FOSSIL MARSUPIALS AND CAINOZOIC CONTINENTAL STRATIGRAPHY IN AUSTRALIA: A REVIEW

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The geological history of the mammals in other parts of the world suggests that marsupials entered the Australian Region and became isolated at an early date, at least by the beginning of the Cainozoic era. However, prior to the discoveries of the last decade, the early palaeontological record of Australian marsupials was most unimpressive, with only one species, *Wynyardia bassiana*, known from lower Tertiary deposits. Their abundance in Quaternary sediments stood in remarkable contrast.

Since then, the work of Professor R. A. Stirton and his colleagues in the eastern part of the Lake Eyre Basin in South Australia has provided a major contribution to the palaeontological record of the marsupials and other vertebrates in Tertiary time. Other significant discoveries have been reported from the Tertiary of Victoria, where the association of some of the fossils with marine beds has enabled more precise dating of the remains. While the bulk of our knowledge is still confined to upper Cainozoic forms, their potential value in continental stratigraphy is apparent. At the same time, the variety of these upper Cainozoic marsupials points to the diversification of the groups in this continent at an early date, and emphasizes that the paucity of the early Tertiary record will have to be overcome before the basic phylogeny of these groups can be established.

TERTIARY

The oldest Tertiary marsupial, the age of which can be stated with any precision, is still *Wynyardia bassiana* from marine sediments at Fossil Bluff near Wynyard, northern Tasmania. The skeleton was originally found in a fallen block of limestone from the " *Turritella* Bed," and the results of the application of the fluorine test, published by Gill (1957), appear to establish that this bed was its true provenance. On the basis of its correlation with the Janjukian Stage in Victoria, an Oligocene age is now generally accepted for the marine section at Fossil Bluff. Following his re-examination of the skeleton, Wood Jones (1931) concluded that the affinities of *Wynyardia* were with the Phalangeridae.

Several fragmentary marsupial fossils have been recovered from shallow water marine beds and from horizons interbedded with marine sediments in Victoria. As our knowledge of such forms increases, their occurrence will provide a basis for correlation of the continental Tertiaries with the marine succession. The oldest of these remains is portion of a macropodid femur reported by Glaessner, McGowran, and Wade (1960) from sand of Balcombian age (Middle Miocene) above the Bochara Limestone in Grange Burn, near Hamilton, Victoria. Younger marine sediments in the same area, the Grange Burn Coquina of lower Pliocene age, have yielded a fragment of a macropodid mandible, referred by Stirton (1957b) to the subfamily Sthenurinae.

Three diprotodontid fossils originally found on the beach at Beaumaris, Victoria, and described by Stirton (1957b) were shown by Gill (1957) to have a fluorine index comparable with a provenance in the Black Rock Member of the Sandringham Sand. These marsupials then belong to the Cheltenham " Stage " of upper Miocene age.

Details of the stratigraphic succession and additional information on the fauna of the Cainozoic sediments of the Tirari Desert in the eastern part of the Lake Eyre Basin, South Australia, have been recently published by Stirton, Tedford, and Miller (1961). While the stratigraphic relationships of the various units have been established through superposition, the authors have expressed difficulty in assigning them ages in terms of the conventional epochs of the Tertiary. The oldest unit recognised, the lacustrine Etadunna Formation, is tentatively assigned to the Oligocene on the basis of comparative evolutionary studies of the macropodid fauna. The formation postdates the development of duricrust on representatives of the Cretaceous Winton Formation and remnants of early Cainozoic fluviatile deposits.

It must be acknowledged that lateritic processes were operative not only over wide areas in Australia, but at more than one time during the Cainozoic. However, Twidale (1956) has postulated that in north-west Queensland uplift and dissection of a widespread lateritized surface, developed on Cretaceous and probable early Tertiary rocks, took place approximately in Miocene time. The surface was apparently of considerable extent in inland Australia, and constitutes the Australian Pediplain of King (1950), the erosion of which, he claims, was initiated by earth movements in late Oligocene or Miocene time. It may well be that a tentative Miocene age for the Etadunna Formation would be more appropriate than a tentative Oligocene age.

The marsupials of the Etadunna Formation recorded by Stirton *et al.* (1961) include a dasyurid, a phascolarctid, *Perikoala,* previously described by Stirton (1957a), two macropodids, and a small diprotodontid with possible palorchestine affinities.

Lithologically the formation is calcareous in part, with some massive limestones carrying chert nodules. Paten (1961) has recently discussed the Cainozoic freshwater limestones and associated sediments, which are widespread in western Queensland, but which show their greatest development in the valleys of the Georgina and Burke Rivers and near Birdsville, all within the present Lake Eyre drainage basin. Their section usually includes detritus from older lateritized profiles at the base, and silicification frequently occurs towards the surface. Paten has suggested a late Tertiary or early Quaternary age for these deposits. Vertebrate fossils have been recovered from only one locality, in the Carl Creek Limestone, near Riversleigh in the Gregory River valley. This is away from the main occurrences, and the fragmental bones, so far recovered, are unsatisfactory for close study.

It is possible that deposition of calcareous lacustrine sediments took place at different times in the Cainozoic over this whole belt. No correlation of any of these deposits with the Etadunna Formation can be suggested on the available evidence ; there is no detailed lithological resemblance, but the similarity in gross stratigraphic relationships indicates that the possibility might be considered in future work.

In the Tirari Desert the next unit recognised by Stirton *et al.* (1961), the Mampuwordu Sands, consist of fluviatile sediments deposited disconformably or possibly unconformably on representatives of the Etadunna Formation. Elements of the fauna of the stream channel deposits, tentatively placed as lower Pliocene in age, were described by Stirton (1955). In the recent work the marsupials of the faunal list now comprise the peramelid *Ischnodon,* four macropodids including *Prionotemnus,* and two diprotodontids, *Meniscolophus* and a form with affinities to *Euowenia.*

Unfossiliferous sandy and argillaceous sediments of the Tirari Formation, which overlie the Etadunna Formation unconformably, are also tentatively referred by these authors to the Pliocene. Fossiliferous Pleistocene sediments, the Katipiri Sands, and younger Quaternary or Recent fluviatile and aeolian sediments complete the succession in the Tirari Desert, the most complete recognised in continental deposits of the Cainozoic of Australia.

To date, elements of the fauna of the Mampuwordu Sands have not been found elsewhere in Australia. Stirton (1955) suggested that *Nototherium watutense,* originally described by Anderson (1937) from the Watut River, New Guinea, was probably referable to *Meniscolophus.* Information from Dow (1961, personal communication) indicates that the New Guinea species occurs in sediments of Pleistocene age, but some occurrences may be older.

Loosely compacted fluviatile and lacustrine sediments which are tentatively referred to the Pliocene are widespread in Queensland. They comprise the Glendower Formation and its lithological equivalents, which are mostly unnamed and unmapped, although the Lynd Formation is known to be extensive in the plains east of the southern part of the Gulf of Carpentaria. Conglomerates containing pebbles of the silicified duricrust, commonly known as "billy," are usually prominent in the section, and the sediments appear to have been derived from the dissection of the extensively lateritized, peneplaned (or pediplaned) middle Cainozoic surface. They, in turn, often display broad ferruginous mottling, usually interpreted as a weak lateritic effect. There is evidence of broad warping, and in places considerable dissection has followed uplift.

Unfortunately these widespread deposits are usually unfossiliferous, but the prevalence of leached non-calcareous clastics lessens the chances of preservation of vertebrate remains. An exception is the Chinchilla Sand (Woods, 1960) which has been traced on the basis of both lithology and fossil content for a distance of nearly 40 miles in its surface and subsurface extent between Warra and Nangram Lagoon in the north-west of the Darling Downs. The maximum thickness is about 100 feet and calcareous horizons occur. Tortoise and crocodile remains are abundant as well as marsupials in the extensive vertebrate fauna. There is a striking difference between the diprotondontid elements of this fauna and those of the superficial deposits of the eastern Downs. Of these *Euryzygoma* is absent from the presumably younger alluvia, while *Euowenia* and *Palorchestes* are represented by distinct species. However superposition has yet to be established.

A few vertebrate fossils are known from deep alluvia, beneath basalts, in southern Australia. Some of these occurrences are probably upper Tertiary, such as those at Buninyong, Victoria, at a depth of 238 feet (Gill, 1957), and the Canadian Lead at Gulgong, New South Wales, at a depth of 130 feet (Dun, 1895). Freshwater sediments are known to occur below the upper Cainozoic volcanics of north Queensland, but only plant remains have been recovered from them.

Additional localities listed by Gill (1957) for the possible occurrence of Tertiary marsupials in southern Australia include One Tree Point, Hobart, and the Geilston Travertine in Tasmania, the site at Smeaton, Victoria, whence came the dasyurid, *Glaucodon ballaratensis* Stirton, and the lacustrine deposits at Coimadai, Victoria.

QUATERNARY

Vertebrate remains assigned to the Quaternary are widespread in fluviatile, lacustrine, and cave deposits, while there are more restricted occurrences in spring deposits, aeolianites, and tuffs. Detailed stratigraphic studies have yet to be made on many of these, and no precise correlation of the various faunas can be made. Indeed, the most comprehensive attempt at a post-Tertiary chronology for Australia is still that of Browne (1945).

While the fragmentary evidence of the upper Tertiary marsupial remains indicates that the major groups were differentiated in this continent by the Miocene, many of them reached their acme in the Pleistocene. The fluctuating climate of that epoch and the consequential rapid changes in the environment no doubt maintained strong selection pressure, especially on browsing and grazing herbivores of the open forests and grasslands. The possible results, rapid evolution, with increasing specialization, gigantism, and extinction, are all evident in the palaeontological record of the Quaternary.

The occurrence of any fossil marsupials to the north of the Australian mainland is of particular interest, in that information may be gained on the times and directions of dispersal of the various marsupial groups. To date, their occurrence is restricted to the diprotodontid, *Nototherium watutense*, and a few fragmentary undescribed macropodids from the Morobe Goldfields area. Information kindly supplied by Dow (1961, pers. commun.) indicates that these fossils are derived from the Otibanda Lake Beds which were deposited in two lakes in the valleys of the Bulolo and Watut Rivers, separated by extensive andesitic volcanics of the Bulolo Gorge. The sediments of the smaller area near Wau comprise conglomerate, sandstone, siltstone, and mudstone, with interbedded andesitic tuff and agglomerate near the base. A Pleistocene age is considered likely for this sequence. The larger lake, in the valleys of the Watut and lower Bulolo, was formed by faulting and regional uplift in the Snake River area. The presence of andesitic volcanic material, apparently subaerially deposited, throughout much of the section, suggests that in part this sequence may be slightly older. The Otibanda Lake Beds are deformed, with dips up to 45°.

In a small collection recently received from this area the only well preserved specimen is portion of a diprotodontid mandible referable to *Nototherium* sp. Its molar pattern is very similar to *Nototherium tasmanicum* from the upper Pleistocene of Tasmania and the more widely distributed *N. mitchelli* of the Pleistocene. However, this comparison does not assist correlation since the isolated upper premolar figured by Stirton (1957b) suggests that the genus *Nototherium* ranged at least from upper Miocene time.

One of the most intensively collected areas of Pleistocene alluvia in Australia occurs in the valleys of the Condamine River and its tributaries of the eastern Darling Downs. Many of the type specimens of the Pleistocene marsupials described by Sir Richard Owen in the last century were obtained from these deposits. In the eastern part of the area, as in the valley of King Creek, the fossiliferous beds comprise brown calcareous clays with lenticular basaltic gravels at rather shallow depths in the creek sections. Along the Condamine River near Dalby and Macalister, the observed sections are thicker and commonly contain sands and grits as well as brown and grey clays. Bore records show up to 167 feet of alluvia in this area. A general Pleistocene age has been assigned to this sequence by Woods (1960) based on the almost complete absence of living species among the fossils. It is feasible that the more superficial fossiliferous alluvia along King Creek are upper Pleistocene in age, while the thicker sediments in the Condamine valley range back to include equivalents of the Chinchilla Sand.

Marsupials are predominant in this fauna from the eastern Darling Downs ; reptiles are not so common as in the Chinchilla Sand. The most common of the giant marsupials is the widespread *Diprotodon optatus,* and the dominant marcopodids are *Macropus titan* and *Protemnodon anak.* The smaller polyprotodont marsupials and the phalangerids are not well represented, but those with a general forest habitat and small size are unlikely to be preserved in the fluviatile deposits of wide valleys and plains.

Following the early work of Owen, a large number of fossil marsupials were described from the Darling Downs by C. W. De Vis. His descriptions are frequently unaccompanied by locality and stratigraphic data, and in some cases type specimens were not designated. This applies, in particular, to his work on the macropodids (De Vis, 1895), which deals in composite fashion with collections from both the Chinchilla area and the eastern Darling Downs, and stratigraphic evaluation of many of his species has not been possible. Currently, revisionary work on these forms is being undertaken by Dr. W. D. L. Ride and Mr. A. Bartholomai.

Diprotodon optatus was widely distributed on the mainland, and while it reached King Island, there is no record of its having reached Tasmania. It was apparently adapted to a wide range of habitats ; Gill (1955) records its occurrence at altitudes between sea level and 2,000 feet. The apparent absence of *Diprotodon* from Tasmania may be due to a relatively late dispersal of the genus and the presence of an indigenous species of *Nototherium* (*N. tasmanicum*) as well as the widespread *N. mitchelli* in the Mowbray Swamp Peat, regarded by Gill and Banks (1956) as upper Pleistocene, may be taken as evidence in support of this view. While the restriction of the range of the family Diprotodontidae in southern Australia to the upper Pleistocene or the upper part of the middle Pleistocene as suggested by Keble (1945) is no longer tenable, indications are that most occurrences of *Diprotodon optatus* in this region are in upper Pleistocene deposits. Furthermore, the species is known to range into early Recent time.

However, *Diprotodon* sp. occurs in the Chinchilla Sand, and Owen (1870) recorded the genus from a depth of 100 feet in the Condamine alluvia. Its apparent variation in time range may reflect the local patterns of sedimentation in different parts of the continent.

Two separate faunas have been recognised by Stirton *et al.* (1961) from the Katipiri Sands of Pleistocene age in the Tirari Desert. These fluviatile deposits rest disconformably on the Tirari Formation. The presumably older mammalian fauna from Lake Kanunka, tentatively referred by these authors to the early Pleistocene, contains not only marsupials but the oldest rodent known from the Australian Region. The marsupials comprise a dasyurid, a thylacoleonid, two phascolomids including one specimen referable to *Phascolonus,* several macropodids of diverse groups, and diprototodontid fragments, possibly referable to *Euowenia. Diprotodon* has not been collected in this fauna.

The other mammalian fauna, placed as late Pleistocene, includes several rodents, as well as marsupials, comprising the dasyurid *Sarcophilus*, the phalangerid *Trichosurus*, the phascolomid *Phascolonus*, several macropodids including the still-living *Bettongia lesueuri*, and the widespread diprotodontid *Diprotodon*.

A large assemblage of living and extinct marsupial genera, including *Diprotodon*, has been obtained from the lowest unit of the aeolian sequence at the archaeological site at Lake Menindee (Tedford, 1955). This fauna was contemporaneous with aboriginal man with the Tartangan culture, and radiocarbon dating of the site shows it to be of early Recent age at approximately 6,570 years before the present time (Tindale, 1957). People with the Tartangan culture and those with the earlier Kartan culture both reached Tasmania, so no zoogeographic basis for the failure of *Diprotodon* to reach there is apparent.

Few of the extinct marsupials seemed to have survived the time of the Mid-Recent Thermal Maximum, about 5,000 years ago. The macropodid *Procoptodon* survived until the time of the Pirrian culture of australoid people, about 4,250 years ago (Tindale, 1957). It would appear that the extinction of Pleistocene marsupial species was progressive, not a catastrophic result of any sudden climatic change, although the demands of the fluctuating enviroment on genetically senile populations were certainly important factors. The arrival of Man probably had a critical effect on certain species, especially those of small numbers in restricted areas.

Cave earths and tufas have yielded abundant fossil mammals, including many not known or poorly represented in other deposits; but these differences largely reflect differences in habitat and mode of accumulation of the remains. Predators, including owls, appear responsible for most of the material. Native rodents and bats are well represented in some occurrences. The assemblages usually comprise a mixture of extinct and living species. While many of the deposits are of upper Pleistocene or even younger age, it is possible that some collections represent material from more than one stratigraphic horizon. Furthermore, the time ranges of many living species of small marsupials have not been established, and the taxonomic evaluation of the fragmentary material often presents difficulties.

Notes on the cave fossils of south-western Western Australia were published by Glauert (1948) and these embody references to his earlier work in the area. A radiocarbon date of $>$ 37,000 years for one of these occurrences, the Mammoth Cave, has been indicated by Ride (1960). In this latter paper the fauna of the Wombeyan Caves, New South Wales, is discussed and regarded as upper Pleistocene in age.

Studies of cave faunas of Recent age in southern Western Australia by Lundelius (1957) show that the geographic ranges of many living species were vastly different in prehistoric time. Very recent material from caves in the Buchan district of Victoria, listed by Wakefield (1960), is of particular interest in that it includes *Burramys parvus*, previously known only from an assemblage of living and extinct species from the Wombeyan Caves.

As biostratigraphic studies involving our Quaternary mammals proceed, it will be necessary to give special consideration to the local time ranges of species, which vary with time of dispersal and time of extinction. This variation becomes of greater significance with the decrease in age of the fauna.

Mr. Duncan Dow, of the Bureau of Mineral Resources, kindly furnished information on the stratigraphy of the Otibanda Lake Beds, in the Morobe Goldfields area, Territory of New Guinea.

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