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A review of the Tertiary fossil Cetacea (Mammalia) localities in Australia

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Abstract

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The stratigraphy, age, lithology, and vertebrate fauna of all 56 pre-Pleistocene fossil Cetacea-bearing localities in Australia are reviewed. The majority of these localities occur in the state of Victoria, and are Miocene in age. The most complete cetacean fossils have been recovered from coastal exposures of the Upper Oligocene Jan Juc Formation, south-west of Torquay in the Torquay Basin (Victoria). The inadequately known fossil record of cetaceans in Australia is due to a lack of research, and not a lack of potentially fossiliferous rock outcrop.

Keywords Cetacea, Archaeoceti, Mysticeti, Odontoceti, Australia, localities, fossil record, Tertiary, Oligocene, Miocene, Pliocene

Introduction

Australia has an incompletely known fossil record of cetaceans (whales, dolphins, and porpoises; Order Cetacea). The oldest fossil cetaceans from Australia are Early Oligocene, with the fossil record being best known from the Late Miocene–Early Pliocene (Fig.1 for correlation of cetacean-bearing stratigraphic units). The majority of Australian fossil cetaceans described (but not necessarily published) have been derived from only a few locations. These fossil sites occur within the Paleogene–Neogene marine sedimentary basins along the southern margin of Victoria. Other described fossil cetaceans have been collected from South Australia and Tasmania, although fossil cetaceans from these states are less well represented in museums.

Mahoney and Ride (1975) provided a synopsis of fossil cetacean genera and species described from Australia with information on the history of collection and study. They did not include all cetaceans in institutional palaeontology collections. Fordyce (1982a, 1982b) published important taxonomic reviews of Australian fossil cetaceans based on museum collections. Bearlin (1987, 1988) continued studies on Australian fossil Cetacea, with analyses of Neogene mysticete specimens and their provenance. In all of these studies, research was conducted primarily on specimens in Museum Victoria, Melbourne (NMV), and to a lesser extent on fossils in the South Australian Museum and the School of Earth Sciences, University of Melbourne. The fossil cetaceans in the palaeontology collections of the Tasmanian Museum, Hobart and Queen Victoria Museum, Launceston remain largely unknown.

The Australian fossil record of cetaceans is so poorly known because little systematic prospecting has been carried out. All significant fossil cetaceans have been discovered by accident, often by amateur palaeontologists or members of the public. Initial steps to advance research are: 1, to identify where fossil cetaceans have previously been discovered in Australia; 2, determine the faunal compositions of these localities based on fossils in museum and other collections; 3, conduct a census of the sedimentary geology of these localities; and 4, determine the geological age of the fossil-bearing localities.

This review aims to document localities in Australia from which pre-Pleistocene fossil cetaceans have been recovered. Because this review is principally based on museum and university collections, it is unlikely that all localities have been recognised. Several large private collections exist that include significant material. If accurate locality and stratigraphic data occur with these specimens, it is likely that the real number of fossil cetacean localities is much larger. This review is intended to serve as a companion to Rich and co-workers' (1991) review of Tertiary terrestrial mammal localities.

Overview of localities and the fossil record

The fossiliferous localities in Australia that have yielded cetaceans occur within the offshore and onshore marine, and in one case freshwater, sedimentary basins in south-eastern and southern central Australia. These areas of Paleogene–Neogene sedimentation correspond to the: Otway, Torquay, Port Phillip, and Gippsland basins in Victoria; St Vincent, Murray, Gambier and Lake Eyre basins in South Australia; and the Bass Basin in

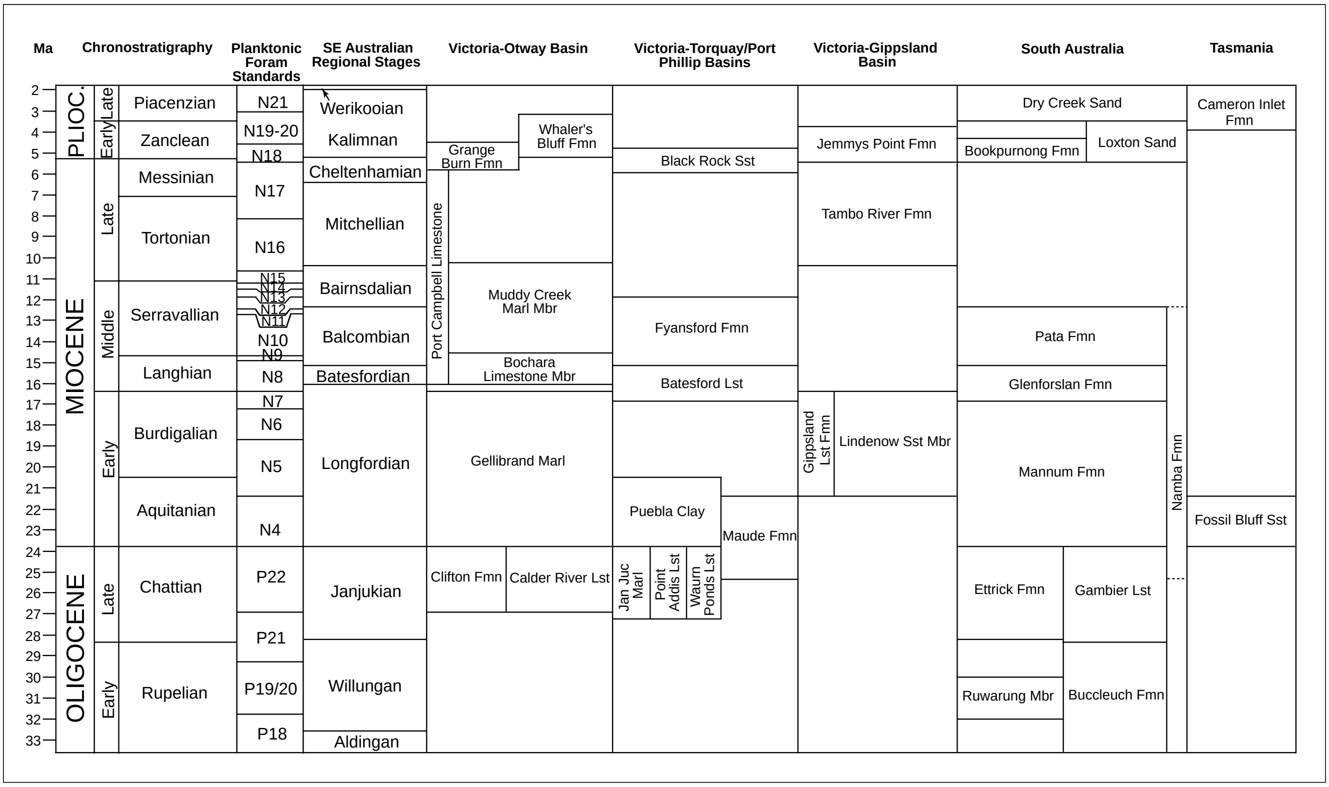

Figure 1. Correlation chart of Oligocene–Pliocene Australian fossil cetacean-bearing stratigraphic units. Abbreviations: Fmn=Formation; Lst=Limestone; Mbr=Member; Sst=Sandstone. Broken lines indicate uncertain maximum and minimum age ranges of stratigraphic units. Ages, chronostratigraphy, and planktonic foram zones modified from Alley et al. (1995) and Holdgate and Gallagher (2003).

Tasmania (Figs 2, 3). The most abundant and diverse fossil records of cetaceans occur in the Otway, Torquay, and Port Phillip basins of Victoria. However, the most complete and best-preserved fossil cetacean material is derived from the Torquay Basin in central coastal Victoria.

The most northern localities are those in the Lake Frome area in north-eastern South Australia (31˚S), whereas the most southern localities occur offshore southern Tasmania (45˚S). The stratigraphic record of cetaceans is most complete for the Miocene, with several localities in South Australia, Victoria, and Tasmania representing the Early, Middle, and Late Miocene (see below). However, most Miocene sites are either Middle or Late Miocene in age. The Late Oligocene record is becoming better known, with a higher diversity of cetaceans than previously recognised (Fitzgerald, 2003, 2004). It is important to note that most of the Late Oligocene fossil cetaceans can probably be referred to Mammalodontidae, and a new undescribed group of archaic toothed mysticetes. No fossil cetaceans have been recorded from the Eocene of Australia (Fordyce, 1982a, 1991). Other poorly documented stratigraphic intervals are the Early Oligocene, early Early Miocene and Late Pliocene.

In Australia, the fossil record of mysticetes is much better known than that for odontocetes (Bearlin, 1987; Fitzgerald, 2004). The Australian Late Oligocene–Late Pliocene record of Mysticeti is particularly informative because it documents stem-group toothed mysticetes (Berta et al., 2003), the archaic baleen-bearing "cetotheres" in the Miocene, early records of Balaenopteridae in the Mid–Late Miocene (Bearlin, 1988), and the transition to a relatively modern mysticete fauna composed of balaenids and balaenopterids in the Late Miocene–early Pliocene (Bearlin, 1987, 1988; Fordyce, 1991).

The Australian fossil record of Odontoceti is known only in broad outlines. This reflects the paucity of complete skulls, preserving diagnostic features, in museum and university collections. There are only two records of fairly complete and diagnostic fossil odontocete skulls in Australia: an undescribed squalodontid from Victoria (Bearlin, 1982), and *Prosqualodon davidis* (Flynn, 1923, 1948) from Tasmania. The skull of the latter specimen is now lost (Mahoney and Ride, 1975) and the former skull lacks the rostrum and most of the dorsal surface of the cranium. However, the remainder of the holotype specimen of *P. davidi*s, consisting of much of the postcranial skeleton and mandibles, is still extant in the collection of the Department of Geology, University of Tasmania. Most odontocete fossils are represented by isolated mandibles, teeth, periotics and tympanic bullae. An exception is an incompletely prepared, partially articulated, postcranial skeleton from the Late Oligocene of Victoria (NMV P48861). Although lacking cranial elements (apart from several teeth), the morphology of the scapula indicates that this specimen may represent a primitive eurhinodelphinid odontocete.

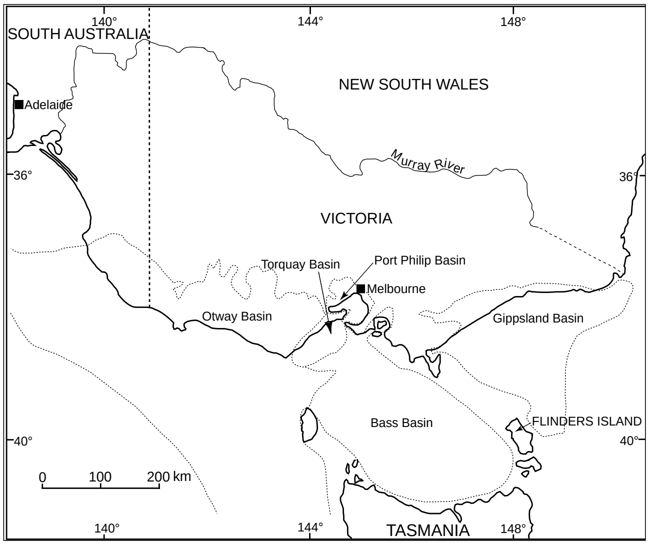

Figure 2. Tertiary sedimentary basins with fossil Cetacea localities in Victoria and Tasmania. Modified from Abele et al. (1988) and Holdgate and Gallagher (2003).

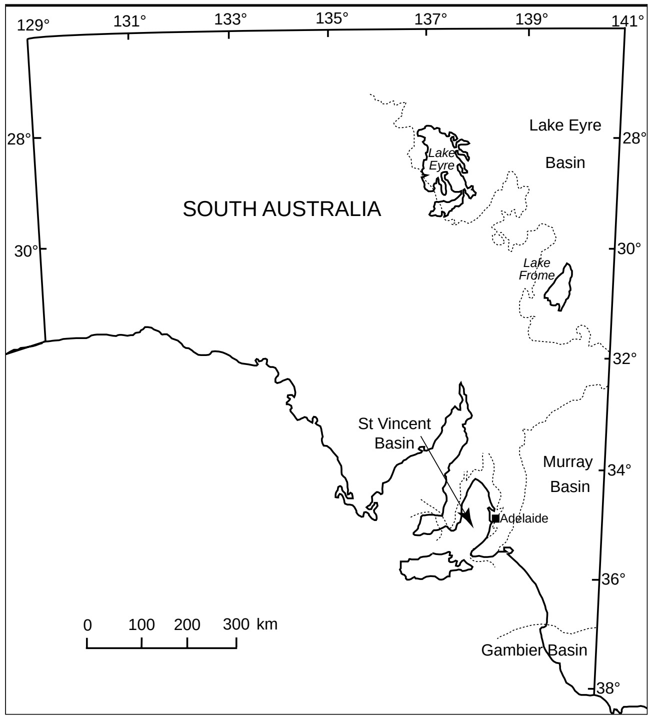

Figure 3. Tertiary sedimentary basins with fossil Cetacea localities in South Australia. Modified from Alley et al. (1995).

Taxonomy

Systematic biologists have yet to reach a consensus on cetacean systematics and taxonomy. This is largely due to the publication of numerous divergent phylogenetic hypotheses, utilising both molecular and morphological data sets, over the last two decades (e.g., Arnason and Gullberg, 1994; Geisler and Luo, 1996; Heyning, 1989, 1997; Messenger and McGuire, 1998; Milinkovitch et al., 1993; Zhou, 1982). Higher classification schemes were reassessed by Geisler and Sanders (2003) but the more conventional classification of Fordyce and Muizon (2001) is followed herein. The classification of non-cetacean mammals follows McKenna and Bell (1997). For non-mammalian tetrapods, osteichthyans, and most chondrichthyans, the classification of Carroll (1988) is used. Some modifications to chondrichthyan taxonomy presented in Carroll (1988) and Kemp (1991) have been made following a recent review by Purdy and colleagues (2001). Fossil species of great-toothed sharks are referred to the genus *Carcharodon*, and not *Carcharocles*, following Gottfried and Fordyce (2001).

Faunal lists

Few Australian workers have studied Cainozoic marine vertebrate faunas in detail, with notable exceptions being Bearlin (1987), Chapman and Cudmore (1924), Chapman and Pritchard (1904, 1907), Fordyce (1984, 1991), Kemp (1970, 1982, 1991), and Pledge (1985). Kemp (1991) outlined the various biases affecting the taxonomic compositions of chondrichthyan faunas in Australia, and his conclusions may be applied to cetaceans. Most of the substantial Tertiary marine vertebrate holdings of Museum Victoria were obtained prior to 1980. Indeed, most of the collection of Cainozoic marine vertebrate fossils dates from the first half of the twentieth century. It is, therefore, inevitable that identifications and alpha taxonomic studies were influenced by the taxonomic references of the time and contemporary philosophical approaches to systematics. The faunal lists presented herein reflect these biases. However, given the paucity of new material (apart from cetaceans) added to museum collections over the last 30 years, it is unlikely that the taxonomy requires major reassessment. Of more singular importance is the incomplete nature of the faunal lists, due to the lack of identification of many specimens. It is highly probable that the faunal lists represent artificially impoverished faunas, particularly of marine tetrapods and osteichthyan fish.

For cetaceans and other marine tetrapods, faunal lists have been compiled from my personal observations and consultation of published (Bearlin, 1988; Fordyce, 1982a, 1984, 1991; Pledge, 1985) and unpublished (Bearlin, 1987) studies. Terrestrial and freshwater vertebrate faunas were adopted from Rich and others (1991), and unpublished data provided by K. Piper. Chondrichthyan and osteichthyan faunas were adapted from information in Kemp (1978, 1991), Pledge (1985) and Stinton (1958, 1963) as well as my own observations. Although Pledge (1967) reviewed South Australian Tertiary chondrichthyans, his published localities for chondrichthyans cannot be correlated with South Australian cetacean localities. Many of the identifications of marine tetrapods, and their taxonomic affinities, are preliminary.

Information on the Australian Cainozoic fossil record of marine birds may be found in: Finlayson (1938), Glaessner (1955), Jenkins (1974, 1990), Simpson (1957, 1959, 1965, 1970), Rich (1975), Vickers-Rich (1991), Vickers-Rich and Rich (1993) and Wilkinson (1969). For more detailed information on Cainozoic fossil marine fish see Chapman (1913, 1917a, 1930), Chapman and Cudmore (1924), Chapman and Pritchard (1904, 1907) and Kemp (1991).

Localities

For the purposes of this review, a locality is defined as a limited area where fossils have been derived from one particular stratigraphic unit. However, there is some variation in the use of the term "locality" when applied to sites that have yielded fossil cetaceans. For example, cetacean fossils have been recovered from an area around Bird Rock, Torquay, which encompasses outcrop in the shore platform, and in the cliff sections, at varying heights above the base of the cliff. Furthermore, fossils may have been derived from an area in the immediate vicinity of the Bird Rock stack, or up to 150 m south-west of Bird Rock. This contrasts with localities such as Clifton Bank, along Muddy Creek, where there is only a small area of outcrop within a limited area. In most cases, field collection data for specimens is not detailed enough to enable precise limits to be placed on the area of a locality. Hence, these localities have a relatively broad definition.

Stratigraphy

Unless otherwise indicated, stratigraphic nomenclature follows that of Abele and colleagues (1988) and Holdgate and Gallagher (2003) for Victoria, and Alley and co-workers (1995) for South Australia. Determination of the stratigraphic position of most localities was based on work in Abele and colleagues (1988, and references therein), data presented by Alley and others (1995), and Lukasik and James (1998).

Australian fossil Cetacea localities

VICTORIA (Fig. 4)

1. The Otway Basin (Fig.5)

1.1 Dutton Way, Portland

Geographic location. This site consists of several disjunct points along south-south-east facing sea cliffs and beach on the north-west side of Portland Bay, north of Portland (38°19'S, 141°38'E). Fragmentary material has also been collected from reefs and the seafloor in Portland Bay, in water depths of up to 100 m.

Stratigraphic position. The fossiliferous horizon that has yielded fossil cetaceans has been identified as a phosphatic nodule bed at the base of the Whaler's Bluff Formation.

Age. Early Pliocene. The onshore Whaler's Bluff Formation has been dated to zones N18-N19 (Mallett, 1977). Dating of the offshore deposits of the Whaler's Bluff Formation indicate that sedimentation continued into the mid-Pliocene (zones N19-N21) (Holdgate and Gallagher, 2003). It is likely that most of the fossil cetacean material was derived from the nodule horizon and therefore has a maximum age of earliest Pliocene.

Lithology. The main lithologies present include a basal phosphatic nodule bed, fossiliferous clays, oyster beds, and sandy limestones (Holdgate and Gallagher, 2003).

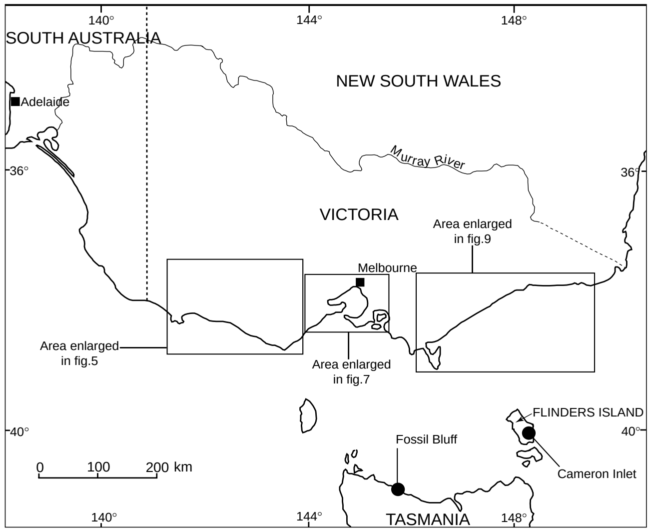

Figure 4. Areas with fossil cetacean-bearing localities in Victoria and Tasmania. Solid circles represent fossil Cetacea localities. Modified from Abele et al. (1988) and Holdgate and Gallagher (2003).

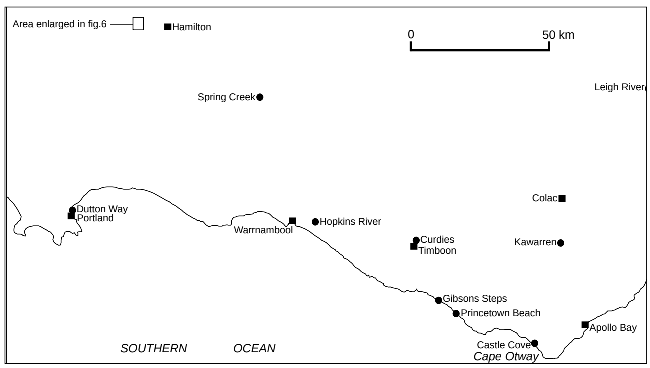

Figure 5. Fossil Cetacea localities in the Otway Basin, western Victoria. Solid circles represent fossil Cetacea localities.

Material. All worn, isolated elements: cranial fragments, periotics, tympanics, teeth, vertebrae, rib fragments.

Fauna. Carcharodon megalodon, Carcharodon carcharias, Isurus hastalis, Isurus sp., Palorchestidae, Vombatidae, Macropodidae, Ektopodontidae, ?Phocidae, Balaenidae, *Balaenoptera* sp., *Megaptera* sp., Physeteridae, Ziphiidae, Delphinidae: 2 species.

1.2 Arch Site, Grange Burn (Fig.6 for localities 1.2–1.4)

Geographic location. Resting on a quartz porphyry bar at the base of a low cliff on the southern bank of Grange Burn, opposite a natural arch, immediately north of "The Caves" property, 8 km west of Hamilton, western Victoria (near 37°43'30"S, 141°56'0"E) (Bearlin, 1987).

Stratigraphic position. Bochara Limestone Member, Port Campbell Limestone, unconformably overlying Devonian Rocklands Rhyolite.

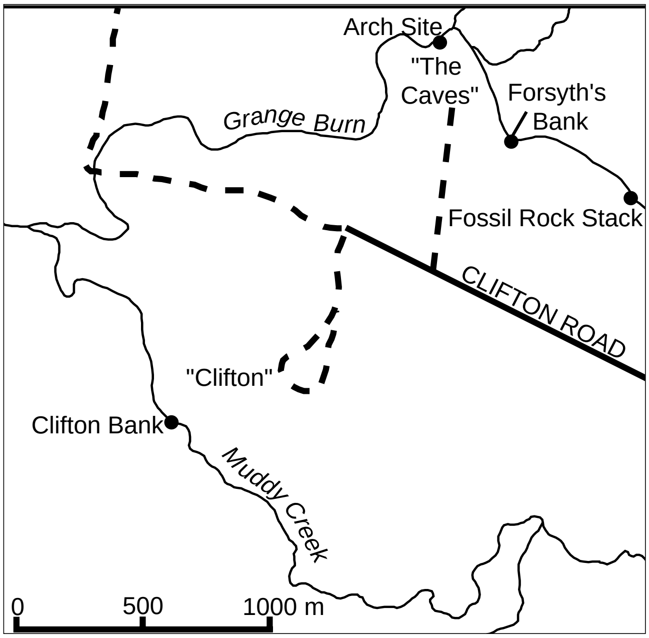

Figure 6. Fossil Cetacea localities in the Grange Burn area, west of Hamilton in western Victoria. Solid circles represent fossil Cetacea localities.

Age. Early Middle Miocene. The foraminifera *Lepidocyclina howchini* in the matrix suggests a zone N8–N9 (Batesfordian) age for the cetacean fossils from this locality (Bearlin, 1987).

Lithology. Yellow-brown bryozoal calcarenite.

Material. One partial skeleton.

Fauna. *Carcharodon megalodon, Isurus hastalis, Pelocetus* sp.

1.3 Clifton Bank

Geographic location. Low cliffs above the riverbank on the western and eastern sides of Muddy Creek (south of the junction of Grange Burn and Muddy Creek), and due west of the "Clifton" property, located 8 km west of Hamilton (near 37˚43'30"S, 141˚56'0"E).

Stratigraphic position. Muddy Creek Marl Member, Port Campbell Limestone. In more complete sections along Grange Burn, e.g. at Pat's Gully (see Gill, 1957), the Muddy Creek Marl is conformably underlain by the Bochara Limestone (Gill, 1957), and disconformably overlain by the Grange Burn Formation.

Age. Middle Middle Miocene to early Late Miocene. Sr/Sr dating of shells from 1 m below the base of the Grange Burn Formation, within the Muddy Creek Marl, yielded an age of 10.8 Ma (Dickinson et al., 2002). The presence of the foraminiferan *Orbulina suturalis* indicates a zone N10 age (Middle Miocene, Serravallian, 12–14 Ma) (Abele et al., 1988). However, the Muddy Creek Marl can range as high as zone N16 (up to ~8 Ma) (Singleton et al., 1976). *Acacia* pollen have been recorded from the base of the Muddy Creek Marl, at Clifton Bank, which indicate that this member lies above the top of the *Cyatheacidites annulatus* Zone (Harris, 1971); this suggests that the Muddy Creek Marl Member is younger than 15 Ma. Gill (1957) suggested a Middle or Lower Miocene age (Balcombian) for the Muddy Creek Marl.

Lithology. Richly fossiliferous grey silty marl.

Material. Fossil cetacean elements are generally very well preserved, although no articulated skulls and skeletons have yet been recovered from this unit. Elements preserved include vertebrae, ribs, and periotics.

Fauna. Carcharias sp., *Carcharias taurus, Odontaspis acutissima, Isurus hastalis, Isurus retroflexus, Isurus desori, Isurus planus, Isurus* cf. *paucus, Isurus* sp., *Carcharodon megalodon, Carcharodon* sp., *Galeocerdo aduncus, Notorynchus primigenius*, Dasyatidae, *Heterenchelys regularis, Muraenesox obrutus, Hypomesus glaber, Merluccius fimbriatus, Trachichthodes salebrosus, Sebastodes fissicostatus, Sillago pliocaenica, Diodon formosus*, Balaenidae, *Scaldicetus lodgei*, cf. *Physeter* sp., Odontoceti indet.

1.4 Forsyth's Bank to Fossil Rock Stack

Geographic location. River bank and river bed exposures along and in Grange Burn, south-east of "The Caves" homestead, 8 km west of Hamilton (37˚43'42±03"S, 141˚56'40±04"E).

Stratigraphic position. Grange Burn Formation, unconformably overlying the Muddy Creek Marl. The base of the Grange Burn Formation is marked by a phosphatic nodule bed horizon (Gill, 1957; Dickinson et al., 2002; Holdgate and Gallagher, 2003). In most sections where the top of the Grange Burn Formation is exposed, a basalt layer disconformably overlies the marine sediments (Gill, 1957). Further to the south-east along the Grange Burn, a terrestrial palaeosol facies is present between the Grange Burn Formation and the basalt.

Age. The Grange Burn Formation has generally been considered as Kalimnan (Early Pliocene) in age, due to the composition of the rich invertebrate macrofauna (Gill, 1957). Foraminifera dates indicate a zone N17 age (Mallett, 1977). The basalt above the Grange Burn Formation has been dated to 4.35 Ma using K-Ar (Turnbull et al., 1965). More recently, Sr/Sr dates from the base of the Grange Burn Formation indicated a 4.0–5.0 Ma maximum age for the formation (Dickinson et al., 2002). These data indicate an earliest Early Pliocene age for the Grange Burn Formation.

Lithology. Shelly marl and sandy to pebbly limestone (Holdgate and Gallagher, 2003).

Material. As is typical of most Mio-Pliocene nodule bed fossil vertebrate material in Victoria, fossils are often rolled, polished, and broken. Almost all specimens represent isolated elements, with associated material being very rare. Typically preserved elements include partial rostra, cranial fragments, isolated periotics and tympanic bullae, teeth, incomplete mandibles, vertebrae, and ribs.

Fauna. Heterodontus cainozoicus, Carcharodon megalodon, Carcharodon carcharias, Isurus escheri , Isurus hastalis, Myliobatis sp., *Edaphodon sweeti, Ischyodus* cf. *dolloi, Kurrabi* sp., Phocidae, "Cetotheriidae", *Balaenoptera* sp., cf. *Scaldicetus* sp., cf. *Physeter* sp., cf. *Mesoplodon* sp., ?Delphinidae.

1.5 Spring Creek

Geographic location. Bed of Spring Creek, near Minhamite, 40 km south-east of Hamilton (near 37°59'S, 142°20'E).

Stratigraphic position. Unnamed unit (Abele et al., 1988). This unit is probably laterally equivalent to the Grange Burn Formation. Gill (1957) mentioned a Kalimnan-aged location "from Goodwood station near Minhamite Railway Station 25 miles (40.2 km) SE of Hamilton" (p. 152).

Age. Presumed Late Miocene–Early Pliocene. T.A. Darragh (pers. comm. to G.G. Simpson, cited in Simpson (1970)) has suggested a Cheltenhamian (Upper Miocene) or older age for the Spring Creek beds near Minhamite. Simpson (1970) suggested that the Spring Creek locality was equivalent in age to the Black Rock Sandstone at Beaumaris.

Lithology. Fossiliferous green-grey marly fine sand approximately 1 m thick (Abele et al., 1988).

Material. Worn and polished isolated elements: periotics and indeterminate bone fragments.

Fauna. Pseudaptenodytes macraei, Balaenoptera sp.

1.6 Kawarren

Geographic location. Old "Alkemade's Quarry", slightly north of Kawarren railway station, on the steep north bank of Loves Creek, Kawarren, about 19 km south of Colac (near 38°29'S, 143°35'E).

Stratigraphic position. Clifton Formation (Abele et al., 1988; McHaffie and Inan, 1988).

Age. In the north-east margins of the Port Campbell Embayment, the Clifton Formation is Late Oligocene (Abele et al., 1988).

Lithology. The Clifton Formation is generally a medium-coarse-grained calcarenite, with about 10% quartz and limonite sand (Tickell et al., 1992). At the Kawarren Quarry, this unit consists of friable, pale yellow limestone interbedded with harder crystalline bands (McHaffie and Inan, 1988). All of the vertebrate fossils have been recovered from the more friable calcarenite layers.

Material. Generally well-preserved isolated elements, exhibiting a low degree of rolling. Elements preserved include teeth, ribs and bone fragments.

Fauna. Carcharias sp., *Isurus* sp., I*surus desori, Carcharoides* sp., *Carcharoides totuserratus, Carcharodon angustidens,* ?Mysticeti new family.

1.7 Leigh River

Geographic location. Outcrop on the eastern bank of the Leigh River, about 5 km north of Shelford, 46 km north-east of Geelong (near 38°00'S, 143°58'E).

Stratigraphic position. Middle section of the Gellibrand Marl (Abele et al., 1988; Dickinson et al., 2002).

Age. Probably Early Miocene. In the north-east part of the Port Campbell Embayment, the Gellibrand Marl ranges in age from Late Oligocene to Middle Miocene (Abele et al., 1988). Outcrop along the Leigh River is Early Miocene in age, as the Late Oligocene-aged base of the formation is not exposed, and the youngest Middle Miocene (Bairnsdalian) section has probably been eroded, or not deposited, due to the Leigh River locality being at the embayment margin (Abele et al., 1988).

Lithology. Marl, calcareous silt, clay, and sand with minor calcarenite layers.

Material. One well-preserved isolated tooth.

Fauna. Isurus sp., Cetacea indet.

1.8 Hopkins River

Geographic location. North end of outcrop in a quarry on the west bank of the Hopkins River, 150 m south of the Princes Highway bridge over the Hopkins River, near Allansford, about 10 km east of Warrnambool (near 38°23'S, 142°35'E).

Stratigraphic position. Port Campbell Limestone sensu stricto (Abele et al., 1988; Tickell et al., 1992).

Age. Middle–Late Miocene, zones N11-N17 (Holdgate and Gallagher, 2003).

Lithology. Yellow fine-grained calcarenite.

Material. A fairly well-preserved posterior part of mandible with two large conical teeth in place.

Fauna. cf. *Scaldicetus* sp.

1.9 Gibson's Steps

Geographic location. Cliff at Gibson's Steps, approximately 12 km east of Port Campbell, western Victoria (near 38°40'S, 143°07'E).

Stratigraphic position. Port Campbell Limestone (Bearlin, 1987; Abele et al., 1988; Tickell et al., 1992).

Age. Bairnsdalian, Middle Miocene, zone N10 (Bearlin, 1987).

Lithology. Yellow-grey fine-grained calcarenite.

Material. One partial skeleton

Fauna. "Cetotheriidae".

1.10 Curdie

Geographic location. "Kurdeez" Quarry (Victorian Agricultural Lime Ltd), 5 km north-north-west of Curdie, near Timboon (approximately 38°27'S, 142°56'E).

Stratigraphic position. Port Campbell Limestone.

Age. Balcombian, correlated with zone N10, Serravallian, Middle Miocene (Bearlin, 1987).

Lithology. Calcarenite.

Material. One partial skeleton.

Fauna. ?Balaenopteridae.

1.11 Princetown Beach

Geographic location. Near Point Ronald, Princetown, 18 km east of Port Campbell, western Victoria (38˚42'S, 143˚09'E).

Stratigraphic position. Nodule bed within the Clifton Formation.

Age. Late Oligocene. Below the unnamed nodule horizon, shells have given Sr/Sr dates of 27.4 Ma (Holdgate and Gallagher, 2003). Immediately above the nodule bed Sr/Sr dates average ~24.0 Ma. Foraminifera from the Clifton Formation indicate a zone P21b-P22 age (Late Oligocene).

Lithology. Thin horizon of phosphate and limonite nodules within limestone-sandy limestone matrix.

Material. One worn and polished incomplete rib.

Fauna. *Odontaspis* sp., Cetacea indet.

1.12 Castle Cove

Geographic location. One of two possible locations: (1) type locality for the Calder River Limestone along the south-eastern bank of the Calder River, north-west of Hordern Vale, or (2) on the coast 1.7 km south-east of Castle Cove. Both sites are on the western side of Cape Otway, and east of Point Reginald, in the Aire district (near 38˚47'S, 143˚25'E). Etheridge (1878) noted that the holotype tooth of *Parasqualodon wilkinsoni* was found west of the Aire River.

Stratigraphic position. Calder River Limestone. Fordyce (1982a) suggested that the holotype specimen of *Parasqualodon wilkinsoni* was derived from the Calder River Limestone, despite the fact that there is no direct evidence that would indicate such a derivation. However, there are two lines of evidence that indirectly suggest the provenance of the holotype of *Parasqualodon wilkinsoni*: (1) the holotype tooth preserves distinctive features suggesting affinities with *Prosqualodon davidis* (indeed, this isolated tooth may be congeneric with *P. davidis*, or even conspecific); the Prosqualodontidae is only known from Late Oligocene–earliest Miocene deposits; (2) McCoy (1867a) stated that the holotype tooth was collected from sandy beds at Castle Cove on the Cape Otway coast; the only fossiliferous marine sediments in this area, which are of suitable age to yield a prosqualodontid tooth, are those of the Calder River Limestone.

Age. Late Oligocene.

Lithology. Sandy bryozoal calcarenite with a thin discontinuous basal layer of phosphatic nodules and quartz pebbles (Abele et al., 1988).

Material. One tooth.

Fauna. *Prosqualodon* sp. (=*Parasqualodon wilkinsoni*).

2. The Torquay Basin (Fig.7)

2.1 Split Point (Fig.8 for localities 2.1–2.7)

Geographic location. Towards lighthouse, at Split Point, near Aireys Inlet, 49 km south-west of Geelong (near 38˚28'S, 144˚06'E).

Stratigraphic position. Point Addis Limestone Member (Webb, 1995).

Age. Late Oligocene.

Lithology. Yellow sandy bryozoal calcarenite.

Material. One incomplete anterior caudal vertebra, and one worn tooth.

Fauna. Carcharias macrotus, Carcharoides totuserratus, Cetacea indet.

2.2 Point Addis

Geographic location. Cliffs on southern side of Point Addis, south-west of Torquay, central coastal Victoria (38˚23'S, 144˚15'E).

Stratigraphic position. Point Addis Limestone. Most vertebrate fossils have been collected from the base of the upper member of the Point Addis Limestone (Nicolaides and Wallace, 1997; Webb, 1995).

Age. Late Oligocene (Abele et al., 1988; Holdgate and Gallagher, 2003).

Lithology. Ferruginous intraclastic conglomerate with abraded shelly and vertebrate skeletal components (Nicolaides and Wallace, 1997; Webb, 1995). This horizon directly overlies a regionally extensive hardground (Nicolaides and Wallace, 1997; Webb, 1995).

Material. Isolated elements: teeth, tympanic bullae, rare post-cranial remains. The material is usually broken and worn.

Fauna. Mammalodontidae.

2.3 Bells Headland

Geographic location. 300 m south-west of Bells Beach, south-west of Torquay (near 38˚22'S, 144˚16'E).

Stratigraphic position. Lower beds of the Point Addis Limestone (Abele et al., 1988).

Age. Late Oligocene.

Lithology. Sandy bryozoal calcarenite (Abele et al., 1988).

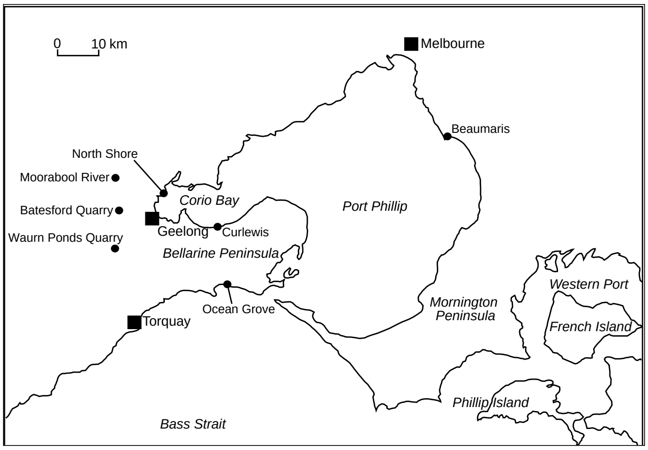

Figure 7. Fossil Cetacea localities in the Torquay and Port Phillip basins, central coastal Victoria. Solid circles represent fossil Cetacea localities. Modified from Holdgate and Gallagher (2003).

Material. Fossil preservation is generally very good. Cetacean material consists of: one skull and associated ear bones; associated vertebrae, and bone fragments.

Fauna. Mysticeti new family; genus and species 2.

2.4 Bells Beach

Geographic location. On shore platform, low tide mark, base of low cliffs at north-east end of Bells Beach, south-west of Torquay, central coastal Victoria (38˚22'S, 144˚17'E).

Stratigraphic position. Point Addis Limestone

Age. Late Oligocene

Lithology. Yellow bryozoal calcarenite (Abele et al., 1988).

Material. One partially articulated incomplete skeleton, isolated periotics, and vertebrae.

Fauna. *Carcharodon angustidens*, Mammalodontidae genus and species indet 1.

2.5 Rocky Point

Geographic location. Low cliffs at Rocky Point, small headland at northern-most end of Bells Beach, about 250 m NE of Bells Beach, south-west of Torquay (near 38˚22'S, 144˚17'E).

Stratigraphic position. ?Lower Jan Juc Marl.

Age. ?Late Oligocene.

Lithology. Yellow-orange silty and sandy marls.

Material. Indeterminate bone fragments.

Fauna. Cetacea indet.

2.6 Deadman's Gully

Geographic location. Cliff exposures 600 m south-west of Fishermans Steps, near Deadman's Gully, south-west of Torquay, central coastal Victoria (near 38˚20'S, 144˚18'E).

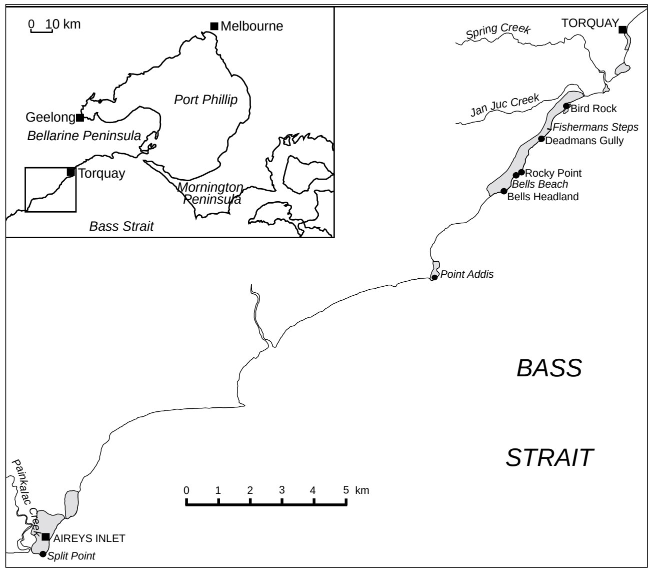

Figure 8. Late Oligocene fossil Cetacea localities on the coast south-west of Torquay, in central coastal Victoria. Shaded areas represent coastal outcrop of the Oligocene–Miocene Torquay Group. Solid circles represent fossil Cetacea localities.

Stratigraphic position. Jan Juc Marl, based on the presence of the molluscs *Liratomina intertexta* and *Chione halli* (which are restricted to the Jan Juc Marl, T.A. Darragh, pers. comm.).

Age. Late Oligocene.

Lithology. Grey-yellow glauconitic and pyritic carbonate-cemented calcarenite.

Material. One partially articulated incomplete skeleton: skull, mandibles, teeth, tympanics, thyrohyal, atlas, axis, cervical vertebra, ribs, scapulae, radius.

Faunal. Mysticeti new family, genus and species 1.

2.7 Bird Rock

Geographic location. Bluff adjacent to Bird Rock stack and cliffs to the south-west, and shore platform exposures from Bird Rock in the north-east, extending 250 m to the south-west; south-west of Torquay, central coastal Victoria (38˚20'54"S, 144˚18'35"E).

Stratigraphic position. Upper Jan Juc Marl (Holdgate and Gallagher, 2003; Webb, 1995).

Age. Late Oligocene. Siesser (1979) suggested that the Oligocene–Miocene boundary occurs 2.5 m below the Jan Juc Marl–Puebla Clay contact. Li and colleagues (1999) noted that the local nannoplankton datum used by Siesser (1979) to estimate the position of the Oligocen–Miocene boundary, is no longer valid because the age of this datum is ~24.5 Ma, while the recognised date of the Oligocene–Miocene boundary is 23.8–23.9 Ma (Berggren et al., 1995). Li and others (1999) provided foraminiferal biofacies evidence indicating that the top of the Jan Juc Marl corresponded to the Late Oligocene–Early

Miocene boundary. Furthermore, the Jan Juc Marl–Puebla Clay contact has yielded Sr/Sr dates of 23 ± 1 Ma (Kelly et al., 2001), consistent with the Oligo–Miocene boundary occurring at the Jan Juc Marl–Puebla Clay contact, and not within the Jan Juc Marl. Foraminifera from the Jan Juc Marl correlate this formation with international foram zones P21-P22, and therefore indicate a Late Oligocene age (Holdgate and Gallagher, 2003). Sr/Sr dates have yielded an age of 23.9–27.4 Ma for the Jan Juc Marl exposed at Bird Rock (Dickinson, 2002; Holdgate and Gallagher, 2003). These data support a Late Oligocene (Chattian) age for the Jan Juc Marl, and indicate that the beginning of the Early Miocene occurs immediately above the top of the Jan Juc Marl, in the Puebla Clay.

Lithology. Silty glauconitic marl and clayey sandy glauconitic calcarenite (Abele, 1979; Glover, 1955; Holdgate and Gallagher, 2003; Raggatt and Crespin, 1955; Webb, 1995).

Material. Fossil preservation is generally fairly good, however fossils from the upper beds exposed in the bluff are often corroded. Typical elements preserved include ribs, vertebrae, teeth, tympanics, and periotics. Less common are skulls and partially articulated skeletons.

Fauna. Heterodontus cainozoicus, Carcharias elegans, Carcharias taurus, Carcharias sp., *Odontaspis incurva, Carcharoides totuserratus, Carcharodon angustidens, Isurus desori, Isurus planus, Isurus* sp., *Dasyatis* sp., *Myliobatis* sp., *Megalops lissa* (Stinton, 1958), *Pterothrissus pervetustus* (Stinton, 1958), *Heterenchelys regularis* (Stinton, 1963), *Astroconger rostratus* (Stinton, 1958), *Urconger rectus* (Stinton, 1963), *Merluccius fimbriatus, Gadus refertus* (Stinton, 1958), *Ophidion granosum* (Stinton, 1963), *Trachichthodes salebrosus* (Stinton, 1958), *Cleidopus carvernosus* (Stinton, 1963), *Sillago pliocaenica* (Stinton, 1958), *Coelorhynchus elevatus, Xiphias* sp., Aves indet., Mysticeti family indet., *Mammalodon colliveri* (Pritchard, 1939), *Mammalodon* sp., *Mammalodon* new species 1, Mysticeti new family, *Prosqualodon* sp., ?Eurhinodelphinidae.

2.8 Waurn Ponds Quarry

Geographic location. Waurn Ponds Quarry, operated by Blue Circle Southern Cement Ltd, south of Waurn Ponds (near 38˚12'S, 144˚16'E).

Stratigraphic position. Waurn Ponds Limestone Member of the Jan Juc Formation; a lateral equivalent of the lower part of the Point Addis Limestone (Holdgate and Gallagher, 2003; Nicolaides and Wallace, 1997).

Age. Late Oligocene (~24–27 Ma) (Abele et al., 1988; Holdgate and Gallagher, 2003; Nicolaides and Wallace, 1997).

Lithology. Bryozoal calcarenite with some interbedded marls. These sediments are capped by a subaerial exposure surface that is laterally equivalent to a similar horizon at Point Addis. At Waurn Ponds Quarry, this horizon is heavily cemented (Abele et al., 1988; Holdgate and Gallagher, 2003; Nicolaides and Wallace, 1997; Webb, 1995).

Material. The completeness and quality of preservation of fossil cetacean material varies. However, the vast majority of cetacean fossils consist of disarticulated and isolated elements. Some fossils preserve fine surface detail on bones and teeth, whereas others are highly polished and worn with no surface detail present.

Fauna. Carcharias taurus, Carcharias macrotus, Carcharoides totuserratus, Carcharodon angustidens, Isurus desori, Isurus sp., ?*Lamna cattica, Lamna* sp., *Carcharhinus* sp., *Galeocerdo* sp., *Notorynchus cepedianus, Myliobatis* sp., Diprotodontidae (D. Pickering and T. Rich pers. comm.), cf. *Mammalodon colliveri, Mammalodon* sp., Mammalodontidae sp. indet., "Cetotheriidae", Mysticeti new genus, Mysticeti family indet., cf. Squalodontidae indet., Odontoceti family indet.

2.9 Ocean Grove

Geographic location. Near Ocean Grove, on the Bass Strait side of the Bellarine Peninsula (near 38˚15'S, 144˚31'E).

Stratigraphic position. Puebla Clay (Abele et al., 1988).

Age. Early Longfordian (Early Miocene).

Lithology. Calcareous sand (Abele et al., 1988).

Material. Bone fragments.

Fauna. Cetacea indet.

3. The Port Phillip Basin (Fig.7)

3.1 Batesford Quarry

Geographic location. Australian Cement Company quarry south of Batesford, on the western bank of the Moorabool River, west of Geelong (38˚06'S, 144˚17'E).

Stratigraphic position. Batesford Limestone; unconformably overlies Palaeozoic granite, and grades conformably up into the overlying Fyansford Formation (Abele et al., 1988; Holdgate and Gallagher, 2003; Webb, 1995).

Age. The lower 21 m of the Batesford Limestone is Longfordian (Lower Miocene) in age, whereas the upper 12 m of the formation is the *Lepidocyclina*-bearing type section of the uppermost Lower to lower Middle Miocene Batesfordian local marine stage (Holdgate and Gallagher, 2003).

Lithology. Fossil cetaceans have been recovered from the basal beds, which are composed of calcareous sand and gravel. The upper Batesfordian part of the formation consists of biocalcarenite (Abele et al., 1988; Bowler, 1963; Webb, 1995).

Material. In both upper and lower parts of the Batesford Limestone, cetacean fossils are generally well preserved with only slight mineralisation of original bone. The majority of cetacean fossils have been found in the Batesfordian-age upper beds. Rib fragments and vertebrae are the most commonly represented elements, with tympanic bullae being poorly represented. Elements of the appendicular skeleton and cranial remains are very rare. Only two skeletons represented by associated elements have been recovered from Batesford Quarry.

Fauna. *Orectolobus* sp., *Carcharias taurus, Carcharodon megalodon, Isurus desori, Isurus hastalis, Isurus oxyrinchus, Isurus* cf. *oxyrinchus, Isurus planus, Isurus retroflexus, Isurus* cf. *paucus*, *Isurus* sp., Lamnidae incerta sedis, *Carcharhinus* cf. *brachyurus, Carcharhinus* sp., *Galeocerdo aduncus*, *Sphyrna* sp., *Notorynchus primigenius, Pristiophorus lanceolatus, Labrodon* sp., Spheniscidae, Diprotodontidae indet., "Cetotheriidae" indet., Physeteridae, ?Squalodontidae new genus and new species.

3.2 Moorabool River

Geographic location. North-west of Geelong (near 37°56'S, 144°09'E).

Stratigraphic position. Lower Maude Formation (Abele et al., 1988).

Age. Latest Late Oligocene–earliest Miocene (zones P22-N4) (Abele et al., 1988; Holdgate and Gallagher, 2003).

Lithology. Shelly bryozoal calcarenite.

Material. Cetacean material consists of one tympanic bulla and bone fragments.

Fauna. Heterodontus cainozoicus, Carcharias sp., *Isurus* sp., cf. Mammalodontidae.

3.3 North Shore, Corio Bay

Geographic location. Outcrop along north shore of Corio Bay, near Geelong (near 38°06'S, 144°24'E).

Stratigraphic position. Fyansford Formation (Abele et al., 1988).

Age. Youngest part of the Fyansford Formation, representing zone N12 (Bairnsdalian, Middle Miocene) (Abele et al., 1988).

Lithology. Basal sandy calcarenite passing upwards into calcareous silt and clay with sandy calcarenite interbeds (Abele et al., 1988).

Material. Bone fragments.

Fauna. *Lamna* sp., Cetacea indet.

3.4 Curlewis

Geographic location. Cliff sections along the northern side of the Bellarine Peninsula, near Curlewis (near 38°11'S, 144°30'E).

Stratigraphic position. Fyansford Formation (Abele et al., 1988).

Age. Early Middle Miocene (Abele et al., 1988).

Lithology. Calcareous clay and marl with thin bryozoal calcarenite interbeds (Abele et al., 1988).

Material. Bone fragments.

Fauna. *Heterodontus cainozoicus, Isurus hastalis, Trachichthodes salebrosus* (Stinton, 1958), *Diodon* sp., Cetacea indet.

3.5 Beaumaris

Geographic location. Coastal exposures located east of Rickett's Point on the west shore of Beaumaris Bay, north-east shore of Port Phillip Bay (37°59'S, 145°03'E).

Stratigraphic position. Basal Black Rock Sandstone (Abele et al., 1988; Holdgate and Gallagher, 2003).

Age. Cheltenhamian to Kalimnan (latest Late Miocene–earliest Early Pliocene) (Abele et al., 1988; Dickinson et al., 2002; Gill, 1957; Holdgate and Gallagher, 2003; Mallett, 1977).

Lithology. Most fossil vertebrates have been recovered from a layer of ferruginous and phosphatic nodules in a matrix of quartz sand and gravel. This nodule bed occurs at the base of the Black Rock Sandstone. Less abundant fossil vertebrates occur in the sediments immediately above the nodule horizon, this layer consisting of calcareous sandstone and sandy marl (Abele et al., 1988; Gill, 1957; Singleton, 1941).

Material. Cetacean fossils derived from the nodule bed consist of fragmentary, isolated elements that are usually highly worn and polished, having undergone significant post-mortem transport. These fossils include indeterminate bone fragments, ribs, vertebrae, forelimb elements, teeth, rostral and cranial fragments, periotics, tympanic bullae, and incomplete mandibles. Vertebrate fossils from the sandy beds overlying the nodule horizon are better preserved than the nodule material, with a lesser degree of replacement of bone by secondary mineralisation. The sandy bed material includes ribs, vertebrae, teeth, mandibles, periotics, tympanic bullae, middle-ear ossicles, and rare partially articulated skeletons.

Fauna. Heterodontus cainozoicus, Carcharias taurus, Carcharodon megalodon, Parotodus benedenii, Isurus desori, Isurus hastalis, Isurus retroflexus, ?*Lamna, Megascyliorhinus* sp., *Carcharhinus* cf. *brachyurus, Carcharhinus* sp., *Galeocerdo aduncus, Pristiophorus lanceolatus, Myliobatis* sp., *Edaphodon mirabilis*, *Edaphodon* cf. *mirabilis, Edaphodon sweeti, Ischyodu*s cf. *dolloi, Sillago pliocaenica* (Stinton, 1958), *Lactarius tumulatus* (Stinton, 1963), ?Trionychidae, *Pseudaptenodytes macraei,* ?*Pseudaptenodytes minor*, Spheniscidae, *Diomedea thyridata* (Wilkinson, 1969), *Zygomaturus gilli* (Woodburne, 1969; Stirton, 1967), *Kolopsis* sp. cf. *K. torus* (Rich et al., 2003), Phocidae (Fordyce and Flannery, 1983), "Cetotheriidae" indet., cf. *Balaena*, Balaenidae indet., *Balaenoptera* sp., *Megaptera* sp., *Physetodon baileyi* (probably Physeteridae indet.), *Scaldicetus macgeei*, Physeteridae indet., Ziphiidae, Delphinidae indet.

4. Gippsland Basin (Fig.9)

4.1 Merrimans Creek

Geographic location. Approximately 25 m from the surface, in the Gippsland Cement Quarry on Merrimans Creek, about 19 km south-east of Rosedale, Gippsland, Victoria (near 38°15'S, 146°51'E).

Stratigraphic position. Gippsland Limestone Formation (Holdgate and Gallagher, 2003).

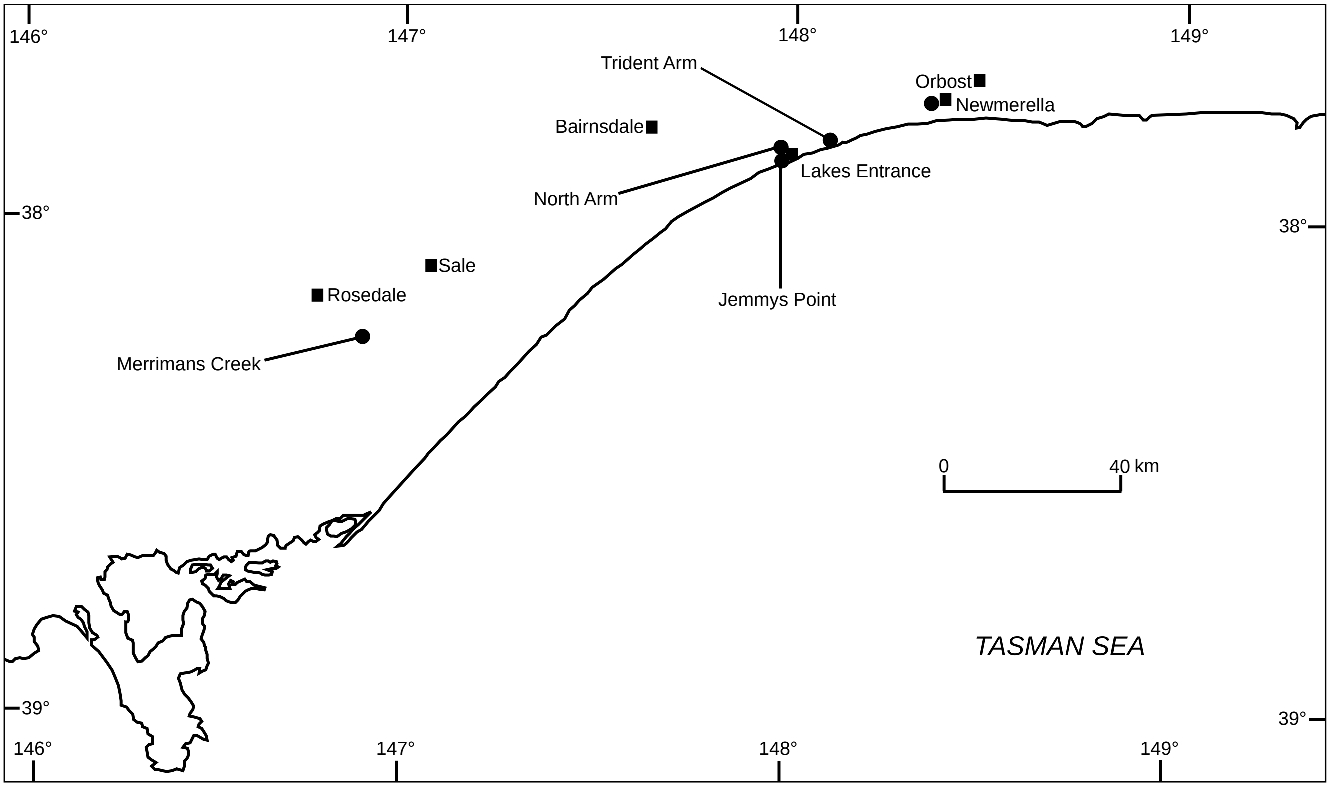

Figure 9. Fossil Cetacea localities in the Gippsland Basin, eastern Victoria. Solid circles represent fossil Cetacea localities.

Age. Longfordian; Early Miocene (planktonic foraminiferal zones N5-N7).

Lithology. Light grey fossiliferous marly limestone and interbedded limestone and marl.

Material. Fragmentary mandible and probable vertebrae.

Fauna. Isurus hastalis, Mysticeti.

4.2 Rose Hill

Geographic location. On Mitchell River, near Bairnsdale, East Gippsland, Victoria (near 37˚49'S, 147˚36'E).

Stratigraphic position. Tambo River Formation.

Age. Mitchellian (Late Miocene), representing planktonic foraminiferal zones N16-N17. Dickinson (2002) recorded Sr/Sr dates averaging 6.0 Ma for the top of the type section of the Tambo River Formation at Swan Reach.

Lithology. Uniform marl and marly limestone, and glauconitic sandy coquinas (Abele et al., 1988).

Material. Bone fragments.

Fauna. Cetacea indet.

4.3 Jemmys Point

Geographic location. Low cliffs at Jemmys Point, between the south-east end of "The Narrows", and the confluence of North Arm and Cunningham Arm, west of Lakes Entrance, East Gippsland (37˚53'S, 147˚58'E).

Stratigraphic position. Jemmys Point Formation (Abele et al., 1988; Singleton, 1941; Wilkins, 1963).

Age. Kalimnan (Early Pliocene); planktonic foraminiferal zones N18-N19 (Holdgate and Gallagher, 2003).

Lithology. Sandy clay with shell beds (Abele et al., 1988; Carter, 1985; Holdgate and Gallagher, 2003; Wilkins, 1963).

Material. Isolated bone fragments, vertebrae, and one incomplete skull.

Fauna. Carcharodon carcharias, Notorynchus cepedianus, Mesoplodon longirostris.

4.4 North Arm

Geographic location. "Golden Point" property, North Arm, Lake King, near Lakes Entrance, East Gippsland (close to 37˚51'S, 148˚58'E) (Bearlin, 1987).

Stratigraphic position. Jemmys Point Formation.

Age. Kalimnan (Early Pliocene); planktonic foraminiferal zones N18-N19 (Holdgate and Gallagher, 2003).

Lithology. Calcareous shelly sand, with phosphorite concretions (Abele et al., 1988; Carter, 1985).

Material. One incomplete skeleton comprising: almost complete skull, mandibles, periotics, tympanic bullae, complete series of cervical vertebrae, isolated thoracic and lumbar vertebrae, and ribs.

Fauna. Megaptera new species 1.

4.5 Trident Arm

Geographic location. Trident Arm of Lake Tyers, east of Lakes Entrance, East Gippsland, Victoria (near 37˚49'S, 148˚08'E).

Stratigraphic position. Phosphatic horizon at the base of the Jemmys Point Formation (M. Wallace, pers. comm.).

Age. Kalimnan (Early Pliocene); planktonic foraminiferal zones N18-N19 (Carter, 1985; Holdgate and Gallagher, 2003).

Lithology. Cemented phosphatic and glauconitic calcarenite with *Ostrea* shells.

Material. One partial cranium.

Fauna. ?Balaenidae.

4.6 Newmerella

Geographic location. Railway cutting 3 km west of Newmerella, Orbost district, East Gippsland, Victoria (near 37˚45'S, 148˚24'E).

Stratigraphic position. Probably the Lindenow Sandstone Member, Gippsland Limestone Formation.

Age. Longfordian (Early Miocene), planktonic foraminiferal zones N5-N7 (Holdgate and Gallagher, 2003).

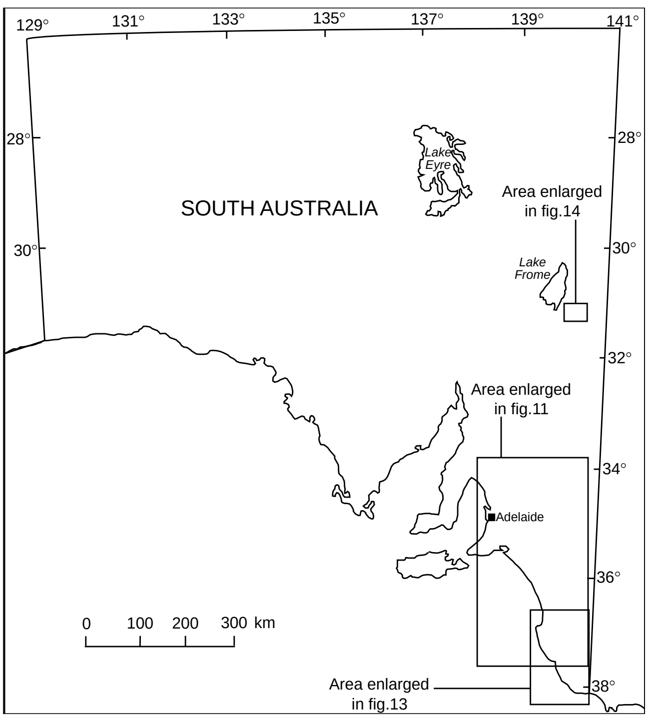

Figure 10. Areas with fossil cetacean-bearing localities in South Australia. Modified from Alley et al. (1995).

Lithology. Ferruginised fine quartz sandstone (Abele et al., 1988)

Material. Cetacean fossils are relatively well preserved. The most significant specimens occur in private collections and these include a mysticete skull and mandibles, and postcranial elements (Bearlin, 1987). Material in Museum Victoria includes the posterior part of a large mandible, and one large vertebra.

Fauna. *Carcharodon megalodon*, ?"Cetotheriidae".

South Australia (Fig.10)

5. St Vincent Basin (Fig.11)

5.1 Port Willunga

Geographic location. 300–400 m south of the old jetty, Port Willunga Beach, approximately 45 km south of Adelaide (this is the locality data for the cranium; the exact location for the radius is unknown, but it was collected in the vicinity of Port Willunga) (Pledge, 1994; N. Pledge, pers. comm.) (near 35˚19'S, 138˚27'E).

Stratigraphic position. Ruwarung Member, Port Willunga Formation (N. Pledge, pers. comm.).

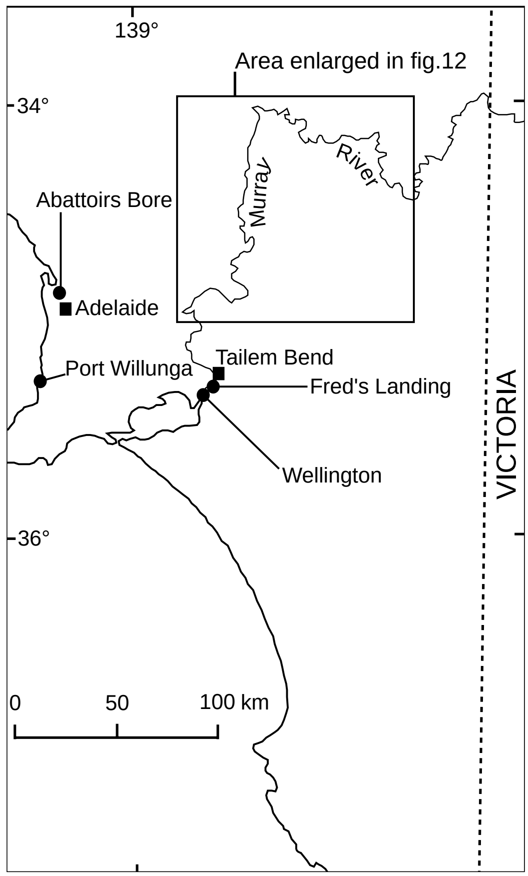

Figure 11. Fossil Cetacea localities in the St Vincent and Murray basins in south-east South Australia. Solid circles represent fossil Cetacea localities. Modified from Alley et al. (1995).

Age. Willungan (Early Oligocene; Rupelian), 30–32 Ma (Alley et al., 1995; Holdgate and Gallagher, 2003).

Lithology. Bryozoal marl limestone containing chert nodules (Alley et al., 1995; N. Pledge pers. comm.).

Material. One right radius (Pledge, 1994) and one incomplete cranium.

Fauna. Cetacea indet., cf. Aetiocetidae (N. Pledge, pers. comm.).

5.2 Abattoirs Bore

Geographic location. Abattoirs Bore, Dry Creek, about 10 km north of Adelaide (34°50'00"S, 138°36'35"E) (Howchin, 1919; Bearlin, 1987).

Stratigraphic position. Dry Creek Sand.

Age. Late Pliocene (Alley et al., 1995).

Lithology. Shelly sand.

Material. One isolated periotic.

Fauna. Carcharodon carcharias, Balaenidae (Howchin, 1919).

6. Murray Basin (Figs 11, 12)

6.1 Fred's Landing

Geographic location. Boat launching area about 3 km downstream from Tailem Bend, on the east bank of the Murray River (35°17'S, 139°27'E) (Pledge, 1994).

Stratigraphic position. Upper Buccleuch Formation (Pledge, 1994).

Age. Early Oligocene.

Lithology. Green and slightly glauconitic fine-grained limestone (Pledge, 1994; Alley et al., 1995).

Material. One heterodont tooth.

Fauna. Cetacea indet.

6.2 Wellington

Geographic location. Near Wellington, on the Murray River, south-east of Adelaide (Pledge and Rothausen, 1977) (near 35°19'S, 139°23'E).

Stratigraphic position. Ettrick Formation (Pledge and Rothausen, 1977).

Age. Late Oligocene (Alley et al., 1995).

Lithology. Glauconitic marl, calcareous clay, and mudstone, with silt and sand (Pledge and Rothausen, 1977; Alley et al., 1995).

Material. Several heterodont teeth (possibly associated).

Fauna. Hexanchus agassizi, Cetacea indet. (=*Metasqualodon harwoodi*).

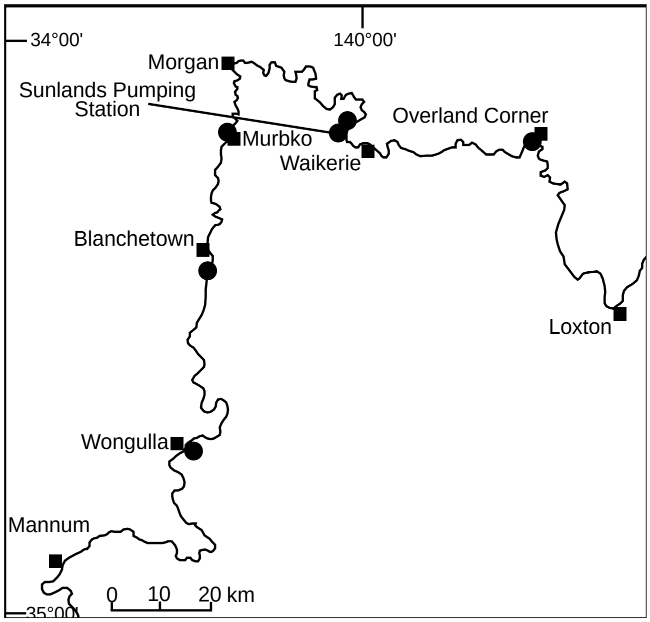

Figure 12. Fossil Cetacea localities along the Murray River north-east of Adelaide. Solid circles represent fossil Cetacea localities. Modified from Lukasik and James (1998).

6.3 Wongulla

Geographic location. Cliffs on east bank of Murray River opposite Wongulla, approximately 5 km south of Devon Downs (near 34°41'S, 139°35'E).

Stratigraphic position. Upper Member, Mannum Formation.

Age. Early Miocene (Lukasik and James, 1998).

Lithology. Yellow-orange calcarenite.

Material. Anterior portions of two large mandibles and associated incomplete vertebrae.

Fauna. Mysticeti.

6.4 Blanchetown

Geographic location. Close to the north end of the channel between Notts Island and Murray River cliffs, about 4 km south of Blanchetown Bridge, north-east of Adelaide (N. Pledge, pers. comm.) (near 34°28'S, 139°36'E).

Stratigraphic position. Upper Member, Mannum Formation (Lukasik and James, 1998).

Age. Cetacean fossils were recovered about 3–4 m below the *Lepidocyclina* Zone (N. Pledge, pers. comm.), and therefore, pre-Batesfordian. The minimum age of the upper Mannum Formation is earliest Longfordian, based on the presence of *Operculina victoriensis* at the base of this unit. The Upper Member of the Mannum Formation is overall no younger than Early Miocene (Lukasik and James, 1998).

Lithology. Fine-grained calcarenite.

Material. One mandible with two posterior teeth in situ and four associated vertebrae. These fossils represent one individual, and other bones remain unprepared at the South Australian Museum.

Fauna. ?Squalodontidae.

6.5 MacBean's Pound

Geographic location. About 6.5 km from Blanchetown, Murray River (near 34˚25'20"S, 139˚37'05"E).

Stratigraphic position. Upper Member, Mannum Formation.

Age. Early Miocene.

Lithology. Bryozoal calcarenite.

Material. Mandibles.

Fauna. ?"Cetotheriidae".

6.6 Murbko

Geographic location. Murray River cliffs near Murbko Homestead, 22.5 km north-east of Blanchetown (34˚07'55"S, 139˚39'05"E).

Stratigraphic position. Glenforslan Formation (sensu Lukasik and James, 1998).

Age. The presence of *Lepidocyclina howchini* indicates a Batesfordian (early Middle Miocene) age (Lukasik and James, 1998).

Lithology. Bryozoal calcarenite.

Material. One almost complete cranium.

Fauna. cf. *Parietobalaena* sp.

6.7 Waikerie

Geographic location. 100 m downstream from the Sunlands Pumping Station, 8 km west of Waikerie, Murray River (near 34˚09'S, 139˚55'E).

Stratigraphic position. Pata Formation.

Age. Balcombian (Middle Miocene) (Lukasik and James, 1998).

Lithology. Yellow-orange fine calcarenite with muddy bands.

Material. One incomplete scapula.

Fauna. Mysticeti indet.

6.8 Winkie

Geographic location. Riverbed, Murray River, Gerard Mission, near Winkie (near 34˚22'45"S, 140˚28'30"E).

Stratigraphic position. ?Bookpurnong Formation (Bearlin, 1987).

Age. ?Mio-Pliocene.

Lithology. ?Marl, silty clay and minor fine sand (Alley et al., 1995).

Material. Incomplete cranium and mandible (Bearlin, 1987).

Fauna. Balaenopteridae.

6.9 Sunlands Pumping Station

Geographic location. Beds immediately above a hardground of cemented sand and oyster shells, 3–4 m above the base of the cliffs, Sunlands Pumping Station, 8 km west-north-west of Waikerie, Murray River (near 34˚09'S, 139˚55'E) (Pledge, 1985).

Stratigraphic position. Loxton Sand (Alley et al., 1995; Pledge, 1985).

Age. Early Pliocene.

Lithology. Poorly sorted coarse sand containing pebbles.

Material. Isolated elements comprising vertebrae and teeth (Pledge, 1985).

Fauna. Heterodontus cf. *cainozoicus, Orectolobus gippslandicus, Carcharias* sp., *Carcharodon* cf. *megalodon, Isurus hastalis, Lamna* cf. *cattica, Mustelus* sp., *Carcharhinus* cf. b*rachyurus, Galeocerdo aduncus, Galeorhinus* cf. *australis, Sphyrna* sp., *Pristiophorus lanceolatus*, cf. *Myliobatis* sp., Labroidei indet., Monacanthidae indet., *Diodon formosus*, cf. *Zygomaturus*, *Phascolarctos maris, Dorcopsis* sp., cf. *Dugong* sp. (Pledge, 1992; Domning, 1996), Mysticeti indet., ?Delphinidae indet.

6.10 Overland Corner

Geographic location. Near Overland Corner, Murray River, about 10 km north-west of Lake Bonney (near 34˚09'20"S, 140˚20'E).

Stratigraphic position. ?Glenforslan Formation.

Age. ?Batesfordian (early Middle Miocene).

Lithology. Bryozoal calcarenite.

Material. One incomplete cranium.

Fauna. Mysticeti.

7. Gambier Basin

7.1 Mount Gambier (Fig. 13)

Geographic location. The old "Knights and Pritchard's" dimension stone quarry, near Marte, 10 km west of Mount Gambier (near 37˚48'S, 140˚09'E).

Stratigraphic position. Camelback Member, Gambier Limestone (Alley et al., 1995).

Age. Late Oligocene (planktonic foraminiferal zones P21-P22) (Li et al., 2000).

Lithology. Pale cream-white porous bryozoal calcarenite.

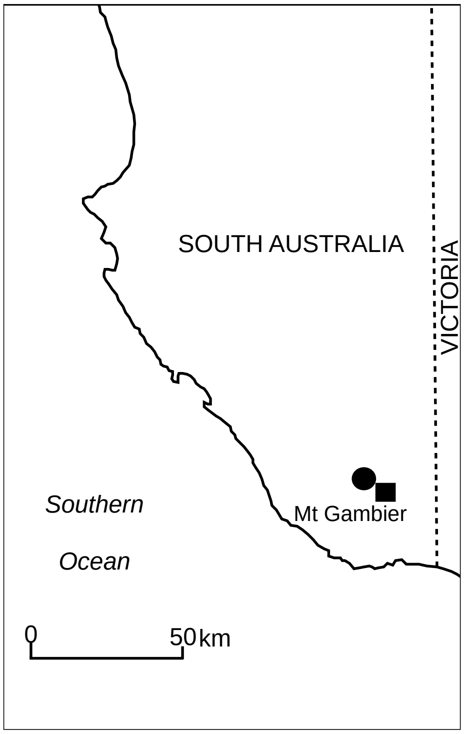

Figure 13. Fossil Cetacea locality in the Gambier Basin, extreme south-east of South Australia. Solid circles represent fossil Cetacea localities. Modified from Alley et al. (1995).

Material. Fossil preservation is generally very good. Cetaceans are represented by isolated teeth, vertebrae, and cranial fragments.

Fauna. Carcharodon angustidens, Spheniscidae, "*Squalodon*" *gambierensis*, Mysticeti indet., Prosqualodontidae.

8. Lake Eyre Basin (Fig. 14)

8.1 Lake Namba

Geographic location. 4 km south of Ericmas Quarry, which occurs at the base of low bluffs just south of track to Billeroo Waterhole on western side of Lake Namba, Lake Frome area, South Australia (31˚14'S, 140˚14'E) (Fordyce, 1983; T.Rich, pers. comm.).

Stratigraphic position. Ericmas Fauna, base of upper member, Namba Formation, equivalent to unit 4 of Namba Formation at Lake Pinpa.

Age. Late Oligocene–Middle Miocene (Callen and Tedford, 1976). Palynofloras suggest a Miocene–Pliocene age range for the Namba Formation (Alley et al., 1995). Fordyce (1983) suggested that the Namba Formation was Middle Miocene in age, and no older than Batesfordian-Balcombian. Recently, Woodburne and colleagues (1993) have indicated that the Etadunna Formation (a correlate of the Namba Formation) is perhaps 24–28 Ma. If the latter dates are accurate, they would imply that the Namba Formation is Late Oligocene in age. However, due to the inconsistent results of various dating methods, the Namba Formation is considered herein as Late Oligocene–Middle Miocene in age.

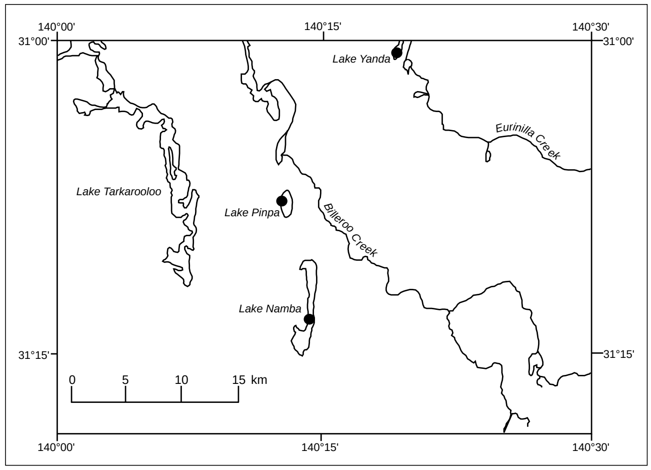

Figure 14. Fossil Cetacea localities east of Lake Frome, in the Lake Eyre Basin, north-east South Australia. Solid circles represent fossil Cetacea localities. Modified from Tedford et al. (1977).

Lithology. Illite and kaolinite clays (Alley et al., 1995).

Material. One right periotic.

Fauna. Neoceratodus djelleh, Neoceratodus eyrensis, Neoceratodus gregoryi, Neoceratodus sp. 1, *Neoceratodus* sp. 4, Osteichthyes indet., Chelidae, Crocodylia, Columbidae, Anseriformes, *Obdurodon insignis*, Dasyuridae, *Raemeotherium yatkolai, Madakoala devisi, Madakoala wellsi, Pildra antiquus, Pildra secundus*, Petauridae, Eurhinodelphinidae.

8.2 Lake Pinpa

Geographic location. Western margin and floor of Lake Pinpa (31˚10'S, 140˚14'E) (Fordyce, 1983).

Stratigraphic position. At top of unnamed member 1, Namba Formation (Fordyce, 1983).

Age. Late Oligocene–Middle Miocene (Alley et al., 1995; Callen and Tedford, 1976; Woodburne et al., 1993).

Lithology. Illite and kaolinite clays.

Material. One incomplete associated skeleton, and isolated left periotics and radius.

F*auna. Neoceratodus djelleh, Neoceratodus forsteri, Neoceratodus eyrensis, Neoceratodus gregoryi, Neoceratodus nargun, Neoceratodus* sp. 1, *Neoceratodus* sp. 2, *Neoceratodus* sp. 3, *Neoceratodus* sp. 4, Osteichthyes indet., *Emydura* sp., Meiolaniidae, Crocodylia, Passeriformes, Rallidae, Podicipedidae, Burhinidae, Phoenicopteridae, Anatidae, *Pelecanus tirarensis*, Phalacrocoracidae, *Obdurodon insignis, Muramura* sp., *Ilaria illumiden*s, Ilariidae indet., *Madakoala devisi*, ?Potoroidae, ?Macropodidae, Petauridae, *Pildra antiquus, Chunia* cf. *illuminata, Pilkipildra handae, Miralina* cf. *minor*, Eurhinodelphinidae.

8.3 Lake Yanda

Geographic location. Western side of Lake Yanda, Lake Frome area, South Australia (31˚01'S, 140˚19'E).

Stratigraphic position. Yanda Fauna, near the contact between the two unnamed members of the Namba Formation (Rich et al., 1991).

Age. Late Oligocene–Middle Miocene (Alley et al., 1995; Callen and Tedford, 1976; Woodburne et al., 1993).

Lithology. Illite and kaolinite clays (Alley et al., 1995).

Material. One incomplete tympanic bulla.

Fauna. Neoceratodus djelleh, Neoceratodus eyrensis, Neoceratodus gregoryi, Neoceratodus sp. 1, *Neoceratodus* sp. 4, Osteichthyes indet., Crocodylia, Phoenicopteridae, Anatidae, *Dasylurinja kokuminola, Ilaria* sp., *Djilgaringa thompsonae*, *Miralina* cf. *minor*, Eurhinodelphinidae.

Tasmania

9. Bass Basin

9.1 Fossil Bluff (Fig.4)

Geographic location. Coastal cliff section at Fossil Bluff, Table Cape, near Wynyard, north-east of Launceston, Bass Strait coast of Tasmania (40˚58.8'S, 145˚43.9'E). Strictly speaking, the Fossil Bluff locality is situated approximately 40–50 km south of the southern margin of the Bass Basin (N. Kemp, pers. comm.).

Stratigraphic position. Fossil Bluff Sandstone.

Age. Longfordian (Early Miocene). The Fossil Bluff Sandstone has a planktonic foraminiferal fauna which corresponds to zone N4 (earliest Early Miocene; Aquitanian = 21–23.9 Ma) (Quilty, 1980). Fordyce (2003) indicated that the Aquitanian in south-east Australia is comparable to the Chattian (Late Oligocene) in New Zealand. The odontocete genus *Prosqualodon* occurs in the Waitakian (latest Oligocene–earliest Miocene) of New Zealand (Fordyce, 1984, 1991), the Late Oligocene of Victoria and perhaps South Australia (Fitzgerald, 2004, and herein), the Early Miocene of Tasmania (Flynn, 1923; Fitzgerald, 2004), and the Early Miocene of Patagonia, Argentina (Lydekker, 1899; Cabrera, 1926; Fordyce, 2002b; Muizon, 2002).

Lithology. Fine siltstones and shales, and glauconitic calcareous sandstone (Kemp, 1991).

Material. Isolated teeth, vertebrae, ribs, partially articulated postcranial skeletons, and one associated skeleton comprising: skull, mandibles, teeth, almost complete right forelimb, ribs, 2+ thoracic vertebrae, 4+ lumbar vertebrae, and other elements. The latter specimens represent the holotype of *Prosqualodon davidis*. Unfortunately the skull is now lost (see Mahoney and Ride (1975) for details). Isolated teeth from Fossil Bluff, that represent prosqualodontids congeneric, and perhaps conspecific, with *Prosqualodon davidis*, are present in Museum Victoria and the South Australian Museum.

Fauna. Heterodontus cainozoicus, Carcharias taurus, Ischyodus mortoni, Wynyardia bassiana, Prosqualodon davidis, Prosqualodon cf. *davidis*. The holotype of *Scaptodon lodderi* was discovered near this locality.

9.2 Cameron Inlet (Fig.4)

Geographic location. Excavations of drains around Memana, near Cameron Inlet, east coast of Flinders Island, Bass Strait, Tasmania (near 39˚59'S, 148˚05'E).

Stratigraphic position. Cameron Inlet Formation (Sutherland and Kershaw, 1971).

Age. Late Early–Late Pliocene (Sutherland and Kershaw, 1971).

Lithology. Fine silty coquina limestones and sands (Sutherland and Kershaw, 1971).

Material. Vertebrae, ribs, incomplete skulls, partial mandibles, teeth, periotics, and tympanic bullae.

Fauna. Carcharodon megalodon, Carcharodon carcharias, Isurus hastalis, Isurus oxyrinchus, Carcharhinus sp., cf. *Balaenoptera*, cf. *Megaptera*, *Physeter* sp., Ziphiidae indet., ?Delphinidae.

10. South Tasman Rise (Fig.15)

10.1 Tasman Fracture Zone

Geographic location. Pipe dredge 147DR013, 2700–3900 m depth, northern end of eastern Tasman Fracture Zone, southwest of Tasmania (45˚07'S, 144˚31'E) (Exon et al., 1995).

Stratigraphic position. Unnamed lithological unit.

Age. Late Neogene (Exon et al., 1995). The one cetacean from this site (a probably indeterminate ziphiid) may indicate a maximum age for these sediments of Late Miocene. Exon and others (1995) suggested that fossil ziphiids from the South Tasman Rise represented a similar fauna to that of Cameron Inlet, which has a mid-Late Pliocene age (Sutherland and Kershaw, 1971).

Lithology. ?Silicified limestones (Exon et al., 1995).

Material. One incomplete rostrum.

Fauna. Ziphiidae indet.

10.2 Seamount east of South Tasman Rise

Geographic location. Dredge 147DR038, 2050–2300 m depth, on a seamount east of South Tasman Rise (near 45˚43.0'S, 149˚00'E) (Exon et al., 1995).

Stratigraphic position. Unnamed lithological unit.

Age. Late Neogene (Exon et al., 1995).

Lithology. ?Silicified limestones (Exon et al., 1995).

Material. One incomplete rostrum.

Fauna. Ziphiidae indet.

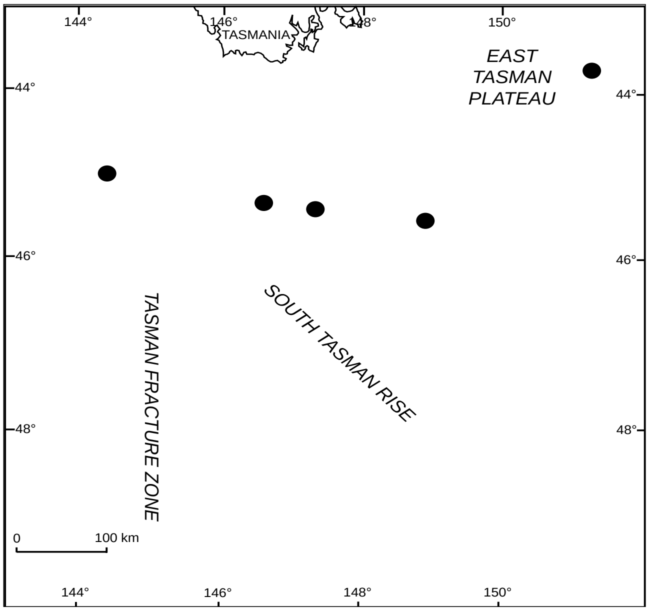

Figure 15. Fossil Cetacea localities offshore southern Tasmania. Solid circles represent fossil Cetacea localities. Modified from Exon et al. (1997).

10.3 Eastern South Tasman Rise

Geographic location. Dredge site 147DR50, 2050–2300 m depth, east-west trending high on the eastern side of the South Tasman Rise (near 45°30'S, 147°20'E) (Exon et al., 1995).

Stratigraphic position. Unnamed lithological unit.

Age. Late Neogene (Exon et al., 1995).

Lithology. ?Silicified limestones (Exon et al., 1995).

Material. One incomplete rostrum, and one skull.

Fauna. ?Mysticeti, Ziphiidae.

10.4 North-east South Tasman Rise

Geographic location. Dredge site 147DR052, 2200–2370 m depth, north-east South Tasman Rise, south-west of Tasmania (near 45°38.1'S, 146°24.5'E) (Exon et al., 1995).

Stratigraphic position. Unnamed lithological unit.

Age. Late Neogene (Exon et al., 1995).

Lithology. ?Silicified limestones (Exon et al., 1995).

Material. One small periotic.

Fauna. Odontoceti.

10.5 East Tasman Rise

Geographic location. Dredge site 147DR043, 3030–3600 m depth, eastern scarp of East Tasman Rise, south of Tasmania (near 43°54'S, 151°18'E) (Exon et al., 1995).

Stratigraphic position. Unnamed lithological unit.

Age. Late Neogene (Exon et al., 1995).

Lithology. ?Silicified limestones (Exon et al., 1995).

Material. One incomplete tympanic bulla (Exon et al., 1995).

Fauna. ?Mysticeti indet.

11. East Tasman Plateau (Fig.15)

11.1 Eastern Scarp

Geographic location. Dredge 147DR043, 3030–3600 m depth, eastern scarp of East Tasman Plateau, south-east of Tasmania (near 43°54'S, 151°18'E) (Exon et al., 1995).

Stratigraphic position. Unnamed lithological unit.

Age. Late Neogene (Exon et al., 1995).

Lithology. ?Silicified limestones (Exon et al., 1995).

Material. One incomplete skull.

Fauna. cf. *Mesoplodon* sp.

Discussion

Fordyce (1984) identified 21 and Fitzgerald (2004) 26 fossil Cetacea localities in Australia. Further discoveries, and more study of museum collections has resulted in the recognition of 56 Tertiary fossil Cetacea localities in Australia. Thirty-two of these localities occur in Victoria, 16 in South Australia, and eight in and around Tasmania. All are geographically distinct and generally include only one stratigraphic unit that has yielded fossil cetaceans. The number of recognised Australian fossil Cetacea localities compares with approximately 58–60 recognised Australian Tertiary terrestrial mammal localities (Rich et al., 1991; pers. obs.). That almost all the fossil cetacean-bearing localities occur in the south-east of the continent, while extensive areas of Cainozoic marine sedimentary rock outcrop occur outside this region, points to a potentially rich record of fossil cetaceans in unexplored areas. Moreover, it is highly probable that many localities in south-east Australia remain unrecognised. This is suggested by the broad distribution of cetacean-bearing localities within marine sedimentary basins. However, a perhaps less fortuitous aspect of this locality distribution and the faunal lists and material derived from these localities is the lack of cetacean fossil density at these localities.

Few localities have yielded diagnostic, reasonably complete skulls and/or skeletons. These localities are: Victoria; Arch Site (Grange Burn), Gibson's Steps, Curdie, Bells Headland, Bells Beach, Deadman's Gully, Bird Rock, Batesford Quarry, North Arm, Newmerella; South Australia; Murbko, Lake Pinpa; and Tasmania; Fossil Bluff. The source stratigraphic units (and lithologies) at the latter localities occur elsewhere, and it may be expected that more reasonably complete specimens will be discovered at these localities in future. The most important g eneral area for fossil cetaceans in Australia is the coastline south-west of Torquay, in the Torquay Basin, Victoria. Eight skulls/skeletons have been collected from this area, with all derived from the Upper Oligocene Jan Juc Marl and its lateral equivalents. Limitations to conducting fieldwork to prospect for, and recover, fossil cetaceans in this area include: extreme rarity of shore platforms being scoured by storm tides to remove sand and algae, thus uncovering larger areas of accessible outcrop; and dangerously unstable, steep, and high cliff sections. Despite these limitations, systematic prospecting of the coastline in this area will likely yield more important fossil cetaceans.

The Australian pre-Pleistocene fossil record of cetaceans, as currently understood, can be summarised thus: Eocene – not present; Early Oligocene – poorly known, but great potential; Late Oligocene – poorly known at present but will probably be the second-best known period of cetacean evolution in Australian waters; Early Miocene – poorly known, but great potential; Middle Miocene — poorly known, but great potential; Late Miocene — reasonably well-known; Early Pliocene — best known period of cetacean evolution in Australian waters; and Late Pliocene — poorly known.

Although the fossil record of Cetacea in Australia is known only in the broadest of terms, the identification of 56 recognised pre-Pleistocene fossil cetacean-bearing localities emphasises the wide distribution of cetacean fossils, and the potential for the elucidation of the details of this fossil record. These localities indicate geographic areas that may be fruitful for future discoveries, as well as stratigraphic horizons that are known to produce fossil cetaceans. Fossil cetaceans have arguably received the least attention of all groups of Australian fossil vertebrates, and yet they have, potentially, the richest pre-Pleistocene fossil record of all mammalian taxa in Australia.

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Table 1. Taxonomy of vertebrates from Tertiary fossil cetacean-bearing localities. * indicates provisional classification.

Class	Order	Suborder	Family	Genus and species
Chondrichthyes	Galeomorpha	Heterodontoidea	Heterodontidae	*Heterodontus cainozoicus* Chapman and Pritchard, 1904
		Orectoloboidea	Orectolobidae	*Orectolobus gippslandicus* Chapman and Cudmore, 1924
		Lamnoidea	Odontaspididae	*Carcharias elegans* Agassiz, 1843
				Carcharias taurus Rafinesque, 1810
				Carcharias macrotus Agassiz, 1843
				Odontaspis acutissima Agassiz, 1843
				Odontaspis incurva Davis, 1888
			Lamnidae	*Carcharodon angustidens* Agassiz, 1843
				Carcharodon megalodon Agassiz, 1835
				Carcharodon carcharias Linnaeus, 1758
				Isurus hastalis Agassiz, 1838
				Isurus retroflexus Agassiz, 1843
				Isurus desori Agassiz, 1843
				Isurus escheri Agassiz, 1843
				Isurus planus Agassiz, 1843
				Isurus oxyrinchus Rafinesque, 1810
				Isurus paucus Guitart-Monday, 1966
				Parotodus benedenii Le Hon, 1871
				Carcharoides totuserratus Ameghino, 1901
				Lamna cattica Philippi, 1846
		Carcharhinoidea	Parascylidae	*Megascyliorhinus* sp.
			Triakidae	*Mustelus* sp.
				Galeorhinus australis Macleay, 1881
			Carcharhinidae	*Carcharhinus brachyurus* Günther, 1870
				Galeocerdo aduncus Agassiz, 1843
			Sphyrnidae	*Sphyrna* sp.
		Hexanchoidea	Hexanchidae	*Hexanchus agassizi* Cappetta, 1976
				Notorynchus primigenius Agassiz, 1843
				Notorynchus cepedianus Peron, 1807
	Squalomorpha	Pristiophoroidea	Pristiophoridae	*Pristiophorus lanceolatus* Davis, 1888
	Batoidea	Myliobatoidea	Myliobatidae	*Myliobatis* sp.
			Dasyatidae	*Dasyatis* sp.
	Chimaeriformes	Chimaeroidei	Chimaeridae	*Edaphodon sweeti* Chapman and Pritchard, 1907
				Edaphodon mirabilis Chapman and Cudmore, 1924
				Ischyodus dolloi Leriche, 1902
				Ischyodus mortoni Chapman and Pritchard, 1907
Osteichthyes	Elopiformes	Elopoidei	Megalopidae	*Megalops lissa* Stinton, 1958
		Albuloidei	Pterothrissidae	*Pterothrissus pervetustus* Stinton, 1958
	Anguilliformes		Heterenchelyidae	*Heterenchelys regularis* Stinton, 1958
			Muraenesocidae	*Muraenesox obrutus* Stinton, 1958
			Congridae	*Astroconger rostratus* Stinton, 1958
				Urconger rectus Frost, 1928
	Salmoniformes	Argentinoidei	Argentinidae	*Hypomesus glaber* Stinton, 1963
	Gadiformes	Gadoidei	Merluccidae	*Merluccius fimbriatus* Stinton, 1958
			Gadidae	*Gadus refertus* Stinton, 1958
	Ophidiiformes		Ophidiidae	*Ophidion granosum* Stinton, 1958
	Beryciformes	Berycoidei	Trachichthyidae	*Trachichthodes salebrosus* Stinton, 1958
			Monocentridae	*Cleidopus carvernosus* Stinton, 1958
	Scorpaeniformes	Scorpaenoidei	Scorpaenidae	*Sebastodes fissicostatus* Stinton, 1963
	Perciformes	Percoidei	Sillaginidae	*Sillago pliocaenica* Stinton, 1952
			Lactariidae	*Lactarius tumulatus* Stinton, 1958
		Labroidei	Labridae	*Labrodon* sp.
		Scombroidei	Xiphiidae	*Coelorhynchus elevatu*s Stinton, 1956
				Xiphias sp.
	Tetraodontiformes	Balistoidei	Monacanthidae	
		Tetraodontoidei	Diodontidae	*Diodon formosus* Chapman and Pritchard, 1907
	Dipnoi		Neoceratodontidae	*Neoceratodus djelleh* Kemp, 1982
				*Neoceratodus eyrensi*s White, 1925
				Neoceratodus gregoryi White, 1925
				Neoceratodus forsteri Krefft, 1870
				Neoceratodus nargun Kemp, 1983

Table 1. Continued.

Class	Order	Suborder	Family	Genus and species
Reptilia	Chelonia	Pleurodira	Chelidae	*Emydura* sp.
		Cryptodira	Meiolaniidae	
			Trionychidae*	
	Crocodylia			
Aves	Columbiformes		Columbidae	
	Passeriformes			
	Gruiformes	Ralli	Rallidae	
	Podicipediformes		Podicipedidae	
	Charadriiformes		Burhinidae	
			Phoenicopteridae	
	Anseriformes		Anatidae	
	Pelecaniformes	Pelecani	Pelecanidae	*Pelecanus tirarensis* Miller, 1966
		Sulae	Phalacrocoracidae	
	Procellariiformes		Diomedeidae	*Diomedea thyridata* Wilkinson, 1969
	Sphenisciformes		Spheniscidae	*Pseudaptenodytes macraei* Simpson, 1970
				Pseudaptenodytes minor Simpson, 1970
Mammalia	Monotremata		Ornithorhynchidae	*Obdurodon insignis* Woodburne and Tedford, 1975
	Dasyuromorphia		Dasyuridae	*Dasylurinja kokuminola* Archer, 1982
	Diprotodontia		Wynyardiidae	*Wynyardia bassiana* Spencer, 1901
				Muramura sp.
			Palorchestidae	
			Diprotodontidae	*Raemeotherium yatkolai* Rich et al., 1978
				Zygomaturus gilli Stirton, 1967
				Kolopsis torus Woodburne, 1967
			Ilariidae	*Ilaria illumidens* Tedford and Woodburne, 1987
			Vombatidae	
			Phascolarctidae	*Madakoala devisi* Woodburne et al., 1987
				Madakoala wellsi Woodburne et al., 1987
				Phascolarctos maris Pledge, 1987
			Potoroidae	
			Macropodidae	*Kurrabi* sp.
				Dorcopsis sp.
			Petauridae	
			Pseudocheiridae	*Pildra antiquus* Woodburne et al., 1987
				Pildra secundus Woodburne et al., 1987
			Ektopodontidae	*Chunia illuminata* Woodburne and Clemens, 1986
			Pilkipildridae	*Pilkipildra handae* Archer et al., 1987
				Djilgaringa thompsonae Archer et al., 1987
			Miralinidae	*Miralina minor* Woodburne et al., 1987
	Carnivora		Phocidae	
	Sirenia		Dugongidae	*Dugong** sp.
	Cetacea			*Metasqualodon harwoodi** Sanger, 1881
		Archaeoceti	Basilosauridae*	"*Squalodon*" *gambierensis* Glaessner, 1955
		Mysticeti	Mammalodontidae	*Mammalodon colliveri* Pritchard, 1939
			Aetiocetidae*	
			"Cetotheriidae"	*Pelocetus* sp.
				Parietobalaena sp.
			Balaenidae	*Balaena* sp.
			Balaenopteridae	*Balaenoptera* sp.
				Megaptera sp.
		Odontoceti	Prosqualodontidae	*Prosqualodon* sp. McCoy, 1866
				Prosqualodon davidis Flynn, 1923
			Squalodontidae	
			Eurhinodelphinidae	
			Physeteridae	*Physetodon baileyi* McCoy, 1879b
				Scaptodon lodderi Chapman, 1918
				Scaldicetus lodgei Chapman, 1917b
				Scaldicetus macgeei Chapman, 1912
				Scaldicetus sp.
				Physeter sp.
			Ziphiidae	*Mesoplodon longirostris* Cuvier, 1823
				Ziphius sp.
			Delphinidae	

Table 2. Classification of formally described Australian fossil Cetacea.

Taxon	**Previous classification**
Suborder Archaeoceti	
Family Basilosauridae	
"*Squalodon*" *gambierensis* Glaessner, 1955	Odontoceti: Squalodontidae, Glaessner, 1955; Odontoceti: Squalodontidae, Pledge and Rothausen, 1977; Archaeoceti: Basilosauridae, Fordyce 2002a; Archaeoceti: Basilosauridae, Fitzgerald 2004
Suborder incerta sedis	
Metasqualodon harwoodi Sanger, 1881	Archaeoceti: Basilosauridae, Sanger, 1881; Odontoceti: Squalodontidae Hall, 1911; Odontoceti: Physeteridae, Chapman, 1929; Odontoceti: Squalodontidae, Pledge and Rothausen, 1977; Odontoceti: ?Squalodontidae, Fordyce, 1991; Autoceta: incertae sedis, Fitzgerald 2004
Cetotolites leggei McCoy, 1879a (nomen dubium; Fordyce, 1988)	Odontoceti: Ziphiidae, McCoy, 1879a
Cetotolites nelsoni McCoy, 1879a (nomen dubium; Fordyce, 1988)	Odontoceti: Ziphiidae, McCoy, 1879a
Cetotolites pricei McCoy, 1879a (nomen dubium; Fordyce, 1988)	Odontoceti: Ziphiidae, McCoy, 1879a
Cetotolites rugosa McCoy, 1879a (nomen dubium; Fordyce, 1988)	Odontoceti: Ziphiidae, McCoy, 1879a
Suborder Mysticeti	
Family Mammalodontidae	
Mammalodon colliveri Pritchard, 1939	Archaeoceti: Basilosauridae, Anonymous, 1939; Cetacea: incertae sedis, Camp et al., 1942; Archaeoceti: Basilosauridae, Romer, 1966; Odontoceti: Squalodontidae, Pledge and Rothausen, 1977; Archaeoceti: Dorudontidae (=Basilosauridae: Dorudontinae of Barnes and Mitchell, 1978; Uhen, 1998), Fordyce, 1979; Mysticeti: incertae sedis, Fordyce, 1982a; Mysticeti: Mammalodontidae, Mitchell, 1989; Mysticeti: incerta sedis, Fordyce, 1991
Suborder Odontoceti	
Family Physeteridae	
Physetodon baileyi McCoy, 1879b	Odontoceti: Physeteridae, McCoy, 1879b; Odontoceti: Physeteridae, Fordyce, 1982a
Scaptodon lodderi Chapman, 1918	Odontoceti: Physeteridae, Chapman, 1918; Odontoceti: Physeteridae, Fordyce, 1982a
Scaldicetus lodgei Chapman, 1917b	Odontoceti: Physeteridae, Chapman, 1917b; Odontoceti: Physeteridae, Fordyce, 1982a
Scaldicetus macgeei Chapman, 1912	Odontoceti: Physeteridae, Chapman, 1912; Odontoceti: Physeteridae, Fordyce, 1982a
Family Prosqualodontidae	
Prosqualodon davidis Flynn, 1923	Odontoceti: Squalodontidae, Flynn, 1920,, 1923,, 1932,, 1948; Odontoceti: Prosqualodontidae: *Prosqualodon australis*, Cozzuol, 1996; Odontoceti: Prosqualodontidae, Muizon 2002
Prosqualodon sp. McCoy, 1866	Odontoceti: Squalodontidae: *Phocodon wilkinsoni*, McCoy, 1866; Odontoceti: Squalodontidae: *Squalodon wilkinsoni*, McCoy, 1867a,, 1875; Odontoceti: Squalodontidae: *Parasqualodon wilkinsoni*, Hall, 1911; Odontoceti: Squalodontidae: *Prosqualodon* sp., Pledge and Rothausen, 1977; Odontoceti: Squalodontidae: ?*Prosqualodon davidi*s, Fordyce, 1982a; Odontoceti: Squalodontidae: *Prosqualodon davidi*s, Fitzgerald 2004
Family Delphinidae	
Gen. et sp. indet. Chapman, 1917b	Odontoceti: Delphinidae: *Steno cudmorei*, Chapman, 1917b; Odontoceti: Delphinidae: Gen. et sp. indet., Fordyce, 1982a

Table 3. Summary of Australian Tertiary aquatic mammal taxa, localities, stratigraphy, ages, and references. Abbreviations: SA, South Australia; Tas., Tasmania; Vic., Victoria; Fmn, Formation; Lst, Limestone; Sst, Sandstone; M, Miocene; O, Oligocene; P, Pliocene. * indicates provisional classification.

Taxa	Locality	Stratigraphy	Age	References
CETACEA				
ARCHAEOCETI				
Basilosauridae*				
"*Squalodon*" *gambierensis*	Mount Gambier; SA	Gambier Lst	Late O	Glaessner, 1955; Pledge and Rothausen, 1977; Fordyce, 2002a
MYSTICETI				
Mammalodontidae				
Mammalodon colliveri	Bird Rock; Vic.	Jan Juc Marl	Late O	Pritchard, 1939; Fordyce, 1982a, 1984; Mitchell, 1989; Fitzgerald, 2004
Mammalodon sp. indet.	Bird Rock, Waurn Ponds Quarry; Vic.	Jan Juc Marl; Waurn Ponds Lst	Late O	Fordyce, 1982a, 1988
Mammalodon sp. nov. 1	Bird Rock; Vic.	Jan Juc Marl	Late O	
Gen. et sp. indet. 1	Bells Beach; Vic.	Point Addis Lst	Late O	Pledge, 1994
Gen. et sp. indet.	Point Addis, Waurn Ponds Quarry; Vic.	Point Addis Lst; Waurn Ponds Lst	Late O	Fordyce, 1982a, 1988
cf. Mammalodontidae	Moorabool River; Vic.	Maude Fmn	Late O-Early M	
?Aetiocetidae*				
Gen. et sp. nov.	Port Willunga; SA	Port Willunga Fmn	Early O	
Cetotheriidae				
Gen. et sp. indet.	Forsyth's Bank to Fossil Rock Stack, Gibson's Steps, Waurn Ponds Quarry Batesford Quarry, Beaumaris, Newmerella; Vic.; MacBean's Pound; SA	Grange Burn Fmn; Port Campbell Lst; Waurn Ponds Lst, Batesford Lst; Black Rock Sst; Gippsland Lst; Fmn; Mannum Fmn	Early P; Middle M; Late O; Middle M; Late M-Early P; Early M; Early M	Bearlin, 1987, 1988; Fitzgerald, 2004
Pelocetus sp.	Arch Site, Grange Burn; Vic	Bochara Lst	Middle M	Bearlin, 1987, 1988
cf. *Parietobalaena* sp.	Murbko; SA	Glenforslan Fmn	Middle M	Bearlin, 1987, 1988
Balaenidae				
Gen. et sp. indet.	Dutton Way (Portland), Clifton Bank, Forsyth's Bank to Fossil Rock Stack Beaumaris, Trident Arm; Vic.; Abattoirs Bore; SA	Whalers Bluff Fmn; Muddy Creek Marl; Grange Burn Fmn; Black Rock Sst; Jemmys Point Fmn; Dry Creek Sand	P; Middle-Late M; Early P; Late M-Early P; Early P; Late P	Howchin, 1919; Fordyce, 1982a, 1984; Bearlin, 1987
cf. *Balaena* sp.	Beaumaris; Vic.	Black Rock Sst	Late M-Early P	Gill, 1957; Fordyce, 1982a
Balaenopteridae				
Gen. et sp. indet.	Curdie; Vic.; Winkie; SA	Port Campbell Lst; ?Bookpurnong Fmn	Middle M; ? M-P;	Bearlin, 1987, 1988
Balaenoptera sp.	Dutton Way (Portland), Forsyth's Bank to Fossil Rock Stack, Spring Creek Beaumaris; Vic.	Whalers Bluff Fmn; Grange Burn Fmn; Unnamed unit; Black Rock Sst	P; Early P; Late M-Early P; Late M-Early P	Fordyce, 1982a; Bearlin, 1987
cf. *Balaenoptera* sp.	Cameron Inlet; Tas.	Cameron Inlet Fmn	P	Fordyce, 1982a
Megaptera sp.	Dutton Way (Portland), . Beaumaris; Vic	Whalers Bluff Fmn; Black Rock Sst;	P; Late M-Early P	Bearlin, 1987
Megaptera sp. nov. 1	North Arm; Vic.	Jemmys Point Fmn	Early P	Bearlin, 1987, 1988; Fitzgerald, 2004
cf. *Megaptera* sp.	Cameron Inlet; Tas.	Cameron Inlet Fmn	P	
Family nov.				
Gen. et sp. nov. 1	Deadman's Gully; Vic.	Jan Juc Marl	Late O	Fitzgerald, 2004
Gen. et sp. nov. 2	Bells Headland; Vic.	Point Addis Lst	Late O	Köhler and Fordyce, 1997
ODONTOCETI				
Physeteridae				
Gen. et sp. indet.	Dutton Way (Portland), Forsyth's Bank to Fossil Rock Stack, Batesford Quarry, Beaumaris; Vic.	Whalers Bluff Fmn; Grange Burn Fmn; Batesford Lst; Black Rock Sst	P; Early P; Middle M; Late M-Early P	Fordyce, 1982a, 1984
Physeter sp.	Cameron Inlet; Tas.	Cameron Inlet Fmn	P	Fitzgerald, 2004

Table 3. continued.

Taxa	Locality	Stratigraphy	Age	References
cf. *Physeter* sp.	Clifton Bank, Forsyth's Bank to Fossil Rock Stack; Vic.	Muddy Creek Marl; Grange Burn Fmn	Middle-Late M; Early P	Fordyce, 1982a; Fitzgerald, 2004
cf. *Scaldicetus* sp.	Forsyth's Bank to Fossil Rock Stack, Hopkins River Beaumaris; Vic.	Grange Burn Fmn; Port Campbell Lst; Black Rock Sst	Early P; Middle-Late M; Late M-Early P	Fitzgerald, 2004
Ziphiidae				
Gen. et sp. indet.	Dutton Way (Portland),	Whalers Bluff Fmn;	P; Late M-	Sutherland and Kershaw, 1971; Exon et al.
	Beaumaris; Vic.; Cameron Inlet, Tasman Fracture Zone, Seamount East of South Tasman Rise, Eastern South Tasman Rise; Tas.	Black Rock Sst; Cameron Inlet Fmn; Unnamed unit	Early P; P; Late Neogene	1995; Fitzgerald, 2004
cf. *Mesoplodon* sp.	Forsyth's Bank to Fossil Rock Stack; Vic.; Eastern Scarp; Tas.	Grange Burn Fmn; Unnamed unit	Early P; Late Neogene	Chapman, 1917b; Fordyce, 1982a; Exon et al., 1995
Mesoplodon longirostris	Jemmys Point; Vic.	Jemmys Point Fmn	Early P	Glaessner, 1947; Fordyce, 1982a
Squalodontidae*				
Gen. et sp. indet.	Waurn Ponds Quarry; Vic.; Blanchetown; SA	Waurn Ponds Lst; Mannum Fmn	Late O; Early M	
?Gen. et sp. nov.	Batesford Quarry; Vic.	Batesford Lst	Middle M	Bearlin, 1982; Fordyce, 1982a, 1984; Fitzgerald, 2004
Prosqualodontidae				
Prosqualodon davidis	Fossil Bluff; Tas.	Fossil Bluff Sst;	Early M;	Flynn, 1920, 1923, 1932, 1948; Mahoney and Ride, 1975
Prosqualodon sp.	Castle Cove, Bird Rock; Vic.; Fossil Bluff; Tas.	Calder River Lst; Jan Juc Marl; Fossil Bluff Sst	Late O; Late O; Early M	McCoy, 1866, 1867a, 1867b, 1875; Tate, 1892; Hall, 1911; Flynn, 1948; Fordyce, 1982a, 1982b, 1984; Fitzgerald, 2003, 2004
Gen. et sp. indet.	Mount Gambier; SA	Gambier Lst	Late O	Hall, 1911; Fordyce, 1984
Eurhinodelphinidae				
Gen. et sp. nov.	Lake Namba, Lake Pinpa, Lake Yanda; SA	Namba Fmn	Late O-Middle M	Tedford et al., 1977; Fordyce, 1982a, 1982b, 1983, 1984
?Gen. et sp. indet.	Bird Rock; Vic.	Jan Juc Marl	Late O	
Delphinidae				
Gen. et sp. indet.	Dutton Way (Portland), Beaumaris; Vic.	Whalers Bluff Fmn; Black Rock Sst	P; Late M -Early P	Chapman, 1917; Fordyce, 1982a; Fitzgerald, 2004
?Gen. et sp. indet.	Forsyth's Bank to Fossil Rock Stack; Vic.; Sunlands Pumping Station; SA; Cameron Inlet; Tas.	Grange Burn Fmn; Loxton Sand; Cameron Inlet Fmn	Early P; Early P; P	Fordyce, 1982a; Pledge, 1985
CARNIVORA				
Phocidae				
?Gen. et sp. indet.	Dutton Way (Portland), Forsyth's Bank to Fossil Rock Stack, Beaumaris; Vic.	Whalers Bluff Fmn; Grange Burn Fmn; Black Rock Sst	P; Early P; Late M-Early P	Fordyce and Flannery, 1983
SIRENIA				
Dugongidae				
cf. *Dugong* sp.	Sunlands Pumping Station; SA	Loxton Sand	Early P	Pledge, 1992; Domning, 1996