The discovery of Miocene vertebrates, Lake Frome area, South Australia*

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This report announces the discovery of a diverse vertebrate fauna from exposures of the Namba Formation in the southern Frome Embayment (Tarkarooloo Basin), South Australia. The fluvio-lacustrine Namba Formation can be divided into two informal members based on regional lithological changes. The lower member bears Balcombian-Batesfordian (medial Miocene) pollen floras representing subtropical rainforest and adjacent savanna habitats. The top of the lower member yields the Pinpa Fauna of aquatic and terrestrial vertebrates including fish, turtles, crocodiles, two genera of dasyurids and seven genera of diprotodontan marsupials and a platanistid porpoise. The base of the upper member contains a similar vertebrate fauna (Ericmas Fauna) but includes a platypus and, significantly, diprotodontid marsupials which are the dominant large mammals in the contemporaneous Ngapakaldi Fauna of the Lake Eyre basin.

Introduction

In 1885 Ralph Tate (1886, pp. 54-55) noted the occurrence of aquatic vertebrate remains from a well 'near Lake Hurd, north of Billeroo trig, in the basin of Lake Frome', where 'they occurred in a stratum of sharp white sand underlying a clay which is reported to me to have embedded in it stems of mulga. The location of Lake Hurd has passed into obscurity but the occurrences of turtle, crocodile and fish remains in an angular sand matrix, were confirmed nearly 90 years later by the work reported below.

Study of the Cainozoic rocks of the Frome Embayment of the Great Artesian Basin by Roger A. Callen of the Department of Mines, South Australia resulted in the rediscovery of vertebrate fossils there in 1970. In 1971 and 1973 the authors obtained collections from Miocene and Pleistocene deposits southeast of Lake Frome. The National Museum, Victoria, assisted by an Australian Army contingent, obtained further materials from this area in 1974.

The outcrop stratigraphic studies of Callen and Tedford have been augmented by subsurface data collected by the Department of Mines, South Australia from its own drilling program and that of the several companies prospecting for uranium in the basin. These data have been synthesized in a detailed analysis of the Tertiary sedimentary history of the southern Frome Embayment (the Tarkarooloo Basin) by Callen (1975a). The Cainozoic stratigraphy and depositional environments have been summarized by Callen (1975b; 1976, & in press), and Callen & Telford (1976b). The following conclusions about the Tertiary deposits and environments are more fully developed in the works cited.

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Stratigraphy

A diverse fauna of aquatic and terrestrial vertebrates has been obtained from the upper part of the fluvio-lacustrine Namba Formation, a newly recognized lithostratigraphic unit restricted to the Frome Embayment. The Namba Formation rests unconformably on the Paleocene-Eocene fluviatile Eyre Formation and extends onto older rocks around the basin margins and across pre-Namba basement uplifts within the basin (Figure 1). Its lower contact is exposed in a limited area on the western side of the basin where post-Miocene faulting has been active. The Namba Formation is divisible into two members that can be recognized over most of the Tarkarooloo Basin. The lower member is characterized by grey and black sandy clays composed predominantly of smectite, interbedded with laminated silt and fine to medium-grained cross-bedded sands, especially toward the basin margins. The upper member is disconformable on the lower, a zone of alunite is sometimes found in the top of the lower member near the contact, and the smectite clays of the lower member change sharply to an illite-kaolinite assemblage characteristic of the green clays of the upper member. Laminated fine sand and silt and cross-bedded stream-channel deposits are more common in the upper member. Both members contain lacustrine dolomite and associated palygorskite claystones. Dolomites were more extensively developed over the Tarkarooloo Basin during the deposition of the upper member, especially at its base. Such lacustrine and low energy fluviatile environments were eventually succeeded by red-coloured coarser clastics and a reappearance of smectite in the Willawortina Formation which intertongues with the uppermost Namba Formation (see legend, Figure 1). Restriction of the poorly sorted clastics of the Willawortina Formation to the western side of the basin indicates that they represent alluvial fans contributed by a rising Flinders Range and accompanying shift in climate toward drier environments in this region.

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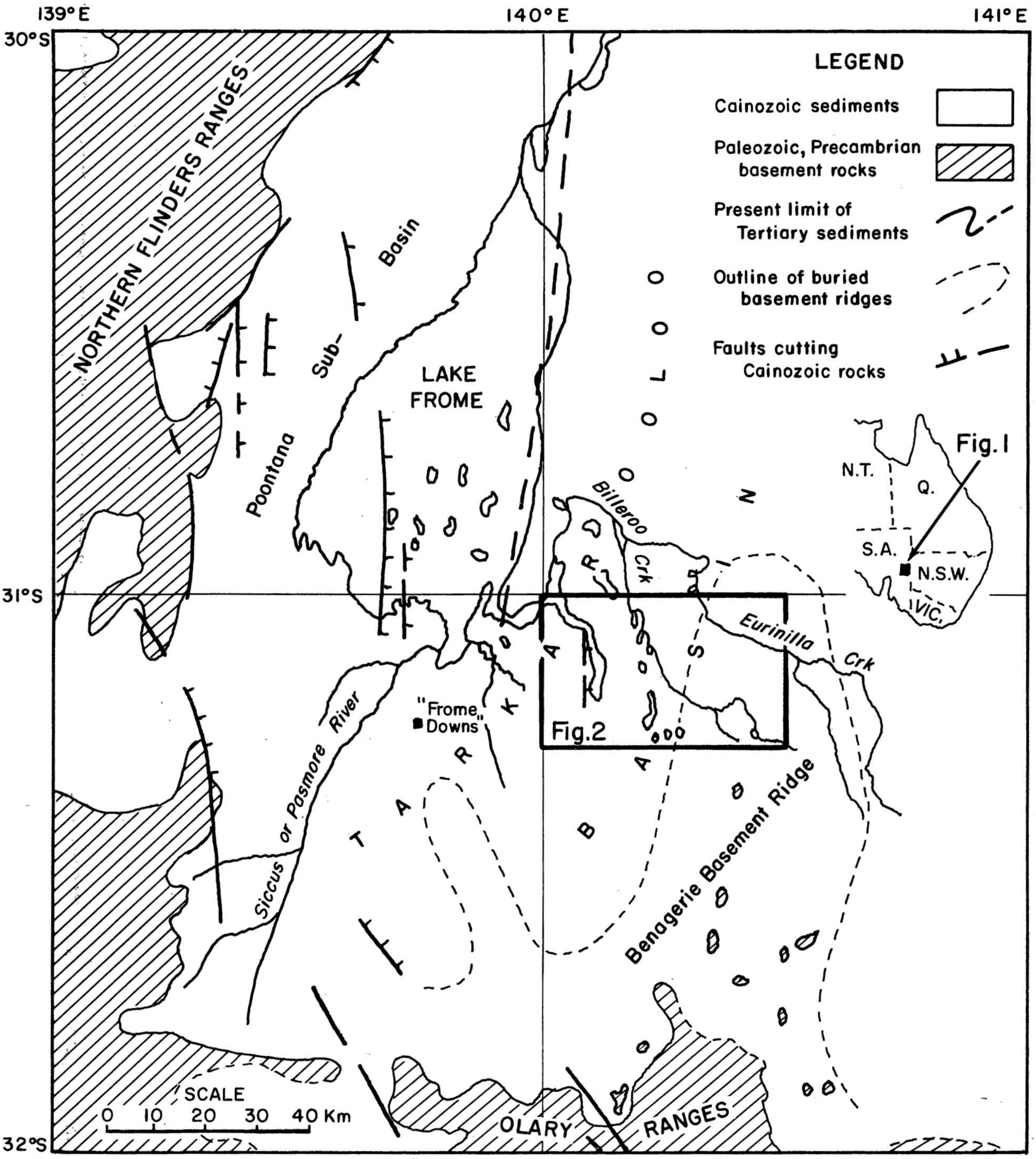

Figure 1. Location of southern Frome Embayment, and its relationship to the Cainozoic Tarkarooloo Basin margin and structure. Namba Formation and overlying Quaternary fluviatile sediments form scattered exposures where revealed by deflation and the action of streams that penetrate the latest Quaternary-Holocene sand sheets and dunes. West of Lake Frome in the Poontana Sub-Basin the Willawortina Formation forms virtually the only surface outcrop of Tertiary rocks. It interfingers with the uppermost Namba Formation just east of the Passmore River. Data from Callen (1975a).

Palaeontology

Outcrops of the Namba Formation at Lakes Namba, Pinpa, and Yanda, and along Billeroo Creek, 35-45 km east and southeast of Lake Frome, appear to include the intraformational contact (Figure 2). Green claystones and dolomitic claystones at the top of the lower member produced a locally abundant vertebrate fauna termed the Pinpa Fauna. These rocks are disconformably overlain by a regionally traceable sequence of thin-bedded fine to medium-grained sands which were deposited in point-bars and overbank sheets on a scoured surface cut in the lower member. The more limited vertebrate assemblage from these basal sands of the upper member is termed the Ericmas Fauna. The Pinpa and Ericmas Faunas are dominated by aquatic vertebrates including ray-finned fish (catfish are represented here), lungfish, chelid turtles, crocodiles and river-dwelling platanistid porpoises. The latter provides clear evidence of external drainage of the Frome Embayment—possibly southward into the Murray Basin, at that time experiencing its greatest Tertiary transgression. In addition to the aquatic forms common to both

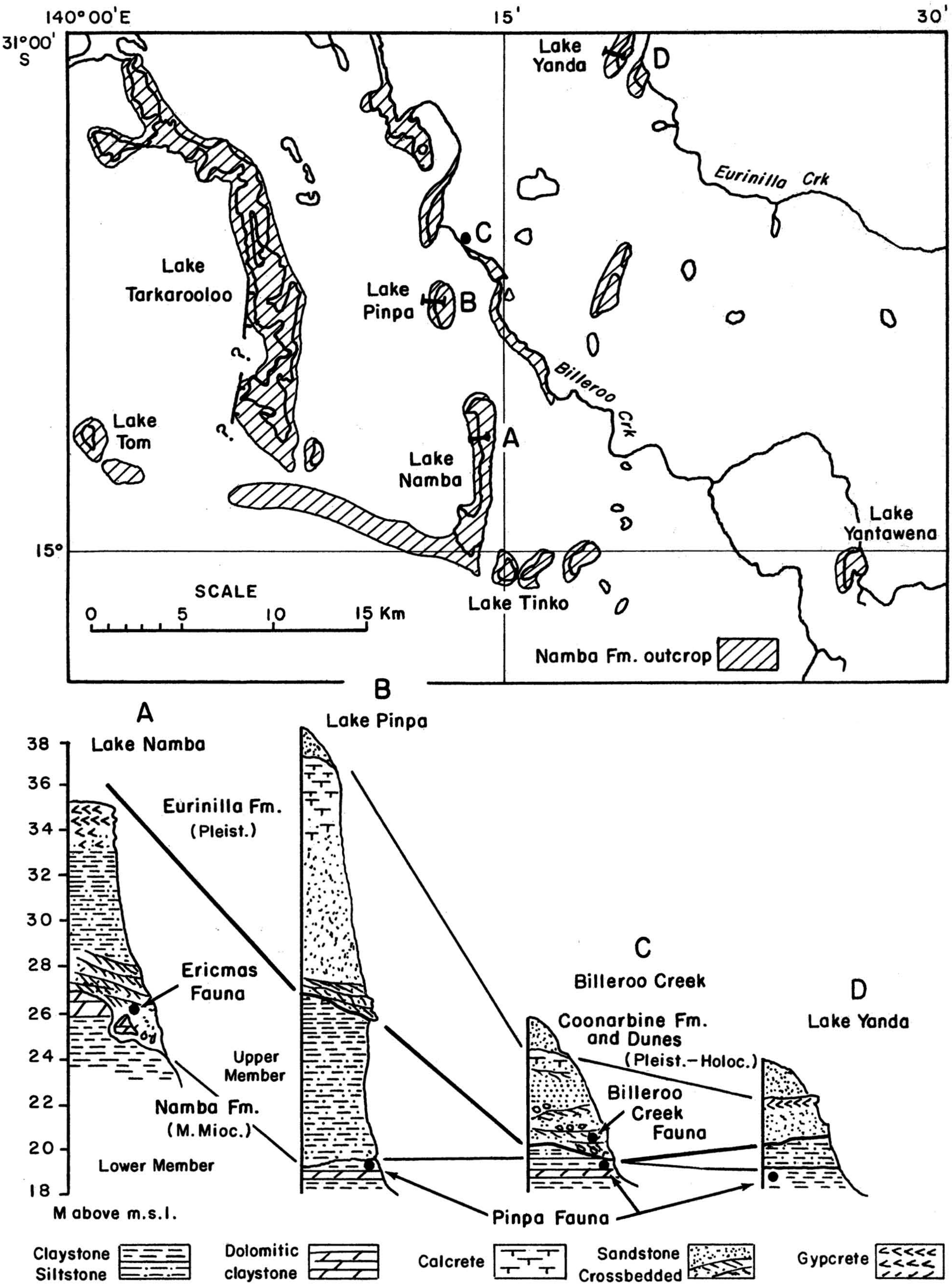

Figure 2. Map and stratigraphic sections showing outcrops of Namba Formation in the Eurinilla 1:63 360 sheet area (From Callen, 1975a, and original observations). Columnar sections at vertebrate fossil sites show mutual stratigraphic relationships of Miocene faunas and a Pleistocene assemblage. Stratigraphic nomenclature after Callen, 1975b. Sections A and B were directly levelled using a barometer with ± 2 m. accuracy; Section C was projected to a nearby similarly levelled point and section D is unlevelled.

faunas, a single platypus tooth (*Obdurodon insignis* Woodburne & Tedford, 1975) one of the two known teeth representing the earliest recorded monotremes, occurs in the Ericmas Fauna. Bird remains are abundant in the lower member, especially water birds including flamingos, cormorants, ducks, geese, rails and the stone curlew.

The terrestrial vertebrates of the Pinpa Fauna include meiolanid turtles, lizards, and a variety of marsupials, most of which are new taxa of generic and higher rank and hence cannot be more precisely listed at the present time than as follows: Dasyuridae (2 species), ?Wynyardiidae (1 species), Vombatoidea (2 species), Phascolarctidae (1 species), Petauridae (1 species), Ektopodontidae (1 species) and Burramyidae (1 species). This fauna is especially noteworthy for the lack of diprotodontids and macropodids and the diversity of terrestrial vombatoids, and arboreal wynyardiids, koalas and small phalengerids. Terrestrial vertebrates are rare in the younger Ericmas Fauna, but a palorchestine diprotodontid close to the Miocene genus *Ngapakaldia* occurs along with a vombatoid of modern type. Remains of a koala and pseudocheirine petaurid in the Ericmas Fauna are clearly related to their Pinpa counterparts, but they appear to be specifically distinct, implying that the intraformational contact records a significant time gap as well as change in environment of deposition.

The following notes will indicate the morphology and relationships of some of the Pinpa Diprotodonta as far as analyses have been taken at the moment. More complete descriptions are in preparation.

1. ?Wwnyardiidae: partial skeletons are present, but unfortunately the one skull available lacks precisely those areas necessary for close comparison with the Tasmanian *Wynyardia*. Close correspondence in the limbs provides the main evidence for the tentative indentification and confirms that these animals were syndactylous. Complete dentitions establish their diprotodonty and show an interesting stage in the development of bilophodont upper molars, in which the labial ends of the lophs are formed from the large stylar cusps b, c and d (Figure 3A). The paracone and metacone take up a median position on the developing lophs. The lower dentition is completely lophodont and very macropodine in appearance (however, the mandibular ramus bears no masseteric canal).

2. Vombatoidea: one species (genus A) is represented by most of a skeleton (the only specimen found in the entrapment position so common among the *Ngapakaldia* skeletons in the Lake Eyre Basin) including a crushed skull but no lower jaw. The other and larger form, (genus B), is represented by crushed skulls, rare jaw fragments and fragments of the skeleton. These are the most abundant large mammals, about wombat-size and a little larger and very wombat-like in the limbs. The delto-pectoral crest of the humerus is not so expanded as in the fossorial living wombats, but otherwise the comparisons are striking. These were heavy-bodied terrestrial animals, diggers but probably not burrowers. Many of the cranial features are also wombat-like, including the phylogenetically important exclusion of the alisphenoid from the auditory cavity through expansion of the squamosal. Dentally these forms are dissimilar: both have the same dental formula including three upper incisors, one canine, a premolar and four molars, but the smaller more wombat-like form shows greatly enlarged central incisors. Behind the fluted sectorial premolar its cheek teeth are brachyodont, root-bearing bilophodont teeth that incorporate the stylar cusps into the crown pattern in a manner very similar to the unworn teeth of living wombats (Figure 3B). The larger form has low crowned selenodont cheek teeth (Figure 3C), molariform premolars and a short-crowned, tightly grouped upper incisor battery and ankylosed lower jaw symphysis. In these features it is koala-like, but the resemblance stops there.

The Pinpa ?Wynyardiid and the vombatoids indicate the ways in which stylar cusps were incorporated into complex molar patterns in the Diprotodonta. This evidence reinforces the contention of Winge (1941), Ride (1971), and Archer (1976b), that selenodont molar patterns resembling those of the peramelids and phascolarctids, with their large stylar cusps and a median valley separating the paracone and metacone, represent the structurally primitive dental pattern among the Diprotodonta.

3. Phascolarctidae: the Pinpa koala is different from *Perikoala* of the Ngapakaldi Fauna and seems more closely related to the living genus than any of the Tertiary genera so far described. It shows an early stage in molarization of M_1 and enlargement of the posterior molars (Figure 3D).

4. Petauridae: a small pseudocheirine is the most abundant mammal in the Pinpa Fauna and congeneric forms are also present in the Ericmas and Ngapakaldi faunas. Interestingly, its dentition suggests an intermediate phase in the development of a bunodont-phalangerid type of dentition from a selenodont one.

5. Ektopodontidae: a single cheek tooth resembles undescribed material from the Etadunna Formation which demonstrates the phalangeroid bilophodont affinities of this family, originally attributed to the Monotremata.

6. Burramyidae: a large *Cercartetus*-like form is present and also appears to be represented in the Etadunna Formation. This taxon demonstrates the antiquity of the bunodont tritubercular type of cheek tooth thought by many to be the primitive pattern among the Diprotodonta, but considered here to be a modification of the primitive selenodont plan.

Age and palaeoecology

Pollen floras from the lower member of the Namba Formation in the Poontana Sub-basin (Figure 1) record subtropical rainforest vegetation including *Nothofagidites* (but no species diagnostic of high temperatures) and abundant grass pollen, suggesting riparian forests with savannas on the better drained interfluves. Very similar floras are present in Batesfordian-Balcombian deposits in Victoria (Muddy Creek Marl) and South Australia (Munno Para Clay) and these comparisons establish the maximum age for the vertebrate assemblages that occur higher in the Namba Formation (W. K. Harris, pers. comm., 1973). These stages are approximately medial Miocene in age, roughly 14-16 million years BP (Ludbrook, 1973).

The Namba Formation faunas have a different composition to the approximately contemporaneous Ngapakaldi Fauna (see Stirton, Tedford & Woodburne, 1968) from the Etadunna Formation in the Lake Eyre Basin 350 km to the northwest of Lake Frome. This correlation is best supported by the presence of four congeneric taxa (a large vombatoid and three small phalangeroids) in the Pinpa Fauna and the Ngapakaldi Local Fauna from the stratotype of the Etadunna Formation. Ngapakaldi local faunas from lakes Pitikanta and Ngapakaldi are dominated by palorchestine diprotodontids and to a lesser extent kangaroos that strongly contrast with the Pinpa assemblage with its abundant large vombatoids, koalas and ?wynyardiids. These faunal differences are believed to at least partly reflect the ecological contrast between the inland Lake Eyre Basin of internal drainage and the coastal Lake Frome Basin that maintained access to the sea in medial Miocene time. The pollen floras obtained from the two basins are very similar in composition and can be used to support the correlation provided by the mammals. However, they imply

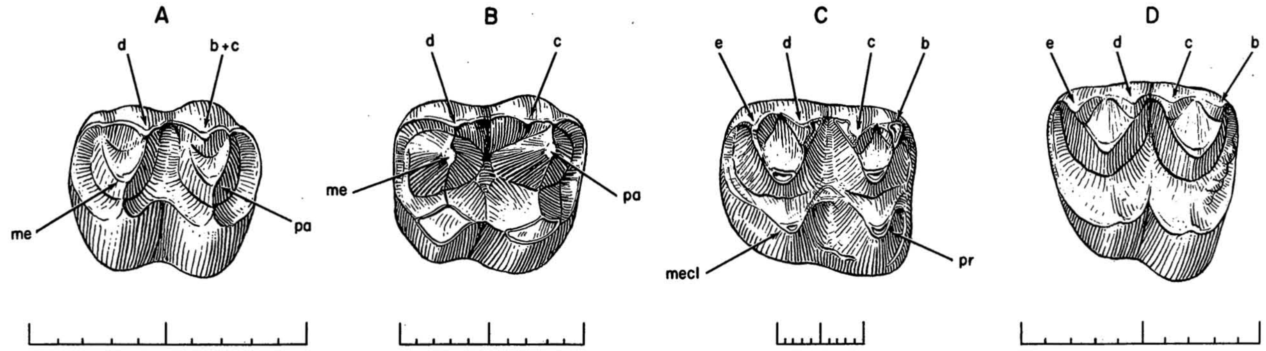

Figure 3. Comparative occlusal views of right upper second molar of four Pinpa Fauna diprotodontans to show importance of stylar cusps in crown pattern. All drawn to the same size, actual sizes indicated by 1 cm. bars. A ?Wynardiidae, QMAM 178, reversed; B. Vombatoidea, gen. A, QMAM 168; C. Vombatoidea, gen. B. QMAM 181; D. Phascolarctidae, QMAM 255. Stylar cusp nomenclature follows Archer, 1976; me, metaconid; mecl, metaconule; pa, paracone; pr, protocone.

little difference in environment at least during the early phases of deposition of these medial Miocene sediments. The Etadunna Formation as exposed (Stirton, Tedford & Miller, 1961), and especially as revealed by drilling in the Lake Eyre Bore 20 (Johns & Ludbrook, 1963), is very similar in lithology to the Namba Formation, except for the dominance of carbonates. Black smectite-rich clays with a ferruginous horizon and alunite as in the lower member of the Namba Formation constitute only a very thin sequence of the base of the Etadunna Formation in Bore 20 (revised log Callen, 1975a). If the clay mineral and attendant lithological changes can be related to synchronous regional environmental change then most of the Etadunna Formation, particularly that containing the Ngapakaldi Fauna, may be more precisely equated with the upper member of the Namba Formation. Such a correlation is also suggested by the presence of the platypus and diprotodontid in the Ericmas Fauna. If this hypothesis is correct the Pinpa Fauna may be older than most of the Ngapakaldi Fauna. For the moment, however, we must conclude that the faunal differences observed between the medial Miocene assemblages of the Lake Frome and Lake Eyre basins may be the result of contrasting ecologies and/or significant age differences.

Despite these uncertainties, the presence of diprotodontids and kangaroos in the Ngapakaldi Fauna of the Lake Eyre Basin suggests an early stage in the development of a marsupial assemblage typical of later Cainozoic time. In contrast, the Pinpa Fauna in the Lake Frome Basin contains a peculiar assemblage of terrestrial and arboreal diprotodont marsupials that probably represent survivors of rainforest inhabiting assemblages of the medial Cainozoic. The Pinpa marsupials are thus exceedingly interesting for they present us with novel morphological combinations that enlarge our concept of the diversity of the Australian Diprotodonta.

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