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Fossil shark teeth from upland Fleurieu Peninsula, South Australia: evidence for previously unknown Tertiary marine sediments

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Introduction

Ongoing investigations of the geological and geomorphological features that make up the complex summit surface of Fleurieu Peninsula, South Australia, continue to provide new insights into its development. In particular, we have been examining the relationships between the often deeply weathered and ferruginised plateau surface developed primarily on Precambrian to early Paleozoic bedrock, which Tokarev and Gostin (2003) describe as the 'pre-Middle Eocene paleoplain', and the Permian and Cenozoic sediments that occur in small intramontane basins, as indicated in schematic cross-sections of Fleurieu Peninsula (Milnes, Bourman and Northcote 1985; Alley and Bourman 1995).

Two water wells (662709607 and 662711613, 'Walker wells') drilled in 1996 between Mount Compass and Victor Harbor (Fig. 1) intersected fossiliferous Cenozoic sediments at depths of 12–30 m below the land surface at an elevation of ~244 m ASL. These findings have never been published and no samples of the sediments have been located, but the landowner (RT Walker, Hundred of Goolwa) collected a selection of shark teeth from the cuttings of well 662709607 (09607), which he made available to the authors for study. Two of us (Bourman and Alley) recently inspected the ground around the bores and collected grab samples in an endeavour (unsuccessful) to recover additional datable materials from any cuttings that remain.

Our paleontological study of the shark teeth has provided important information about the age of the Cenozoic sediments and this significantly expands our understanding of the geological history of the

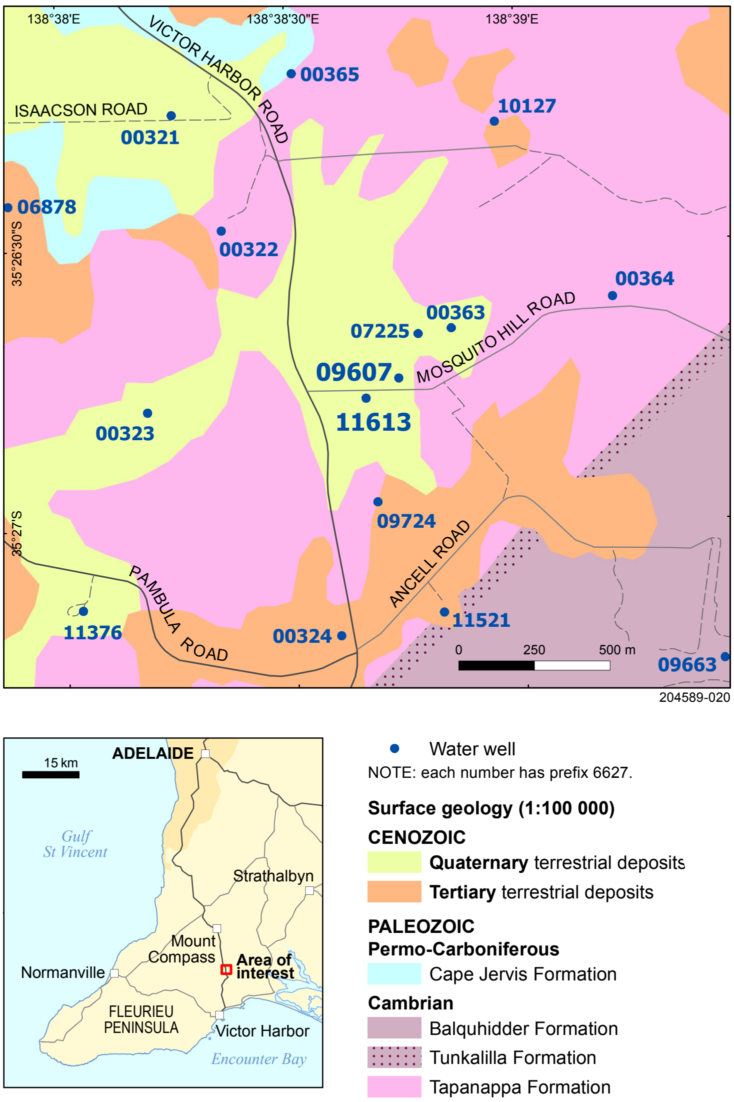


Figure 1 Locality map highlighting water wells discussed in this study and surface geology. (Source DSD 2014)

region. The aim of this note is to describe the shark teeth, assess their age and depositional environment in relation to other occurrences, and suggest the implications of these findings to the development of the landscape in this part of Fleurieu Peninsula. Additional drilling, sampling and stratigraphic investigations in this locality are foreshadowed before more definitive statements can be made.

Geological setting

Fleurieu Peninsula separates the St Vincent Basin and the Murray Basin (Fig. 2), with some of their Cenozoic sedimentary successions onlapping the older rocks of the peninsula. Repeated marine transgressions from the Middle Eocene to the Pliocene encroached on and within the peninsula leaving remnant Late Oligocene to Middle Miocene marine sediments in now isolated intramontane basins, including the Myponga and Hindmarsh Tiers basins (Fig. 2; Furness, Waterhouse and Edwards 1981; Lindsay and Alley 1995). These are likely to have been formed in part by gouging of the underlying bedrock (largely Cambrian Kanmantoo Group metasediments) by Permian glacial ice. Glacigene sediments (Cape Jervis Formation) are widespread on the peninsula, but the nearest outcrop to the Walker wells is about 1 km to the west (Fig. 1). Tertiary sand, gravel and weathered rock occur on ridge tops and valley sides. Locally, valley bottoms are filled with Quaternary sediments.

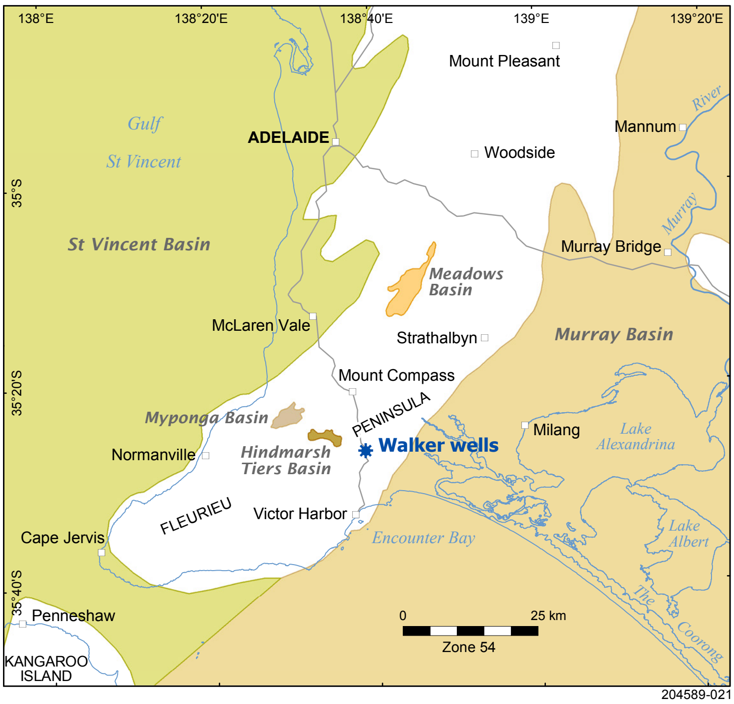


Figure 2 *Cenozoic basins marginal to and within Fleurieu Peninsula. (Source DSD 2014)*

The Walker wells were drilled in a small drainage depression at an elevation of ~250 m, a little below the summit surface of Fleurieu Peninsula in the headwaters of Currency Creek. The fossiliferous sediments were intersected at depths of 12–30 m below the land surface. Both wells ended at 30 m in 'bedrock' or 'hard blue rock' (according to the driller logs) which is interpreted to be Kanmantoo Group metasediments. In the case of the Hindmarsh Tiers and Myponga basins, the Cenozoic sediments overlie Permian glacigene sediments.

Limestones in the Hindmarsh Tiers Basin (Fig. 2) range in age from Late Oligocene to Early Miocene (Lindsay and Alley 1995). In the Myponga Basin they are Middle Miocene in age (Lindsay and Alley 1995) and, on the basis of foraminiferal evidence, four transgressive–regressive episodes have been recognised. The marine connections with the Murray and St Vincent basins that facilitated deposition of the limestones in the Myponga and Hindmarsh Tiers basins are unknown. A connection with the St Vincent Basin is favoured but a marine passage across Fleurieu Peninsula during a eustatic high is possible.

Given that a number of transgressions occurred during the Middle Eocene to Middle Miocene (Fig. 3) in the St Vincent and Murray basins, and that eustatic sea level was at least 200 m higher than present in the Eocene and ~100 m higher than present from Late Oligocene to Middle Miocene (Benbow et al. 1995), it is possible that Fleurieu Peninsula was inundated more frequently than has been recognised.

Paleontology

Most of the shark teeth specimens consist of only the enamel crown of the tooth, at best with partial root, but a few are more or less complete (App). Nevertheless, identification to generic level is possible in one case, at least. Although the specimens show two preservational modes, and thus indicate two oxidation states and two geological facies, the collection appears to be taxonomically uniform, and comprises only four or five different species. The dark grey overall appearance and general morphology of most of the collection resemble specimens in the South Australian Museum collections from several bores near Ki Ki, Naracoorte and Robe in the southeast of the state where they have been determined to be of Late Eocene age (Pledge 1967). On the other hand, the light-colored bleached specimens are reminiscent of material of Early Miocene age from Strathalbyn and the Monarto area, although there is also a resemblance to Middle Eocene material from the South Maslin Sand at Maslin Bay. The morphospecies concerned, as far as can be determined, have a rather long time range, and thus the collection from well 09607 could extend from Late Eocene into the Miocene.

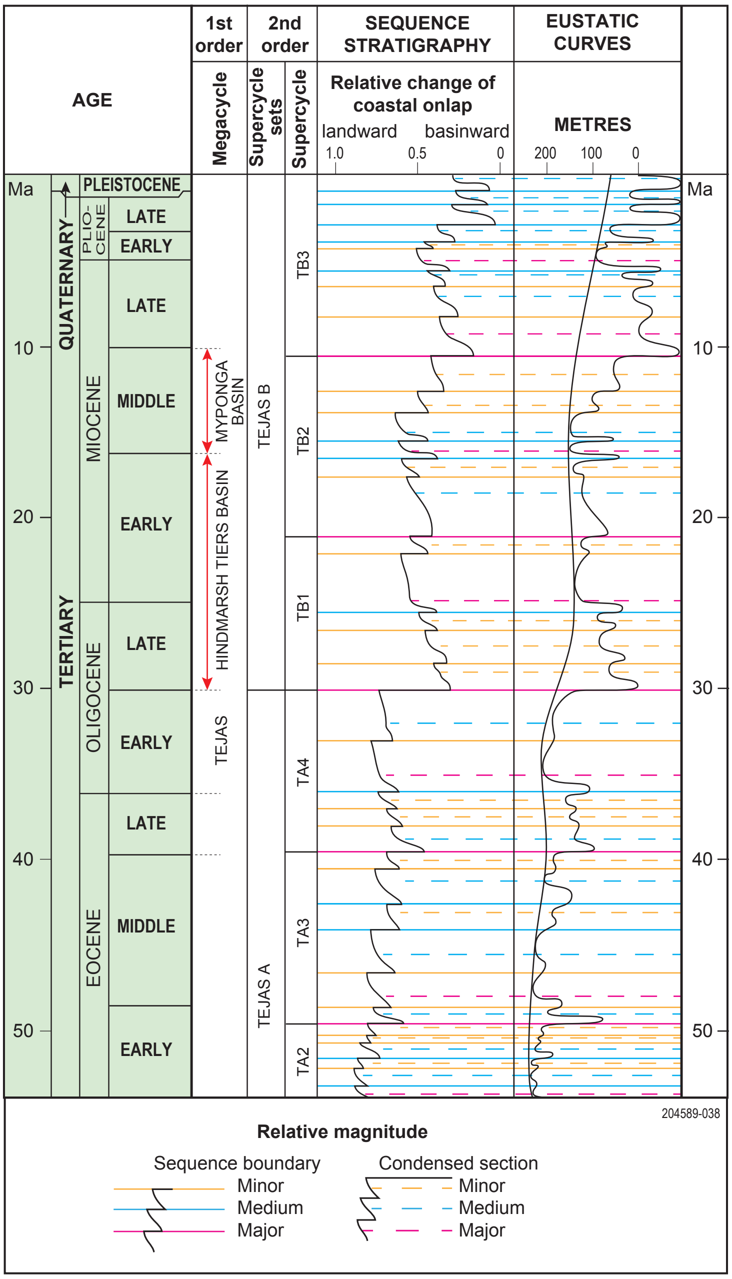


Figure 3 *Sea-level curve for part of the Cenozoic showing the elevated sea levels during the intervals of time when limestone was deposited on parts of Fleurieu Peninsula. (Modified from Benbow et al. 1995)*

The collection is noteworthy in containing two specimens of a shark not previously recorded from the early Cenozoic in South Australia, and quite different to its early Pliocene congener (Pledge 1985), namely a species of Port Jackson shark (*Heterodontus*; App.)

Implications

While a Late Eocene age for the shark teeth is favoured, the interpreted affiliations of the teeth with dated fossils, as well as the differences in preservation, also suggest that both Late Eocene and Miocene limestone facies may be present in the small intramontane basin at the Walker property. Further drilling and sampling is foreshadowed to help to clarify this.

Two possible scenarios might account for these sediments:

1. A small Late Eocene marine incursion may have penetrated from the Murray Basin into the basin where the Walker wells occur.
2. A possible marine passage between the St Vincent and Murray basins as proposed by Tokarev and Gostin (2003) could have been present in Late Oligocene to Middle Miocene times (Fig 4).

In the Hindmarsh Tiers Basin, ~6 km to the northwest of the Walker wells, the base of the Late Oligocene to Early Miocene Port Willunga Formation fill is ~80 m ASL with the top between ~150 to 230 m ASL (Furness, Waterhouse and Edwards 1981; Fig. 5). A younger deposit of Middle Miocene Port Willunga Formation in the Myponga Basin has a base close to present sea level with the top between ~140 to 200 m ASL, although a small isolated occurrence to the southeast reaches 238 m ASL (Furness, Waterhouse and Edwards 1981). The differences between the current height of sediments in the Myponga, Hindmarsh Tiers and Walker wells basin, relative to the same sequences in the St Vincent Basin (Willunga Embayment) and Murray Basin, are interpreted to be the result of faulting and differential uplift since the Miocene. The marine sediments from the Walker wells, if confirmed to be Late Eocene, would be the highest-level remnant of sediments of this age on Fleurieu Peninsula. As further studies are completed, details of the tectonic movements that have played a significant part in the evolution of the landscape of Fleurieu Peninsula may be elucidated.

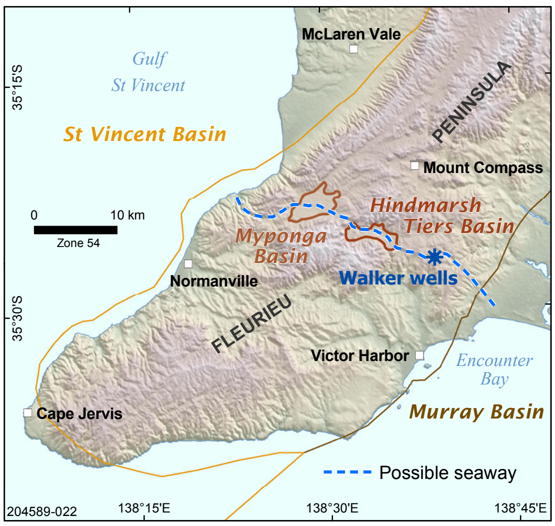


Figure 4 *Interpretation of the position of a possible seaway across Fleurieu Peninsula in the mid Cenozoic, based on the distribution and height of Cenozoic sediments.*

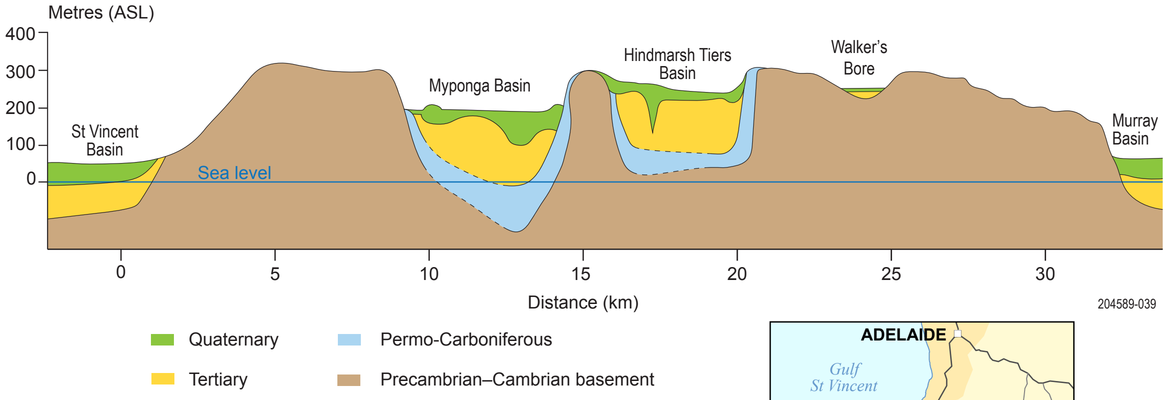
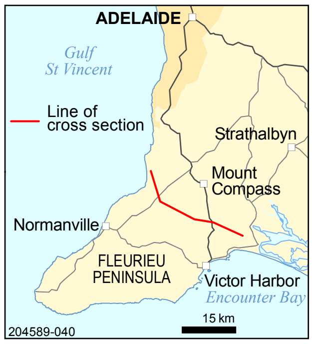


Figure 5 *Cross-section across part of Fleurieu Peninsula showing the height relationships between the basins.*



Appendix: Tentative species list

Heterodontus species

Heterodontidae sharks are named after their heterodont dentition (Cappetta 1987), wherein there are, in each upper and lower jaw of *Heterodontus*, a median or symphyseal file separating four or more rows or files of sharply cuspate anterior teeth. These are flanked by two files of small, low, sub-cuspate intermediate teeth, then one file of small pre-lateral teeth, two files of large convex crushing lateral teeth, one file of smaller post-lateral teeth and two files of smaller, flat hexagonal teeth forming a mosaic pavement. Each post-anterior file can contain up to seven teeth where the outer ones are not yet functional in the jaw.

In a South Australian Museum (SAM) specimen of the dried lower jaws of a small *Heterodontus portusjacksoni* (SAM P10631), there is a series of seven teeth in each file of the lateral, post-lateral and posterior teeth, with a higher number in the anterior and pre-lateral teeth. In the first file of the laterals, the teeth range from 6.5–6.9 mm long and 3–3.5 mm wide; they are 9.8–9.9 mm long and 3.9–4.5 mm wide in the second file. In both, the medial edges of the teeth are convex, extending on to the anterior edge, while the lateral edges are concave, ending with an acute angle with the anterior edge. Posterior edges are roughly normal to the length of the teeth. Teeth in the first file have a more pronounced median hump and an almost sigmoidal outline compared with the second file. Here the teeth are relatively lower, a little more rectangular, their anterior edge wider and produced to an acute outer angle, the posterior edge narrower and truncated almost square to the length.

The two fossil teeth of interest from well 09607 (SAM P49417, P49418) are from the lateral files (Fig. 6h, Fig. 7). They are the first recorded specimens of *Heterodontus* from the Tertiary in South Australia, their age being suggested by their preservation, although Tate (1894) reported one specimen from the 'Lower Murravian' or Lower Miocene. Other than Pliocene teeth referred to *H. cainozoicus* (Pledge 1985), they differ in several respects from *Heterodontus portusjacksoni*. It is not yet clear whether they are upper or lower teeth, or both. Assuming they are both lower teeth, then the larger (SAM P49417) is from the right second file and the smaller from the left, possibly first file. They are both more evenly curved than in *H. portusjacksoni* and, although polished (but not worn), they lack the sub-medial longitudinal crest of this modern species, but exhibit narrow longitudinal facets not seen in *H. portusjacksoni*. They are also rather more-coarsely punctate (Fig. 7).

Chapman and Pritchard (1904) provided measurements for some of their specimens of *Cestracion cainozoicus* and *Asteracanthus* (= *Strophodus*) *eocenicus*, and Tate (1894) for his *Strophodus eocenicus*, as shown in Table 1. Specimens from well 09607 may represent a new species, but additional samples will be required to confirm this.

Chapman and Cudmore (1924) subdivided their *C. cainozoicus* into four species: *C. cainozoicus*, *C. coleridgensis* (Chapman 1918), *C. novozelandicus* (Chapman 1918) and *C. longidens* (Table 1).

Examination of these data, admittedly few, suggests that tooth proportions do not differentiate the named species. Specimens from well 09607 fall close to the size range of Upper Miocene *Heterodontus cainozoicus* (Chapman and Pritchard 1904; Chapman and Cudmore 1924), which overlaps in size with *H. novozelandicus*. Only morphological characters can be relied on to separate the species.

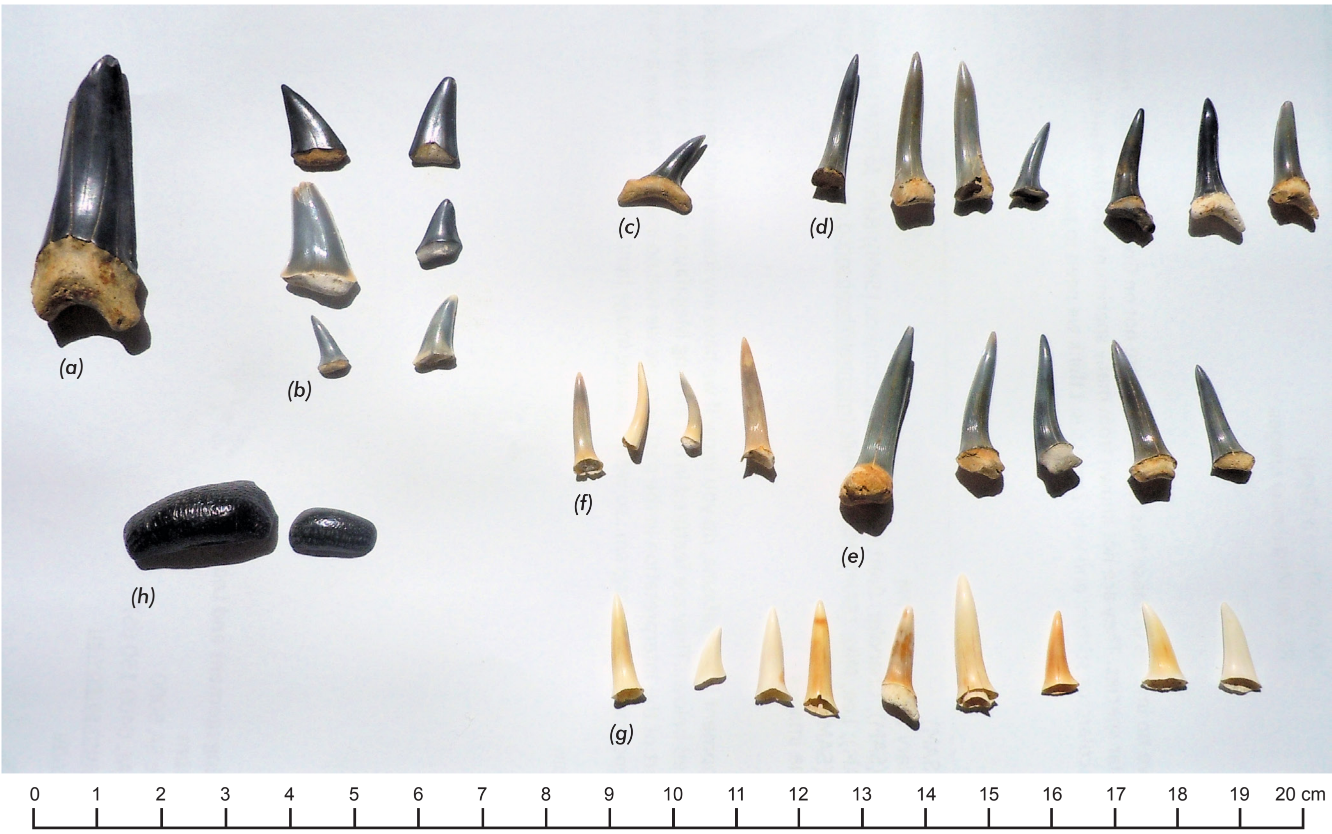


Figure 6 *Selection of shark teeth from well 09607.* ***(a)*** Isurus *species?* ***(b)*** Lamna *species.* ***(c)*** Odontaspis *species, cf.*'cuspidatus' *posterior tooth.* ***(d)*** Odontaspis *species, cf.* 'cuspidatus'. ***(e)*** Striatolamia *species, cf.* macrota. ***(f)*** Carcharias *species, cf.* maslinensis. ***(g)*** *'Bleached' teeth.* ***(h)*** Heterodontus *species* (novozelandicus?). *(Photo 414535)*

Figure 7 Heterodontus *species lateral teeth from well 09607: SAM P49417 (top) and P49418. Note the faceted and punctate appearance of the occlusal surfaces. (Photo 414536)*

The teeth differ markedly in size and preservation from the abundant specimens of *H. cainozoicus* reported from the Pliocene Loxton Sands at Waikerie (Pledge 1985), and in morphology, in being slightly more convex, and with the occlusal surface bearing faint parallel longitudinal facets. They are more like '*Cestracion longidens*' (Chapman and Cudmore 1924) and '*Strophodus eocenicus*' (Tate 1894; Chapman and Cudmore 1924). These teeth would have been assigned to *Strophodus* by Tate or Chapman and Cudmore, but are now regarded as *Heterodontus*, partly because of their Cenozoic age, *Strophodus* not being definitely known younger than early Cretaceous. Most of the specimens for which there is published information (Tate 1894; Chapman and Cudmore 1924) appear to be quite worn, as are the few Victorian reference specimens in the South Australian Museum. The two specimens here are, to our knowledge, unlike in shape or morphology any Cretaceous or early Cenozoic examples of lateral teeth (such as *H. rugosus*, *H. vincenti* and *H. woodwardi*; Agassiz 1839; Leriche 1905; Casier 1946) in being relatively shorter/broader and lacking a well-defined median carina.

Odontaspis *species*

This is almost a 'grab-bag' assignation for some of the commonest fossil shark teeth from the South Australian Cenozoic. They are slender, curved, with smooth enamel, sharp lateral edges and a pair of small to minute curved lateral denticles at the base of the crown (Fig. 6d). Their roots are strong and extended. Both denticles and roots are commonly broken off during deposition, leaving just

Table 1 Measurements of some Heterodontus *lateral teeth*

Specimen	Reference	Comment	Length (mm)	Breadth (mm)	Height (mm)
Cestracion cainozoicus	Chapman and Pritchard (1904)	Semicircular	13	7	5
Cestracion cainozoicus	Chapman and Pritchard (1904)	Sub-rhomboidal	18.5	11	7
Cestracion cainozoicus	Chapman and Pritchard (1904)	Elongate-oblong	18	7	5
Asteracanthus eocenicus	Chapman and Pritchard (1904)	Small	17	6.5	2.5
Asteracanthus eocenicus	Chapman and Pritchard (1904)	Medium	29	11.5	8
Asteracanthus eocenicus	Chapman and Pritchard (1904)	Large	32.5	11.5	8.5
Strophodus eocenicus	Tate (1894)		30	8–11	7
Well 09607		Large	24.2	7.8–10.6	7
Well 09607		Small	14	6.1–7.0	3.3
Cestracion cainozoicus	Chapman and Cudmore (1924)	Median series	23	12	6.5
Cestracion coleridgensis	Chapman (1918); Chapman and Cudmore (1924)	Table cape	20.5	12	4
Cestracion novozelandicus	Chapman (1918); Chapman and Cudmore (1924)	Smaller	9	4.5	—
Cestracion novozelandicus	Chapman (1918); Chapman and Cudmore (1924)	Larger	15	7	—
Cestracion longidens	Chapman and Cudmore (1924)	Holotype	30	11	6
Cestracion longidens	Chapman and Cudmore (1924)	Kershaw specimen	28.5	10	—

the enamelled crown. Posterior teeth have a more compressed triangular crown, inclined posteriorly in upper teeth. There is only one specimen in the 09607 collection that matches this last type (Fig. 6c). Because all except this tooth lack the roots and consequently the lateral denticles, there can be no definitive identification.

Striatolamia macrota

Previously known as *Odontaspis elegans* and *Carcharias macrotus*, this worldwide species almost defines the Eocene marine vertebrate fauna (Pledge 1967). Teeth of this species are typically (for anterior and anterolateral teeth) sinuously curved, with sharp edges and a pair of small, curved, sharp-pointed lateral denticles. The species is distinguished from *Odontaspis* species by having the convex inner surface of the tooth finely striated vertically. Posteriorly, the teeth become shorter and laterally compressed and almost triangular towards the corners of the mouth. The roots and denticles are commonly broken off during deposition. About half the 09607 collection fits this description (Fig. 6e).

A few smaller teeth (Fig. 6f) may fit the description of the anterior teeth of this 'species', except for being almost cylindrical (circular in cross-section) and very twisted. These have been named *Carcharias [Mitsukurina] maslinensis* (Pledge 1967; Cappetta 1987) and may indicate a Late Eocene age, although some specimens have been found in younger deposits.

Lamna *species?*

The identification of small flat triangular teeth (Fig. 6b), usually inclined posteriorly, is fraught with difficulty if they are incomplete, as teeth in the 09607 collection are. They have, in the past, commonly been referred to extinct species of *Lamna*, the living porbeagle or mackerel shark of cooler pelagic seas. However, *Lamna* is now known to have appeared in the Oligocene, and has few fossil species. Previous earlier records may be ascribed to *Cretolamna*. Without roots or lateral denticles, the teeth cannot be identified or dated. Some may in fact belong to species of *Odontaspis* as posterior teeth.

Isurus *species?*

Mako sharks are possibly represented by a single specimen (Fig. 6a) of a large sharp-edged tooth lacking signs of lateral denticles. It is the largest tooth in the 09607 collection, but is damaged and lacks its tip and roots. It appears to be very similar to a tooth of *Isurus retroflexus* that was found in a post-hole at Myponga, and is believed to be of Miocene age (Pledge 1967). *Isurus* typically has no lateral denticles on its teeth.

Other biota

Also present amongst the shark teeth in the 09607 collection is a fragment of bryozoan colony ('*Cellepora*'?), together with an indeterminate cidaroid echinoid (ambulacral plate and spine fragments). Their preservation suggests a limy sand to silt formation, possibly of Miocene age.

Remarks

Apart from the Heterodontids, only one shark tooth (Fig. 6c) is relatively complete in retaining much of its roots, but even here the tooth has lost its tiny lateral cusps, which can be diagnostic for species. In view of the tentative identifications of the teeth, a precise age determination is not possible but the general indication is for most to be Late Eocene to Miocene.

The preservation of the teeth suggests deposition in two different geological facies:

- a reducing environment of sand or mud, possibly glauconitic, for the dark coloured specimens
- an oxidising sand–silt or limestone environment for the pale-coloured (bleached) teeth, bryozoan and sea-urchin.

The bleached teeth consist only of the hollow crown enamel, the bony dentine having been oxidised and removed (Fig. 6f, g). When preserved in reducing environments, the tooth enamel is dark bluish or greenish grey and the dentine is grey-to-almost black and well preserved (Fig. 6a–e, h). An example of other reducing environments from which Cenozoic shark teeth have been recovered is at Wellington with a squalodont whale *Metasqualodon* and shark tooth '*Notidanus*' (Pledge and Rothausen 1977). The estimated age of these fossils is Late Oligocene. Examples of oxidising environments from which shark teeth have been recovered are at the Myponga cheese factory (*Isurus retroflexus*; Pledge 1967), Strathalbyn cemetery (Pledge 1967) and a sand quarry, and at Monarto. The estimated age of these fossils is Early Miocene.

Acknowledgements

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References

Agassiz L 1839. *Recherches sur les poissons fossiles*. Tome III (livr. 10, 12). Imprimérie de Petitpierre, Neuchatel, pp. 141–156.

Alley NF and Bourman RP 1995. Troubridge Basin. In JF Drexel, WV Preiss and AJ Parker eds, *The geology of South Australia, Volume 2, The Phanerozoic,* Bulletin 54. Geological Survey of South Australia, Adelaide, pp. 65–70.

Benbow MC, Alley NF, Callen RA and Greenwood DR 1995. Geological history and palaeoclimate. In JF Drexel, WV Preiss and AJ Parker eds, *The geology of South Australia, Volume 2, The Phanerozoic,* Bulletin 54. Geological Survey of South Australia, Adelaide, pp. 208–218.

Cappetta H 1987. *Chondrichthyes II, Mesozoic and Cenozoic Elasmobranchii*, Handbook of Palaeoichthyology Volume 3B. Gustav Fischer Verlag, Stuttgart, New York.

Casier E 1946. La faune ichthyologique de l'Yprésien de la Belgique. *Mémoires du Musée Royal d'Histoire Naturelle de Belgique* 104:1–267.

Chapman F 1918. Descriptions and revisions of the Cretaceous and Tertiary fish remains of New Zealand. *Palaeontology Bulletin* 7:1–46. New Zealand Department of Mines, Geological Survey Branch.

Chapman F and Cudmore FA 1924. New or little-known fossils in the National Museum, Part XXVII, Some Cainozoic fish remains, with a revision of the group. *Proceedings of the Royal Society of Victoria* 36(new series)(2):107–162.

Chapman F and Pritchard GB 1904. Fossil fish remains from the Tertiaries of Australia, Part 1. *Proceedings of the Royal Society of Victoria* XVII(new series):267–297.

DSD – see Department of State Development

Department of State Development 2014. SARIG Map Layers (Geology; Groundwater). Department of State Development, South Australia, viewed December 2014, <www.statedevelopment.sa.gov.au/sarig>.

Furness LJ, Waterhouse JD and Edwards DR 1981. *The hydrogeology of the Hindmarsh Tiers and Myponga basins*, Report of Investigations 53. Geological Survey of South Australia, Adelaide.

Leriche M 1902. Les poissons paléocènes de la Belgique. *Mémoires du Musée Royal d'Histoire Naturelle de Belgique* 2(5):1–48.

Lindsay JM and Alley NF 1995. Myponga and Hindmarsh Tiers basins. In JF Drexel, WV Preiss and AJ Parker eds, *The geology of South Australia, Volume 2, The Phanerozoic,* Bulletin 54. Geological Survey of South Australia, Adelaide, pp. 199–201.

Milnes AR, Bourman RP and Northcote KH 1985. Field relationships of ferricretes and weathered zones in southern South Australia: a contribution to 'laterite' studies in Australia. *Australian Journal of Soil Resources* 23:441–465.

Pledge NS 1967. Fossil Elasmobranch teeth of South Australia and their stratigraphic distribution. *Transactions of the Royal Society of South Australia* 91:135–160.

Pledge NS 1985. An Early Pliocene shark tooth assemblage in South Australia. In JM Lindsay ed., *Stratigraphy, palaeontology, malacology - papers in honour of Dr Nell Ludbrook*, Special Publication 5. Department of Mines and Energy South Australia, pp. 287–299.

Pledge NS and Rothausen K-H 1977. *Metasqualodon harwoodi* (Sanger, 1881)—a redescription. *Records of the South Australian Museum* 17(17):285–297.

Tate R 1894. Unrecorded genera of the older Tertiary fauna of Australia, including diagnoses of some new genera and species. *Journal and Proceedings of the Royal Society of New South Wales* 37:167–197.

Tokarev V and Gostin V 2003. Mount Lofty Ranges, South Australia. Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME), viewed February 2015, <http://crcleme.org.au/RegLandEvol/MtLofty.pdf>.

FURTHER INFORMATION

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