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MESOZOIC TO EARLY QUATERNARY MAMMAL FAUNAS OF VICTORIA, SOUTH-EAST AUSTRALIA

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Abstract: Twenty-two terrestrial and over 20 marine mammal faunas are currently recognized in the fossil record of Victoria, representing one of the most complete records of mammal evolution in Australia. Although the earliest recorded terrestrial mammals come from the Early Cretaceous, the majority of the faunas are concentrated in the Pliocene and Pleistocene, whereas the marine mammal record spans the Late Oligocene–Holocene. Despite the generally fragmentary nature of the fossil remains, many of the faunas are diverse and offer insights into the changes in palaeoecology and palaeoenvironmental conditions of the region over time. The terrestrial mammal faunas follow the global trend with the appearance of more arid-adapted species in the late Pliocene; however, a number of Pliocene–Pleistocene coastal sites indicate the continued presence of wet forest refugia, with several relict species occurring in the Early Pleistocene. Most of the faunas are well dated, providing a basis for the production of a biostratigraphic framework, essential for the more accurate dating of mammals in Australia. Two new diverse mammal sites, Childers Cove and Portland, are a welcome addition to the Pliocene records of both terrestrial and marine mammals. Marine mammal research is only in its early stages, but the Victorian record is fundamental in understanding the evolution of cetaceans in the southern oceans. The known diversity of species has increased substantially as a result of recent research. Some well-preserved specimens, including complete skulls, have implications for cetacean systematics, including basal mysticetes. However, much more work needs to be focused on the cataloguing, preparation, description and interpretation of the faunas to take full advantage of this excellent record.

Key words: Australia, Victoria, Marsupialia, Cetacea, fossil sites, faunas.

Several reviews of the Australian terrestrial mammal fossil record have been produced over the last century (e.g. Stirton *et al.* 1968; Woodburne *et al.* 1985; Rich *et al.* 1991). For Victoria, where the fossil record is slightly more complete, a Pliocene–mid Pleistocene faunal succession was compiled by Tedford (1994). For the marine mammals, Fitzgerald (2004*a*) included reviews of the then known fossil records in Australia. However, the majority of the taxonomic work was necessarily preliminary, and did not discuss any details of the marine mammal taxa present in each fauna. No paper has included reviews of both the terrestrial and the marine mammal fossil records. This paper builds on previous reviews, updating ages and faunal descriptions, adding new sites, and outlining prospects for the future.

MATERIAL AND METHODS

The fossil mammal sites are presented in stratigraphic order from the Cretaceous to the Pleistocene. Owing to the large number of Late Pleistocene sites and space restrictions, detailed reviews of the faunas are restricted to Mesozoic through early Quaternary sites only. Pre-Pleistocene faunas are emphasized owing to their relative importance in Australian palaeomammalogy, and significance in establishing the relative ages of Australian terrestrial mammal localities. Furthermore, Victorian Late Pleistocene mammals require extensive revision, which is beyond the scope of the present work.

Text-figure 1 shows the location of all sites discussed in this paper. A correlation chart (Text-fig. 2) shows the relative ages of the faunas, and lithological units from which the fossil material has been collected. All dates determined by magnetic polarity stratigraphy have been updated to the most recent revision of the geomagnetic timescale of Cande and Kent (1995). All K-Ar ages reported prior to 1977 have been corrected using the tables in Dalrymple (1979). Faunal lists for all Victorian Cenozoic terrestrial mammal sites are given in the Appendix. For marine mammal faunal lists, see Fitzgerald (2004*a*).

Dental notation follows that outlined by Smith and Dodson (2003), and dental terminology follows Flower (1867) and Luckett (1993). Institutional abbreviations are as follows; NMV, Museum Victoria, Melbourne; USNM, National Museum of Natural History, Smithsonian Institution, Washington DC.

MESOZOIC TERRESTRIAL MAMMALS

Cretaceous

1. Flat Rocks. The Flat Rocks locality is situated on the coastal shore platform 5 km west of Inverloch (38°39′40 ± 2″ S, 145°40′52 ± 3″ E) (Rich and Vickers-Rich 2004). The first fossil vertebrates were found at the Flat Rocks site in 1991 by L. Kool and M. Cleeland. The locally abundant fossil vertebrates are derived from the Wonthaggi Formation, Strzelecki Group, which is regarded as early Aptian in age (Rich *et al.* 1999).

The first mammal fossil was discovered in 1997 by N. Sanderson (*née* Barton). Fossil mammals are collected by manually breaking up indurated rock and examining each surface thus exposed. Owing to the small size of mammals present in the assemblage, individual teeth are rarely encountered, most specimens being partial mandibles. At present, three mammalian species have been named from this locality. Two are regarded as eutherians, *Ausktribosphenos nyktos* (Rich *et al.* 1997) and *Bishops whitmorei* (Rich *et al.* 2001*a*), and the third, a monotreme, *Teinolophos trusleri* (Rich *et al.* 1999). The allocation of *A. nyktos* and *B. whitmorei* to the Eutheria has been challenged (Rich *et al.* 2001*b*, 2002; Luo *et al.* 2002). In addition to the three formally proposed species from this site, there are at least four more mammals in the assemblage. However, the fossils that indicate the presence of additional species are not regarded as complete enough to serve as adequate holotypes (Rich and Vickers-Rich 2004).

2. Dinosaur Cove. Two mammalian fossils have been recovered from The Pillar, Slippery Rock site, Dinosaur Cove, 12 km north-west of Cape Otway (38°46′53 ± 1″ S, 143°24′15 ± 2″ E) (Rich and Vickers-Rich 2004). Fossil vertebrates were first discovered at Dinosaur Cove in 1980 by M. Archer and T. Flannery. Systematic excavation began in 1984 and continued through 1994. No mammals were recognized from the site until two years after operations were discontinued. Rock collected in a part of Slippery Rock called The Pillar was the only material to have yielded mammalian fossils, although excavations occurred at three separate sites at Dinosaur Cove (Rich and Vickers-Rich 2000). These mammalian fossils were recovered from the Eumerella Formation, Otway Group, this unit being regarded as early Albian (Early Cretaceous) in age (Wagstaff and McEwen-Mason 1989; Constantine 2001). Fossil mammal material comprises the humerus of a monotreme, and a fragment of a mammalian premolar (Rich and Vickers-Rich 2004; Pridmore *et al.* 2005).

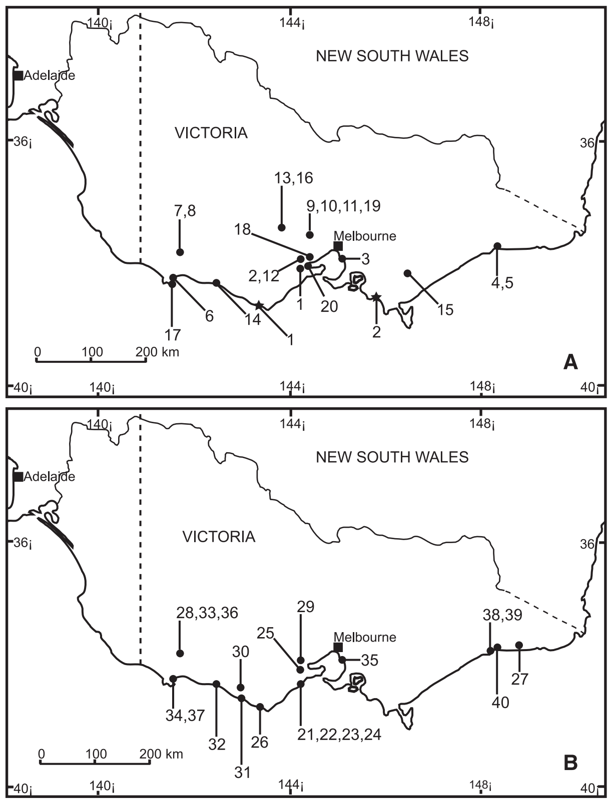
CENOZOIC TERRESTRIAL MAMMALS

Oligocene

1. Waurn Ponds Quarry. One isolated upper incisor (NMV P218425) of an undetermined diprotodontid has been recovered from this locality. This tooth was derived from the Upper Oligocene Waurn Ponds Limestone. See the Waurn Ponds Quarry entry under the marine mammal section for further information on the stratigraphy, and associated fauna of this locality.

Miocene

2. Batesford Quarry. One terrestrial mammal fossil has been recovered from the lower Middle Miocene Batesford Limestone at Batesford Quarry, south of Batesford,



TEXT-FIG. 1. Locations of fossil mammal sites in Victoria. A, terrestrial mammal sites. Stars, Mesozoic sites; circles, Cenozoic sites. B, marine mammal sites. Numbers correspond to site numbers given in the text.

west of Geelong (38°06′ S, 144°17′ E). This specimen (NMV P164999) is the posterior part of the horizontal ramus of a dentary, with the alveoli for two molars present, of a large indeterminate diprotodontid (Rich *et al.* 1991).

3. Beaumaris. Terrestrial fossil mammal material has been collected from the foreshore at Beaumaris sporadically since the 1890s (Hall and Pritchard 1897; Cudmore 1926; Gill 1957; Rich *et al.* 2003). Although not found *in situ*, they have been correlated through fluorine analysis with a nodule bed outcropping at the base of the Black Rock Sandstone in sea cliffs, near Beaumaris, Port Phillip Bay (37°59′ S, 145°03′ E) (Gill 1953, 1957; Rich *et al.* 1991). The Black Rock Sandstone consists of calcareous sands and marl containing an abundant invertebrate fauna (Gill 1957; Abele *et al.* 1988). The nodule bed contains phosphatic, calcareous and ferruginous nodules in a quartz-rich sandy matrix, and marks a regional unconformity that can be correlated with other fossil sites in Victoria, e.g. Grange Burn, Dutton Way (Portland), Lake Tyers (Carter 1978; Dickinson *et al.* 2002). Most fossil material is derived from the nodule bed, but some rarer (and better preserved) specimens, primarily teleost fish, marine birds, pinnipeds and cetaceans, have been retrieved from sediments just above it (Gill 1957; Wilkinson 1969; Fitzgerald 2004*a*).

The nodule bed, and sediments immediately above it, is the type section of the Cheltenhamian Stage (Early Miocene) based on its invertebrate fauna (Singleton 1941; Beu 1973; Mallett 1977). However, some workers have considered it to be lower Pliocene (e.g. Stirton *et al.* 1967, 1968). The rest of the Black Rock Sandstone is Kalimnan (early Pliocene) in age (Abele *et al.* 1988). Recent strontium dates (4·5–5·5 Ma) from molluscs within these sediments supports an early Pliocene age for these sediments (Dickinson *et al.* 2002). It is possible that some of the vertebrate material, including the terrestrial mammals, is reworked from Miocene sediments. A conservative age of latest Late Miocene to earliest early Pliocene is usually given for the Beaumaris Local Fauna (Rich *et al.* 1991; Warne *et al.* 2003).

The material consists of six specimens including partial lower and upper jaws and isolated teeth of two genera of diprotodontoids. They are often highly polished and water-worn. Four specimens including partial upper jaws and an isolated P3 and m4 have been referred to *Zygomaturus gilli* (Stirton 1957, 1967; Woodburne 1969; Rich 1976; Rich *et al.* 2003). The P3, the first terrestrial mammal tooth found at Beaumaris, was previously referred to *Palorchestes* (Hall and Pritchard 1897; Cudmore 1926; Stirton 1957; Woods 1958). Two partial lower jaws have been referred to *Kolopsis* cf. *torus* (Rich 1976; Rich *et al.* 2003). One (NMV P15911a-b) was previously referred to *Sthenurus* (?) (Cudmore 1926; Gill 1957) and *Zygomaturus gilli* (Woodburne 1969). The other (NMV P16279) was bought by Museum Victoria in 1910 and was thought to have come from Queensland, but its origin from Beaumaris has since been verified (Rich *et al.* 2003). In addition, a single M4 of cf. *Palorchestes* sp. (NMV P150124) has been recovered from the Pliocene sediments above the nodule bed. The terrestrial mammal material is associated with more common marine vertebrates (Cudmore 1926; Gill 1957; Rich 1976; Fitzgerald 2004*a*) (see marine mammal entry for Beaumaris).

Pliocene

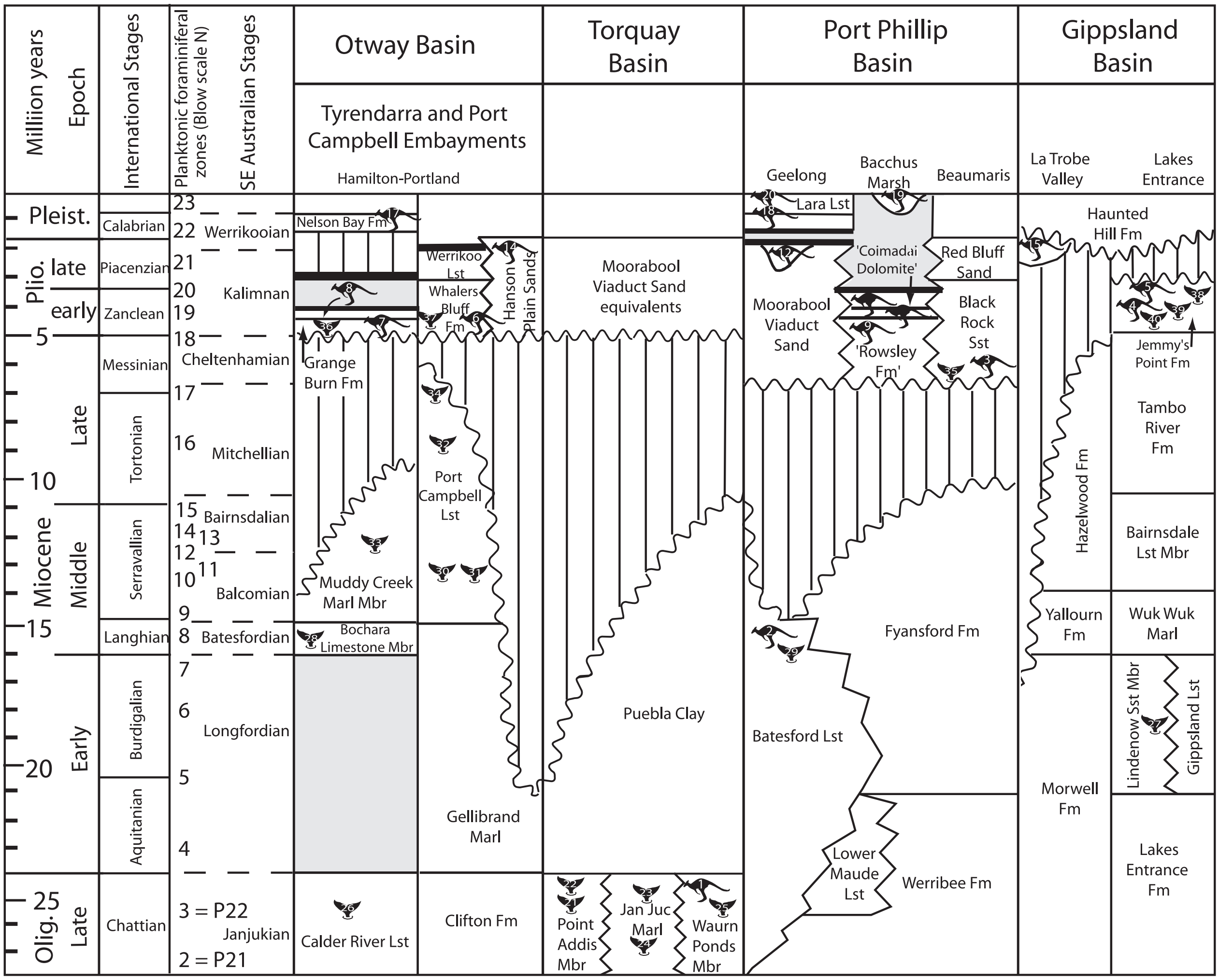
4. Lake Tyers. The material was collected in 1969 from the Jemmy's Point Formation, a marine succession of variable calcareous sandstones with shell beds and rounded pebbles, interpreted as being deposited in a near-shore environment (Warren 1965; Jenkin 1968). The Jemmy's Point Formation is early Kalimnan based on its molluscan fauna (early Pliocene; 3·3–5·0 Ma) (Warren 1965; Jenkin 1968; Abele *et al.* 1988).

The single specimen recovered from a headland on the Nowa Nowa arm of Lake Tyers (37°49·5′ S, 148°7·5′ E) (Plane 1972; Rich *et al.* 1991) consists of portions of the left maxilla, palatine and frontal bones, the complete left lacrimal, four molars and the posterior alveolus of the permanent premolar of a macropod (NMV P26893) (Plane 1972). Originally identified as *Protemnodon otibandus* by Plane (1972), it was later re-examined by Flannery and Archer (1984) who referred it to *Protemnodon chinchillaensis*. The latter species is also present in the Pliocene Bow (New South Wales) and Chinchilla (Queensland) local faunas.

5. Bunga Creek. A single specimen was recovered at this locality from the 'upper shell bed' of the lower Pliocene Jemmy's Point Formation, exposed in a road cutting on the Princes Highway near Bunga Creek (37°50′ S, 148°00′ E) (Warren 1965; Rich *et al.* 1991).

This specimen consists of an incomplete, isolated, left humerus (NMV P22650) belonging to an unidentified marsupial (Warren 1965). Warren (1965) compared it to many different taxa and concluded that it bears the greatest resemblance to didelphoids, in as much as it lacks apomorphic features of more derived marsupials, but could not assign it to any particular group of marsupials.

6. Portland Pliocene beds. This fauna is known from sea cliffs near Dutton Way, north of the township of Portland (38°19′ S, 141°38′ E). The fossil material has



TEXT-FIG. 2. Cenozoic stratigraphy of the Otway, Torquay, Port Philip and Gippsland basins, and relative ages of fossil mammal sites. Terrestrial mammal sites are indicated by a kangaroo symbol, and marine mammal sites by a whale fluke symbol. Numbers in symbols correspond to site numbers given in the text.

been collected since the late 1980s *in situ* from clays, oyster beds and sandy limestone outcropping in cliffs, as float on the beach, and from a reef offshore in Portland Bay. The sediments referred to as the Whaler's Bluff Formation represent shallow marine and barrier system deposition associated with the initial marine incursion in this part of the Otway Basin (Boutakoff 1963; Dickinson *et al.* 2002). Initial deposition of the Whaler's Bluff Formation occurred in the early Pliocene (planktonic foraminifera zone N19; *c.* 4·7 Ma), with sedimentation continuing into zone N21 (late Pliocene) (Dickinson *et al.* 2002). The basalt that caps the formation in the Portland section has been dated using K-Ar to 2·58 Ma (Singleton *et al.* 1976), thus providing an upper constraint on the age of the fauna.

The material consists of isolated teeth and one partial jaw. It is highly polished and rounded and is yellow, brown or black in colour. Where specimens have been exposed to sea-water they have lost their shine, e.g. material from the reef. It is possible that some of the specimens may have been derived from the underlying Port Campbell Limestone. The fauna, yet to be described, includes members of Diprotodontidae, Ektopodontidae, Macropodidae, Palorchestidae and Vombatidae. It is associated with marine mammal material and comparatively rare shark teeth (see marine mammal entry for Portland Pliocene beds) (Fitzgerald 2004*a*).

7. Forsyth's Bank. The fossil material was collected in 1933 from the west bank of Grange Burn, 8 km west of Hamilton (37°43·7′ S, 141°56·7′ E), 1 km downstream from the Hamilton Local Fauna (Colliver 1933; Rich *et al.* 1991; Flannery *et al.* 1992). It is derived from the shallow marine shelly limestones of the Grange Burn Formation, which is Kalimnan (early Pliocene; 3·3–5·0 Ma) based on its molluscan fauna (Ludbrook 1973). Its age cannot be well constrained by magnetic polarity stratigraphy. However, it is older than 4·47 ± 0·1 Ma as it lies stratigraphically below the basalt overlying the Hamilton Local Fauna (Whitelaw 1991). Strontium dating at the base of the Grange Burn Formation gave an age of 5·0–4·0 Ma, supporting the age determined from the molluscan fauna (Dickinson *et al.* 2002).

The material consists of a partial mandible containing alveoli for p3 and m1, and a well-preserved m2 (Gill 1954; Stirton 1957). It was originally identified as belonging to the Sthenurinae (Stirton 1957). This was questioned by Tedford (1966), reported as *Protemnodon* in Rich *et al.* (1991) and finally assigned to *Kurrabi* (Flannery *et al.* 1992). A macropodid right fourth metacarpal (NMV P165577), and a fifth metatarsal (NMV P165576) from the 'upper nodule bed' at Grange Burn are also present in Museum Victoria Palaeontology Collection.

8. Hamilton. The terrestrial fossil mammals were first discovered at Hamilton in the early 1950s (Gill 1957; Stirton 1957) in an unnamed fossil soil horizon that crops out in the banks of the Grange Burn, 7 km west of Hamilton (37°42′ S, 141°57′ E) (Rich *et al.* 1991). The fossil soil is about 1·3–1·5 m thick and overlies the marine marls and limestones of the Grange Burn Formation. It is overlain by a basalt from the Newer Volcanics Series (Gill 1957; Turnbull *et al.* 1965; Rich *et al.* 1991). Subsequent collecting was carried out in 1966–67 and 1977–81 by wet sieving sediment from the fossil soil horizon.

The basalt was sampled directly above the fossil-bearing layer and dated radiometrically using K-Ar to give an age of 4·47 ± 0·1 Ma (Turnbull *et al.* 1965). In addition, further work by Whitelaw (1991) on the magnetic polarity of the basalt and palaeosol provided an age range of 4·35–4·42 Ma (the early Gilbert Chron). The Geomagnetic Polarity Timescale has since been updated (Cande and Kent 1995), and the K-Ar age now fits better within the 4·48–4·62 Ma normal polarity interval. The re-dating of the overlying basalt using a more accurate method such as Ar-Ar would be useful either to confirm or to dispute this older age.

The material collected consists of isolated teeth, jaws and bone scrap. Preservation is generally poor, with only the crowns of teeth being preserved, and enamel is solution-pitted. Bone is very rarely preserved, and there is no trace of non-mammalian vertebrate remains (Turnbull and Lundelius 1970; Flannery *et al.* 1992).

The fauna is well documented and has been described by Turnbull and Lundelius (1970), Rich (1986), Flannery *et al.* (1987, 1992), Turnbull *et al.* (1987*a–c*, 2003), Ride (1993) and Prideaux (2004). It is very diverse, containing members of the Burramyidae, Dasyuridae, Diprotodontidae, Ektopodontidae, Hypsiprymnodontidae, Macropodidae, Palorchestidae, Peramelidae, Petauridae, Phalangeridae, Potoroidae, Pseudocheiridae, Vombatidae and Microchiroptera. Several species are unique to the Hamilton Local Fauna, e.g. *Dorcopsis wintercookorum*, *Kurrabi pelchenorum*, *Milliyowi bunganditj*, *Pseudokoala erlita*, *Pseudocheirus marshalli*, *Strigocuscus notialis*, *Thylogale ignis* and *Trichosurus hamiltonensis*. This fauna records the first appearance of *Thylogale* and *Antechinus* in the fossil record of Australia (Archer 1982; Woodburne *et al.* 1985; Flannery *et al.* 1992) and also records the last occurrence of *Kurrabi*, *Dendrolagus* and *Dorcopsis* in Victoria (Tedford 1994). Even though the sediments were sieved, no rodents were found, but many small marsupials were recovered. This is strong evidence to support the theory that rodents had not yet arrived in Australia or at least not arrived in the south of the continent before the early Pliocene (Marshall 1973).

9. Parwan. The fossil material was collected in 1882 from sediments occurring between two basalt flows during the excavation of a railway cutting, 2 km south-east of Bacchus Marsh, 1·5 km west of Parwan Railway Station (37°41·5′ S, 144°27′ E) (Whitelaw 1991, 1992). Further collecting was carried out in 1968.

The fauna was originally dated as > 3·31 or 3·64 Ma based on the correlation of the overlying basalt with other flows in the surrounding area, and with the K-Ar dated Bullengarook basalt flow 15 km north of Parwan (Woodburne *et al.* 1985; Whitelaw 1991). However, work on the magnetic polarity stratigraphy of the area by Whitelaw (1991, 1992) indicates that the correlations made by Woodburne *et al.* (1985) are not possible as the Parwan sediments and basalts retain normal polarity, whereas the Bullengarook basalts retain reversed polarity. Whitelaw proposed a new age of 4·06–4·20 Ma based on a K-Ar date of 4·14 ± 0·04 Ma obtained from a basalt flow with normal polarity 3·25 km north-west of Parwan (Aziz-ur-Rahman and McDougall 1972), which allowed a correlation of the normal polarity of the Parwan sediments to an interval within the Gilbert Chron (Whitelaw 1991, 1992). As with the Hamilton Local Fauna, since the revision of the Geomagnetic Polarity Timescale (Cande and Kent 1995), this correlation no longer holds true. It is, therefore, suggested that the Parwan Local Fauna correlates with the last normal polarity interval of the Gilbert Chron (4·18–4·29 Ma), and that re-dating of the basalt flows in the area is required.

The undescribed fossil mammal material consists primarily of postcranial material, plus some isolated teeth and partial jaws. The taxa present include the earliest occurrence of *Sarcophilus* (NMV P161351, NMV P30784) in the south-east of Australia (Tedford 1994), a vombatid, a phalangerid (NMV P30782) and rodents (Woodburne *et al.* 1985). This is the earliest reported occurrence of rodents in south-eastern Australia, but the specimens are missing from Museum Victoria so this cannot be confirmed (Tedford 1994).

10. Boxlea. The fossil material was collected in the 1950s from a sandy clay bed of the Rowsley Formation, *c.* 2·7–4·3 m above a coal seam exposed in the Boxlea coal mine, 1·5 km east of Bacchus Marsh (37°41·6′ S, 144°27·3′ E), at the mouth of the Parwan Creek (Whitelaw 1991). This section of the mine is now inaccessible because of flooding (Whitelaw 1992).

The fossiliferous sediments underlie the lower basalt flow of the Parwan Local Fauna as correlated by Woodburne *et al.* (1985) and confirmed by Whitelaw (1991, 1992). As a result this site was initially given the same incorrect age as the Parwan Local Fauna. No magnetic polarity stratigraphic study has been carried out at this site, but as it underlies the Parwan Local Fauna, whose underlying basalt has a normal polarity, an age of > 4·18 Ma can be assigned to the Boxlea Local Fauna (Whitelaw 1991, 1992).

The undescribed material consists of isolated teeth, partial jaws and postcranial fragments. It includes *Propleopus* (NMV P31862), *Trichosurus* (NMV P161330), *Vombatus* (NMV P161329, NMV P201846) and small macropodids (NMV P161329) (Woodburne *et al.* 1985). The *Propleopus* is possibly one of the earliest occurrences of the genus (Tedford 1994).

11. Coimadai. Fossil mammals were first found in the 1890s in the lacustrine Coimadai Dolomites exposed in Alkemades Quarry, *c.* 8 km north-east of Bacchus Marsh (37°37′ S, 144°29·5′ E) (Turnbull *et al.* 1990; Whitelaw 1991). Material continued to be collected up to the early twentieth century while the quarry was operational (Turnbull *et al.* 1990). The site is no longer accessible, as the exposure is now under the waters of Lake Merrimu (Whitelaw 1991).

The initial poorly constrained Miocene or Pliocene age for the Coimadai Dolomites (Officer and Hogg 1897; Coulson 1924) has been improved significantly by the application of magnetic polarity studies. Overlying the dolomites is a 15-cm-thick volcanic ash, sand and gravel layer, which has been correlated to an ash layer that underlies the Bullengarook basalt flow (Woodburne *et al.* 1985). As previously noted in the discussion of the Parwan Local Fauna, K-Ar ages for the Bullengarook basalt flow are 3·31 ± 0·1 and 3·64 ± 0·1 Ma. Whitelaw (1991, 1992) found the dolomites and Bullengarook flow to have reversed polarity, thus correlating them to the 3·58–4·18 Ma interval of the Gilbert Chron. The fauna also supports an early to mid-Pliocene age, as it is similar in composition to the Hamilton, Chinchilla and Bow local faunas from the Pliocene of Victoria, Queensland and New South Wales, respectively (Turnbull *et al.* 1990).

The material consists of isolated teeth, fragmentary cranial and mandibular remains, and limb fragments. Some associated elements are articulated, although preservation is very poor. Most specimens are preserved as moulds, or with only the spongy inner sections of bone remaining, as the more resistant periosteal bone and enamel is destroyed by fluid dissolution. As a result, many specimens are casts made by injecting epoxy resin into the natural moulds (Turnbull *et al.* 1990). The fauna was first described by De Vis (1898). It has since been redescribed by Turnbull *et al.* (1990) and consists of seven taxa, two of which are extant. The collection also includes numerous specimens, mainly postcranial, of unidentifiable macropodids and diprotodontoids (Turnbull *et al.* 1990).

12. Dog Rocks. The Dog Rocks Local Fauna is located in the Australian Portland Cement quarry at Batesford, 7 km north-west of Geelong (38°6·5′ S, 144°17′ E) (Whitelaw 1989; Rich *et al.* 1991). Mammalian fossils were collected by Museum Victoria field parties between 1975 and 1986, from fissure-fill sediments in the Moorabool Viaduct Sand (Rich 1976; Whitelaw 1989). The formation consists mainly of shallow marine sands. Some of the upper units contain leaf material indicating a probable subaerial depositional environment (Bowler 1963). The fissures that cut through these units are filled with sulphurous clay and reworked material from the underlying formations. They are overlain by a basalt flow of the Newer Volcanics series (Whitelaw 1989).

The Moorabool Viaduct Sand is dated as Kalimnan–Cheltenhamian based on its invertebrate fauna (Abele *et al.* 1988). The overlying basalt flow has been assigned an average age of 2·06 ± 0·13 Ma based on K-Ar ages of a series of flows exposed 3 km south of the cement quarry (Aziz-ur-Rahman and McDougall 1972; Woodburne *et al.* 1985). The Moorabool Viaduct Sand, the fissure fills, and the basalt all have a reversed magnetic-polarity signature, but cannot be certainly constrained to a single reversed-polarity interval owing to the presence of erosional unconformities within the sampled sequence (Whitelaw 1989, 1991). However, based on the constraints of the age of the overlying basalt, the stage of evolution of the fauna (which includes diverse rodents), and a maximum age of

4·0 Ma from the presence of the foraminiferan *Globorotalia crassaformis*, it was correlated to the early Matuyama reversed-polarity interval (1·95–2·58 Ma), giving an age of 2·06–2·58 Ma for the Dog Rocks Local Fauna (Whitelaw 1989, 1991).

The material consists of mainly isolated teeth, lower jaws and bone fragments (Whitelaw 1989). A faunal list in Whitelaw (1989) recorded a total of 29 taxa including members of the Dasyuridae, Diprotodontidae, Macropodidae, Peramelidae, Pseudocheiridae and Vombatidae. *Glaucodon ballaratensis* (NMV P207018) has also been reported from this fauna (Gerdtz and Archbold 2003*a*). The first fossil discovered was the left and right mandibles of a large *Zygomaturus* sp. (NMV P42530) (Rich 1976). It was recovered from a block on the quarry floor, originally thought to have come from fissure-fill sediments in the Batesford Limestone (Rich 1976), but has since been correlated with the fissure-fill sediments in the stratigraphically higher Moorabool Viaduct Sand (Whitelaw 1989). The fauna contains the earliest reported occurrence of *Wallabia bicolor* and the earliest secure record of *Macropus* (*Macropus*) sp. in south-east Australia (Tedford 1994). As well as mammals, unidentified remains of fish, amphibians, reptiles and birds have been found (Whitelaw 1989).

13. Smeaton. The fossil material was presented to Museum Victoria in 1914 following its discovery in a well 25 km north of Ballarat, Victoria (37°16′ S, 143°54′ E) (Gill 1957; Stirton 1957; Rich *et al.* 1991). The site was reinvestigated in 1964, mainly to study the stratigraphy. Tuffaceous material plus reworked ash was found to occur within the alternating layers of clay and gravel, indicating that volcanic activity was contemporaneous with the deposition of the fossiliferous sediments (Turnbull *et al.* 1993).

It was originally not possible to date the site accurately, but it was noted that the sediments overlay volcanics, and was tentatively dated as late Pliocene or Pleistocene by Gill (1957) based on geological survey maps. Stirton (1957, p. 133), comparing the stage of evolution of the *Glaucodon* specimen with *Sarcophilus*, suggested it may be 'as old as late Miocene or slightly older', but may be Pliocene if it represented a primitive form. Turnbull *et al.* (1993, p. 437) suggested an age of 'no older than the latest Pliocene' based on the *Macropus* (*Macropus*) remains, occurring first in south-east Australia in the Dog Rocks Local Fauna. A date of 2·17 ± 0·03 Ma was given by Aziz-ur-Rahman and McDougall (1972) for a basalt 4·2 km north of the site, but it has not been directly correlated with the basalt in the well. Therefore only an unsure age of < 2·17 Ma can be assigned to the Smeaton Local Fauna. Turnbull *et al.* (1993) suggested that radiometric dating of the nearby Mt. Moorookyle basalts and shallow seismic surveys could allow the age to be constrained more certainly.

Originally only a single mandible of *Glaucodon ballaratensis* (NMV P16136) (Stirton 1957) was known from the fauna. During the re-excavation of the site, postcranial material of two species of *Macropus*, and the furcula and radius of a bird, cf. *Cygnus*, were recovered (Rich *et al.* 1991; Turnbull *et al.* 1993).

14. Childers Cove. This fauna is known only from a gully in sea cliffs, west end of Childers Cove, 20 km east of Warrnambool (38°29′ S, 142°40′ E). This site was first brought to the attention of Museum Victoria in 1989 by a member of the public. The site was found again in 2001, and further collecting has since been carried out by Museum Victoria and Monash University. The material has been recovered from within and below thin bands of gravel closely associated with calcareous nodule layers present throughout an approximately 1-m-thick horizontally bedded, pale yellow-brown, quartz-rich silty sand. More complete specimens such as partial jaws have been collected from the interface between the sandy sediments and the underlying nodular limestone. These sediments unconformably overlie Port Campbell Limestone and are overlain by Upper Pleistocene dune sands of the Bridgewater Group (Orth 1988).

The Port Campbell Limestone directly underlying the sediments is dated as latest Miocene based on the presence of the foraminiferan *Globorotalia conomiozea* (zone N17–18) (Mallett 1977; Tickell *et al.* 1992). The Childers Cove Local Fauna is suggested to be late Pliocene–early Pleistocene based on the faunal composition and stratigraphic position. The sediments are also of a similar lithology, and may be tentatively interpreted as correlates of the Hanson Plain Sands, which have been dated as Pliocene based on spores and pollen (Tickell *et al.* 1992).

The undescribed material consists of isolated teeth, a few partial jaws and small postcranial elements. Bone is very poorly preserved and often very crumbly. Some teeth are coated in a black residue and may have been exposed to fire. The fauna contains members of the Dasyuridae, Diprotodontidae, Ektopodontidae (Rich *et al.* 2006), Macropodinae, Muridae, Palorchestidae, Phalangeridae, Phascolarctidae, Pseudocheiridae, Sthenurinae, Thylacoleonidae and Vombatidae. Some fish vertebrae have also been collected from this locality.

15. Morwell. The material was collected in 1975 from lacustrine clay that fills depressions formed by fires in a coal seam in the Morwell Open Cut Mine, La Trobe Valley (38°15′ S, 146°29′ E) (Rich 1976; Flannery 1980, 1981; Rich *et al.* 1991). Unfortunately these 'fireholes' no longer exist (Rich *et al.* 1991). The Morwell Formation containing the coal seam has been dated as Late Oligocene–Early

Miocene by Partridge (1971) based on palynology. It is overlain unconformably by the Haunted Hill Gravels, which also overlie the firehole clays (Rich 1976). Pollen studies on the clays suggest an age of early Pliocene–middle Pleistocene (Kirshaw and Sluiter in Rich *et al.* 1991). Based on the mammalian fauna and all other evidence, Flannery (1980) considered the clays to be late Pliocene–early Pleistocene. This is the best estimate so far, but currently no certain age can be assigned to the Morwell Local Fauna.

The fauna includes approximately 40 well-preserved, partially articulated skeletons and skulls, which are often crushed (Rich 1976; Flannery 1980). It includes *Macropus giganteus*, *Protemnodon anak*, a bird, *Pedionomus* sp. (Rich and McEvey 1980), and the endemic *Macropus mundjabus*. Some specimens of *Macropus mundjabus* and *Protemnodon* have preserved cartilage, skin impressions and stomach contents (Flannery 1980, 1981). *Macropus mundjabus* has been interpreted as a rock-dwelling marsupial based on the similarity of its limbs to *Macropus* (*Osphranter*), *Petrogale* and *Dendrolagus* (Flannery 1980). If interpreted correctly, *M. mundjabus* is the only *Macropus* species known to occupy this niche. As well as mammals, fish, ostracods and gastropods have also been collected (Rich 1976; Flannery 1980).

16. Great Buninyong Estate Mine. The fossil mammals were recovered in 1899 from a lacustrine carbonaceous clay at a depth of 67 m in a shaft of the Great Buninyong Estate mine, 10 km south-east of Ballarat, Victoria (37°39′ S, 143°53′ E) (Rich *et al.* 1991). The sediments are overlain by basalts, which have not been directly dated owing to flooding of the mine (De Vis 1899; Keble 1945; Rich *et al.* 1991).

Basalts 10 and 12 km north-east of Ballarat have been assigned K-Ar ages of 2·6 ± 0·07 Ma and 4·0 ± 0·10 Ma, respectively (McDougall *et al.* 1966). Aziz-ur-Rahman and McDougall (1972) suggested that many of the basalts in that region were generated at the same time; however, it is not possible certainly to assign an age of late Pliocene to the site.

The fauna consists of a partial skeleton of *Macropus giganteus*, another small macropodid and unidentified diprotodontid remains (De Vis 1899; Rich 1976; Flannery 1981). If the age is correct the Great Buninyong Estate Mine *Macropus giganteus* is the oldest known occurrence of this species (Rich *et al.* 1991).

Pleistocene

17. Nelson Bay. This fauna is known from sea cliffs of Nelson Bay, 5 km south-west of Portland (38°36′ S, 141°35′ E). The collection of a substantial amount of material has been carried out since the 1970s from Unit B, of the lower member of the Nelson Bay Formation (Boutakoff 1963; Hann 1983). Some material has also been recovered from other clay and sandy beds higher in the cliffs (White 2002). The Nelson Bay Formation is composed of an alternating series of lacustrine and aeolian horizontal and cross-bedded calcarenites, and palaeosols, unconformably overlying a basalt of the Newer Volcanics series, and are in turn unconformably overlain by dune sands of the Bridgewater Group (Boutakoff 1963; Allnutt 1975; Hann 1983).

The Nelson Bay Formation was first dated as early Pleistocene by Boutakoff (1963). He based this age on the presence of a 27–30-m marine abrasion platform that truncates the top of the Nelson Bay Formation and the surrounding basalts, which he correlated to a European interglacial stage (Yarmouth). Aziz-ur-Rahman and McDougall (1972) reported K-Ar ages of 2·83 ± 0·03 Ma and 3·20 ± 0·04 Ma from the Cape (Sir William) Grant basalt which underlies the Nelson Bay Formation. In 1983, McFadden carried out preliminary palaeomagnetic studies on samples from the lower member, and found them to have a reversed magnetic polarity (Hann 1983). This was later confirmed by a more extensive study, which sampled the Nelson Bay and Bridgewater formations. The reversed polarity of the sediments was correlated with the upper part of the Matuyama Chron (1·77–0·78 Ma) based on the ages indicated by the underlying basalts and the presence of *G. truncatulinoides* (zone N22) found within the lower and upper members (Hann 1983; MacFadden *et al.* 1987).

There are over 1000 specimens from this location in the Museum Victoria Palaeontology Collection. The majority of the material consists of isolated teeth, but some partial jaws and associations of teeth are present. Approximately one-third of the collection consists of postcranial material. Bone is less well preserved than enamel and is often shattered and crumbly. The fauna was initially described by Hann (1983), and individual taxa have been described by Flannery and Hann (1984), Archer *et al.* (1997), Gerdtz and Archbold (2003*b*) and Rich *et al.* (2006). Since then substantially more material has been collected. The fauna is currently being re-described by one of us (KP). It is diverse, comparable to the Hamilton Local Fauna, and includes members of the Dasyuridae, Diprotodontidae, Ektopodontidae, Macropodinae, Muridae, Palorchestidae, Peramelidae, Petauridae, Phalangeridae, Phascolarctidae, Pseudocheiridae, Sthenurinae, Thylacinidae, Thylacoleonidae and Vombatidae (Hann 1983; Piper 2005, 2006; Rich *et al.* 2006). Species unique to the Nelson Bay Local Fauna include *Baringa nelsonensis* and *Pseudokoala cathysantamaria*. New species of *Palorchestes* and *Protemnodon* currently being described are shared with the Hamilton Local Fauna (Piper 2006, in press).

18. Duck Ponds. The fauna was discovered in 1875 during the excavation of foundations for a railway viaduct at Lara, near Geelong (38°2′ S, 144°24·4′ E), and as a result is no longer accessible (Wilkinson 1972; Whitelaw 1991, 1993). After some initial confusion over its origin, the material was eventually assigned to the fluviatile muds, clays, sands and gravels that are overlain by the freshwater Lara Limestone and underlain by a Newer Volcanics basalt flow (Wilkinson 1972; Whitelaw 1991). Numerous gastropods and molluscs are found in the sediments and indicate a freshwater, marginal creek environment (Wilkinson 1972).

The fauna was originally dated as 'at least middle Pleistocene, or perhaps older' by Wilkinson (1972, p. 41) based on the combination of taxa present. Aziz-ur-Rahman and McDougall (1972) published a K-Ar age of 1·66 ± 0·03 Ma for the basalt flow exposed on the nearby Werribee Plain, 7 km north-east of Lara. Woodburne *et al.* (1985) correlated the basalt exposed in the viaduct foundations with this flow, so assigned an age of < 1·66 Ma for the Duck Ponds Local Fauna. As the Duck Ponds section is no longer exposed, work on the magnetic polarity stratigraphy of an older section in Limeburner's Bay, 6 km from the viaduct, was carried out (Whitelaw 1991, 1993). The results show that the basalts and older sediments correlate to reversed-polarity intervals of 0·78–0·99 or 1·07–1·77 Ma (Whitelaw 1991, 1993). This provides confirmation of the age of < 1·66 Ma and adds an upper limit of > 0·78 Ma but cannot be constrained further.

The material, described by Wilkinson (1972), consists of isolated teeth, an incomplete jaw, vertebrae and limb fragments. The assemblage contains megafauna only, but is affected by collection bias. The taxa present are: *Thylacoleo carnifex* (NMV P5287), *Diprotodon* cf. *D. optatum* (originally identified as *D. longiceps*) (NMV P1892-3), *Protemnodon* cf. *anak* (NMV P30209) and *Macropus titan* (Wilkinson 1972; Turnbull *et al.* 1992). The combination of *Macropus titan* and *Protemnodon* cf. *anak* is the earliest evidence of the coexistence of these two common elements of Pleistocene faunas (Tedford 1994).

19. Hines Quarry. This fauna was derived from the Hines Kaolin Pit, 9 km south-west of Bacchus Marsh (37°44′ S, 144°22′ E) (Rich 1976; Whitelaw 1991). A large concentration of material was collected during the 1970s from a series of channels that had been cut into the underlying Werribee Formation clay. These channel deposits consist of sands, gravels and reworked clays, and basalt blocks derived from a flow that caps the present-day surface (Rich 1976; Whitelaw 1991).

Woodburne *et al.* (1985) suggested an age of post-Pliocene but pre-late Pleistocene based on the geomorphology of the area. Magnetic polarity stratigraphy carried out in the quarry suggests an age of < 1·07 Ma based on correlation with either the normal-polarity interval of the Brunhes Chron (0·0–0·78 Ma) or Jaramillo Normal Event (0·99–1·07 Ma) (Matuyama Chron) (Whitelaw 1991). A Pleistocene age is also supported by the inferred arid palaeoenvironment of the Hines Quarry site (Long and Mackness 1994).

Numerous partial skeletons, skulls, jaws and postcranial material in varying degrees of articulation and preservation have been collected, but have not yet been described (Rich 1976; Long and Mackness 1994). Taphonomic studies were carried out by Long in 1979 (Long and Mackness 1994). The fauna is dominated by *Diprotodon* sp., but other taxa include *Macropus* sp., *Protemnodon roechus*, *Prionotemnus* sp., *Sminthopsis crassicaudata*, peramelids and murids (Long in Whitelaw 1991; Long and Mackness 1994).

20. Limeburner's Point. The fossil assemblage was collected during the mid nineteenth–early twentieth century from a series of freshwater lacustrine limestones exposed in a section 80 m west of the abandoned Limeburner's Point lime kiln works, Geelong (38°10′ S, 144°24·4′ E) (Pritchard 1895; Whitelaw 1993). These sediments are considered to have been deposited at the same time as the Lara Limestone exposed in the Duck Ponds section. The middle units are compact or thinly bedded, whilst the under- and overlying units are rubbly (Keble 1945; Turnbull *et al.* 1992).

The age of the fauna has been estimated several times based on the vertebrate taxa, geomorphology and stratigraphy (late Pliocene–Late Pleistocene) (Keble 1945; Gill 1964; Wilkinson 1972). Magnetic polarity stratigraphy work by Whitelaw (1991, 1993), together with the constraint of the age of the older Duck Ponds Local Fauna, correlates it to either the normal polarity interval of the Brunhes Chron (0·0–0·78 Ma) or the Jaramillo Normal Event (Matuyama Chron) (0·99–1·07 Ma), giving an age of < 1·07 Ma for the Limeburner's Point Local Fauna (Whitelaw 1991, 1993).

The material mainly consists of isolated teeth, jaws and limb bones. Preservation is fairly good in the compact and thinly bedded limestones and some pieces were found in articulation; however, specimens from the rubbly limestone are poorly preserved owing to fluid dissolution similar to that seen at Coimadai, sometimes leaving only moulds. Taphonomic studies suggest that the material may have been trampled and broken before burial (Turnbull *et al.* 1992). Elements of this fauna have been described by Turnbull *et al.* (1992) and Prideaux (2004); they include members of the Dasyuridae, Diprotodontidae, Macropodidae and Vombatidae.

CENOZOIC MARINE MAMMALS

The State of Victoria has the most complete fossil record of marine mammals in Australia, but paradoxically, this fauna remains almost entirely undocumented. Thirty-six recognized Tertiary marine mammal localities occur in Victoria, the age of these localities spanning the early Late Oligocene to the end of the Pliocene (Fitzgerald 2004*a*). This represents an almost unbroken stratigraphic record for the Late Oligocene through the Neogene. Unfortunately, most occurrences consist of isolated remains, or more rarely, one or two associated (but incomplete) skeletons. This overview is limited to those faunas represented by skeletal elements that can be referred to families. For more complete discussions of the fossil record of cetaceans and other marine vertebrates in Victoria, and the rest of Australia, see Fordyce (1982, 1984, 1991*a*) and Fitzgerald (2004*a*, *b*).

Oligocene

21. Bells Headland. Only one informative specimen has been derived from Bells Headland, located 300 m south-west of Bells Beach, near Torquay, central coastal Victoria (near 38°22′ S, 144°16′ E) (Fitzgerald 2004*a*). This mysticete skull was collected from the lower beds of the Point Addis Limestone Member, a shallow facies equivalent to the Jan Juc Marl. The Jan Juc Marl and its Point Addis Limestone Member are Late Oligocene in age (Abele *et al.* 1988; Holdgate and Gallagher 2003). This specimen (NMV P216928) consists of a very well-preserved, almost complete cranium with the left periotic *in situ*, and the right periotic and ectotympanic separated from the basicranium.

Fordyce (1984) and Köhler and Fordyce (1997) mentioned this specimen very briefly, and suggested that it was perhaps congeneric and/or conspecific with *Mammalodon colliveri* Pritchard, 1939. However, it differs from *Mammalodon colliveri* in several morphological features of the cranium, periotic and tympanic. Its closest affinities lie with an undescribed toothed mysticete from the Jan Juc Marl (see entry for Deadman's Gully), and is almost certainly not referrable to the Mammalodontidae as currently defined (Fitzgerald 2005*a*).

22. Bells Beach. Bells Beach is located south-west of Torquay, along the coast south-west of Melbourne (38°22′ S, 144°17′ E). Isolated cetacean vertebrae and one incomplete skeleton were collected from the Upper Oligocene Point Addis Limestone in 1992. The skeleton (NMV P199587) was referred to the mysticete stem-family Mammalodontidae by Fitzgerald (2004*a*). Although only partially prepared, this specimen does not appear to include any cranial elements apart from one incomplete tympanic bulla and some upper teeth. All of the teeth are heavily worn, as in the holotype specimen of *Mammalodon colliveri* (NMV P199986).

The right mandible is almost complete, although only one tooth (m1) is present. Other preserved elements include a radius, ulna, one metacarpal, several cervical, thoracic and lumbar vertebrae, and at least 14 ribs. Some thoracic ribs display pachyostotic (*sensu* Ricqlès and Buffrénil 2001) histological specializations, although there is no evidence for the pachyosteosclerosis (*sensu* Domning and Buffrénil 1991) seen in some basilosaurid archaeocete ribs (Buffrénil *et al.* 1990). Although the incompleteness of this specimen prohibits taxonomic assignment below the family level, the bulbous roots of m1 differ from those of *Mammalodon colliveri* (which are relatively delicate) to indicate that NMV P199587 may not be referrable to *M. colliveri*.

23. Deadman's Gully. The most complete Palaeogene cetacean skeleton from Australia was recovered from a location near Deadman's Gully, on the coastline south-west of Torquay in Victoria (near 38°20′ S, 144°18′ E) (Fitzgerald 2004*a*, *b*). The skeleton was discovered in a large concretion that had eroded out of the cliff-face. It was derived from the Jan Juc Marl, and is therefore Late Oligocene in age (Fitzgerald 2004*a*). Collected in the late 1990s, this specimen (NMV P216929) has undergone intermittent preparation over the last five years. However, only recently has significant progress been made in removing this specimen from its surrounding matrix. It cannot be assigned to any described family of cetaceans (Fitzgerald 2005*a*). The skull from Bells Headland (NMV P216928) may belong in the same family as NMV P216929 (see above).

24. Bird Rock. The single most productive locality for Palaeogene cetaceans in Australia is at Bird Rock, south-west of Torquay, central coastal Victoria (38°20′54″ S, 144°18′35″ E) (Fitzgerald 2004*a*). All the fossil cetaceans have been recovered from the Jan Juc Marl exposed in extensive cliff and shore platform outcrop, which here represents the stratotype of the local marine Janjukian Stage (Late Oligocene; zones P21–P22) (see Fitzgerald 2004*a* and references therein). The cetacean fossils usually consist of isolated teeth, tympanics, vertebrae and ribs, with skulls and associated skeletons being rare. Only three skulls and four incomplete skeletons have been recovered from this site. This fauna includes *Mammalodon colliveri*, an undescribed mammalodontid, a toothed mysticete related to those from Bells Headland and Deadman's Gully, the odontocete *Prosqualodon* and a probable waipatiid odontocete (Fitzgerald 2004*a*).

25. Waurn Ponds. The Waurn Ponds cetacean fauna has been recovered from only one locality, the Waurn Ponds Quarry (operated by Blue Circle Southern Cement Ltd), south of the township of Waurn Ponds, south-west of Melbourne (near 38°12′ S, 144°16′ E) (Fitzgerald 2004*a*). Most fossil vertebrates have been recovered from a ferruginous intraclastic conglomerate that overlies a hardground (representing a subaerial exposure surface) within the Waurn Ponds Limestone Member (Webb 1995; Nicolaides and Wallace 1997; Fitzgerald 2004*a*). The Waurn Ponds Limestone is a lateral equivalent of the Point Addis Limestone, and in turn, the more basinward facies of the Jan Juc Marl (Abele *et al.* 1988; Holdgate and Gallagher 2003). The Waurn Ponds Limestone is therefore Late Oligocene in age. Rare cetacean fossils have been collected from sandy marl and bryozoan calcarenite that occur above and below the major hardground horizon. One diprotodontid marsupial incisor has been collected from the finer-grained, lower energy, calcarenite beds (see terrestrial mammal entry for Waurn Ponds).

The cetacean remains largely consist of damaged and isolated elements, mostly tympanics and periotics. Vertebrae, rib fragments, teeth and mandibles are comparatively rare. The fauna is dominated by probable mammalodontid mysticetes, and as yet undetermined mysticetes. Relatively large tympanic bullae are superficially similar to those of *Kekenodon onamata* (figured in Kellogg 1936 and Fordyce 1978), and *Eomysticetus whitmorei* (Sanders and Barnes 2002), but precise taxonomic determinations are not possible. Isolated tympanics provide some of the oldest evidence for the presence of 'cetothere' grade baleen-bearing mysticetes in Australia. These tympanics are more derived than those of Mammalodontidae, Aetiocetidae and Eomysticetoidea, being most similar to the tympanics of Early Miocene 'cetothere' (e.g. Kimura and Ozawa 2002). Odontocetes are represented by isolated teeth tentatively referred to ?Squalodontidae, and Odontoceti *incertae sedis*, although the fragmentary nature of these odontocetes does not permit any definitive taxonomic identifications.

26. Castle Cove. Castle Cove has the distinction of yielding the first fossil cetacean (and marine mammal for that matter) formally described from Australia (McCoy 1866, 1867; Mahoney and Ride 1975; Fitzgerald 2004*a*, *b*). This locality occurs north-west of Cape Otway, in limited exposures of the Upper Oligocene Calder River Limestone (near 38°47′ S, 143°25′ E) (Fitzgerald 2004*a*).

Only one cetacean fossil has been recovered from this locality, the holotype specimen of *Parasqualodon wilkinsoni* McCoy, 1866. This specimen consists of a heterodont postcanine tooth. Fitzgerald (2004*a*) summarized previous classification schemes for this specimen. Although it is generally difficult to assign heterodont cetacean teeth with certainty to any particular taxon, the ornamentation of the enamel on this tooth is highly characteristic of *Prosqualodon*, and this tooth is considered to represent an indeterminate prosqualodontid odontocete (Fitzgerald 2004*a*). The overall morphology and size is similar to the teeth of *Prosqualodon davidis* Flynn, 1923, but there are subtle differences (Flynn 1948). These differences may be attributable to intraspecific variation, as suggested by Fordyce (1982), who indicated that *P. wilkinsoni* may be conspecific with *Prosqualodon davidis*, but pending the discovery of more complete material, the more conservative classification of Fitzgerald (2004*a*) is followed here.

Miocene

27. Newmerella. Fossil cetaceans have been collected from a railway cutting about 3 km west of Newmerella, near Orbost in East Gippsland (near 37°45′ S, 148°24′ E). The source unit for these fossils was probably the Lindenow Sandstone Member, Gippsland Limestone Formation (Fitzgerald 2004*a*). This formation is Late Miocene (Longfordian; zones N5–N7) in age (Holdgate and Gallagher 2003).

Most fossils consist of isolated vertebrae and there is one incomplete mandible, which are all probably referable to Mysticeti *incertae sedis* (Fitzgerald 2004*a*). However, Bearlin (1987) has reported a partially prepared mysticete skeleton consisting of a skull, both mandibles and vertebrae. Although regarded by Bearlin (1987) as a balaenopterid, there is no evidence to suggest placement in any cetacean taxon below the level of Mysticeti.

28. Arch Site, Grange Burn. One incomplete mysticete skeleton has been collected from this locality, which is on the southern bank of Grange Burn, opposite a natural arch, north of 'The Caves' property, about 8 km west of the township of Hamilton in western Victoria (near 37°43′30″ S, 141°56′0″ E) (Bearlin 1987; Fitzgerald 2004*a*). The stratigraphic unit from which this skeleton was collected is the Bochara Limestone Member, Port Campbell Limestone. The Bochara Limestone is Batesfordian in age (early Middle Miocene; zones N8–9).

This mysticete skeleton (NMV P26040) is one of the more complete Miocene mysticetes known from the south-west Pacific. It is represented by the following elements: an incomplete skull (mostly from the left side), left periotic, almost complete left mandible, incomplete left scapula and a fairly complete left humerus. Fordyce (1984) suggested that this specimen was a Late Miocene balaenopterid, whereas Bearlin (1988) identified NMV P26040 as a new species of the 'cetothere' *Pelocetus*. Bearlin's (1988) identification was largely based on the very close similarity between the periotic of NMV P26040 and an isolated periotic (USNM 23059) referred by Kellogg (1965) to *Pelocetus calvertensis*. Recently, Geisler and Sanders (2003) have noted that USNM 23059 is not referable to *Pelocetus*, as it differs significantly from the holotype periotic (USNM 11976) of *Pelocetus calvertensis*. USNM 23059 may belong to either *Diorocetus* or *Parietobalaena* (Geisler and Sanders 2003). Renewed comparisons of NMV P26040 with *Diorocetus* and *Parietobalaena* are needed in order to ascertain whether NMV P26040 represents a species of *Diorocetus* or *Parietobalaena*, or perhaps a new genus of 'cetothere'.

29. Batesford Quarry. Cetacean fossils are comparatively rare at Batesford Quarry in the light of the abundance of shark teeth recovered from this locality (Fitzgerald 2004*a*). For locality details and stratigraphic information, see terrestrial mammal entry for Batesford Quarry and Fitzgerald (2004*a*). Almost all cetaceans have been collected from biocalcarenite that comprises the upper 12 m of the Batesford Limestone. This is the type section for the local marine Batesfordian Stage (early Middle Miocene) (Holdgate and Gallagher 2003).

The Batesford cetacean fauna includes only five identifiable specimens: (1) a very fragmentary 'cetothere' mysticete skeleton represented by a tympanic bulla, cervical vertebrae and well-preserved appendicular elements; (2) a 'cetothere' known from a large mandible (*c.* 2 m in length); (3) the symphyseal region of a small (?juvenile) mysticete mandible; (4) an undescribed fragment of mandible with two teeth that appears to be a small physeterid; and (5) the incomplete skeleton of a large squalodontid-like odontocete. This last specimen was described by Bearlin (1982) in a university thesis of limited circulation, and was referred to the Squalodontidae by Fordyce (1982, 1984). The skeleton is represented by: a cranium lacking most of the dorsal presentation, two large heterodont upper cheek teeth, complete left periotic, left malleus, left stapes, left tympanic bulla, left mandible, two thoracic vertebrae, left thyrohyal, left stylohyal and rib fragments. This specimen is superficially similar to squalodontids *sensu stricto* such as *Squalodon calvertensis* and *S. bariensis*, but it has not been demonstrated that the Batesford odontocete is unequivocally a squalodontid. Muizon (1991) formally defined Squalodontidae as including only the genera *Eosqualodon*, *Kelloggia*, *Phoberodon* and *Squalodon*.

The morphology of the teeth would seem to preclude prosqualodontid relationships. The squalodontid relationships of the Batesford 'squalodontid' are difficult to establish, as the definition of the Squalodontidae *sensu stricto* is yet to be clarified. In particular, unequivocal synapomorphies of Squalodontidae have not been identified, despite active inquiry into odontocete phylogeny (e.g. Muizon 1991, 1994; Fordyce 1994; Messenger 1994; Messenger and McGuire 1998; Geisler and Sanders 2003). The Batesford 'squalodontid' periotic is quite unlike that of *Waipatia maerewhenua* (Fordyce 1994), *S. bariensis* (Muizon 1991), *S. bellunensis* (Pilleri *et al.* 1989), *Squalodon calvertensis* (Kellogg 1923), and Late Oligocene 'squalodontoids' from South Carolina (Luo and Eastman 1995). The upper cheek teeth of the Batesford 'squalodontid' do not resemble those of *Patriocetus* (Dubrovo and Sanders 2000), and the figured periotic of *Patriocetus kazakhstanicus* (Dubrovo and Sanders 2000) is too incomplete to warrant meaningful comparisons with the Batesford 'squalodontid' periotic. Further detailed comparisons between the basicranium, tympanic and periotic (which are very well preserved) of the Batesford odontocete with the taxa noted above, *Phoberodon arctirostris*, and prosqualodontids (*sensu* Muizon 2002), are needed to clarify the systematics of this interesting odontocete.

30. Curdie. One incomplete mysticete skeleton has been collected from a limestone quarry, located 5 km north-north-west of Curdie, near Timboon in western Victoria (approximately 38°27′ S, 142°56′ E) (Bearlin 1987; Fitzgerald 2004*a*). The source unit is the Balcombian Port Campbell Limestone (Middle Miocene; zone N10) (Bearlin 1987). This skeleton (NMV P48793) includes an incomplete cranium, left and right periotics, right stapes, fragmentary right mandible, incomplete atlas, axis and a right radius. Bearlin (1988) considered this specimen to represent a primitive balaenopterid; however, in the light of recent work in mysticete systematics (Geisler and Luo 1996; Geisler and Sanders 2003) and new fossil discoveries (Kimura and Ozawa 2002; Dooley *et al.* 2004), this mysticete requires reassessment.

31. Gibson's Steps. One partial mysticete skeleton has been collected from the Middle Miocene (zone N10) Port Campbell Limestone exposed in a cliff section at Gibson's Steps, about 12 km east of Port Campbell, in western Victoria (near 38°40′ S, 143°07′ E) (Bearlin 1987; Fitzgerald 2004*a*). This specimen is too incomplete to allow accurate comparisons with other mysticetes, and is considered herein as 'Cetotheriidae' indeterminate.

32. Hopkins River. The Hopkins River locality occurs on the west bank of the Hopkins River, near Allansford, about 10 km east of Warrnambool in western Victoria (near 38°23′ S, 142°35′ E) (Fitzgerald 2004*a*). Here, the Middle–Upper Miocene (zones N11–N17) Port Campbell Limestone has yielded one partial physeterid odontocete mandible. The teeth of this specimen are very similar to those of other sperm whales referred to the likely form genus *Scaldicetus*.

33. Clifton Bank. The Clifton Bank locality occurs above the riverbank on the west and east sides of Muddy Creek (south of the confluence of Grange Burn and Muddy Creek), and due west of the 'Clifton' property, about 8 km west of Hamilton, in western Victoria (near 37°43′30″ S, 141°56′0″ E) (Fitzgerald 2004*a*). At this locality, the Muddy Creek Marl Member, Port Campbell Limestone, has yielded cetacean fossils. This stratigraphic unit was deposited during the middle Middle–earliest Late Miocene (Fitzgerald 2004*a*). The Muddy Creek Marl is richly fossiliferous, but cetaceans are fragmentary and rare. Most fossils consist of ribs and indeterminate bone fragments, but they are very well preserved.

The cetacean fauna includes indeterminate balaenid mysticetes, cf. *Scaldicetus*, cf. *Physeter* and an indeterminate odontocete (Fitzgerald 2004*a*). *Physeter* may be represented by one well-preserved physeterid periotic.

34. Portland Limestone Cliffs. Cliffs along Portland beach in western Victoria have recently yielded one of the more diverse late Neogene marine vertebrate faunas in the south-west Pacific. These remains, consisting of isolated elements (mostly teeth, tympanics and periotics), are recovered from sandy beds within the Port Campbell Limestone. Although not discussed in detail here, this fauna is noteworthy for producing diverse small chondrichthyan and teleost fish taxa in abundance (Wright, pers. comm. 2004 to EF), unlike most Neogene marine faunas from Australia (as noted by Kemp 1991). At Portland, the Port Campbell Limestone is regarded as representing planktonic foraminiferal zone N16 (Dickinson *et al.* 2002), thus implying that the Port Campbell Limestone at Portland is Late Miocene in age (Mitchellian; *c.* 8·2–10·8 Ma).

This fauna is currently being studied by one of us (EF) and S. Wright. So far, marine mammal taxa identified include two types of small delphinoid, one larger delphinoid, a physeterid similar to the form genus *Scaldicetus*, balaenids and balaenopterids. No pinnipeds have yet been recovered from this fauna, perhaps supporting the hypothesis that pinnipeds were absent in the south-west Pacific until the Cheltenhamian, when they are recorded from the slightly younger Beaumaris Local Fauna.

35. Beaumaris. See the Beaumaris entry under the terrestrial mammal section above, and Fitzgerald (2004*a*), for discussion of the locality, sedimentology and stratigraphy. Fossil marine mammals have been derived from two distinct horizons at Beaumaris: (1) the phosphatic nodule horizon, and (2) the calcareous sandstone immediately above the nodule horizon. Whereas marine mammal material from the nodule horizon is latest Late Miocene–earliest early Pliocene in age, the less abundant fossils from above the nodule horizon are almost undoubtedly earliest early Pliocene, and not Miocene. However, for convenience, both fossiliferous horizons are discussed under the Miocene heading.

Fossil marine mammal material from the nodule horizon consists invariably of isolated, worn and damaged elements. This makes identification of specimens below the family level problematic. Late Miocene–early Pliocene marine mammals from the Beaumaris nodule horizon include phocid pinnipeds, 'cetotheres', balaenids, *Balaenoptera* sp., *Megaptera* sp., large and small physeterids, ziphiids, and small delphinoids (Fitzgerald 2004*a*). Early Pliocene marine mammals from above the nodule horizon include phocid pinnipeds, balaenopterids, a relatively small physeterid and several small delphinoids.

Beaumaris is probably the most diverse fossil marine mammal fauna in Australia. It represents the beginning of relatively modern marine mammal communities in the south-west Pacific. However, there are still archaic elements in the fauna, such as the 'cetotheres' and some of the delphinoids. There appear to be two types of delphinoid present: early delphinids, and more enigmatic forms that are less derived than Delphinidae but possess a suite of features of the periotic and malleus which are difficult to interpret phylogenetically. Some features suggest phocoenid or kentriodontid affinities, but these may only indicate the relatively primitive position of this material in delphinoid phylogeny. Assignment of these dolphins to genera may not be possible because the known material consists only of periotics, tympanics, middle ear ossicles, mandibles, isolated teeth and humeri.

Fordyce and Flannery (1983) identified an isolated right temporal bone (NMV P160399) as that of a monachine phocid pinniped. Other recognized (but undescribed) pinniped fossils from Beaumaris include an articulated series of eight thoracic vertebrae with ribs (NMV P160433), fused sacral vertebrae (NMV P41759) and an isolated tooth (NMV P16198) that may be a phocid incisor (Fordyce and Flannery 1983). The taxonomic affinities of the postcranial remains have yet to be determined. Although these specimens were collected as float derived from the Black Rock Sandstone, the preservation of the fossils and the adhering matrix indicate the stratigraphic provenance of the fossil pinniped material. NMV P41759 was almost certainly derived from the basal nodule horizon, but NMV P160399 and NMV P160433 were derived from the calcareous sandstones immediately above the phosphatic nodule horizon. The articulated vertebrae and temporal are therefore earliest early Pliocene in age, not latest Late Miocene–early Pliocene.

Pliocene

36. Forsyth's Bank to Fossil Rock Stack. See Forsyth's Bank entry in the Pliocene terrestrial mammal section for locality and stratigraphic information, and Fitzgerald (2004*a*). This early Pliocene marine mammal fauna is approximately contemporaneous with the Beaumaris marine mammal fauna (see above). All Grange Burn Formation marine mammals are derived from the basal phosphatic nodule horizon (Fitzgerald 2004*a*). The majority of marine mammal fossils are highly worn and polished, with most occurrences consisting of isolated elements.

Mysticetes are by far the most abundant component of the fauna, being represented by indeterminate 'cetotheres', balaenids and balaenopterids that are close to *Balaenoptera*. These taxonomic identifications are based on incomplete mandibles, basicranial remains, periotics, tympanic bullae, large vertebrae and ribs. Odontocetes include at least two types of Physeteridae, including cf. *Physeter*, and cf. *Scaldicetus*, ziphiids that may be species of *Mesoplodon*, and indeterminate delphinids (Fitzgerald 2004*a*). Phocid seals are represented by one isolated right temporal bone (NMV P160441) (Fordyce and Flannery 1983).

37. Portland Pliocene beds. See the terrestrial mammal entry for Portland for locality and stratigraphic information, and Fitzgerald (2004*a*). Fossil cetaceans from this locality include undetermined balaenids, balaenopterids, cf. *Physeter*, a kogiid, ziphiids and at least 2–3 types of delphinid. Pinnipeds of undetermined affinities are represented by fragmentary remains. The Pliocene marine vertebrate fauna at Portland is currently being studied by one of us (EF).

38. Jemmy's Point. Fossil cetaceans have been recovered from the sandy clays and mollusc-rich beds of the Jemmy's Point Formation exposed in low cliffs at Jemmy's Point, west of Lakes Entrance, East Gippsland (37°53′ S, 147°58′ E). At this locality they represent the type section for the local marine Kalimnan Stage (early Pliocene; zones N18–N19) (Singleton 1941; Wilkins 1963; Carter 1985; Abele *et al.* 1988; Holdgate and Gallagher 2003; Fitzgerald 2004*a*). Very few fossil cetaceans have been collected from this locality, but they include bone fragments, vertebrae and one ziphiid rostrum referred to *Mesoplodon longirostris* by Glaessner (1947).

39. North Arm. Bearlin (1987, 1988) reported a new species of *Megaptera* (Mysticeti: Balaenopteridae) from a locality on the north-west shore of North Arm, Lake King, about 2·5 km north of the township of Lakes Entrance, East Gippsland (close to 37°51′ S, 148°58′ E) (Bearlin 1987; Fitzgerald 2004*a*). This specimen (NMV P179005) was listed by Bearlin (1988) as being from the uppermost Miocene Jemmy's Point Formation. However, the Jemmy's Point Formation is early Pliocene in age, equivalent to planktonic foraminiferal zones N18–N19 (Holdgate and Gallagher 2003). NMV P179005 represents one of the most complete fossil cetaceans from Australia, consisting of an almost complete skull, left and right periotics, left tympanic bulla, fairly complete left and fragmentary right mandible, cervical, thoracic, lumbar and caudal vertebrae, and several ribs. This specimen is unusual among mysticete skeletons of this age from Australia in being well-preserved and consisting of a reasonably complete skeleton.

40. Trident Arm. One identifiable fossil cetacean has been collected, by a University of Melbourne School of Earth Sciences field party, from shoreline outcrop of the lower Pliocene Jemmy's Point Formation at Trident Arm, Lake Tyers, east of Lakes Entrance, East Gippsland (near 37°49′ S, 148°08′ E) (Fitzgerald 2004*a*, *b*). The specimen consists of the partial basicranium of a ?balaenid mysticete. This specimen is too incomplete to allow identification below the family level.

DISCUSSION

Terrestrial mammals

The Victorian fossil record of Mesozoic mammals has been discussed at length in several articles, and at present, little can be added to the picture we currently have of these mammal faunas.

The Pliocene–early Quaternary Victorian terrestrial mammal fossil record appears to be relatively rich compared with the rest of Australia, with approximately the same number of local faunas (LFs) known from Victoria as there are in the other states and territories combined (Rich *et al.* 1991). The total number of taxa recorded from the faunas is also relatively high (150+) compared with Queensland (115+), South Australia (60+) and New South Wales (60+), the next most fossiliferous states in Australia. However, this is due to two highly diverse sites, Hamilton and Nelson Bay, that have yielded over 30 different species each, along with the unconfirmed 24 taxa of the Dog Rocks LF and 20+ from Childers Cove. All other Victorian local faunas contain fewer than ten species, with four containing only one or two. This is in contrast to the other Australian faunas, which contain (on average) 16 taxa, with five containing more than 20 species: Bluff Downs, Chinchilla, Kanunka and Bow LFs and the recently described Mt Etna LF (Hocknull 2005). This is possibly an artefact of the relative amount of attention that has been paid to the other Australian sites compared with the Victorian record. Despite efforts by Museum Victoria in the 1970s and 1980s to prospect for and collect fossil mammal material, only Hamilton, Limeburner's Point, Coimadai, Beaumaris and Smeaton have undergone recent revisions (e.g. Turnbull *et al.* 1990, 1992, 1993, 2003; Flannery *et al.* 1992; Rich *et al.* 2003), and much material remains uncatalogued and undescribed. In recent years, greater focus has been on prospecting for, researching and publishing Australia's Mesozoic and Oligocene–Miocene terrestrial mammal record (Rich 1999).

The majority of the Victorian terrestrial mammal faunas are well dated thanks to the palaeomagnetic work of Whitelaw (1989, 1991, 1992, 1993), abundant Pliocene–Pleistocene volcanics from which radiometric dates can be recorded, and rarer marine intertongues within terrestrial units. The reasonably well-constrained ages of the faunas makes further faunal analyses important for palaeoenvironmental interpretations, and use in Australian fossil terrestrial mammal biochronology. The ages of the Victorian Pliocene–mid Pleistocene faunas span the whole range of the period, which facilitated Tedford's (1994) compilation of a faunal succession for south-east Australia. The rest of the Australian terrestrial mammal record is mainly confined to the early Pliocene, with a few poorly dated late Pliocene sites and a single confirmed early Pleistocene fauna (Jandakot), consisting of a single taxon (Balme 1980). The dating of these sites has mainly relied on stage-of-evolution assessment. This makes the complete description of the Victorian faunas even more crucial, in particular the Dog Rocks and Childers Cove LFs, which lie in the late Pliocene and appear to be relatively diverse.

Although the Pliocene–Pleistocene terrestrial mammal fossil record of Victoria is relatively good, the Oligocene–Miocene record is virtually non-existent. This is a consequence of the geological history of the region; marine basin environments occurred across most of Victoria during this interval. By comparison, the Oligocene–Miocene terrestrial mammal record of Queensland and central Australia is good as a result of the widespread deposition of fluvio-lacustrine sediments during this period. The singular Late Oligocene and Middle Miocene records of terrestrial mammals from Victoria only indicate that relatively large diprotodontoid marsupials were present in Victoria then. Any new discoveries of reasonably complete terrestrial mammals from the Late Oligocene and Middle Miocene marginal marine faunas of Victoria would be of major significance in providing more accurate relative ages for several Oligocene–Miocene terrestrial mammal faunas in central and northern Australia, which currently have poorly constrained ages.

Climate may have played a prominent role in relatively enriching the Pliocene terrestrial mammal record in Victoria. The south-east of Australia appears to have stayed wetter for longer than the rest of the country, resisting the drying trend initiated at the end of the Miocene (Martin 1990, 1991, 1998; Quilty 1994; Macphail 1997). This climatic change resulted in a worldwide increase in plants employing C4 photosynthesis and a significant terrestrial mammal faunal turnover (i.e. decline in arboreal taxa and diversification in terrestrial herbivorous mammals) (Janis 1993; Cerling *et al.* 1997). Although the entire continent experienced a relatively wetter and more humid period during the early Pliocene, only the far south-east saw the return of rainforests (Martin 1990, 1994). This is evidenced by the abundant arboreal and browsing fauna recorded from Hamilton. The unexpected occurrence of ektopodontids, previously thought to be an Oligocene–Miocene obligate rainforest family, in four Victorian Pliocene–Pleistocene sites also indicates that the south-east was experiencing more humid climatic conditions for longer, compared with the rest of Australia. In contrast, an early Pliocene northern Queensland fauna, the Bluff Downs LF, contains primarily large terrestrial forms, with browsing macropodids being comparatively rare, indicating drier and more open conditions (Archer and Wade 1976; Bartholomai 1978; Archer *et al.* 1995).

The collection and description of more material from the Parwan LF (the only other early Pliocene Victorian site for which further prospecting could be made), and description of the Boxlea LF could potentially provide an interesting palaeoenvironmental comparison with the South Australian Palankarinna, Kanunka and Toolapinna LFs that show the climate was becoming increasingly arid in central Australia at this time.

The majority of the mammal genera that appear at the beginning of the Pliocene are either extant or survive until the Late Pleistocene extinction event. Only a few genera are so far endemic to Victoria, e.g. *Baringa* and *Milliyowi*. A faunal turnover has been recorded for the terminal Pliocene, but only at the species level (Tedford 1994). This is in contrast to the terrestrial mammal record on other continents, where a faunal turnover occurs at the genus and species level. However, comparisons between Australian, and for example, North American Miocene–Pliocene terrestrial mammal faunas are made difficult by the fact that the Miocene–Pliocene was a time of increased immigration from Eurasia and South America into North America (Janis *et al.* 1998). Furthermore, the Victorian, indeed the entire Australian, Miocene–Pliocene record is relatively incomplete compared with every other continent except Antarctica (Rich 1991). Because Australia has been isolated for long periods of time, migration has not played a major part in its terrestrial mammal faunal evolution. Only some eutherians, specifically rodents and bats, dispersed south from the south-east Asian archipelago into Australia. Bats had arrived in Australia by the Late Palaeocene (Hand *et al.* 1994; Long *et al.* 2002), whereas rodents probably arrived no earlier than the early Pliocene (Archer *et al.* 1999). There is only one Pliocene record of bats in Victoria in the Hamilton LF, and the first confirmed record of rodents in Victoria is in the Dog Rocks LF.

The Victorian fossil faunas record some of the oldest occurrences of marsupial genera in the Australian continental and south-east Australian fossil record, e.g. *Thylogale* at Hamilton, *Macropus* (*Macropus*) at Great Buninyong and Dog Rocks, *Sarcophilus* at Parwan, and *Propleopus* at Boxlea (Tedford 1994). The Nelson Bay LF is the only diverse early Pleistocene site in Australia known to date, and is Victoria's only pre-Late Pleistocene record of the Tachyglossidae and Thylacinidae. In comparison with the Late Pleistocene, it contains some relatively small species of diprotodontoids and macropodines, plus a large species of ringtail possum. These faunal elements, together with the last known occurrence of the Ektopodontidae, has led to suggestions that the Nelson Bay LF may represent an endemic island fauna (Warne *et al.* 2003). However, large possums and koalas are known from other Pliocene sites (e.g. Curramulka), and the small species appear to be slightly more primitive relative to their Late Pleistocene relatives (Piper 2006), suggesting that the anomalous sizes may in fact be due to the age of the fauna, rather than any selection for body size resulting from an insular environment (Piper 2004, 2006).

Detailed analysis and description of the Dog Rocks and Childers Cove LFs, which between them also contain ektopodontids, small zygomaturines and other small marsupials, should help clarify the faunal changes occurring during the late Pliocene–early Pleistocene. All of these faunas occur on the coast, and contain a large proportion of browsers and arboreal species, indicating that the south coast of Victoria may have become a refuge for forest-dwelling marsupials as climatic change forced grasslands and open woodland to expand across the rest of the region. It is therefore possible that some endemism would occur in these faunas, and may have implications for future biochronological applications. What remains to be explained are the environmental and/or palaeoecological parameters that favoured the longevity of the Ektopodontidae in Victoria, whereas so many other forest-adapted taxa became extinct.

In terms of future work, a considerable amount of material remains to be described. A large collection of Late Pleistocene–Holocene material exists in Museum Victoria. It has been recovered from numerous localities around the state, mainly caves, lakes and creeks, most of which are listed in Horton (1984). No attempt has so far been made to date this material, with the exception of a few of the more diverse sites, e.g. Spring Creek and Lancefield, which have received some attention (Gillespie *et al.* 1978; Flannery and Gott 1984; White and Flannery 1995; Van Huet 1999). The majority of this material is isolated teeth, dentaries and postcranial fragments of typical megafaunal species, e.g. *Diprotodon optatum* and *Macropus giganteus titan*. As collecting has been carried out since the early 1800s, some locality data have been lost. However, there is potential to learn much about the effect of climate change on Victorian faunas and possible reasons for the subsequent extinction of the Pleistocene megafauna.

Marine mammals

Fossil marine mammal faunas in Victoria are abundant and diverse relative to the rest of Australia, areas outside Victoria being studied in less detail and having yielded more fragmentary material. However, compared with fossil marine mammal faunas in New Zealand, the north and south-east Pacific, west Atlantic and south-west Atlantic, the Victorian record is quite poor. The scattered nature of the Victorian (and in general, Australian) record of marine mammals is directly related to the number of reasonably complete specimens available for study, and the amount of effort undertaken to prospect for, and collect, fossil marine mammals. Only very tenuous points can be made about the systematics, composition, palaeoecology, zoogeography and evolution of Victorian marine mammal faunas. Because all interpretations must be based upon accurate systematic work, descriptions of the more complete and diagnostic specimens (skulls) are fundamental to proceeding with higher levels of inference with regard to the areas noted above. All of the most informative specimens remain undescribed, and in many cases incompletely prepared. Because the systematics of most specimens has not been determined, only very broad zoogeographical patterns may be surmised. Despite these problems, the better quality marine mammal fossils from Victoria contribute the majority of our knowledge of Tertiary marine mammal evolution in the seas around Australia.

Most marine mammal fossils discovered in Australia represent mysticete and odontocete cetaceans. One tooth from the Late Oligocene sediments of South Australia may represent a late-surviving dorudontine archaeocete (Fordyce 2002*a*, 2004; Fitzgerald 2004*a*). Fossil records of aquatic Carnivora and Sirenia begin, respectively, in the latest Miocene and early Pliocene, and are only fragmentary. No sirenians have been reported from the diverse and abundant Late Miocene–early Pliocene marine mammal faunas of Victoria, but the extant dugong (*Dugong dugon*) has been recorded from the Holocene of this state (Fitzgerald 2005*b*). In South Australia, an early Pliocene probable dugongine mandible has been reported by Pledge (1992).

Although fragmentary Early Oligocene mysticetes have been reported from South Australia (Fitzgerald 2004*a*; Pledge 2005), representing the oldest fossil marine mammals in Australia, the Victorian record begins in the Late Oligocene. Almost all Victorian Late Oligocene cetaceans are referable to Mammalodontidae and other as yet undetermined toothed mysticete taxa. None of these archaic mysticetes appears closely related to the well-known Oligocene north Pacific Aetiocetidae or terminal Eocene Antarctic Llanocetidae. However, preliminary observations suggest that some Victorian toothed mysticetes share features with an undescribed family of mysticetes reported by Barnes and Sanders (1996) from Late Oligocene deposits in the western Atlantic. Further comments on zoogeographical implications of the possible close relationship between south-west Pacific and western Atlantic mysticetes are inappropriate until the Victorian and western Atlantic forms have been described and compared.

In notable contrast to the Late Oligocene record from New Zealand (Fordyce 1980, 1982, 1988, 1991*b*, 2002*b*) baleen-bearing mysticetes have almost no known Oligocene record in Victoria, or for that matter, Australia. The remains that do exist are very fragmentary and of poor taxonomic utility (isolated and incomplete tympanic bullae). All that may be said is that mysticetes with tympanics displaying more derived morphology than those of mammalodontids, aetiocetids, other toothed mysticetes and Eomysticetoidea were present in Victorian waters during the Late Oligocene. The overall morphology of these tympanics is close enough to that of Early–Middle Miocene 'cetotheres' to indicate that these mysticetes were probably members of that paraphyletic group.

Three distinct types of odontocete are known from the Late Oligocene deposits of Victoria: prosqualodontids, ?squalodontids and ?waipatiids. None of these taxa is represented by diagnostic skull material or periotics. The evidence for the presence of prosqualodontids is based on the distinctively rugose enamel ornamentation characteristic of *Prosqualodon davidis* (see Flynn 1948). The possible squalodontids are represented by isolated teeth, and it is likely that these may not belong to Squalodontidae *sensu stricto* but to another unrecognized family of odontocetes. A partially articulated, incomplete postcranial skeleton may belong to a waipatiid odontocete; however, this tentative taxonomic assignment is based on postcranial elements, which, due to homoplasy in the cetacean postcranial skeleton, are generally unreliable for making definitive identifications of fossil cetaceans. Several posterior cheek teeth associated with this skeleton are superficially similar to those in *Waipatia maerewhenua* Fordyce, 1994; however, further comparisons are required either to refute or to corroborate any relationship between *W. maerewhenua* and NMV P48861.

By the Middle Miocene, Victorian cetacean faunas are generally similar to those from the north-east Pacific and north-west Atlantic, with 'cetotheres', possible balaenopterids, squalodontid-like odontocetes and physeterids present. This fauna is almost certainly artificially impoverished, and further discoveries of new taxa are anticipated. Some of these cetaceans may represent austral antitropical counterparts to well-known boreal taxa.

All Late Miocene–early Pliocene cetaceans comprise representatives of extant families, except for 'cetothere' mysticetes. This stratigraphic interval is the best known section of the Australian fossil record of marine mammals. This is due to the collection of a large volume of material over the last 150 years from sites such as Beaumaris, Grange Burn, Portland and the Gippsland Lakes area. At these locations, marine vertebrate fossils are comparatively abundant in phosphatic nodule horizons (see above). The uppermost Upper Miocene at Beaumaris marks the earliest record of phocid pinnipeds in the south-west Pacific. Due to the large amount of material in museum and university collections, odontocetes are best represented in the Victorian fossil record at the Miocene/Pliocene boundary. Smaller odontocetes, including early delphinids, have a richer Upper Miocene–lower Pliocene record, at Beaumaris and Portland, than previously thought. Study of the late Neogene odontocetes from Victoria will better elucidate relationships with those from the north Pacific and Atlantic, as well as determine whether some of these dolphins are of kentriodontid grade, or are basal delphinids.

A well-preserved, and unusually complete, skull and associated incomplete postcranial skeleton of a megapterine balaenopterid from the lowest Pliocene near Lakes Entrance in East Gippsland is of potential importance in addressing balaenopterid systematics and the megapterine-balaenopterine divergence.

The Victorian fossil record of marine mammals, at present, contributes little to general issues of marine mammal palaeozoogeography, palaeoecology, phylogeny and palaeobiology. However, this is not a reflection of a lack of fossils, rather, a lack of dedicated research.

CONCLUSIONS

Research on fossil mammals in Victoria may be conveniently divided into four main categories: (1) Early Cretaceous terrestrial mammals; (2) late Neogene–early Quaternary terrestrial mammals; (3) late Quaternary terrestrial mammals; and (4) Cenozoic marine mammals. Category 3 on this list is not considered in this review, as noted in the introduction. The relative amounts, and types, of information that 1, 2 and 4 provide to the study of the Australian mammalian fauna vary.

The Victorian Early Cretaceous Flat Rocks locality is the only one of Mesozoic age in Australasia that consistently produces mammalian fossils, and shows no sign of being exhausted in the short term. As such, and due to the significance of the fossil mammals being discovered there, plans are in place to maintain a field programme at this locality for the foreseeable future. That the likelihood of discovering new taxa remains high is emphasized by recent discoveries of entirely new forms, making the Flat Rocks locality among the most diverse Early Cretaceous mammal faunas in the world. Despite over two decades of intensive prospecting for fossil sites within the Otway and Strzelecki ranges of Victoria, it remains plausible that other, as yet undiscovered, fossiliferous sites producing fossil mammals may be discovered in the future. Pending the discovery of skull remains and upper dentitions, knowledge of the phylogeny and palaeobiology of the Ausktribosphenidae is unlikely to advance much beyond its current state.

Late Neogene (latest Miocene onwards) to early Quaternary terrestrial fossil mammals from Victoria are highly significant in that, in some instances, they may be reasonably accurately dated using isotopic approaches and/or biostratigraphy of marine invertebrates. Such absolute and/or reasonably accurate relative dating of terrestrial mammal faunas in Australia is rare (e.g. Rich 1991). The generally well constrained ages of many category 2 terrestrial mammal faunas, and their relatively close stratigraphic relationships, suggest detailed palaeoecological analyses may yield important results with regard to the evolution of south-east Australian mammal faunas during the later Cenozoic environmental perturbations. Of particular note is the occurrence of several well-dated and reasonably diverse late Pliocene–early Pleistocene faunas, of which there are very few in Australia as a whole. Although individual specimens tend to be relatively incomplete, several new species already are emerging as a result of recent research. This suggests that the Victorian record still has much information to reveal, and its study is therefore of key importance in terms of elucidating evolutionary relationships between many common Pliocene–Pleistocene taxa, and is a well-dated source of comparative material for the rest of Australia. With the exception of the *Diprotodon* specimens from Hines Quarry, the incompleteness of many of the fossil specimens indicates that the Victorian record will never enable detailed studies of functional morphology or other aspects of their palaeobiology.

We concur with earlier suggestions by Rich (1999), and Rich in Warne *et al.* (2003), that the greatest potential for significantly advancing knowledge of fossil mammals, indeed fossil vertebrates, in Victoria (and, arguably, Australia; Rich 1999) lies in category 4 research: the Cenozoic marine mammals. There are several reasons to support this claim. First, research on fossil marine mammals (and other Cenozoic marine tetrapods) in Australia is in its infancy, such that the fossil record and evolutionary history of these mammals in and around Australia is known in the only broadest of outlines. Thus, there is wide scope for fundamental description and analysis of fossils in order to fill in the details of this record. Secondly, onshore exposures of Cenozoic marine sedimentary rocks ranging in age from Eocene to Holocene occur over a large area in Victoria and other states in southern and western Australia. Prospecting within these rocks is almost certain to result in the discovery of more important marine mammal, especially cetacean, fossils. Finally, due to the excellent preservation and completeness of many marine mammal fossil specimens, the amount of palaeobiological information that these fossils may yield is very high.

Fossils present in current museum collections (e.g. Museum Victoria) are merely indicative of a potentially rich record of marine mammal, in particular cetacean, evolution in the Southern Ocean. The fact that so little is known of this evolutionary history is only a reflection of a poor history of research and collection in this country. The latter statement is equally applicable to those Victorian late Neogene terrestrial mammal faunas which have well-constrained ages. We anticipate that increased efforts in prospecting for, and collection in the field of, Early Cretaceous–early Quaternary fossil mammals in Victoria will add significantly to knowledge of Australian, and international, palaeomammalogy.

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APPENDIX

Mammalian taxa present in all Cenozoic terrestrial mammal sites discussed in the text. Numbers at top of columns correspond to site numbers in the text. Circles, genus/species present in fauna; cf. tentative identification; ?, possible/unconfirmed presence. Species are listed alphabetically within their family/subfamily.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Monotremata																				
Tachyglossidae																				
'*Zaglossus*' sp.																	•			

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Marsupialia					•															
Dasyuridae								•												
Antechinus sp.								•				•					•			
Dasyurus sp.												•		•						
Glaucodon ballaratensis												•	•							
Sarcophilus l. dixonae																	•			cf.
Sarcophilus sp.									•					•						•
Sminthopsis crassicaudata																			•	
Thylacinidae																				
Thylacinus cynocephalus																	•			
Peramelidae																			•	
Isoodon sp.												•								
Perameles bougainville																	cf.			
Perameles gunnii																	cf.			
Perameles sp.												•								
Peroryctes tedfordi								cf.												
Peroryctes sp.								cf.												
Phascolarctidae																				
Phascolarctos stirtoni														cf.			cf.			
Diprotodontidae	•	•														•				
Diprotodontinae						?														
Diprotodon optatum																	cf.	cf.		cf.
Diprotodon sp.																			•	
Euowenia sp.											•									
Zygomaturinae						•								•						
Kolopsis torus			cf.																	
Kolopsis sp.			•																	
Zygomaturus gilli			•																	
Zygomaturus sp.											cf.	•					•			•
Palorchestidae																				
Palorchestes parvus														cf.			cf.			
Palorchestes sp. nov.								•									•			
Palorchestes sp.			•			•														
Vombatidae						•		•	•					•			•			
Phascolomys medius																				cf.
Phascolonus sp.												•								
Vombatus ursinus											cf.	•								
Vombatus sp.										•										
Thylacoleonidae																				
Thylacoleo carnifex																		•		
Thylacoleo hilli														cf.			cf.			
Thylacoleo sp.														•			•			
Phalangeridae																				
Phalanger sp.								•												
Strigocuscus notialis								•												
Trichosurus hamiltonensis								•												
Trichosurus sp.									cf.	•				•			•			
Ektopodontidae																				
Darcius duggani								•									•			
Ektopodon paucicristata						•								•						
Burramyidae																				
Burramys triradiatus								•												
Pseudocheiridae																				
Pseudocheirus marshalli								•												
Pseudocheirus peregrinus																	cf.			
Pseudocheirus sp.								•				•		•						

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Pseudokoala cathysantamaria																	•			
Pseudokoala erlita								•												
Petauroides stirtoni								•												
Petauridae																	•			
Petaurus australis								cf.												
Petaurus norfolcensis								cf.												
Macropodinae						•	•	•		•		•	•	•		•	•			•
Baringa nelsonensis														cf.			•			
Dendrolagus sp.								cf.												
Dorcopsis wintercookorum								•												
Dorcopsis sp.								•												
Kurrabi pelchenorum								•												
Kurrabi sp.							•				•									
Macropus giganteus/titan												cf.		•	•	•	•	•		
Macropus (*Macropus*) sp.											•	•								
Macropus mundjabus															•					
Macropus irma												cf.								
Macropus parryi																				cf.
Macropus (*Notamacropus*) sp.								•									•			
Prionotemnus sp.																			•	
Protemnodon anak												cf.		cf.	•			cf.		
Protemnodon brehus																	cf.			
Protemnodon chinchillaensis				•																
Protemnodon roechus																	•		•	
Protemnodon sp.								•			•	•		•			•			
Thylogale billardierii																	•			
Thylogale ignis								•												
Troposodon sp.								•			cf.	•								
Wallabia bicolor												cf.								cf.
Wallabia sp.								cf.				•								
Sthenurinae														•			•			
Archaeosimos sp.								cf.												
Metasthenurus newtonae														•						
'*Procoptodon*' *browneorum*														•						
'*Procoptodon*' *mccoyi*																				•
Simosthenurus maddocki														•						
Simosthenurus occidentalis												cf.		•			cf.			
Potoroinae														?			?			
Bettongia sp.												cf.								
Hypsiprymnodon sp.								•												
Jackmahoneya toxonensis								•												
Milliyowi bunganditj								•												
Potorous sp.												•								
Propleopus sp.										•										
Placentalia																				
Muridae									?					•			•		•	
Mastacomys fuscus																	cf.			
Pseudomys higginsi																	cf.			
Pseudomys shortridgei												•								
Pseudomys sp.												•					•			
Microchiroptera								•												