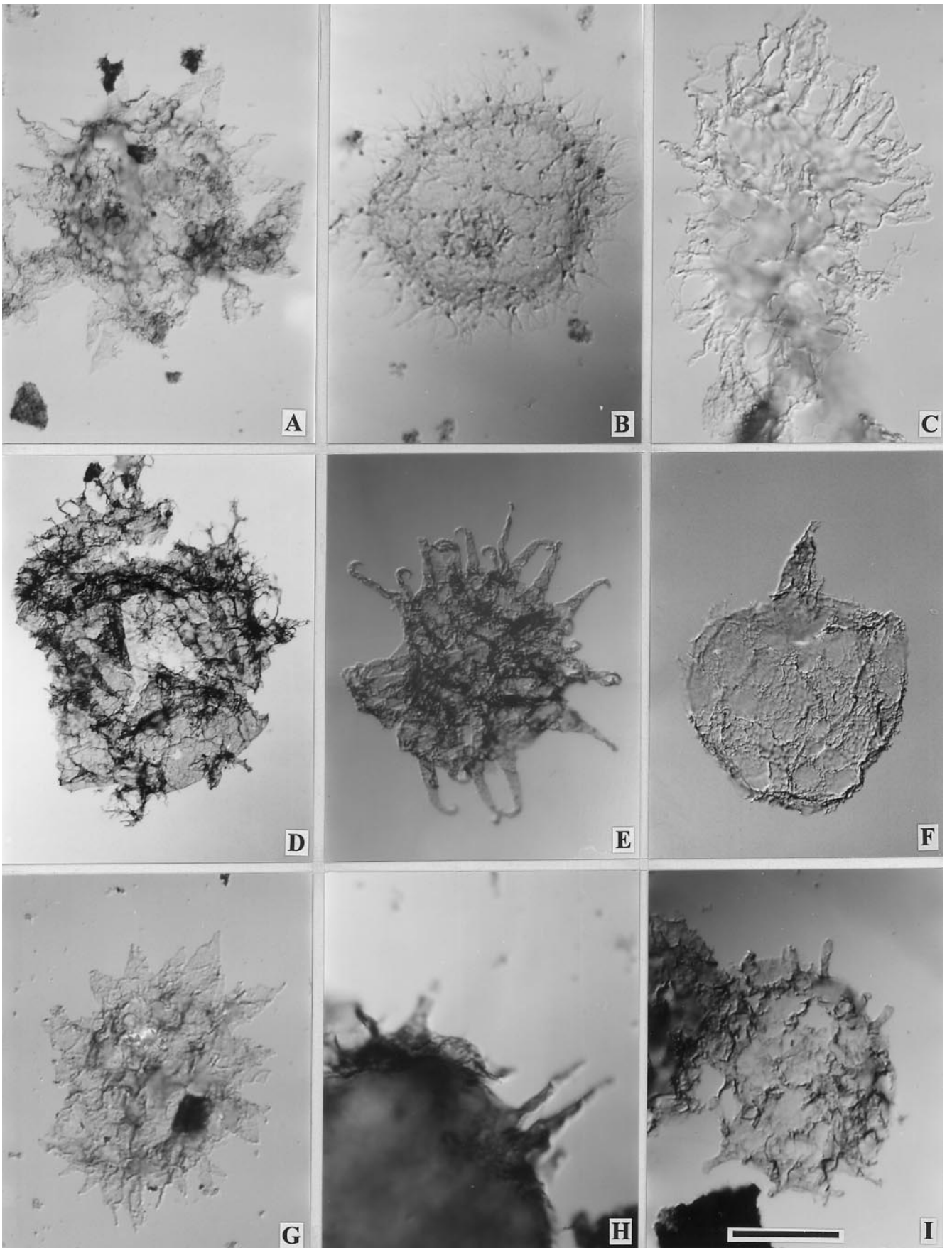
Fig. 7.1 Eastern Officer Basin Neoproterozoic lithostratigraphy and acritarch assemblages. The curved line in the right-hand column represents relative acritarch species abundance (after Zang, 1994, 1995b).



*Acritarchs from the upper Younghusband Conglomerate, a possible equivalent of the Pindyin Sandstone, in Manyá 5.*  
**A** *Amadeusphaeridium* sp. **B** *Acritarch* with a prominent process. **C** *Trachyhystrichosphaera aimika* Hermann, 1976 emend. Butterfield, Knoll and Swett, 1994.

*Acritarchs from the Alinya Formation in Giles 1.*  
**D** *Comasphaeridium tonium* Zang, 1995. **E** *Lomentunella* sp. **F** *Trachyhystrichosphaera* sp.

*Acritarchs from the Meramangye Formation in Meramangye 1.*  
**G** ? *Vandalosphaeridium* sp. **H** *Acritarch* with a prominent process. **I** *Pterospermella* sp.  
 Scale bar (in F) is 20  $\mu\text{m}$  for D, G, H, I; 25  $\mu\text{m}$  for B; 32  $\mu\text{m}$  for C, E, F; and 80  $\mu\text{m}$  for A.

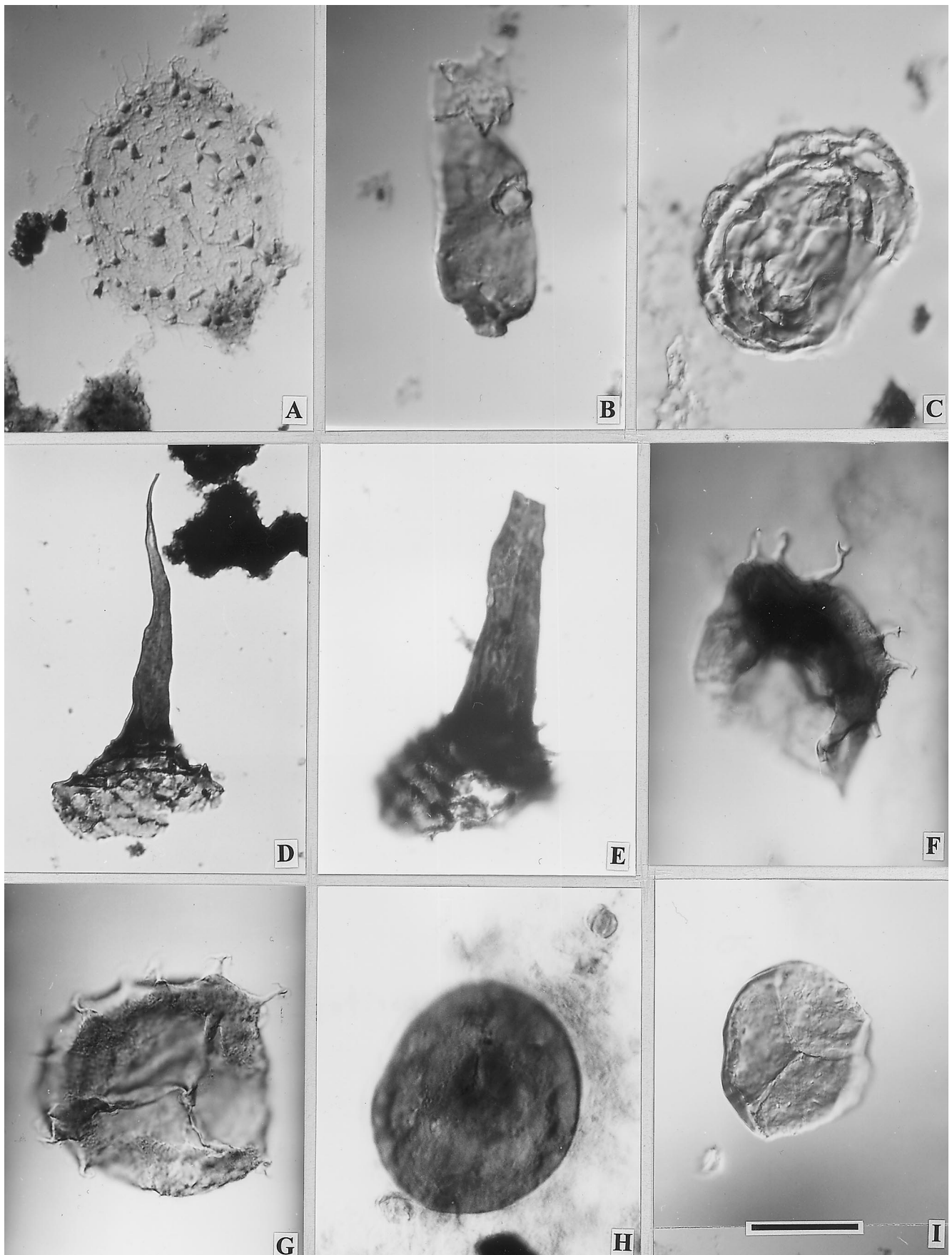


*Acritarchs from the Dey Dey Mudstone in Lake Maurice West 1. A* *Tanarium* sp. *B* *Comasphaeridium* sp. *C* *Unnamed species*.

*Acritarchs from the Tanana Formation in Giles 1. D* *Multifronsphaeridium pelorium* Zang in Zang and Walter, 1992. *E* *Hocosphaeridium scaberfacium* Zang in Zang and Walter, 1992. *F* *Acritarchs with a prominent process and numerous conical spines*.

*Acritarchs from the Munyarai Formation in Munyarai 1. G* *Goniosphaeridium* sp. *H* *Trachyhystrichosphaera* sp. *I* *Gyalosphaeridium* sp.

Scale bar (in I) is 20  $\mu\text{m}$  for B, H, I; 32  $\mu\text{m}$  for C, G; 50  $\mu\text{m}$  for F; 63  $\mu\text{m}$  for E; and 125  $\mu\text{m}$  for A, D.



*Acritarchs from the Narana Formation in Munta 1 (A) and Lairu 1 (B, C). A Comasphaeridium sp. B Brevitrichoides sp. C Leiosphaeridia sp.*

*Acritarchs from the Early Cambrian Ouldburra Formation in Many 6. D Ceratophyton sp. E Ceratophyton sp.*

*Miospores from the Devonian Mimili Formation in Munyarai 1. F Ancyrospora sp. G Ancyrospora sp. H Punctatisporites sp. I Retusotriletes sp.*

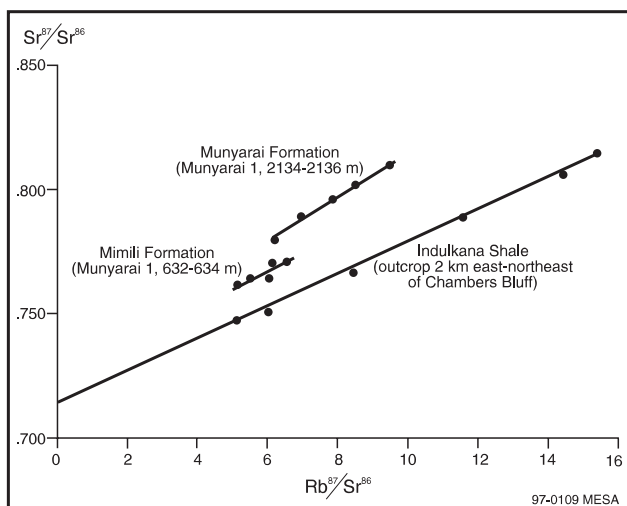
*Scale bar (in I) is 20  $\mu\text{m}$  for A, B; 25  $\mu\text{m}$  for C, D, E; 32  $\mu\text{m}$  for F, G, I; and 40  $\mu\text{m}$  for H.*

variations in isotopic signatures within and even between basins, so providing another correlation tool. The Neoproterozoic of the Officer Basin has few carbonate-rich units but nevertheless preliminary  $\delta^{13}\text{C}$  measurements have been made and tentative correlations suggested. A slight contrast ( $\sim 3\%$ ) between the  $^{13}\text{C}$ -enriched Karlaya Limestone in Murnaroo 1 and the negative to moderately positive Tanana–Narana Formations in Ungoolya 1 was noted by Jenkins *et al.* (1992), and attributed to the different sample ages with some contribution from facies effects.

Pell *et al.* (1993) presented a preliminary carbon isotope curve for the South Australian late Marinoan stage based on values from the Wonoka and Billy Springs Formation of the Adelaide Fold Belt, augmented by data from Observatory Hill 1 and Ungoolya 1. This curve displays consistently negative values ( $-6$  to  $-8.5\%$ ) through 360 m of Wonoka Formation in Bunyerroo Gorge, implying low rates of burial of organic carbon and hence poor source rocks from this interval. In contrast, total organic carbon of the slightly older Dey Dey Mudstone (=Bunyerroo Formation) in Lake Maurice West 1 and Karlaya 1 is  $\sim 0.8$  to  $1.5\%$  (see Ch. 8), which is moderately rich. These wells are on the Murnaroo Platform which subsided at one quarter the rate of the Munyarai Trough (Moussavi-Harami and Gravestock, 1995), and thus even richer source rocks are anticipated there. These should equate to strongly positive  $^{13}\text{C}$  values. Clearly, the isotopic results from the limited data set in the Officer Basin are very preliminary and it is likely that facies effects will loom large in any interpretation.

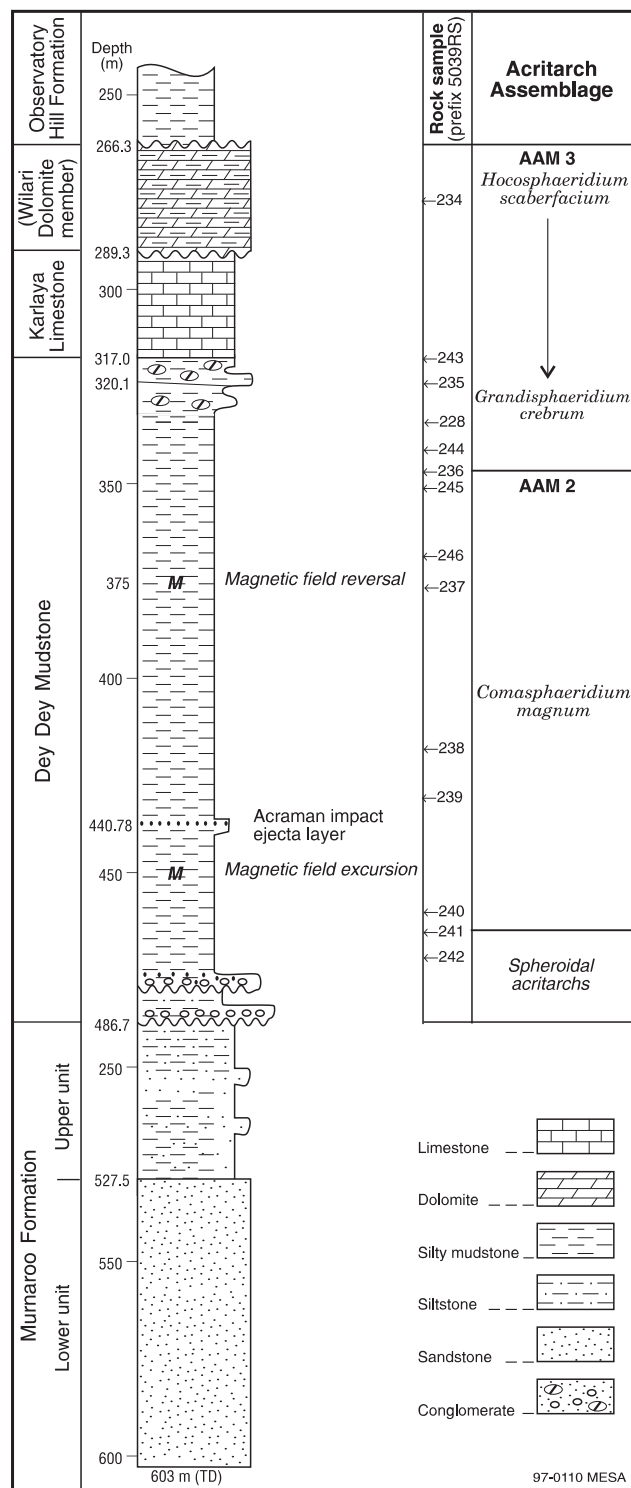
The magnetostratigraphic characteristics of cores from Observatory Hill 1 and Lake Maurice West 1 have been documented by Chamalaun *et al.* (1990). The remanent magnetisation of  $\sim 400$  samples was measured with a spinner magnetometer through the lower Karlaya Limestone, Dey Dey Mudstone and upper Murnaroo Formation after carefully fitting the core together. Since the cores are vertical and not orientated with respect to azimuth, an arbitrary fiducial line was scribed and directions were measured relative to it.

Two magnetic events are represented within the Dey Dey Mudstone in both wells. Magnetic inclination values are



**Fig. 7.2** Rb–Sr isochrons of the Neoproterozoic Murnyarai Formation, Ordovician Indulkana Shale and Devonian Mimili Formation. See text for details.

more variable in the lower event which may represent an epoch of magnetic field excursions rather than a reversal. The upper event is sharp and probably a true reversal. As shown on Figure 7.3, both events are within the *Comasphaeridium magnum* acritarch assemblage zone (AAM 2, Table 7.1), which suggests that magnetostratigraphy holds promise for more detailed correlations within acritarch zones. The two events are 75 m apart and, assuming a subsidence rate of 15 m per million years



**Fig. 7.3** Lake Maurice West 1 Neoproterozoic lithostratigraphy, acritarch assemblages, and depths of magnetic field excursions and the Acraman impact layer.

(Moussavi-Harami and Gravestock, 1995), they are separated in time by about five million years.

### Lithology and event stratigraphy

It should have been obvious at the time of drilling that the tracheidal wood fragments claimed to have been recovered from total depth in Munyarai 1 did not come from the hard, laminated dolomitic siltstone characteristic of the Dey Dey Mudstone intersected in that well. The lithologic succession is now sufficiently well known to enable wireline log correlations to be carried out with some confidence. It is only in the Marla Overthrust Zone where Proterozoic intersections are few, and at the Rodda beds type section which exceeds 3 km in thickness (Preiss and Krieg, 1992), that correlation remains a problem within the basin. Correlation with other basins is still a matter of debate. On a sequence stratigraphic basis, Sukanta *et al.* (1991) correlated the Marinoan in the Officer Basin with the Adelaide Fold Belt. A key argument for this is a set of submarine canyon incisions common to both regions which suggested correlation from the Narana Formation in the Officer Basin to the Wonoka Formation in the Adelaide Fold Belt. However, from acritarch studies, Zang (1995b) correlated the canyon surface at the base of the Narana Formation with the disconformity at the base of the Rawnsley Quartzite and not the Wonoka Formation which is stratigraphically older.

One key horizon for interbasinal correlation is low in the Dey Dey Mudstone in the Officer Basin and low in the Bunyeroo Formation of the Adelaide Fold Belt. This is the 'Acraman impact layer', a bed of ejecta which resulted from a bolide impact on the Gawler Craton. The impact crater is modern Lake Acraman and impact debris was spread over a wide area to form a unique marker bed. The bed has been identified in cores from Observatory Hill 1 and Lake Maurice West 1, and comprises medium to coarse-sand-sized acid volcanic clasts. A thin, pale green alteration halo is evident in the surrounding red-brown mudstone. The preservation of the layer suggests that the Dey Dey Mudstone is a deep water deposit (Wallace *et al.*, 1990). The impact layer is a few metres above the magnetic polarity excursion in both wells (Fig. 7.3) which lends weight to magnetostratigraphy as a correlation tool.

### CAMBRIAN STRATIGRAPHY AND AGE

As no Cambrian body fossils have been found in outcrops, correlation prior to their discovery in a drillhole in 1978 was by lithological comparison with the well-known succession of the Flinders Ranges (e.g. Wopfner, 1969). A possible hyolith conch (?*Biconulites*) was reported from float in a modern claypan near the Observatory Hill Formation type section (Gatehouse, 1976). However, the oolitic lithology which encloses the specimen does not occur in this formation and the specimen is presumed to have been transported. Biostratigraphic and lithological correlations of Cambro-Ordovician strata are shown on Figure 7.4.

#### Invertebrate fossils

Marine invertebrates have been found in the Ouldburra Formation which, prior to stratigraphic revision (Brewer *et*

*al.*, 1987), had been incorporated within the Observatory Hill Formation. Fragments of two small trilobites in a core from 87.85 m in Marla 1 were identified as belonging to a genus of redlichiids, and are therefore Early Cambrian in age (Jago and Youngs, 1980). One further specimen from this depth, and other trilobite remains from 333 m in the adjacent Marla 1B, remained unidentified.

Well-preserved trilobites from 967.7 to 970.1 m in Manya 6 also came from the Ouldburra Formation. These belong to a new species of *Abadiella* and indicate an Early Cambrian (Atdabanian) age (Jago *et al.*, 1994). Trilobite fragments have been recorded over a 394 m interval (889–1263 m) in this well by Dunster (1987a). He also noted the lowest fossils (sponge spicules) at 1391 m. Detailed core logging by him also revealed trilobites between 357.8 and 385 m in Manya 3; this interval is in sequence C1.3, considered Early Cambrian (Botomian) in age (Gravestock and Hibbert, 1991). Possible archaeocyaths recorded at 1207 m in Manya 6 are calcite pseudomorphs of aragonite fan cements from a reworked bioherm.

Dunster (1987a) has documented archaeocyath-calcimicrobe biohermal buildups between 399 and 654 m in Marla 6, as well as wackestones with fossil hyoliths (suggesting a provenance for Gatehouse's (1976) sample), sponges and ostracods. This fauna indicates an Early Cambrian age of the Ouldburra Formation even though fossil preservation is too poor to permit identification to genus level.

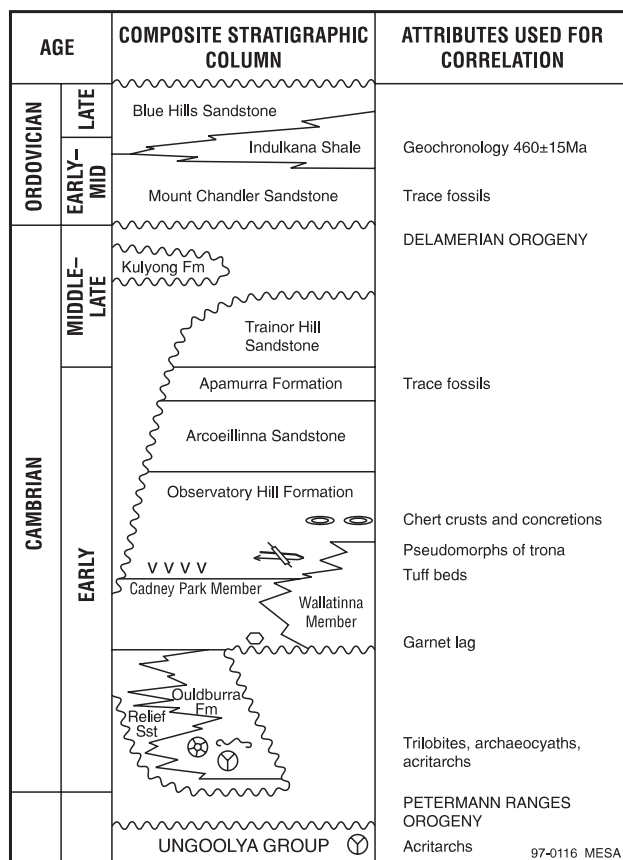


Fig. 7.4 Cambro-Ordovician lithostratigraphy, fossils and geochronology.

The presence of chitinophosphatic shelly fossil fragments, reported from Wilkinson 1 by Kantsler (*in Gatehouse*, 1979), could not be verified from thin section examination.

### Acritarchs

An impoverished assemblage of acritarchs was reported from between 314.5 and 512.2 m in Wilkinson 1 by Muir (*in Gatehouse*, 1979), an interval now correlated with the Ouldburra Formation. At that time, Muir considered the Tommotian Stage to be latest Proterozoic, whereas it is regarded now as the second stage of the Early Cambrian. In any event, the stratigraphic range of the four species reported by her can only be regarded as Neoproterozoic to Middle Cambrian and better age resolution is not possible. Re-examination of the same interval in Wilkinson 1 failed to find any microfossils, although sheet-like or granular organic matter was found to be fairly common (van Neil, 1984). Acritarchs have been suggested as possible source organisms for dinosterane which occurs in samples from the Ouldburra Formation in Karari 1 (Kamali, 1995a,b).

Cambrian acritarchs recovered from the Early Cambrian of the Manya Trough and Marla Overthrust Zone are poorly preserved and of low diversity in comparison to coeval deposits in the Arrowie and Stansbury Basins (W-L. Zang, MESA, unpublished data, 1996). Only one assemblage has been assigned (AAC 1, Table 7.1), and the characteristically Cambrian genus *Skiagia* has not yet been recognised.

### Geochronology

An outcropping silty shale in the Chambers Bluff area, and reported as 'apparently conformable beneath the Mt Chandler Sandstone', had a calculated Rb–Sr age of  $574 \pm 34$  Ma (Webb, 1978). The shale was thought to be Observatory Hill Formation but, if this was the case, the contact would not be conformable. Given the magnitude of the associated error, this age does not improve correlation. Still less accurate ages of  $524 \pm 68$  and  $660 \pm 60$  Ma were obtained from the Observatory Hill Formation in Byilkaora 1 (Webb, 1978) and Cadney Park Member in Byilkaora 3 (Henry and Brewer, 1984). In the Ouldburra Formation in Wilkinson 1, strontium levels are too high for reliable age determination by the Rb–Sr method (Webb, 1978), and it may be that the Observatory Hill Formation and Cadney Park Member are unsuitable for the same reason.

### Lithology

Diagnostic lithologies have been employed to demonstrate or reinforce correlations in the absence of fossil data. The most widely correlated lithology is chert, which occurs abundantly as concretions, sheets and breccias at two key levels of the Observatory Hill Formation — the Moyles Chert Marker Bed and the Parakeelya Alkali Member. Brewer *et al.* (1987) considered the chert lags and concretions found at the type section near Observatory Hill (Wopfner, 1969) to correlate with the Parakeelya Alkali Member.

As part of their objective of correlating Munyarai 1 with Ungoolya 1, Womer *et al.* (1987) employed three key lithologies associated with the Observatory Hill Formation

— chert, calcite-after-trona pseudomorphs and green garnet. The first two correlate with the Moyles Chert Marker and Parakeelya Alkali Member respectively, and the green garnet is a common accessory in lag gravel at the disconformable base of the formation in both wells. This disconformity is currently known only in the Ungoolya area and on the Munyarai structure; no garnets have been noted where the lower boundary of the Observatory Hill Formation is conformable.

Fine-grained, centimetre-thick crystal tuff bands have been recognised in the Cadney Park Member which is dominantly a gypsiferous redbed suite. The tuff bands (at 545.2 and 562.3 m in Manya 2; 436.2 m in Manya 4; 625.9 and 636.6 m in Byilkaora 3) are buff-grey and composed of subhedral, partly sericitised feldspar crystals and relict shards in a glassy groundmass. Henry and Brewer (1984) noted this tuffaceous component and suggested a tentative correlation between the Cadney Park Member and the basaltic Cadlareena Volcanics (their Welbourn Volcanics). These basalts are now known to be Proterozoic and unrelated, but that does not lessen the correlation potential of the tuffs within the Cambrian succession. Pontifex (1984, p.190) commented that 'The source of this fine tuffaceous material...is uncertain, but seems likely to be deposited from high-level drifting clouds from a volcanic centre, maybe 1000 plus kilometres away'. Their presence supports correlation of the Cadney Park Member with formations of the upper Hawker Group and/or Billy Creek Formation in the Arrowie Basin (sequences C1.3 and C2.1 of Gravestock and Hibbert, 1991), where tuff beds up to 1.5 m thick attest to active rift volcanism. It is possible that the Officer Basin tuffs represent fallout from the same volcanic complexes on the palaeo-Pacific margin of Gondwana.

## ORDOVICIAN STRATIGRAPHY AND AGE

Ordovician strata are interpreted in Munyarai 1 between 1018 and 1355 m depth, based on lithological similarity with outcrops of Blue Hills Sandstone, Indulkana Shale and Mount Chandler Sandstone in the EVERARD 1:250 000 map area. These outcrops have been correlated with the Ordovician succession in the Amadeus Basin, relying strongly on 'similarities of the lithology, sequence and tectonic setting' (Krieg, 1973, p.14). No body fossils have been found and acritarchs have not been recovered from the few, mainly sandy well intersections. The Ordovician acritarch assemblages shown in Table 7.1 are in the Warburton Basin.

### Ichnology

Trilobite resting traces (*Rusophycus*) and *Skolithos* and *Diplocraterion* burrows in the Mount Chandler Sandstone suggested equivalence with the Pacoota Sandstone, although some differences were noted (Packham and Webby, 1969; Krieg, 1973; Benbow, 1982). Trace fossils are usually considered to be good facies and palaeoenvironmental indicators, and as most types have long time ranges they are not often used for stratigraphic correlation and age dating. However, the exception to this rule are the trace fossils associated with trilobites in early Palaeozoic rocks. These trace fossil types include *Rusophycus*, *Cruziana*, and



Rusophycus sp. in Apamurra Formation siltstone, Mount Johns Range. Photo courtesy of Dr J.B. Jago. (Photo 44430)

*Diplichnites*. There are 19 species of *Cruziana* that have restricted ranges in the Cambrian and Ordovician (Crimes, 1975). In the Mount Johns Range adjacent to the Marla Overthrust Zone, trilobite trace fossils are common, and there is potential for stratigraphic correlation of the Marla and Munda Groups based on trace fossils. Although bioturbation has been recorded in drill cores, diagnostic trace fossils have not been found.

### Geochronology

Six samples were collected from outcrops 2 km east-northeast of Chambers Bluff to determine the age of the Indulkana Shale. Rb–Sr analysis produced the ratios plotted on Figure 7.2, which represents a Late Ordovician isochron of  $460 \pm 15$  Ma (Webb, 1978). An additional surface sample was collected some years later and its age determined as  $438 \pm 10$  Ma (Early Silurian) using the K–Ar method (Womer *et al.*, 1987). Webb’s (1978) age is preferred because of the consistency of data from the six samples. No fossils have been found in the Blue Hills Sandstone and the age of this unit may well range into the Silurian.

### Lithology

The Mount Chandler Sandstone, besides containing trace fossils, is distinctive by virtue of its clean, well-sorted, mature quartzose lithology, which contrasts with other more feldspathic or micaceous units in the basin (Krieg, 1973). It is an attribute that can be used for correlation in the absence of other data. The Mount Chandler Sandstone in Manya 5 has been identified in this manner. The Blue Hills Sandstone is the only other lithologically similar formation.

Detailed aeromagnetic maps show a distinctive magnetic marker bed which is clearly associated with continuous outcrops of Indulkana Shale on the eastern rim of the Munyarai Trough. Shallow subcrops having the same magnetic character occur northeast of the Marla Overthrust Zone and, though undrilled, have been correlated confidently with the Indulkana Shale by Hamer (1994). The magnetic source, presumably magnetite, has not been identified.

## DEVONIAN STRATIGRAPHY AND AGE

Devonian fossils occur *in situ* in the Mimili Formation and comprise vertebrate remains and spores (Fig. 7.5).

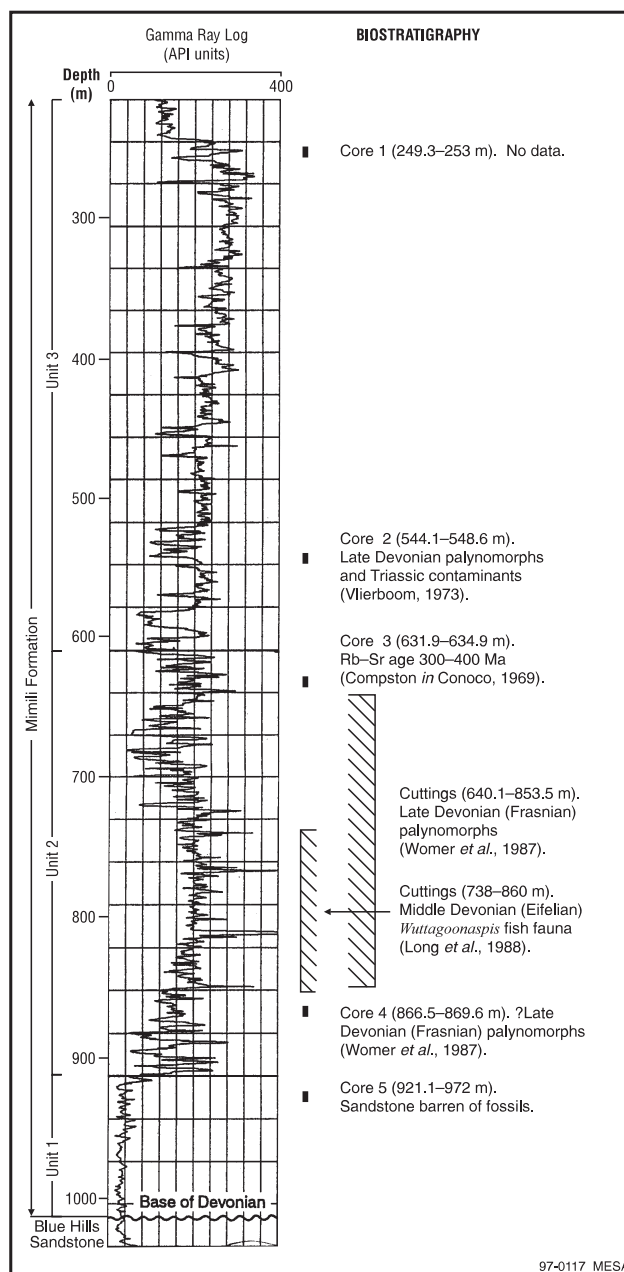


Fig. 7.5 Munyarai 1 Devonian lithostratigraphy, fossils and geochronology.

### Vertebrate fossils

Cuttings between 816.9 and 823.0 m in Munyarai 1 yielded scales from thelodont, acanthodian and ganoid (osteichthyan) fish (Gilbert-Tomlinson *in* Conoco, 1969), indicating a maximum age of Early Devonian for this part of the section. The fossiliferous interval was extended to lie between 738 and 860 m (J. Hibburt, MESA, pers. comm., 1987) and the fossils were examined by Long *et al.* (1988). These authors identified scales of thelodonts, an acanthodian, teeth, plates and bone fragments, and correlated this assemblage with the early Middle Devonian (Eifelian) *Wuttagoonaspis* fish fauna of the Georgina and Amadeus Basins. The Munyarai fauna is not large enough to determine whether the host strata are marine or non-marine.

## Palynomorphs

Palynomorphs were not recovered from the fish-bearing strata by Long *et al.* (1988) and, despite preparation of large quantities of material, only two spores were recovered from core 3 by Harris (*in Conoco*, 1969). The specimens (cf. *Leiotriletes*) only indicate a Devonian or younger age. Fragments of tracheidal wood reported from the bottom core and as high as core 3 are now known to be contaminants, but it was these that stood for many years as testimony to the supposed Devonian age of the Munyarai 1 succession below the fish scale zone.

Further sampling was carried out by Vlierboom (1973) who was the first to report palynomorphs from core 2, at a depth of 548.6 m (189 m above the top of the fish fauna). Vlierboom carried out two preparations on this sample to improve the microfossil yield; he stated 'In the first sample preparation several well-preserved Triassic sporomorphs were found but as the samples were previously determined as Siluro-Devonian it was suspected that the samples had been contaminated'. The first preparation yielded only seven specimens, two of which — *Platysaccus queenslandi* and *Alisporites* sp. — indicated a Triassic age. The second preparation yielded 34 specimens, all of which were concluded by Vlierboom to indicate a Late Devonian (probably Famennian) age. Further work is planned to examine the Triassic question.

More recently, Eames and Miller (*in Womer et al.*, 1987) identified well-preserved miospores in three samples from 640.1 to 853.5 m. The good preservation of this assemblage contrasted strongly with the very poor preservation of eight samples recovered from the much deeper interval (1652.0–2225.1 m) in Munyarai 1. Although the lower samples were regarded as 'probably Middle Devonian', they are now known to be Neoproterozoic in age. The upper assemblage of miospores was confidently assigned a Late Devonian (Frasnian) age because of similarity to a Frasnian assemblage from the Carnarvon Basin in Western Australia. The stratigraphic position of the Devonian assemblage is shown on Figure 7.5, which indicates an overlap of 116 m that may be either Middle Devonian (based on fish fossils) or Late Devonian (based on spores). The interval which may be positively correlated with Devonian strata based on fossil content comprises only 30% of the top 1000 m drilled. At least half the drilled section, from the surface to 548.6 m, may be considerably younger than Devonian, but this section is mainly sandy and lacks fossils. A sample of core 1 (249.3–253.0 m) has been submitted to Geotrack in Melbourne for assessment of its zircon fission track age.

## Geochronology

Whole-rock samples of core in the depth range 632.5–634.3 m and 2133.6–2136.4 m were analysed for Rb–Sr age information by Compston (*in Conoco*, 1969). Compston showed clearly that the shallower samples occupied a distinct field with a lower gradient and an equivalent age between 300 and 400 Ma, i.e. Carboniferous to Devonian (Fig. 7.2). Interpreted simply as an isochron, the slope of the well-aligned deeper samples gave an equivalent age of 650 Ma, clearly Neoproterozoic as was concluded much later.

