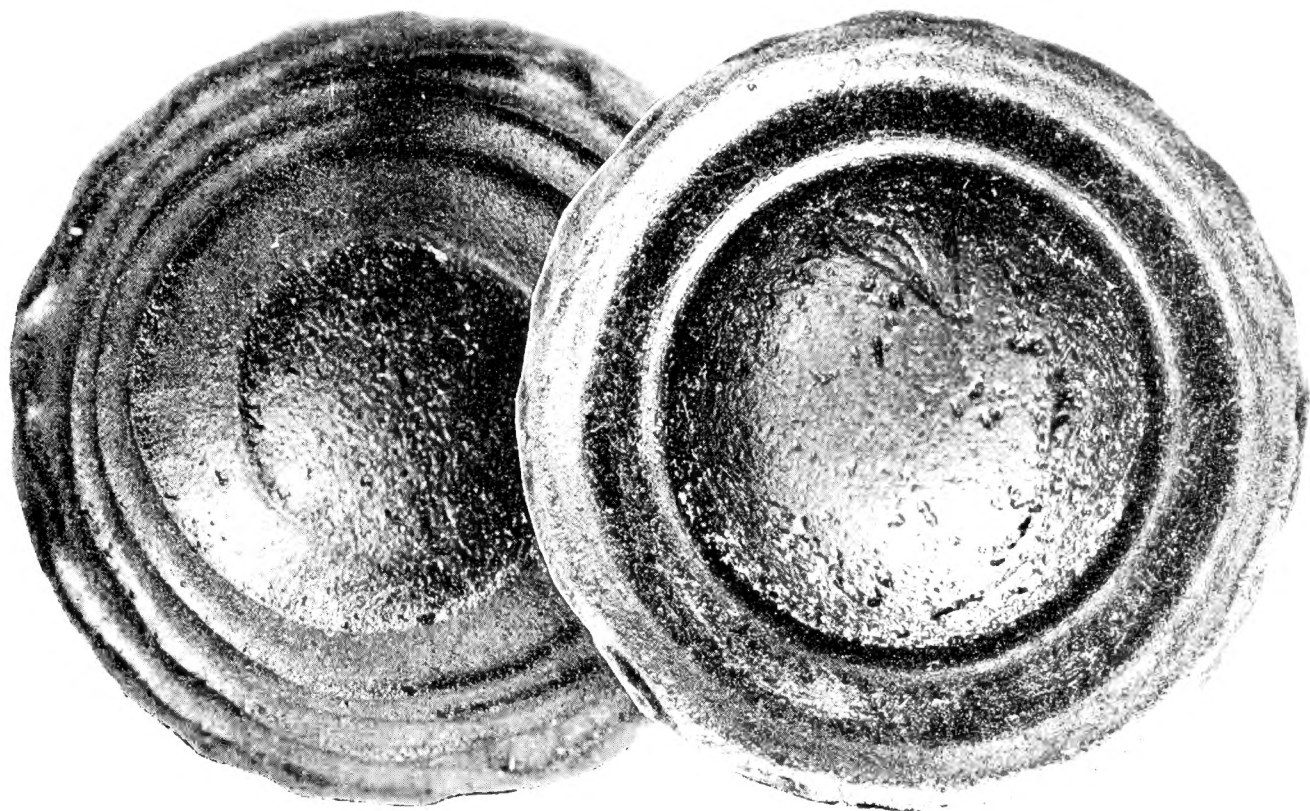# MEMOIRS of the NATIONAL MUSEUM of VICTORIA

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1969

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No. 29

CONTENTS

BEACH SANDS OF THE SOUTHERN SHORE OF PORT PHILLIP BAY, VICTORIA, AUSTRALIA

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Abstract

The textural and constituent composition of 23 samples of beach sand collected along the S. shore of Port Phillip Bay are described. The sand is coarse along the shore of Dromana Bay but grain size diminishes to the W., the median diameters from McCrae to Point Nepean ranging between 0·18 and 0·52 mm. Except for two samples, all sands are well sorted. The sands are composed mainly of quartz grains and shell particles. The content of acid-soluble (mainly shell) material is low in the E. part of the study region, but between Rye and Point Nepean it ranges between 22·2 and 50·1 per cent. The heavy mineral composition of the samples is given and the minerals described. It is concluded that most of the sand constituents have been derived from disintegration of granitic rocks and dune-limestone which outcrop along the coast in the study region. Much of the shell material in the sand from Rosebud to Point Nepean is considered to have come from the dune-limestone which is composed largely of shell fragments of sand size. The beaches are relatively stable, but human interference appears to be partly responsible for coastal erosion at certain places.

Introduction

The sandy beaches on the S. shore of Port Phillip Bay, Victoria, being not far distant from the city of Melbourne, are popular playgrounds. They constitute a scenic and recreational resource of major importance, and thereby are of commercial value. No previous work has been carried out on the beach sands of Port Phillip Bay's S. shore. The present research was conducted primarily to obtain information about the nature of the sands and to enquire into their origin. However, is was realized that the work could be of value in projects associated with the prevention of coastal erosion and the control of sand accumulation.

Field work was carried out during July, 1966, when mid-tide beach sand samples were collected at approximately one-mile intervals from the NE. corner of Dromana Bay to Point Nepean, a distance of 22½ miles. During the period of collection, calm weather prevailed and wind conditions were fairly constant. The position of each sampling station was fixed by surveying methods with reference to the maps of the Mornington Peninsula Area Base Map Series (scale 400 ft to 1 in.). Figure 1 shows the localities whence the samples were collected; information about precise locations and remarks about the places of collection are given in the Appendix.

Sand samples of approximately 350 grams were collected at about the reported time of low tide, by pushing down a thin metal cylinder to a depth of 3 in., removing the sand around the outside of the cylinder, and sliding a thin board underneath. Width and gradient of the shore at each collecting locality were determined. Rock samples were collected from coastal cliffs, to assist in the enquiry into the origin of the sands.

Coastal Geomorphology, Geology and Environment

The S. shore of Port Phillip Bay extends along the NW. and N. margins of the Mornington Peninsula—that region of the Victorian mainland between Western-port Bay and Port Phillip Bay. The shore consists of sandy beaches alternating with rock-cliffed sections and headlands. Topographic relief varies along the coast. The surface is usually low and hummocky behind long sandy beaches, and gently undulating to hilly behind rock-cliffed sections of the shore. At Mount Martha and Arthur's Seat, near the coast, the land rises to heights of 520 ft and 1,000 ft respectively.

The extreme E. part of the region of study is known as Dromana Bay. The N. shore of this Bay consists of a cliffed coastline cut in the Mount Martha Grano-diorite (Palaeozoic). From the S. limit of the granodiorite cliffs a broad sandy beach stretches for 11 miles to White Cliffs. The beach is bordered in many places by a belt of weakly defined sand ridges which are fixed by vegetation. The sand ridge bordering the shore is subject to wave attack during gales, and rock sea-walls have been constructed at a number of places to prevent coastal erosion. There are small outcrops of granite on the sandy shore at The Rocks, Dromana. White Cliffs is a headland of Pleistocene dune-limestone (aeolian calcarenite).

From White Cliffs a sandy beach extends for about 3 miles in a WNW. direc-tion to The Sisters. This stretch of shore is bordered for most of its length by vegetated sand ridges which are higher than those between White Cliffs and Dromana. In the vicinity of Blairgowrie and at certain other places between White Cliffs and The Sisters, groynes and retaining walls have been constructed to control erosion. The Sisters are two headlands of dune-limestone separated by a small sandy beach.

The shore extends in a WNW. direction from The Sisters for 8 miles to Point Nepean. It consists of a series of sandy beaches separated by cliffed sections and headlands of dune-limestone. Between Sorrento and Portsea, Point King, Point McArthur and Point Franklin form conspicuous headlands, and cliffs of dune-limestone rise steeply from the shore in many places. These cliffs reach a height of 70 ft in the vicinity of Point McArthur. From the Army Officer Cadet School at Portsea to Point Nepean the shore mainly consists of a broad sandy beach bordered by sand ridges. At Point Nepean (the E. Head of Port Phillip Bay) a broad, hori-zontal shore platform is developed in dune-limestone but this wide platform dies out inside the Bay. Erosion is active at Point Nepean, and the headland is partly protected by a sea-wall.

The width of sandy shore varies along the coast (see Appendix), reaching 250 ft near the Rosebud Jetty. Where the beach is wide, the angle of slope is small, being only 1° near the Rosebud Jetty. Where the shore is comparatively narrow, the gradient is higher, reaching 7° at some places. Since the tide range is small, the foreshore is narrow where the slope is relatively steep; the spring tide range diminishes from 3·5 ft at Point Nepean Jetty to 3 ft at Dromana Jetty. However, where the shore gradient is low, the foreshore is wide; this is so in the Rosebud-Rye area where the sandy foreshore attains a width of 200 ft.

The S. shore of Port Phillip Bay lies approximately at right angles to the direc-tion of maximum fetch in the Bay and is exposed to N. and NW. winds but pro-tected from both S. and E. winds. Strong winds from the N. and NW. generate powerful waves which erode sand off some of the beaches and deposit it in the off-shore region; but smaller waves generated by weaker winds transport sand back on to the beaches. Bowler (1966) regards the coast from Dromana to Point

Nepean as a zone of sediment accumulation by N. to S. and W. to E. movement, and he believes that the protection afforded by the coastal orientation permits little drift. The accumulation of sand alongside groynes on various beaches along the coast certainly is not great; and variable drift is indicated at different places and at different times by the building up of sand on opposite sides of groynes. At the time when field work was carried out most accumulation of sand was on the W. side of groynes in the Rye-Sorrento region.

Emerged beach deposits and other evidence of emergence of the land can be seen at various places along the S. coast of Port Phillip Bay. These features have been described by Hills (1940), Bowler (1966) and others, and are believed to have formed in mid-Holocene times when sea-level was about 10 ft higher than now. There are no streams of any significance entering Port Phillip Bay along its S. shore.

Figure 1 shows the geology of the region of study. Maps showing the geology of the coastal region immediately to the N. are included in papers by Keble (1950) and Gostin (1966). A cliffed coast of Mount Martha Granodiorite extends N. from Safety Beach to Balcombe Bay, and from there for about 11 miles the coastal sections are composed largely of Upper Tertiary ferruginous sandstones known as the Baxter Sandstones.

With reference to submarine topography, bathymetric contours indicate that much of the near-shore region is fairly shallow. The near-shore profile off the cliffed coastline of Mount Martha Granodiorite is relatively steep, but flattens S. in Dromana Bay. Proceeding SW. as far as Tootgarook the near-shore gradient is also low. A system of shallow sand bars begins off the beach at McCrae, and these off-shore bars continue W. subparallel to the beach to near Sorrento. Off-shore between The Sisters and Point King, the Bay floor is nearly flat over a large area (part of the region known as the South Sand) and the 5-fathom line is about 2 miles from the coastline. Between Point King and Point Nepean the 1-fathom and 5-fathom contours are closely spaced near the shore for long distances, particularly where the coast is steeply rock-cliffed.

Sand covers the floor of Port Phillip Bay for a considerable distance N. from its S. shore (Beasley 1966), extending out to about the 10-fathom line. In shallow areas off-shore between Sorrento and Point Nepean dune-limestone outcrops through a thin cover of sand to form rocky shoals or 'reefs'; and in deeper water near Port Phillip Heads tidal scour has exposed dune-limestone. Tidal currents are fairly strong in the channels off the southern shore of the Bay, the tidal streams in the entrance to Port Phillip attaining velocities up to 8 knots.

Laboratory Procedure

Each beach sand sample was dried and reduced in bulk with a Jones splitter to about 50-75 g. Soluble marine salts and organic (weed) matter were removed by decantation and, after drying, the material was sieved using Wentworth intervals. A cumulative frequency curve and a histogram were constructed for each sample, and the median diameter and Trask's sorting coefficient were determined. Size fractions were examined with a binocular microscope, recombined and treated with dilute 1:2 hydrochloric acid to determine the weight percentage of acid-soluble (mainly carbonate) material in each sample. Sieve analysis of the acid-insoluble residue was carried out and the median diameter and sorting coefficient of the

Fig. 1—Map showing location of sand sampling stations, geology and submarine contours.

RECENT
ALLUVIUM
SAND, ETC.

PLEISTOCENE
DUNE-LIMESTONE,
ETC.

OLIGOCENE
PEBBLE BEDS

EOCENE
OLDER BASALT

DEVONIAN
GRANODIORITE,
GRANITE,
DACITE, ETC.

SCALE OF MILES

leached sand (free from shell fragments, etc.) were determined. A histogram was constructed for each sample of acid-treated sand.

Heavy minerals were separated from the acid-treated $\frac{1}{16}$ to $\frac{1}{4}$ mm size-grades of each sand sample using bromoform, and the weight percentage of heavy minerals (index number) for this size range was determined. An Alnico hand magnet was used to detect the presence of magnetite; its relative abundance was estimated and the grains returned to the heavy mineral fraction prior to mounting in Canada balsam for examination under the microscope. Heavy mineral species were identified under the petrological microscope and their relative proportions were determined by counting random fields of grains in each microscope slide. Percentages were determined to the closest whole per cent; less than $\frac{1}{2}$ per cent was recorded as a trace. Types of rock fragment and the nature of composite grains in the beach sediments were determined by microscopic examination.

Rock samples from coastal cliffs were crushed in a steel mortar and each sample was reduced in bulk by coning and quartering to about 75 g. The weighed sample was then soaked in water and completely disaggregated by wet crushing. Clay and water-soluble salts were removed by decantation. The sample of disaggregated rock (minus clay and soluble salts) was then sieved and the median diameter and sorting coefficient were determined. Each size-fraction was examined with a binocular microscope. After recombining these fractions, the sample was treated with dilute hydrochloric acid and the weight percentage of acid-soluble material was calculated. The acid-insoluble residue was sieved, and the median diameter and sorting coefficient of this material was determined. Heavy minerals were separated from the $\frac{1}{16}$ to $\frac{1}{4}$ mm size-grades of the acid-treated sample with bromoform and the index number determined. The heavy mineral grains were identified and their relative abundance calculated.

Textural Composition of the Sands

Results of the mechanical analysis of the sands and their acid-insoluble residues are presented in Table 1 and Figure 4.

Median Grain Size

Figure 2 shows the median grain size of the sands and their acid-insoluble residues plotted against distance along the coast. The median grain size of the sands ranges from a maximum of 0·83 mm at station 1 to a minimum of 0·18 mm at station 11 (Rye). From station 1 to station 11 there is an almost continuous decrease in median grain size. The decrease from station 1 (adjacent to granodiorite cliffs) to station 2 is particularly steep, and this trend continues to station 3, indicating that appreciable S. drift of the larger sized particles does not occur. From station 3 the median grain size coarsens slightly to station 4 and this coarsening continues to station 5 (Md 0·62 mm) at The Rocks, Dromana. This local increase in the median may be related to the occurrence of granite outcrops near station 5. There is a sharp decrease in median grain size from station 5 to station 7 (Md 0·27 mm) near Rosebud Jetty, but the differences from there to station 11 are less great. The comparatively small medians in the Rosebud-Rye region may be related to low wave energies there, much of the wave energy having been expended over the wide near-shore zone of shallow water with numerous sand bars.

From station 11 the median diameter increases to station 12 and continues to coarsen W. to station 13 (Md 0·40 mm). The larger median at station 13 can be related to an unusually great content of large shell fragments, presumably broken

TABLE 1

Statistical constants of beach sands from Port Phillip Bay

Sample No.		Md (mm)	Q3 (mm)	Q1 (mm)	So	Acid-soluble per cent
1		0·83	1·70	0·26	2·56	4·0
1	A.I.R.*	0·81	1·63	0·29	2·37	
2		0·66	0·79	0·55	1·20	0·4
2	A.I.R.	0·64	0·76	0·54	1·19	
3		0·55	0·71	0·44	1·27	0·5
3	A.I.R.	0·55	0·71	0·44	1·27	
4		0·58	0·64	0·49	1·17	0·5
4	A.I.R.	0·56	0·68	0·50	1·14	
5		0·62	0·76	0·46	1·28	1·6
5	A.I.R.	0·62	0·73	0·48	1·22	
6		0·48	0·57	0·42	1·16	8·2
6	A.I.R.	0·47	0·56	0·40	1·18	
7		0·27	0·32	0·23	1·18	4·6
7	A.I.R.	0·27	0·33	0·23	1·20	
8		0·30	0·36	0·26	1·18	15·2
8	A.I.R.	0·31	0·37	0·26	1·19	
9		0·28	0·34	0·24	1·19	18·1
9	A.I.R.	0·28	0·32	0·25	1·14	
10		0·21	0·24	0·17	1·17	28·6
10	A.I.R.	0·20	0·24	0·17	1·20	
11		0·18	0·20	0·15	1·16	39·5
11	A.I.R.	0·17	0·20	0·15	1·15	
12		0·33	0·44	0·26	1·29	28·6
12	A.I.R.	0·32	0·41	0·27	1·24	
13		0·40	>4·00	0·23	>4·17	50·1
13	A.I.R.	0·29	0·40	0·16	1·60	
14		0·33	0·46	0·26	1·34	31·8
14	A.I.R.	0·35	0·45	0·26	1·31	
15		0·33	0·37	0·29	1·12	23·7
15	A.I.R.	0·33	0·38	0·28	1·16	
16		0·29	0·34	0·27	1·12	24·8
16	A.I.R.	0·32	0·37	0·28	1·14	
17		0·52	0·59	0·42	1·19	22·2
17	A.I.R.	0·52	0·59	0·43	1·17	
18		0·52	0·60	0·48	1·12	27·5
18	A.I.R.	0·52	0·56	0·47	1·10	
19		0·26	0·33	0·23	1·19	38·1
19	A.I.R.	0·28	0·33	0·25	1·15	
20		0·28	0·34	0·24	1·20	34·8
20	A.I.R.	0·28	0·31	0·24	1·13	
21		0·22	0·26	0·19	1·15	50·1
21	A.I.R.	0·24	0·27	0·20	1·15	
22		0·25	0·33	0·21	1·27	46·8
22	A.I.R.	0·26	0·31	0·23	1·14	
23		0·30	0·35	0·25	1·18	36·6
23	A.I.R.	0·30	0·36	0·26	1·19	

Key: Md = Median, Q3, Q1 = Quartiles, So = Sorting coefficient, A.I.R.* = Acid-insoluble residue.

and transported by fairly powerful waves. The median diameters at stations 14, 15 and 16 are all very close to that at station 12, suggesting similar wave energies and similar source materials at these localities. There is a marked coarsening of the sand at stations 17 and 18 (near Sorrento); this appears to be due more to higher wave energy and the removal of finer fractions by wave and current action than to
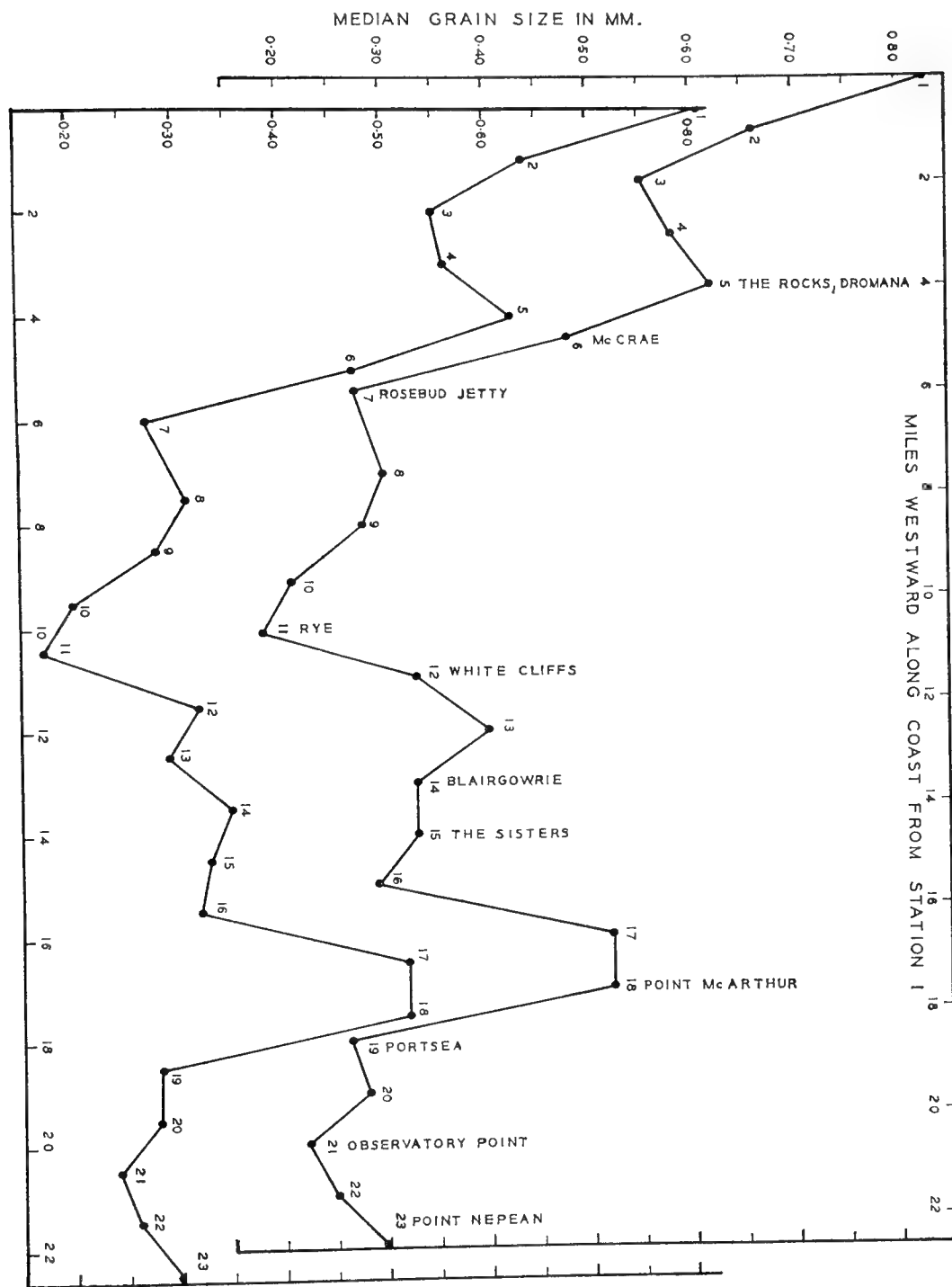
MEDIAN GRAIN SIZE IN MM.

FIG. 2—Median grain size of sands (top) and their acid-insoluble residues (bottom) plotted against distance along coast.

the presence of small fragments of dune-limestone in the sand. The median diameters at stations 19 to 23 do not differ greatly from one another, that at station 23 (Point Nepean) being the coarsest of these five samples.

The upper graph in Fig. 2 reveals two regional characteristics. The first is the occurrence of relatively coarse sand in the far E. part of the study region. Median diameters at station 5 and all stations E. are greater than the other samples. This coarseness appears to be due more to the proximity of source material (Mount Martha Granodiorite) than to higher wave energies; wave energies are similar on other sections of the coast. The second observation is that the sands from stations 7 to 23 do not have a wide range in median diameter, if those from stations 13, 17 and 18 are excluded. The similarities in median grain sizes along this stretch of coast from Rosebud to Point Nepean suggest that the source materials of the sand are essentially similar. The coarser sand at stations 13, 17 and 18 is probably due to local variations in wave energies and current velocities at these localities.

In most cases the median grain size of the acid-insoluble residues is slightly finer than that of the beach sand samples. However, treatment with acid resulted in a marked decrease in the median of the sand from station 13. The median diameters of the acid-insoluble residues of the sand from stations 17 and 18 are identical with those of the untreated samples. The coarseness of the sand at these stations therefore is not due to marine skeletal material or to fragments of dune-limestone.

Sorting

Trask's (1932) coefficient of sorting (So) of the beach sand samples and their acid-insoluble residues are listed in Table 1 and are plotted against distance along the coast in Fig. 3.

The sand from station 13 has a coefficient of sorting considerably greater than that of any other sample and, adopting Trask's (1932) classification, is poorly sorted. Sorting values of the other sand samples range from a maximum of 2·56 at station 1 to a minimum of 1·12 at stations 15, 16 and 18; they are all well sorted sands except that from station 1 which has moderate sorting. Sixteen of the 23 sand samples have sorting coefficients of 1·20 or less.

The occurrence of sand with only moderate sorting at station 1 may be related to its location adjacent to cliffs of decomposed granodiorite. Sorting improves markedly along the shore away from the granodiorite cliffs, but there is a local decrease at station 5 (The Rocks, Dromana) near small outcrops of granite. From station 6 (McCrae) to station 12 (White Cliffs) the sorting coefficients are almost identical, and the sands are very well sorted. Poor sorting at station 13 may be related to an unusually large shell content with shell fragments of various sizes. This poor sorting indicates turbulent conditions, but it is only local in occurrence and at station 14 the sand is well sorted. From station 15 to station 23 the sorting values are all very similar.

The upper graph in Fig. 3 indicates that, apart from the marked improvement in sorting from station 1 to station 2, there are no regional trends of sorting with shoreline distance. The improvement in sorting in the far E. part of the study region suggests that the direction of drift there is SW. along the shore.

There appears to be a relationship between the sorting coefficient of the beach sand and its median diameter. Sands which are very well sorted usually have small values for their median diameter, and a decrease in the degree of sorting commonly corresponds with an increase in median grain size.

Most commonly sorting was improved slightly after removal of the acid-soluble
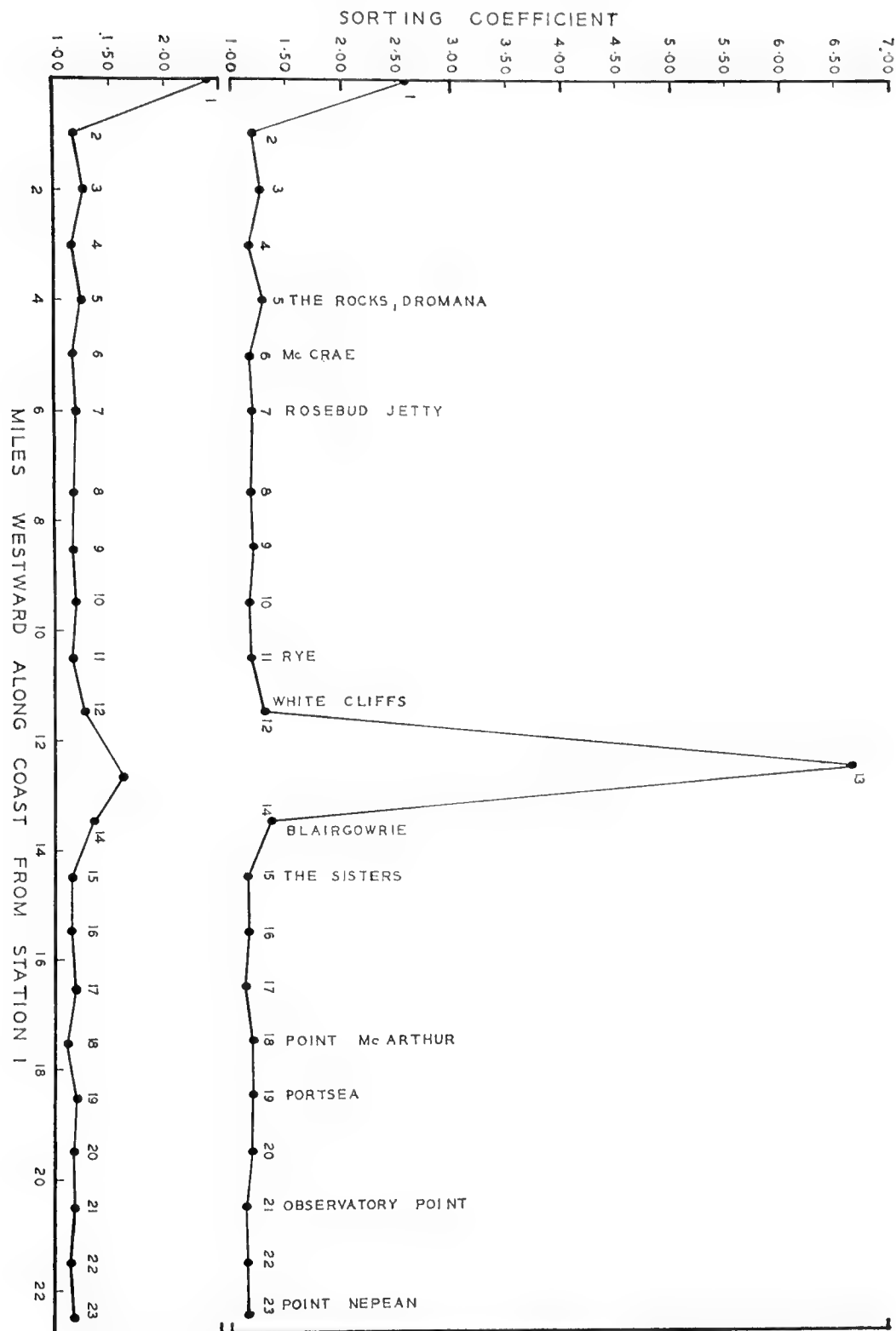
FIG. 3—Sorting coefficient of sands (top) and their acid-insoluble residues (bottom) plotted against distance along coast.

fraction. However, the sorting coefficient of the acid-insoluble residue of the sand from station 13 is considerably less than that of the untreated sand. After removal of the acid-soluble fraction from each sample, the residues are all well-sorted sands and most are very well sorted.

Histograms

In the histograms, weight percentage of material greater than 4 mm in size is indicated by vertical lines, since it represents material retained on the coarsest sieve used. In most cases none or very little material was retained on this sieve.

The sands from stations 1, 5 and 13 are bimodal but the other 20 are unimodal. Sand from station 1 has a primary mode in the very coarse sand size-grade and a lesser mode in the fine sand. Its large secondary maximum and spread indicate an immature condition of sorting. Two sources for this sand are suggested by the nature of the histogram; there appears to be loading with coarse material supplied from the nearby granodiorite. A very conspicuous maximum size-grade occurs in the coarse sand grade of the samples from stations 2, 3 and 4, and fine proximate admixture exceeds coarse proximate admixture in each of them. The bimodal nature of the sand at station 5 suggests two sources, one of which is granitic rock nearby. The maximum size-grade in the samples from stations 6 to 9 is medium sand, but this maximum shifts to fine sand at stations 10 and 11. The histograms reveal a coarsening in size and a lower degree of sorting at station 12, and show that 30% of the sand from station 13 is greater than 4 mm in size. The bimodal character of the latter sample is due to the mixing of finer quartzose sand with coarser bioclastic material mainly of molluscan origin. There is a conspicuous maximum in the medium sand grade at stations 14, 15 and 16. At stations 17 and 18 the maximum size-grade is coarse sand, but at stations 19 and 20 it has shifted back to medium sand and fine proximate admixture is considerably greater than coarse. The histograms reveal a decrease in size at station 21 and 22, but at station 23 (Point Nepean) the maximum is again in the medium sand grade and fine proximate is the dominant admixture.

Of the 20 unimodal sands, five have the maximum in the coarse sand grade, 11 in the medium sand grade and four in the fine sand grade. It is a common characteristic for the histograms to have few grades with a conspicuous maximum size-grade towering above the neighbouring grades; the narrow spread indicates a high degree of sorting. None of the samples west of station 13 have a secondary maximum.

Acid-insoluble residues of the beach sands from stations 1, 5 and 13 are bimodal like the sands, but the other acid-treated samples are unimodal. Since the histograms for the acid-insoluble residue and the untreated sand from station 1 are almost identical, shell content does not cause the bimodality of that beach sand. Comparison of histograms also indicates that bimodality at station 5 is not due to calcareous shell content. Histograms for most of the acid-insoluble residues very closely resemble those for the untreated sand, but show that the acid-insoluble residues commonly are slightly finer. Histogram shape for the acid-treated sand from station 13, however, is very different from that for the untreated sand and, although a wide spread still exists, a marked decrease in size is apparent.

Constituent Composition of the Sands

The constituent composition refers to the acid-soluble (mainly carbonate) content and the acid-insoluble content of the beach sediments. Some of the samples
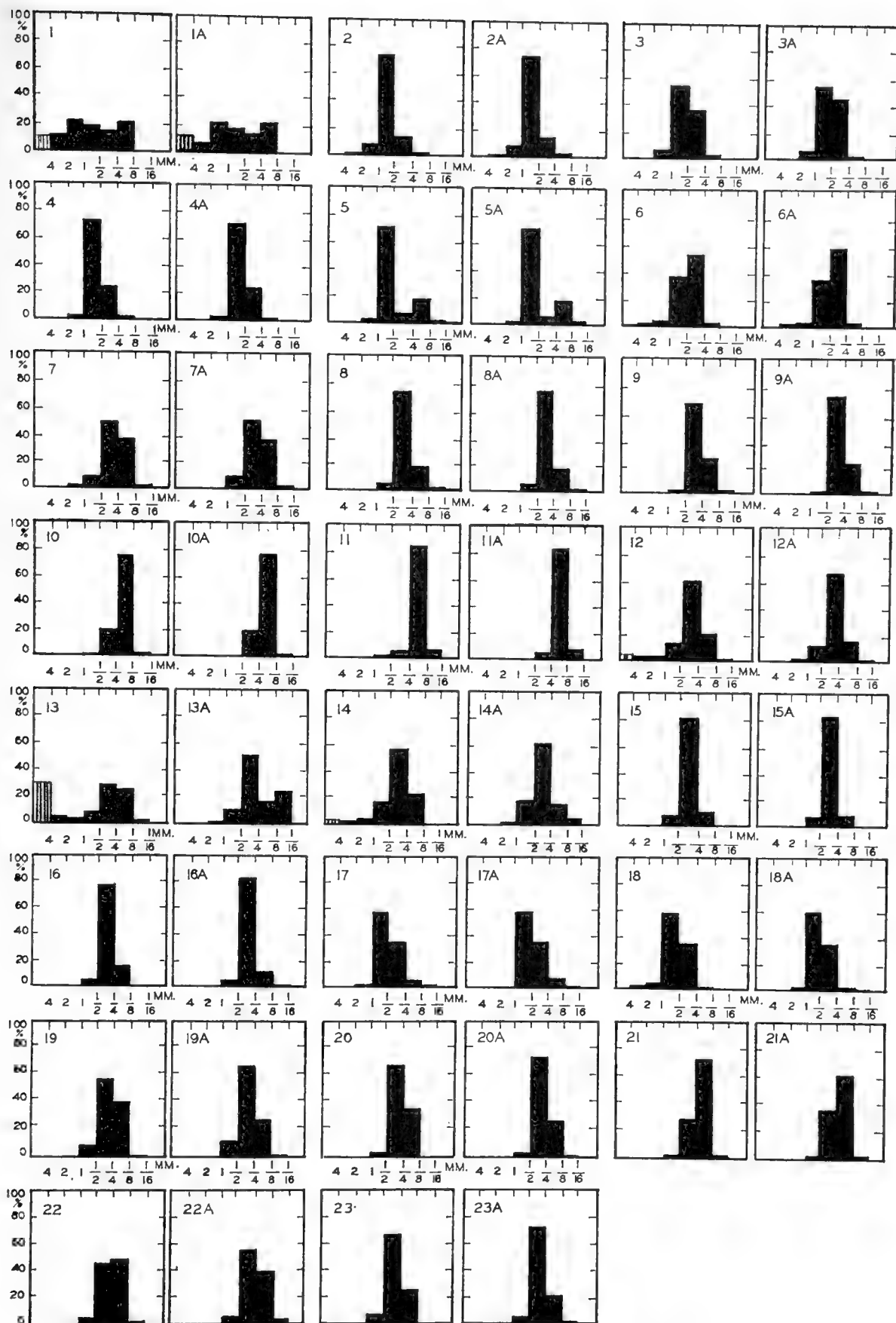
FIG. 4—Size-analysis histograms of sands and their acid-insoluble residues (A).

contain rock fragments, and a separate statement is made concerning them, since they serve as important indicators of source and assist in tracing sediment drift along the coastline.

Acid-soluble Content

The weight percentage of acid-soluble material in each sample is listed in Table 1 and these percentages are plotted against distance along the coast in Fig. 5. The acid-soluble content ranges from a minimum of 0·4 per cent at station 2 to a maximum of 50·1 per cent at station 13. From station 1 W. for 6 miles the acid-soluble content is less than 8·5 per cent, but from there is rises steeply reaching 39·5 per cent at station 11 (Rye). Between Rye and Point Nepean it varies between 22·2 per cent and 50·1 per cent. There is, accordingly, a low content of acid-soluble material in the sands from the E. part of the study region, and a relatively high content in those from the central and W. parts.

Microscopic examination indicates that organogenic material makes up almost all of the acid-soluble content. It comprises whole shells and shell fragments of Holocene age as well as material derived from the disintegration of Pleistocene dune-limestone, which is composed largely of shell fragments of sand size. It seems likely that much of the shell material in the sand from Rosebud to Point Nepean has come from disintegration of the dune-limestone which outcrops along the coast. All size-fractions of the sand from this region contain shell material, and it is common in most fractions. The low content of shell material in the sands east of McCrae seems to have come mainly from organisms indigenous to the nearby seafloor; it is present mainly in the coarser size-fractions of the sand. Microscopic examination indicates that shell material greater than 2 mm in size in the other sand samples is of similar Holocene origin. The presence of a large amount of shell derived from the indigenous marine fauna in the sand at station 13 points to considerable on-shore drift in the vicinity at certain times.

Rock Content

Fragments of granitic rock and hornfels occur in the sand at station 1. Apparently they have come from local sources; hornfels occurs around the Mount Martha Granodiorite as well as at The Rocks, Dromana (Baker 1938, Keble 1950). Much of the granitic rock is of pebble size but the fragments range down through granule to coarse sand size; most of the smaller fragments exhibit a fairly low degree of roundness and it is clear that they have not been subjected to much transportation. The amount of granitic rock at stations 2, 3 and 4 is considerably less than at station 1, but at station 5 there is a slight increase apparently due to local outcrops. Much less granitic rock is present at stations 6 to 9, and there is a decrease in size and increase in roundness of the fragments as one proceeds W. Granitic rock was not found at stations 10 and 11, but one small fragment was present in the sample from station 12 and a few from station 13; it is probable that these came from material used in the construction of retaining walls in the vicinity. No fragments of granitic rock occur in the samples W. of station 13.

Dune-limestone fragments are present in all samples from station 12 (White Cliffs) to Point Nepean but do not occur in the samples E. of White Cliffs. The fact that fragments do not occur far distant from dune-limestone outcrops may be related to the friable nature of much of this rock which is fairly easily disintegrated. The absence of dune-limestone fragments from the sands E. of Rye, however, may
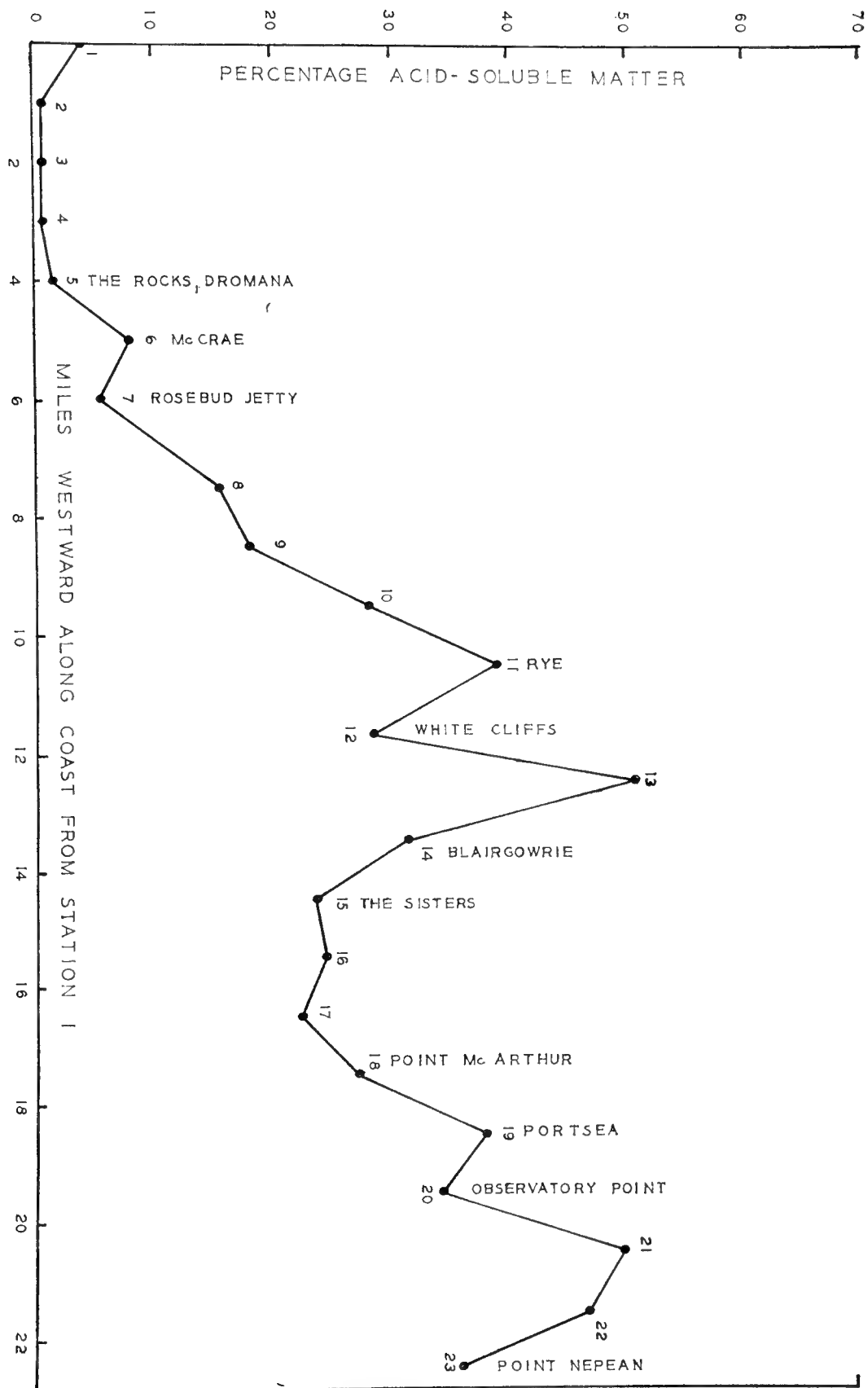
FIG. 5—Weight percentages of acid-soluble material in beach sands plotted against distance along coast.

indicate that sediment drift from the W. and central parts of the study region E. along the coastline is not very considerable.

A few granules and sand-size particles of ironstone occur in many of the samples. Their amount is never great, but they are more common in the Dromana-Safety Beach area than elsewhere.

Acid-insoluble Mineral Content

The acid-insoluble mineral content of the beach sands consists mainly of quartz. This is chiefly the transparent to translucent variety originally of granitic origin, but small amounts of opaque reef quartz occur. Feldspar grains are fairly common in certain samples, rare in others and not recognized in some. White mica occurs in minor amounts in the finer size-grades of certain samples.

The quartz grains are usually either colourless or yellowish and brownish from a thin coating of limonite; occasionally they are coated with hematite and are pinkish. Most ironstained grains reveal films of secondary iron hydroxide or iron oxide along cracks and flaws. Reef quartz grains are usually whitish-grey in colour, but some are deeply ironstained to a reddish colour.

Most of the quartz grains at station 1 are colourless and subangular to subrounded. Reef quartz is conspicuous there and feldspar is relatively common. Most of the mineral grains at station 1 appear to have come from the granitic rocks nearby and to have been transported little. The degree of roundness of the quartz grains in the sands from station 2 (Safety Beach) to station 6 (McCrae) ranges from angular to well rounded, but the majority are subangular to subrounded and most grains are colourless. Some of the quartz grains in the coarser size-fractions of the sands at these stations are angular; this points to a short detrital history, since rounding of larger size particles occurs at a relatively rapid rate. The ratio of ironstained quartz grains to colourless ones increases in a SW. direction along the shore from Safety Beach to McCrae. There are a larger number of subrounded quartz grains at station 7 (Rosebud) and station 8 (Rosebud West) than at the stations to the E. Feldspar and reef quartz particles diminish in amount in a SW. direction along the coast from Safety Beach.

From station 9 (Tootgarook) to Point Nepean colourless quartz grains are more abundant than ironstained ones; the former are commonly subangular and the latter are commonly subrounded. This fact suggests two different sources for the quartz. The less rounded colourless grains may have come from granitic rocks not far away, whereas the ironstained grains have a longer detrital history. The ratio of colourless to ironstained quartz grains remains almost constant along the central and W. parts of the study region. Some of the grains have frosted surfaces and others are well polished.

Heavy Fractions

The index number for the $\frac{1}{16}$ to $\frac{1}{4}$ mm size-grades of each acid-treated sand sample is listed in Table 2. The weight percentages of heavy minerals (index numbers) range from a maximum of 3·97 at station 3 (Dromana) down to a minimum of 0·22 at stations 11 (Rye) and 12 (White Cliffs). The relatively high values at Dromana and Safety Beach may be attributed to the location near the E. end of the arcuate stretch of shore between Point Nepean and Martha Point. Presumably the heavy minerals, transported by wave and current action, have become more concentrated along the shore of Dromana Bay partly because of the configuration of the coastline; they are prevented from moving northward by the headland of Mount Martha Granodiorite which has steep cliffs and relatively deep

water near-shore. Some of the heavy minerals in these sands have apparently been derived from the granodiorite, and the higher index numbers may be partly due to closer proximity to this source rock.

In the central part of the region under consideration the index numbers are low in value but typical of most beach sands. The index number is 0·55 at station 7 near Rosebud Jetty and, with the exception of the sample from station 13, the values are all below unity until station 18 (Point McArthur) is reached. These low values may be connected with low-energy wave conditions resulting from the shallow near-shore topographic profile and the presence of sand bars subparallel to the beach. The higher value at station 13 may be related to higher wave energy in the vicinity connected with a steepening of the near-shore profile, greater heavy mineral concentration being affected by more powerful wave action.

The index numbers of samples from the W. part of the region are usually higher than those from the central (Rosebud-Sorrento) part, the value at station 23 (Point Nepean) being 1·35. The higher values may be attributed to the interruption to heavy mineral sand movement along and near the shore caused by the Rip, as well

TABLE 2

Mineralogical composition of heavy fractions (in % by number) and index numbers

STATION	ANATASE	ANDALUSITE	APATITE	AUGITE	BIOTITE	BLACK OPAQUES	BROWN OPAQUES	CHLORITE	EPIDOTE	GARNET	HORNBLENDE	IDDINGSITE	KYANITE	LEUCOXENE	MAGNETITE	MONAZITE	OLIVINE	PYRITE	RUTILE	SPHENE	STAUROLITE	TOPAZ	TOURMALINE	ZIRCON	ZOISITE	OTHERS	INDEX NUMBER
1	-	tr	tr	-	2	67	1	tr	tr	tr	2	-	-	9	C	tr	-	tr	1	-	-	-	7	8	-	tr	1.90
2	tr	-	tr	-	3	61	1	-	-	1	1	-	-	9	C	-	-	-	1	tr	-	tr	10	10	-	1	2.00
3	-	tr	tr	-	2	67	1	-	tr	1	1	-	-	7	C	tr	-	-	2	-	-	-	9	9	-	tr	3.97
4	-	-	-	tr	2	66	tr	tr	-	-	2	-	-	8	C	-	-	tr	2	-	-	-	8	8	-	1	1.99
5	tr	tr	tr	tr	1	52	tr	-	tr	tr	3	-	-	15	C	-	-	-	1	tr	-	-	11	11	tr	tr	0.55
6	-	-	-	tr	2	64	tr	-	tr	tr	4	-	-	7	C	tr	tr	-	2	-	-	tr	7	12	tr	-	1.06
7	-	tr	-	1	1	56	-	tr	1	1	2	-	-	7	C	-	1	-	2	tr	-	-	18	8	tr	tr	0.55
8	-	-	tr	2	1	59	-	-	1	-	3	-	-	10	O	tr	1	-	tr	-	-	-	11	8	tr	-	0.65
9	-	tr	-	3	1	54	-	-	1	-	5	-	tr	9	O	-	3	-	tr	-	-	tr	12	8	2	-	0.73
10	-	-	-	2	tr	56	-	-	1	-	4	-	tr	10	O	-	2	-	tr	tr	-	-	11	10	1	tr	0.34
11	tr	-	-	2	tr	45	-	-	2	tr	9	-	-	10	O	-	4	-	tr	-	-	-	12	10	2	-	0.22
12	-	-	-	2	tr	61	tr	-	1	-	3	-	-	10	O	-	2	-	tr	-	-	-	11	10	1	-	0.22
13	-	tr	-	3	-	66	-	-	1	-	2	tr	-	8	O	-	2	-	1	tr	-	-	7	9	1	tr	1.34
14	-	-	-	4	-	63	-	-	2	-	2	-	tr	8	O	-	3	-	1	-	tr	-	7	7	1	-	0.38
15	-	-	-	6	-	55	-	-	tr	-	2	tr	-	11	O	-	4	-	1	-	-	-	6	10	2	tr	0.37
16	tr	-	-	6	-	44	tr	-	2	-	2	tr	-	15	O	-	5	-	1	-	tr	-	10	12	2	-	0.27
17	-	-	-	4	-	62	-	-	2	-	2	tr	-	11	O	-	4	-	1	-	-	-	4	6	1	-	0.69
18	-	-	-	3	-	56	-	-	1	tr	1	1	-	12	O	-	5	-	2	-	tr	-	4	12	1	tr	1.14
19	-	-	-	4	-	53	-	-	1	tr	2	1	tr	15	O	-	4	-	1	-	-	-	5	9	1	-	0.52
20	-	tr	-	4	-	54	tr	-	1	-	2	tr	tr	14	O	-	4	-	2	-	tr	-	4	10	1	tr	1.29
21	tr	-	-	5	-	55	-	-	2	tr	3	tr	-	12	O	-	4	-	1	-	-	-	4	12	2	-	1.24
22	-	-	-	5	tr	50	-	-	2	-	4	1	-	10	O	-	6	-	1	-	tr	-	5	11	1	tr	1.11
23	-	-	-	4	-	58	-	-	1	-	2	tr	-	12	O	-	5	-	1	-	-	-	6	7	2	-	1.35

tr = less than ½%   - (hyphen) = not detected   C = common   O = occasional

as to the close proximity of a source rock (dune-limestone) and somewhat higher-energy wave conditions near the entrance to Port Phillip Bay.

Magnetite is present in the heavy fraction of each sample. Its relative abundance is listed in Table 2, estimated according to the following scale: A = very abundant; a = abundant; C = common; o = occasional; r = rare; V = very rare. Magnetite is classed as common in the heavy fraction of the sands from stations 1 to 7, that is, from the E. part of the region under consideration. In all samples W. of station 7 the relative abundance of magnetite is classed as occasional.

The mineralogical composition of the heavy fractions is given in Table 2. In this Table, 'others' refers to grains which could not be positively identified, usually because their weathered condition obscured diagnostic optical properties; it also includes some composite grains.

The heavy fractions of the sands from the E. part of the region (from station 6 E.) contain a granitic and metamorphic group of minerals, basaltic minerals such as augite and olivine being absent or present only in trace amounts (less than ½ per cent). Black opaque minerals (mainly magnetite and ilmenite) comprise more than 50 per cent of the heavy fractions, and magnetite is more common in them than in the other samples. This is also the case with brown opaque minerals (limonite and other coloured opaque ferruginous minerals) and biotite. The nature of the heavy mineral assemblages and the fact that many of the mineral grains do not have a high degree of roundness suggest that they were derived from local sources —mainly from granitic rocks nearby. Many of the zircon grains are euhedral and subhedral, and tourmaline occurs commonly as prismatic crystals showing only slight abrasion. Some grains of zircon, tourmaline, rutile and ilmenite are rounded and well-rounded, and apparently have had a longer detrital history; they may have come from the Tertiary sandstones exposed in coastal cliffs to the N.

The heavy fractions of the sands from W. of McCrae (station 6) contain basaltic minerals (olivine, augite and iddingsite) as well as granitic and metamorphic minerals. The amount in the sands from McCrae to Rye is small, but it is somewhat larger and remains nearly constant between Rye and Point Nepean. The olivine and augite are commonly coarser grained than the granitic-metamorphic group of heavy minerals. Some of the grains of basaltic minerals are angular and many are subangular to subrounded. The relatively slight abrasion of so many of these grains indicates that they have not had a very long detrital history. Black opaque oxide minerals comprise more than 40 per cent of the heavy fraction of the sands W. from McCrae, and ilmenite is more abundant than magnetite. Some ilmenite grains show partial alteration to leucoxene, and the percentage of leucoxene grains is higher along this stretch of shore than along that to the E. The zircon content of the heavy mineral assemblages does not vary greatly, but the amount of tourmaline is less in the samples W. of White Cliffs.

Grain Characteristics of the Heavy Minerals

Anatase. The very rare grains are usually blue but a few are yellow. They are commonly tabular and prismatic. Some grains show striations and zoning.

Andalusite. Occurs as pink and colourless grains which are elongate to irregular in shape. Some grains are cloudy from alteration.

Apatite. This mineral is rare in the assemblages. It may have been partly or wholly removed from the samples by acid digestion, since it is soluble in HCl. The grains are colourless and usually rounded, although slightly worn elongate prismatic ones are present.

Augite. Most grains are pale brownish-violet; some are greenish, greyish, various shades of brown and almost colourless. Grains are often elongate cleavage fragments of irregular shape, sometimes with dentate ends. Most particles do not show a high degree of roundness, many being subangular. Grain size is commonly larger than most of the other heavy minerals. Some particles show corrosion features.

Biotite. Occurs as brown and greenish-brown grains which are commonly irregular in outline with jagged edges. Many flakes are fresh but some show partial alteration to chloritic matter and others are bleached almost white. The flakes are usually larger than most of the other heavy minerals.

Black Opaques. These grains are mostly magnetite and ilmenite. The degree of roundness of the magnetite grains ranges from angular to well-rounded. Some magnetite grains show edges of crystal faces and a few octahedra occur. Ilmenite grains generally have a higher degree of roundness than magnetite; many are sub-angular but most are subrounded. Some ilmenite grains are partly altered to leucoxene.

Brown Opaques. These are mostly limonite but include other coloured opaque ferruginous minerals. Most of these grains are subrounded and irregular in shape.

Chlorite. Occurs as greenish grains often of blotchy colour. The grains are irregular in outline and often have a ragged appearance.

Epidote. The grains are pale greenish-yellow in colour and usually subangular or subrounded. Pleochroism is weak.

Garnet. Most grains are pink, but some are colourless and a few brown. The grains are often angular and subangular, and some show surface etching. Crystal faces are seen on some grains.

Hornblende. Grains range in colour from green to brown, brownish-green ones being most common. Grains are usually elongate cleavage fragments and many appear relatively fresh. They are often larger than most of the other heavy minerals.

Iddingsite. Occurs as reddish-brown grains of irregular shape. Most grains are subangular.

Kyanite. Grains are colourless and usually elongated with rounded ends. Traces of cleavage at right angles to the length of the grains are common.

Leucoxene. Occurs as creamy-white, greyish-white and yellowish-white grains with a dull lustre. Most grains are subrounded or rounded. The surface is some-times minutely pitted. A few grains reveal remnants of residual ilmenite.

Monazite. Grains are pale yellow in colour. They are usually rounded and faintly pleochroic.

Olivine. Most grains are colourless but some are pale yellowish-green. Many appear relatively fresh but some show traces of decomposition and others are clouded from alteration. Grains are commonly subangular and irregularly shaped; some show edges of crystal faces. The grains are often larger than most of the other heavy minerals.

Pyrite. The rare pyrite occurs as small pale brass-yellow crystals.

Rutile. The foxy-red variety is most common, yellow and yellowish-brown grains being less common. Grains are usually elongate and subrounded; some show edges of prism faces.

Sphene. The rare grains are pale-yellow and pale-brown. They are usually subangular and irregular in outline. Some grains are clouded through decomposition.

Staurolite. Occurs as brown and brownish-yellow grains which are subangular

and irregular in shape. Inclusions are fairly numerous in some grains.

Topaz. The grains are clear and colourless. They are mostly subangular and irregularly-shaped.

Tourmaline. Brown varieties predominate but there are yellow, green, blue, grey, pink and parti-coloured grains. Grains show all degrees of roundness. Elongate prismatic crystals showing only slight abrasion are present, and some grains are well-rounded. The well-rounded grains, some of which show a high degree of sphericity, point to survival through more than one sedimentary cycle.

Zircon. Most grains are clear and colourless but a few are pale-yellow. The grains range from euhedral and subhedral to well-rounded. Rounded grains in most assemblages are approximately equal in number to those showing well-preserved crystal edges and faces. A polycyclic origin is postulated for the well-rounded grains. Inclusions are common in well-preserved crystals but the rounded grains are generally free from inclusions. Zoning is sometimes observed, and some grains have a dusky appearance due to the crowding of inclusions.

Zoisite. Occurs as colourless, prismatic grains which are usually subrounded.

Sources of the Sand Constituents

To enquire into the origin of the sand constituents, samples of dune-limestone from White Cliffs (near station 12) and Point Franklin (near station 19) were studied. Use is made of Baker's (1938, 1942) studies of the heavy minerals of granitic rocks in the area.

The relative abundance of the mineral species in the heavy fraction of the Mount Martha Granodiorite, as determined by Baker (1942) is: apatite (common), biotite (very abundant), chlorite (very rare), garnet (very rare), hematite (rare), hornblende (occasional), ilmenite (rare), limonite (very rare), magnetite (rare), pyrite (rare), rutile (very rare), sphene (very rare), zircon (common). Baker (1942) lists the heavy mineral assemblage of the Dromana Granite as: anatase (very rare), apatite (occasional), biotite (common), chlorite (occasional), epidote (rare), hornblende (common), magnetite (common), pyrite (occasional), sphene (occasional), zircon (common), zoisite (very rare).

It is clear that granitic rocks have been the primary source for most of the detrital minerals in the beach sands, and it can be presumed that the Mount Martha Granodiorite and the Dromana Granite have been important contributors. The Mount Martha Granodiorite is decomposed and soft along the NE. shore of Dromana Bay where erosion makes the rock an important source for supply of the sand constituents. Fragments of granitic rock are not uncommon in the beach sands of Dromana Bay but are rare or absent in the samples to the W. At station 1 particularly a large proportion of the acid-insoluble constituents are coarse-grained and have a relatively low degree of roundness, and the sand there shows only moderate sorting. Apparently, many of the constituents have been derived directly from the granodiorite. The mineral species in the heavy assemblages of the Dromana Bay sands and the freshness and state of abrasion of many grains reflect the close proximity of granitic rock. In particular, the presence of well-preserved zircon, tourmaline and magnetite crystals and fresh brown biotite flakes in the samples E. of McCrae indicates relatively recent liberation from granitic rocks.

The median grain size of the disaggregated dune-limestone from White Cliffs is 0·18 mm and that from Point Franklin is 0·17 mm; the sorting coefficients are 1·29 and 1·30 respectively. The median diameters are both somewhat smaller than those of the sand nearby (at stations 12 and 19). The degree of sorting of

the material composing the White Cliffs rock is identical with the beach sand nearby, but the detrital constituents of the Port Franklin rock are somewhat less well sorted than the beach sand from station 19.

The weight percentage of acid-soluble (mainly shell) material in the disaggregated dune-limestone from White Cliffs is 63·9 per cent and that from Point Franklin is 67·1 per cent. These percentages compare with 28·6 and 38·1 per cent in the beach sands from near these two places.

Median grain size of the acid-insoluble residue from the disaggregated White Cliffs dune-limestone is 0·20 mm, which is slightly coarser than the material before acid treatment; but the median diameter of the acid-insoluble residue from the Point Franklin material (namely 0·17 mm) is identical with that of the untreated disaggregated rock.

Median diameters of the acid-insoluble residues from the disaggregated dune-limestones are both less than those of the acid-insoluble residues of the beach sands from nearby stations (0·32 mm and 0·28 mm). This fact suggests that there are contributors other than dune-limestone to the mineral composition of the beach sands in this region.

Sorting coefficients of the acid-insoluble residues of the disaggregated dune-limestones from White Cliffs and Point Franklin are 1·27 and 1·21 respectively. As with most of the sand samples, sorting improved slightly after removal of the acid-soluble (mainly carbonate) content. The sorting of the acid-insoluble residues of the disaggregated rocks is not quite as good as that of the acid-treated beach sands from stations 12 and 19.

Microscopic examination of the various size-fractions of the disaggregated dune-limestones shows that the rock is composed mainly of quartz grains and fragments of marine skeletal material. Most of the quartz grains are subangular or subrounded, but some are angular, rounded and well rounded. The quartz grains closely resemble those in the beach sands, colourless grains being more abundant than yellowish, ironstained ones. The colourless quartz grains are commonly subangular while the yellowish grains tends to be subrounded. Some quartz grains have a frosted surface. Marine skeletal material is common in all size-fractions.

Fragments of dune-limestone, derived from coastal erosion, are found in the beach sands from White Cliffs to Point Nepean, and it is clear that this rock is an important source of the sand constituents in this region. The relatively high content of marine skeletal material in the sands from Rosebud West to Point Nepean may be related to the high content of bioclastic material in the dune-limestone. E. of Rosebud, farther away from the coastal outcrops of dune-limestone, the content of marine skeletal material in the beach sands is much lower.

The weight percentages of heavy minerals (index numbers) for the $\frac{1}{16}$ to $\frac{1}{4}$ mm size-grades of the acid-treated disaggregated dune-limestones from White Cliffs and Point Franklin are 0·42 and 0·45 respectively. These compare with index numbers of 0·22 for the acid-treated beach sand from near White Cliffs and 0·52 for that from near Point Franklin. The index numbers for the dune-limestones and nearby beach sands thus are approximately of the same order of magnitude. They are considerably smaller than the index numbers for the beach sands from the E. part of the coastal region under consideration. The mineralogical composition of the heavy fractions of the dune-limestone samples is very similar, and there is a close similarity to that of the neighbouring beach sand samples.

The present research indicates that the acid-insoluble mineral content of the beach sands has been derived mainly from the rocks forming the cliffs and wave-

cut platforms in the study region. The shell fragments, which make up most of the acid-soluble content of the beach sands, have originated by comminution of material derived from organisms indigenous to the nearby seafloor, as well as by disintegration of coastal outcrops of dune-limestone.

Conclusions

The beach sands of the S. shore of Port Phillip Bay consist essentially of quartz grains and shell fragments. The relatively high content of shell fragments in the sand W. of Rosebud is due largely to the disintegration of dune-limestone which is composed largely of shell fragments.

The main source materials are the rocks which outcrop along the coast in the study region. Dune-limestone is the major source rock. In the E. (Dromana Bay) area the Mount Martha Granodiorite is an important source rock. This is why the sand there is coarser and less well-sorted, and composed mainly of granitic minerals. Shell material derived from marine organisms living nearby is constantly being added to the sands.

The beaches are relatively stable. Powerful waves generated by strong N. and NW. winds erode sand from some of the beaches and deposit it off-shore, but smaller waves generated by weaker winds transport sand back to the beaches. Sand drift along the shore occurs in different directions at different times according to seasonal weather. It does not have very considerable or markedly permanent effects on the sandy beaches. Where the sand ridge bordering the shore is subjected to wave erosion during stormy weather, 'new' material is made available to the beach. In some places where coastal erosion has made the construction of rock sea-walls necessary, man appears to have been partly responsible for the erosion by interfering with vegetation and removing portion of the sand ridge bordering the shore. This is so particularly between Dromana and Rye, and it will be necessary to guard against further human interference.

Heavy minerals are not common in the beach sands, but local concentrations occur at the N. end of Safety Beach.

Results of the present research will be of value in any subsequent study of sand drift.

Acknowledgements

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Explanation of Plate

PLATE 1

Fig. 1—View from station 1 showing the cliffed coastline cut in the Mount Martha Grano-diorite which forms the N. shore of Dromana Bay.

Fig. 2—Wave-cut beach scarp showing parallel layers of heavy mineral sand near station 1, Safety Beach.

Fig. 3—The Sisters (western headland) looking towards Sorrento. This headland of dune-limestone is undergoing erosion and supplying sand-size detritus to the neighbouring beaches.

Fig. 4—Sandy beach between Point King and Point McArthur, near Portsea. Vegetated cliffs of dune-limestone rise steeply from the shore.

Appendix

Sample stations

1. 40′ S. of line of projection of S. boundary, Bruce Rd., m.s.* 70; s.w.† 52′, s.g. 6°.
2. 300′ SW. of line of projection of S. boundary, Wattle St., m.s. 90; s.w. 81′, s.g. 6°.
3. 310′ NE. of line of projection of S. boundary, Nepean Highway, m.s. 89; s.w. 87′, s.g. 5°.
4. 350′ NE. of line of projection of W. boundary, Verdon St., m.s. 89; s.w. 48′, s.g. 7°.
5. 345′ WSW. of line of projection of W. boundary, Burrell Rd., m.s. 108; s.w. 62′, s.g. 3°.
6. 300′ WSW. of line of projection of W. boundary, Bartels St., m.s. 108; s.w. 87′, s.g. 5°.
7. 610′ ENE. of Rosebud Jetty, m.s. 108; s.w. 250′, s.g. 1°.
8. On line of projection of W. boundary, Brendel St., m.s. 127; s.w. 107′, s.g. 3°.
9. 150′ ESE. of line of projection of W. boundary, Truemans Rd., m.s. 127; s.w. 97′, s.g. 3°.
10. 200′ W. by S. of line of projection of W. boundary, Romney Avenue, m.s. 126; s.w. 100′, s.g. 3°.
11. 175′ W. of line of projection of W. boundary, Weir St., m.s. 126; s.w. 111′, s.g. 2°.
12. 125′ E. of line of projection of W. boundary, White Cliffs Rd., m.s. 125; s.w. 67′, s.g. 5°.
13. 470′ E. by S. of line of projection of W. boundary, Murray St., m.s. 125; s.w. 24′, s.g. 7°.
14. 800′ WNW. of line of projection of W. boundary, Inverness Av., m.s. 125; s.w. 84′, s.g. 4°.
15. 1180′ N. by W. of line of projection of W. boundary, Hughes Rd., m.s. 104; s.w. 162′, s.g. 2°.
16. 405′ SE. by E. of line of projection of W. boundary, St. Pauls Rd., m.s. 104; s.w. 43′, s.g. 6°.
17. 685′ NNW. of line of projection of N. boundary, St. Aubins Way, m.s. 84; s.w. 27′, s.g. 7°.
18. On line of projection of E. boundary, Hemston Av., m.s. 83; s.w. 56′, s.g. 6°.
19. 600′ E. of Portsea Jetty, m.s. 83; s.w. 83′, s.g. 5°.
20. 1024′ ESE. of Quarantine Jetty, Portsea, m.s. 62; s.w. 36′, s.g. 6°.
21. 1170′ ESE. of Observatory Pt., m.s. 62; s.w. 98′, s.g. 5°.
22. On compass bearing 115° from base of Pt. Nepean Jetty, m.s. 62; s.w. 110′, s.g. 5°.
23. 125′ WSW. of most northerly part of Pt. Nepean, m.s. 62; s.w. 170′, s.g. 1°.

* = Map sheet, Mornington Peninsula Area Base Map Series.
† s.w. = shore width, s.g. = shore gradient.

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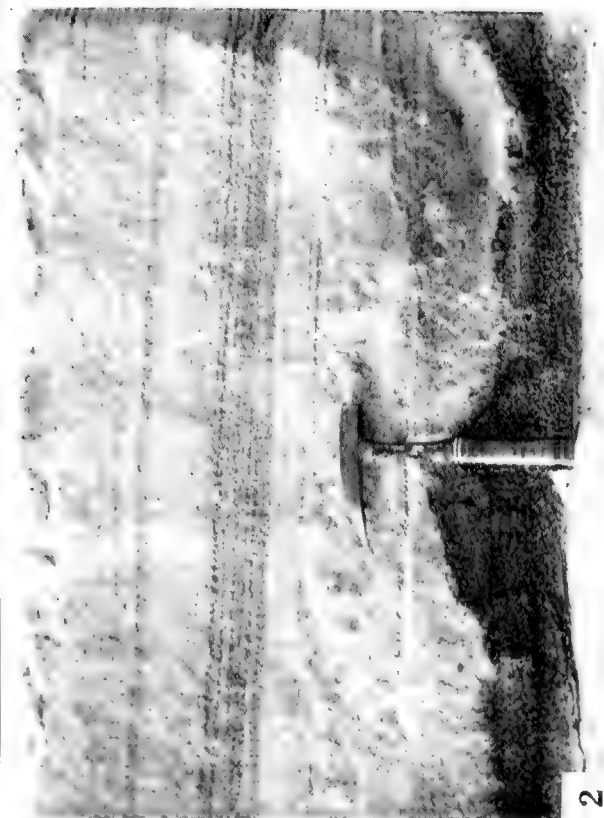
A FOSSIL CHELONIAN OF PROBABLE
LOWER CRETACEOUS AGE FROM VICTORIA, AUSTRALIA

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Abstract

A fossil chelonian from Carapook, Western Victoria, originally recorded by F. Chapman is re-described. Due to the nature of the matrix it is concluded that the provenance of the specimen is within the Lower Cretaceous Merino Group. The fossil possesses characters that exclude it from any known family of Chelonia and it is described (*Chelycarapookus arcuatus*) as a new genus within a new family (Chelycarapookidae) that is erected to include it.

Introduction

The single specimen described in this paper is housed in the palaeontological collection of the National Museum of Victoria, (P13160). It was presented to the National Museum by Mr J. S. Macpherson and has been illustrated and described by Chapman (1919). He referred it 'with some reservation' to the same species as the extant Murray River tortoise, *Emydura macquari*, and suggested that it probably was of Pleistocene age. There is now some doubt about this age assignment and, furthermore, it is clear from Chapman's published figure and his description of what he thought to be impressions on the carapace of remains of the pelvic girdle, that he misinterpreted several aspects of the morphology of the specimen. For these reasons a re-description of this unique fossil is justified.

Occurrence

The exact provenance of this fossil cannot be established with absolute certainty; the museum label states that it came from an ironstone bed, three feet from the surface, at Carapook, near Casterton. The community of Carapook, as well as the entire Parish of Carapook, lies well within exposures of the Lower Cretaceous Merino Group. In this region the Merino Group is a series of gently dipping arkosic sandstones of Lower Cretaceous age (Kenley 1954, Evans 1961, Dettman 1963). The interfluves are commonly tablelands capped by a thin layer of lateric ironstone and the fossil, which is preserved as an ironstone cast with little bone remaining, almost certainly came from this ironstone horizon.

Kenley (op. cit.) has shown that the ferruginous capping layer is not a stratigraphic rock unit but most likely represents an old erosional surface and is, therefore, found in rocks of different age. In some areas the laterites are fossil soils (referred to as the 'Dundas laterites') developed in Cainozoic deposits, while to the W. along the Kanawinka and Weecurra faults, the Merino Group is bounded by ferruginous Tertiary marine deposits. However, in the Parish of Carapook no Tertiary sediments have been recorded, although the W. portion of the Parish has been mapped in detail, and in at least one locality the ironstone horizon is seen to transgress the bedding in the Merino Group (P. R. Kenley, pers. comm.) and is, therefore, an alteration of that Group and of Lower Cretaceous age.

It is likely that the fossil tortoise came from this Lower Cretaceous ironstone horizon for two reasons: (1) it is the only known source within the Parish of Cara-

pook from which to derive a fossil preserved in ironstone, and (2) in thin-section the matrix of the specimen is similar in its constituents and grain size to rock of the ironstone horizon, which is predominantly limonite with about 20 per cent quartz grains (Kenley, pers. comm.).

Description

The fossil is an internal mould of the shell of a chelonian with some bone remaining in the centre of the plastron and along the left margin and right posterior quarter of the carapace (Plate 2). Impressions are present of vertebrae, ribs, some of the sutures of the dermal bones, and the anterior buttress. There are no impressions of scutes on the external surface of the bone. The matrix also contains fragments of wood.

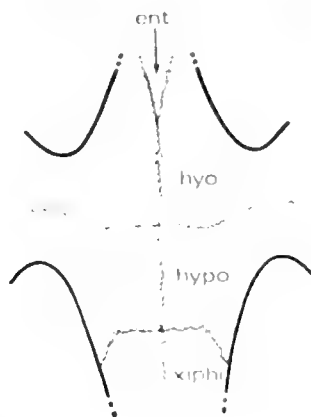PLASTRON: The bones of the plastron are shown in Fig. 1. As the anterior

Fig. 1—The plastral bones of the holotype of *Chelycarapookus arcuatus* sp. nov. (Nat. Mus. Vict. P13160). Abbreviations are for entoplastron, hyoplastron, hypoplastron, and and xiphiplastron. x 2/3.

portion is missing the shapes of the epiplastral bones and the anterior extension of the entoplastron cannot be determined. However, it is clear that the posterior portion of the entoplastron was wedge-shaped and intercalated between the anterior regions of the hyoplastral bones. The hyoplastral and hypoplastral bones make up most of the plastron with each hypoplastron extending slightly posteriorly to partially bound the lateral margin of the adjoining xiphiplastron. The posterior portion of the plastron is missing, so nothing is known of the shape of the xiphiplastral notch, nor can it be deduced if the pelvic girdle was attached to this area. There are no mesoplastra.

CARAPACE: Sutures of the costals, a few neurals, and some of the peripheral bones can be discerned. It is not possible to make out sutures of a proneural and, as the posterior margin of the carapace is missing, any remnant of a pygal bone is absent. There is no indication as to whether the pelvic girdle was attached to the carapace or not.

Neurals are probably present between costals 1 through 4, though detail is not well preserved in the anterior half of the carapace, so there may be some doubt about this. However, neurals are clearly present between costals 4 through 7 and

these increase in size posteriorly (Plate 2). On the first pair of costals anterior to the fusion of the ribs are a pair of fossae ('f' on Plate 2 and Fig. 2A). This area is smooth in other chelonians and the function of these unique depressions is not clear.
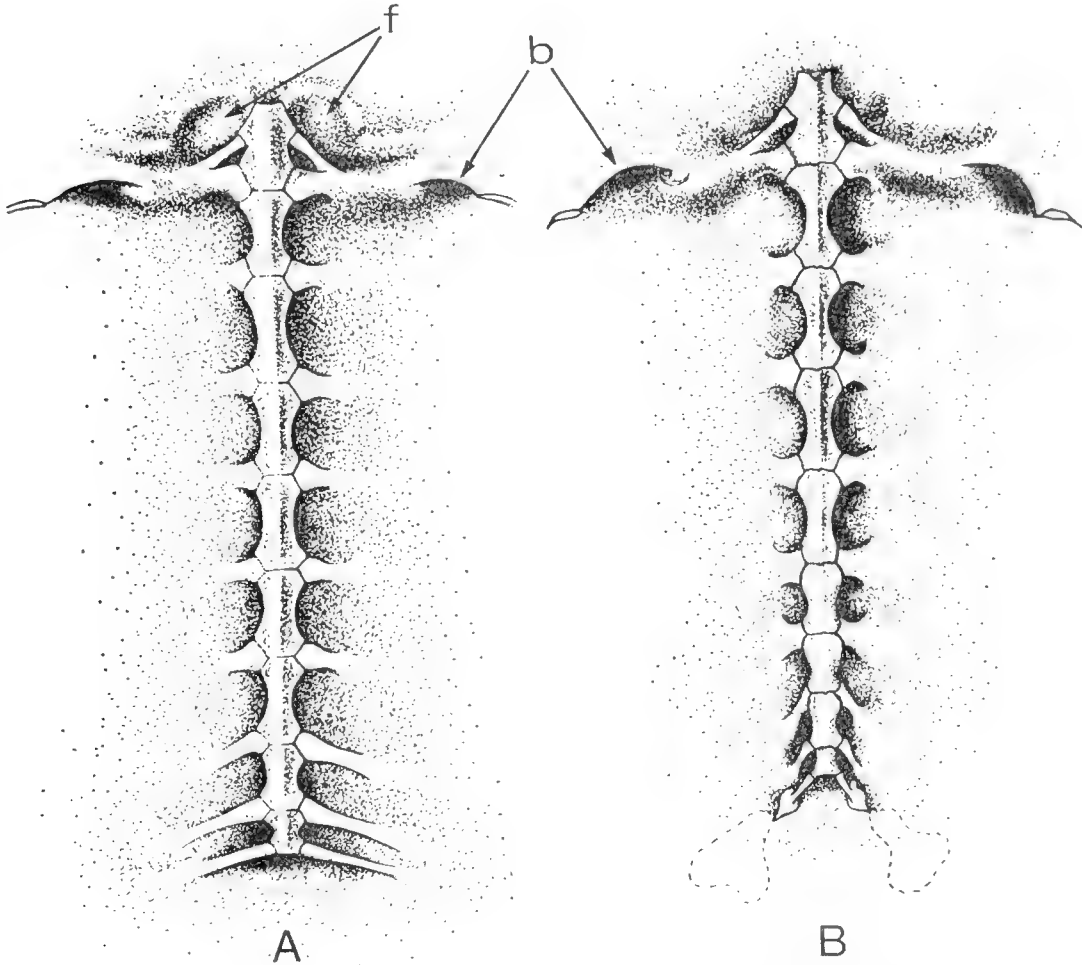
Fig. 2—A. A reconstruction of a portion of the anterior buttress and the dorsal vertebrae and ribs of the holotype of *Chelycarapookus arcuatus* sp. nov. Note the increasing extension of the posterior ribs before their fusion with the carapace. B. The same region of the extant chelid, *Emydura macquari*, for comparison. Abbreviations. b, anterior buttress; f, fossae unique to *C. arcuatus*. x 3/4.

A peculiar feature of this fossil is the extension of the posterior sets of ribs to result in their fusing to the costals a greater distance from the midline than do the anterior ribs. A reconstruction of that portion of the vertebral column with ribs associated with the carapace is shown in Fig. 2 along with the same region from an extant Australian chelid tortoise, *Emydura macquari*. In *E. macquari* the last few sets of ribs become slightly reduced in size and their points of fusion to the

carapace are not extended laterally. This is the case with all extant chelonians as well as those fossils in which this area has been described.

The lateral shift of the point of fusion to the costals of the posterior ribs is accommodated on the carapace by the previously mentioned increase in size of the posterior neurals.

There are no characters remaining on this fossil to indicate to which suborder, Cryptodira, Pleurodira, or Amphychelydia, it may belong. Furthermore, the combination of characters on the specimen does not fit the description of any family of chelonians, and I therefore propose that a new family with the following systematic position be erected to include it.

<div align="center">

Class REPTILIA

Subclass ANAPSIDA

Order CHELONIA

Suborder uncertain

CHELYCARAPOOKIDAE fam. nov.

</div>

It is premature, with only a single specimen in hand, to provide a complete diagnosis for the family. The description of the specimen as a new, monospecific genus will suffice for this purpose until more material is uncovered.

<div align="center">

Chelycarapookus gen. nov.

Type species: **Chelycarapookus arcuatus** sp. nov.

</div>

DIAGNOSIS OF GENUS: Chelonians possessing the following features: paired fossae on the first costals at the dorsal end of the anterior buttress; a posterior extension of the entoplastron to separate the anterior one-third of the hyoplastra; hypoplastra projecting posteriorly on to the lateral margin of the xiphiplastra; mesoplastra lacking; buttress narrow (less than one-quarter the overall length of the carapace); neurals probably present between all costals, but certainly present between costals 4 through 7 and increasing in size posteriorly beginning with number 5; point of fusion of the ribs to the costals becoming further from the midline in passing from the 4th costal to the 9th.

ETYMOLOGY: From *chelys*, a turtle, and Carapook, the name of the Parish from which the specimen was collected.

<div align="center">

Chelycarapookus arcuatus sp. nov.

(Pl. 2; Figs. 1, 2A)

</div>

HOLOTYPE: National Museum of Victoria P13160. This is a cast in ironstone of the inside of a chelonian shell which shows most of the sutures of the dermal bones and the positions of the ribs and vertebrae. No elements of the skull, girdles, nor limbs are preserved and there is no trace of the scute pattern. There are no referred specimens.

LOCALITY AND HORIZON: The holotype was collected by Mr J. W. Macpherson at Carapook, Victoria. The exact provenance was not recorded at the time of collection but it seems certain, due to the limonitic nature of the matrix, that the specimen came from a known ironstone horizon in the Merino Group, which is of Lower Cretaceous age.

DIAGNOSIS: The same as for the genus. The specific name refers to the bow-like structure formed by the arcuate costals and extended ribs immediately anterior to the sacral region.

Discussion

The existence of *Chelycarapookus arcuatus* sp. nov. in a fluviatile environment in the Cretaceous of Australia does not throw much light on the ancestry of the turtle fauna of inland Australian waters, which today consists of a single family of pleurodires, the Chelidae. The fossil record of freshwater and terrestrial chelonians in Australia is scant and may be summarized as follows. From the Merino Group at Casterton, only 8 miles from Carapook, Krausé (1886) has recorded a fragment of a turtle shell which unfortunately can no longer be located. Lydekker (1889), de Vis (1897) and Longman (1929) have identified pieces of turtle shell from the Pleistocene of Queensland as chelids though these are fragmentary and lack diagnostic generic characters. There is only one occurrence of chelids so far recorded from the Tertiary of Australia (Warren 1969) though others are known and are currently being studied by Mr E. S. Gaffney of the American Museum of Natural History (Gaffney, pers. comm.). The described specimens are from Oligocene-Miocene sediments of Tasmania and cannot be distinguished from the extant chelid, *Emydura macquari*, which suggests a conservative evolutionary rate in this group. The only terrestrial chelonian known from Australia is the Pleistocene amphychelidian, *Meiolania platyceps*, recorded from Queensland and Lord Howe Island (Anderson 1925).

Chelycarapookus arcuatus possesses a suite of characters that exclude it from the Meiolaniidae, which probably had a reduced shell with fontanelles, and from the Chelidae. It is possible that the Australian Chelidae could have evolved from such an ancestor by the loss of neurals, which is characteristic of Australian chelids with the exception of *Chelodina oblonga* where a variable number may be present (Burbidge, pers. comm.), and by the reduction of the lateral extension of the posterior ribs. This is, however, a premature speculation. The phylogenetic position of *Chelycarapookus arcuatus* cannot be established with certainty until the anatomy of the skull and cervical vertebrae are known and the relationship of the pelvic girdle to the shell has been established, that is whether it was sutured to the carapace and plastron as it is in most amphychelidians (but not in the more advanced genus *Meiolania*) and in all members of the Chelidae.

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Explanation of Plate

PLATE 2

Dorsal view of the holotype of *Chelycarapookus arcuatus* sp. nov. (Nat. Mus. Vict. P13160). Abbreviations: f, fossae (which appear as eminences in the internal cast); n, neural; m, remnants of bony marginals; r, casts of ribs at point of fusion with costals; v, casts of vertebrae; w, piece of wood in matrix. Note the increasing divergence of posterior ribs from the midline.
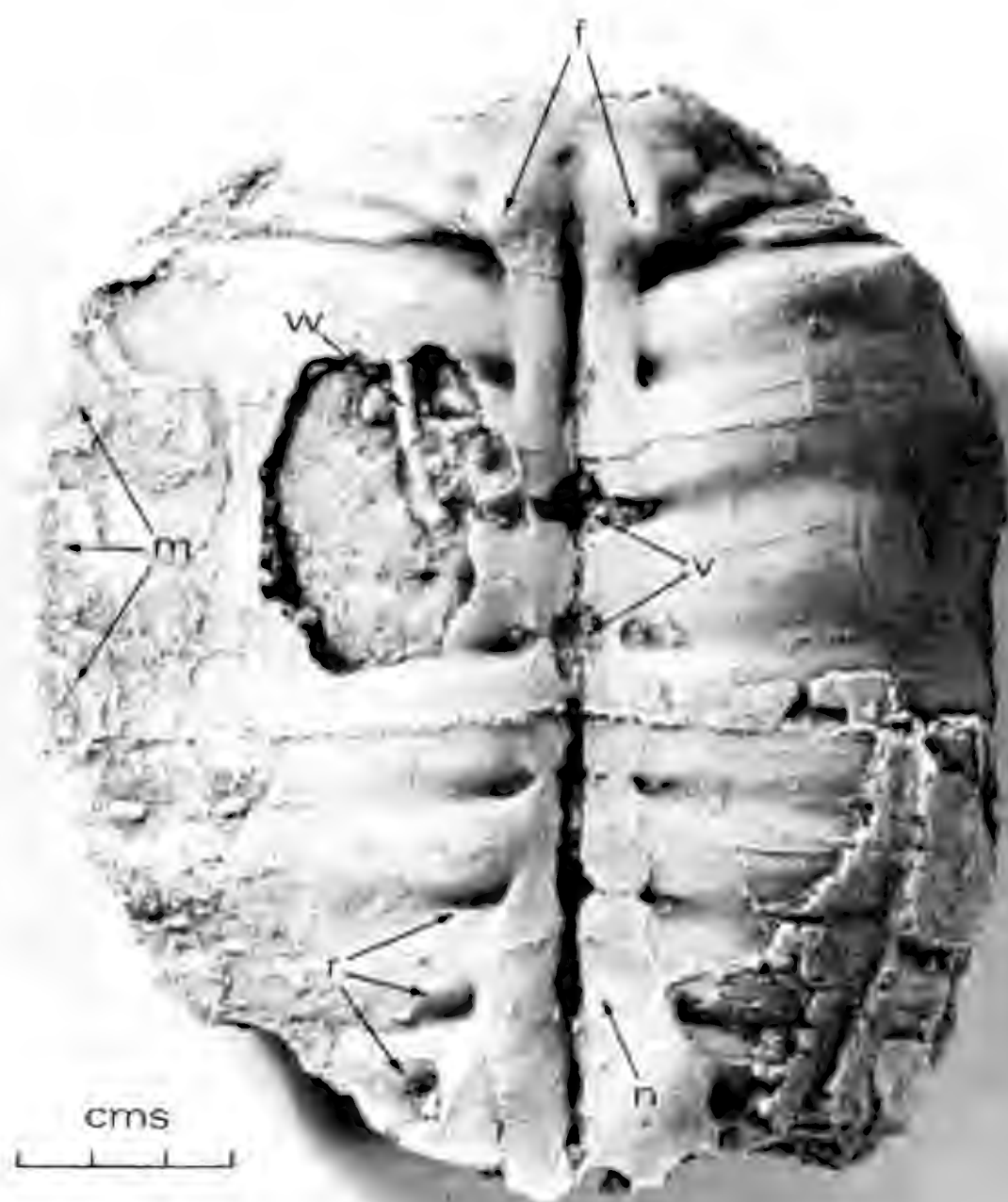
A LOWER MANDIBLE OF *ZYGOMATURUS GILLI* FROM THE SANDRINGHAM SANDS, BEAUMARIS, VICTORIA, AUSTRALIA

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Introduction

Stirton (1957) described three diprotodontid specimens which had been recovered from the Black Rock Sandstone of the Brighton Group (Kenley 1967), on the shore of Port Phillip Bay near Beaumaris, Victoria. One of the specimens, M.U.G.D. No. 2020, subsequently became the type of *Zygomaturus gilli* (Stirton 1967) and the second, N.M.V. P15905, was also assigned to that species (*ibid.*). The third specimen, a fragment with the symphysis and part of the horizontal ramus containing the alveoli of P_3, base of M_1, and most of M_2, was also discussed by Stirton (1957), but at that time information on Tertiary diprotodontids was insufficient for a close determination of its affinities. In 1967, Mr Colin Macrae found the rear portion of a mandible containing M_3 and M_4 which proved to fit perfectly onto the former specimen. With this surprising discovery, a nearly complete mandible is represented, lacking only the angle, coronoid process, and anterior tip of the symphysis. Now that this individual is more completely represented, it is possible to compile a sufficiently adequate description to allow an analysis of its affinities. Such is the purpose of the present report. The specimen originally described by Stirton is catalogued as N.M.V. P15911A; the portion collected by Macrae is P15911B. The complete specimen will be designated here as N.M.V. P15911A-B.

I am grateful to Mr H. E. Wilkinson, Assistant Curator of Fossils, National Museum of Victoria, for giving me the opportunity to describe this specimen. The manuscript has been read and criticized by R. H. Tedford, Department of Vertebrate Paleontology, American Museum of Natural History, New York, and by W. A. Clemens, Department of Paleontology, University of California, Berkeley. D. E. Savage, Director of the Museum of Paleontology, University of California, Berkeley, gave permission for the specimen to be illustrated by Owen J. Poe, staff artist. Responsibility for any statements made in this report rests on me alone. Such measurements as could be made are presented in Table 1.

Gill (1957) has summarized the evidence showing that the specimen described herein was derived from rocks of the Black Rock Sandstone which also yielded the invertebrate fossils used by Singleton (1941) in defining the Cheltenhamian Stage. Stirton, Tedford and Woodburne (1968) present a summary of the age determinations proposed for the Cheltenhamian, and conclude that it is probably early Pliocene, but Kenley (1967), Darragh in Wilkinson (this memoir) and other authors cited in Stirton, Tedford, and Woodburne (*op. cit.*) support a late Miocene age for this Stage. N.M.V. P15911A-B apparently represents the lower mandible of *Zygomaturus gilli*. The general stage of evolution displayed by the lower mandible and dentition is similar to that of the previously described upper dentition of this species, i.e. more advanced than the Alcoota zygomaturines (Woodburne 1967a, b) and more primitive than those from the Palankarinna fauna (Stirton 1967).

This tends to corroborate the post Alcoota-pre Palankarinna age assigned to the Beaumaris fauna, as based on the phyletic position of *Zygomaturus gilli* (see Stirton, Tedford, and Woodburne 1968, for a review). If the age of the Cheltenhamian, and therefore that of the Beaumaris fauna, is late Miocene, the temporal position of the older faunas found in the Northern Territory and South Australia may need to be revised downward somewhat. It is also possible that both the Alcoota and Beaumaris faunas could be late Miocene in age, with the Alcoota being the older of the two.

Both parts of the specimen have a rich brown to yellowish brown colour, the lingual surface of the symphysis is stained a deep maroon. Remnants of the drab brown siltstone matrix are found on the antero-lingual surface of the symphysis and partially filling the anteroventral portion of the pterygoid fossa above the antero-lingual edge of the angular process. A small remnant of matrix remains on the internal surface of the coronoid process lateral to the postalveolar shelf. The bony surface of the mandible bears numerous small cracks and pits, and a large piece of bone is missing from the ventral surface below M_2 and M_3. Most of the projecting edges of the specimen are abraded and rounded to a variable extent. In particular, abrasion has affected the anterior tip of the symphysial portion, the leading edge of the coronoid process, the rear of the preserved portion of the angular process and, to a lesser extent, the lingual edge of the postalveolar shelf and the entire lingual side of the ventral edge of the horizontal ramus. A chip of bone about 22 mm long has been lost from this edge of the ramus immediately antero-ventral to the pterygoid fossa. Another, flat, shallow flake of bone nearly 24 mm long is missing from the ventral surface of the angle immediately ventral to the fossa. The edges of the break along which the two parts of the mandible fit together are still sharp, however, so it appears that most postmortem abrasion of the specimen was sustained while it was all in one piece. There can be no doubt that the two pieces form the partial right mandible of a single individual diprotodontid.

Zygomaturus gilli

Mandible. When the two parts are fitted together (Fig. 1A, C) the mandible is of rather normal diprotodontid construction. The alveolar border and ventral edge of the horizontal ramus are both moderately convex ventrally. Below M_2 and M_3 the lateral surface is dorsoventrally convex, but becomes flatter anterior to M_2. A nearly circular mental foramen is located about 9 mm below and slightly anterior to the exposed anterior root of P_3. The vertically elongate, narrow, and slightly concavo-convex posterior portion of the incisor root is visible immediately below and medial to the mental foramen (see Stirton 1957, text-figure 5D). The incisor root is open at this point which, to judge from most other Tertiary diprotodontids, is not far from the tip. There is no evidence as to the nature of the pre-cheek tooth diastema above the mental foramen, but below it the ventral edge of the symphysis extends downward approximately 4 mm below the ventral edge of the horizontal ramus. The masseteric fossa is partly preserved posteroventral to M_4, and although its leading edge is not preserved the coronoid process probably rose past the posterior half of M_1. The angle at which this took place is not determinable, however. The ventrolateral surface of the ramus slopes sharply ventromedially below the masseteric fossa. The faintly developed digastric process and post-digastric sulcus is not visible in lateral view.

In occlusal view (Fig. 1B) both the labial and lingual surfaces of the horizontal ramus are nearly straight, although they converge slightly anteriorly. The postal-
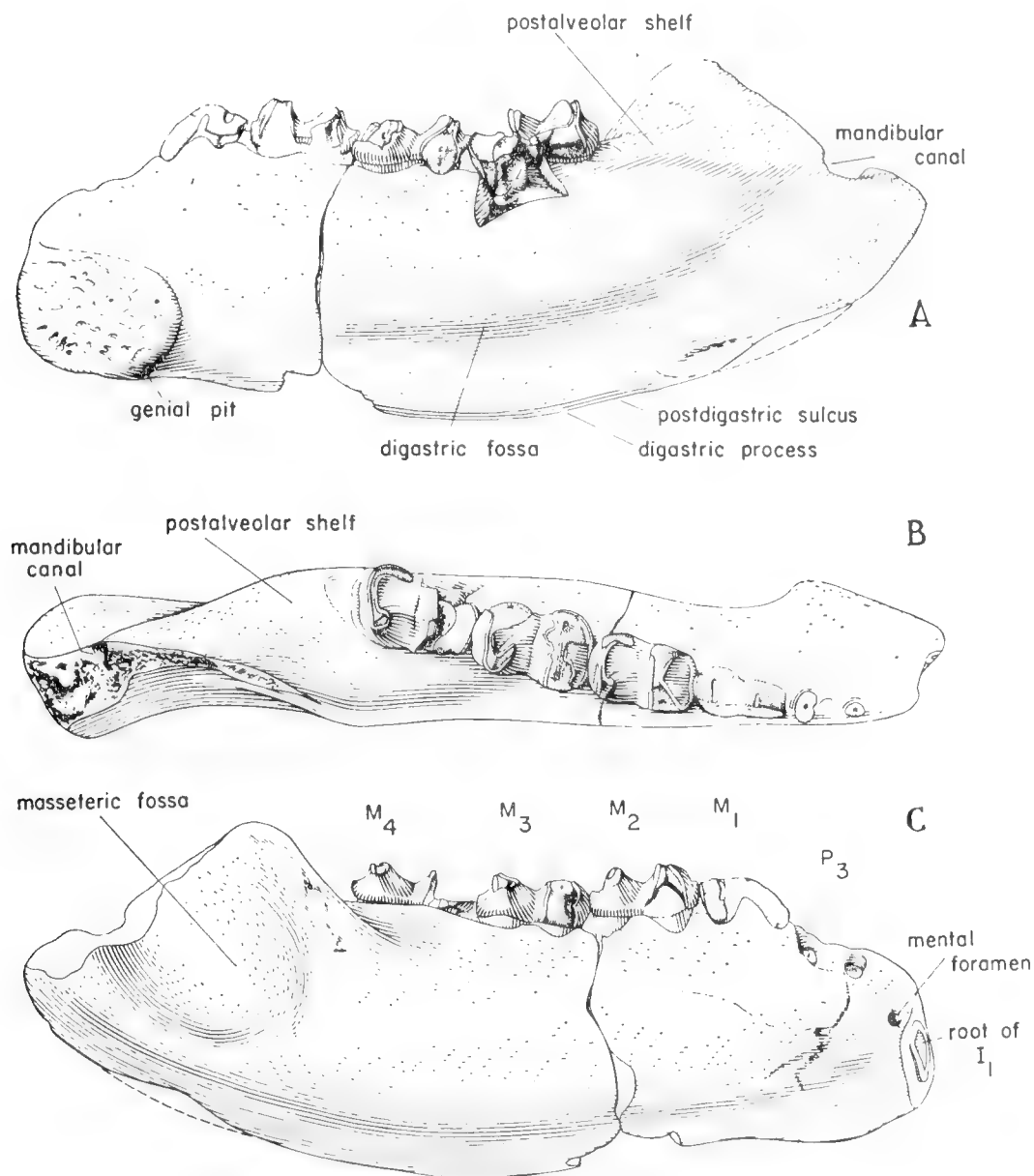
Fig. 1—*Zygomaturus gilli*, right mandible with symphysial and angular portions partly preserved, three fourths natural size. Nat. Mus. Vict. P15911A (symphysis) and P15911B (horizontal ramus). A. Lingual view. B. Occlusal view. C. Labial view.

veolar shelf has a nearly flat upper surface posterior to M_4; its lingual surface is smoothly continuous with that of the rest of the mandible, and curves gradually posteromedially toward the area of the pterygoid fossa. A strongly developed postalveolar process was probably never present, but the lingual edge of the shelf is slightly abraded so that there may have been a small process in this area. Upon clearing away some matrix it was found that the mandibular canal is exposed medial to the surface of the pterygoid fossa about 41 mm posterior to the rear edge of the alveolus of M_1. The foramen would then emerge from the pterygoid fossa at some distance beyond the point in question and would lie well below the plane of the upper surface of the postalveolar shelf.

In lingual aspect (Fig. 1A) the anteroventral portion of the pterygoid fossa is filled with matrix, and extends about 15 mm anterior to the exposed mandibular canal. The ventral border of the fossa extends downward to a point within the ventral one-quarter of the mandible. Below the fossa, the anterior portion of the angle is incompletely preserved; it does not seem to have been strongly inflected at this point. In Tertiary diprotodontids, the digastric process, when present, is usually located below M_1. In this specimen the critical area is abraded, but there seems to have been a very small digastric process and a very shallow postdigastric sulcus posterior to it. The digastric fossa extends anteriorly from the pterygoid fossa along the ventral third of the horizontal ramus. The fossa becomes shallower and narrower anteriorly and fades out entirely at a point below the anterior end of M_3, about 30 mm from the genial pit. The latter is exposed beneath the posterior portion of the mid-sagittal symphysial surface. The symphysis merges smoothly with the adjacent surface of the mandible. Except where it begins to curve downward posteriorly the supra-symphysial surface extends forward in a nearly horizontal plane. The posterior surface of the symphysis is smoothly convex and extends back to a point below the middle of M_1.

Dentition. It is unfortunate that P_3 is represented only by the tips of its roots and that M_1 lacks the coronal surface because these two teeth are probably the potentially most diagnostic elements of the lower dentition. To judge from the preserved tips, the anterior root of P_3 was smaller than the posterior and the anterior portion of the tooth was narrower than the posterior portion. The available evidence indicates that P_3 was about 17 per cent shorter than M_1. The length for P_3 given in the table of measurements is probably relatively close to the actual length of the tooth in that the dimension was taken from the rear of the alveolus, to a point directly above the foremost edge of the anterior root. In Teriary diprotodontids, the anterior edge of the crown of P_3 is commonly directly above, or only slightly anterior or posterior to, the foremost edge of the anterior root. The anterior root of P_3 may be vertically emplaced or slant slightly anteriorly (see illustrations in Stirton 1967, Woodburne 1967a, and Plane 1967).

Likewise, the length of M_1 given in the table of measurements may also closely approximate the true length of the tooth although the anterior cingulum of the crown commonly extends a millimetre or so beyond the immediately subjacent root. M_1 was probably about 21 per cent shorter than M_2. Inasmuch as the anterior root of M_1 is narrower than the posterior, the anterior moiety of the crown may have been narrower than the posterior.

The surface of M_2 is the most completely preserved of all of the cheek teeth, but the labial and lingual surfaces of the protolophid and the lingual surface of the hypolophid are abraded. However, I estimate that the actual widths of the protolophid and hypolophid were approximately equal. The tooth is constricted at the

transverse valley and apparently had a bilobed occlusal outline. An anterior cingulum is present, but it is not thick anteroposteriorly. The presence of a weakly developed paralophid is suggested by a slight bulge in the anteriolabial quadrant of the protolophid. This is more pronounced in M_2 than in the corresponding part of M_3. The protolophid was apparently aligned transversely although it probably had an anteriorly concave occlusal pattern. It is separated from the hypolophid by a broadly V-shaped transverse valley in which the anterior wall is directed more vertically than the posterior wall. This can be best seen in lingual view (Fig. 1A). A moderately developed metalophid descends the anterior face of the hypolophid in an anteromedial orientation, but is aligned more anteriorly when it reaches the transverse valley. The metalophid blends into the posterior base of the protolophid near the longitudinal midline of the tooth. The hypolophid is aligned slightly posteromedially, rather than transversely as for the protolophid, and has an anteriorly concave occlusal pattern. The posterior cingulum is highest at the longitudinal midline of the tooth, but makes no conspicuous connection to the hypolophid.

The third molar is about 11 per cent longer than M_2, and has a bilobed occlusal outline. Although the labial end of the protolophid and the lingual end of the hypolophid are abraded, I estimate that the protolophid was at least 2 mm wider than the hypolophid. As in M_2, the anterior cingulum in M_3 is narrow anteroposteriorly and apparently did not extend around to the labial or lingual sides of the protolophid. Although much of the enamel is missing from the protolophid, enough remains to show that the paralophid, if present, was not as well developed as in M_2. The transverse valley separating the anterior and posterior moieties of the tooth is broadly V-shaped with the anterior wall being more nearly vertical than the posterior. If the features of the dentine reflect the basic configuration of the enamel, the protolophid was aligned transversely to the long axis of the tooth. As in M_2, the hypolophid is aligned somewhat posterolingually. The metalophid of M_3 is similar to that in M_2 except for more clearly demonstrating its anterior orientation as it approaches the transverse valley. The posterior cingulum is similar to that in M_2.

Only the posterior moiety is adequately preserved in M_4 although it is probable that the greatest width of the tooth would have been measured across the protolophid. Except for being about 5 per cent longer, the construction of M_4 is apparently not significantly different from that of M_3.

MEASUREMENTS:

Length P_3 (approximate)	12·8 mm
Length M_1 (approximate)	15·4
Length M_2	19·5
Width M_2 (posterior, minimum)	12·9
Length M_3	21·9
Width M_3 (anterior, minimum)	15·1
Length M_4	23·0
Width M_4 (posterior, minimum)	14·5
Length P_3-M_4 (measured at the alveoli)	93·1
Depth below alveolar border, anterior edge M_1	42·6
Depth below alveolar border, between M_3 and M_1	46·5

Comparisons. N.M.V. P15911A-B is a zygomaturine diprotodontid. This is shown by its relatively long P_3 and by its rather close resemblance to *Kolopsis torus, Plaisiodon centralis*, and *Zygomaturus keanei*, as detailed below. Tertiary

nototherine diprotodontids have a characteristically short P_3 and labial cingula on the lower molars which are incipiently or markedly developed depending upon the genus in question. Palorchestine diprotodontids typically have relatively non-bilobate lower molars, all of which have prominently to well developed paralophids and metalophids, at least in faunas of late Miocene or later age.

The Beaumaris mandible closely resembles that of *Kolopsis torus*, described (Woodburne 1967a) from the late Miocene Alcoota fauna of the Northern Territory. This similarity includes the position and orientation of the masseteric fossa and leading edge of the coronoid process, the shape and configuration of the labial and lingual surfaces of the horizontal ramus and symphysis, the position of the mental foramen, the configuration of the digastric and pterygoid fossae, the horizontal alignment of the supra-symphysial surface, the development of the postalveolar shelf, the probable position of the mandibular foramen, the poorly developed digastric process and postgastric sulcus, and the general outline of the molars, as represented.

Points in which the Beaumaris specimen differs from the Alcoota species are the better developed metalophid and the asymmetrically V-shaped rather than symmetrically U-shaped transverse valley of the molars, the relatively narrower molar proportions, the more anterior position of the genial pits, the smaller development of the postalveolar process and the flattened, concavo-convex cross section of the proximal root of the incisor.

The Beaumaris specimen also shows similarities to *Plaisiodon centralis* of the Alcoota fauna. *P. centralis* differs from N.M.V. P15911A-B in that the ventral border of the angle is straight in lateral view and rises sharply posterodorsally from the ventral surface of the horizontal ramus. In the Beaumaris specimen this area of the angle is smoothly curved. In addition, the mandibular canal would lie below a horizontal line drawn along the lingual alveolar border below M_2-M_1 in the Beaumaris specimen, rather than at or slightly above such a line in *P. centralis*. Moreover, the anteroventral edge of the pterygoid fossa reaches down only to a point located about midway between the dorsal and ventral edges of the ramus in *P. centralis*, while in the Beaumaris mandible this part of the fossa lies well down in the lower one quarter of the ramus.

The dentition of N.M.V. P15911A-B resembles that of *P. centralis* in the general occlusal outline, the relative development of the metalophid, the shape of the transverse valley, and in the somewhat narrower, more elongate proportions of the molars. The posterior root of the lower incisor of *P. centralis* is bi-concave in cross section, and the posterior tip is closed.

Kolopsis rotundus, of the middle Pliocene Awe fauna, New Guinea (Plane 1967), has the same relative molar proportions as *K. torus* and thus differs from the Beaumaris specimen. *K. rotundus* is also distinguished from N.M.V. P15911A-B in that the lower incisor displays a widely open root and extends posteriorly to the rear of the symphysis. Further, in *K. rotundus*, the sulcus between the rear of M_4 and the anterolingual surface of the coronoid process is broad, the postalveolar process, digastric process and postdigastric sulcus are prominent, the ventral edge of the pterygoid fossa reaches downward only to a point about halfway between the dorsal and ventral edges of the mandible, the supra-symphysial surface rises anterodorsally, genial pits are absent, and the metalophid is essentially straight, although obliquely oriented. *K. rotundus* resembles the Beaumaris specimen in the degree of development of the metalophid on the molars.

Kolopsoides cultridens (Awe fauna) differs sharply from the Beaumaris speci-

men in that the jaws are more massive, the symphysis extends posteriorly to below M_2, the digastric process is stronger, the genial pit is flat, and the metalophid of the molars is formed from the protolophid as well as from the hypolophid. The lower incisor has a subovate posterior cross section and the tip of the tooth is closed.

The mandible of *Zygomaturus keanei* (Palankarinna fauna, Stirton 1967) is considerably larger than the Beaumaris specimen, but if the dorsoventrally crushed nature of the former is taken into account, it resembles the Beaumaris mandible in general shape as well as in the position and nature of the genial pits, the slightly developed postalveolar process, the occlusal proportions of the molars, the curved metalophid, the absence of labial cingula and in the general shape and degree of closure of the posterior tip of the incisor root.

TABLE 1

			Kolopsis torus			*Zygomaturus gilli*		
	N	OR	$\overline{X}$	s	V	"$\overline{X}$"	"S"	"$\overline{X}$"±2"s"
P3								
Length	14	17·1-20·5	18·7 ± 0·28	1·05 ± 0·20	5·60 ± 1·05	23·0a	1·28	20·4-25·6
Width across paracone and protocone	13	13·7-15·8	15·1 ± 0·20	0·73 ± 0·14	4·83 ± 0·95	17·4	0·83	15·7-19·1
M2								
Width, post.	9	17·8-21·4	19·3 ± 0·38	1·15 ± 0·27	5·96 ± 1·40	20·7	1·23	18·2-23·6
M3								
Length	16	21·5-25·0	23·6 ± 0·25	1·00 ± 0·18	4·24 ± 0·75	27·7	1·17	25·4-30·0
Width, ant.	15	20·4-23·2	21·9 ± 0·22	0·87 ± 0·16	3·97 ± 0·73	25·7	1·02	23·7-27·7
M4								
Length	16	21·2-25·3	23·6 ± 0·27	1·08 ± 0·19	4·58 ± 0·81	27·0	1·10	24·8-29·2
Width, ant.	15	20·1-23·5	21·7 ± 0·23	0·90 ± 0·16	4·15 ± 0·76	23·5	0·97	21·6-25·4

			Kolopsis torus			N.M.V. P15911A-B		
	N	OR	$\overline{X}$	s	V	"$\overline{X}$"	"S"	"$\overline{X}$"±2"s"
P3								
Length	21	12·3-15·5	14·0 ± 0·17	0·78 ± 0·12	5·57 ± 0·86	12·8	0·71	11·4-14·2
M1								
Length	12	17·2-19·0	18·0 ± 0·16	0·54 ± 0·11	3·00 ± 0·61	15·4	0·46	14·5-16·3
M2								
Length	19	18·7-21·6	20·2 ± 0·19	0·83 ± 0·13	4·11 ± 0·67	19·5	0·80	17·9-21·1
Width, post.	17	13·8-16·0	15·1 ± 0·13	0·55 ± 0·09	3·64 ± 0·62	12·9	0·47	12·0-13·8
M3								
Length	14	21·8-25·8	23·3 ± 0·35	1·30 ± 0·24	5·58 ± 1·05	21·9	1·22	19·5-24·3
Width, ant.	13	16·4-19·7	18·2 ± 0·25	0·90 ± 0·17	4·95 ± 0·97	15·1	0·75	13·6-16·6
M4								
Length	19	22·1-27·0	24·2 ± 0·32	1·43 ± 0·23	5·91 ± 0·96	23·0	1·36	20·3-25·7
Width, post.	15	15·6-20·0	17·2 ± 0·28	1·10 ± 0·20	6·40 ± 1·17	14·4	0·94	12·5-16·3

"$\overline{X}$" ± 2"s" = range of two standard deviations on either side of the "mean". The "mean" is taken as the dimension measured on *Z. gilli* and N.M.V. P15911A-B, "s" being computed from V of *K. torus*. All measurements in mm.

a = approximate, ant. = anterior, post. = posterior, N = number of specimens, OR = observed range, $\overline{X}$ = mean, s = standard deviation, V = coefficient of variation.
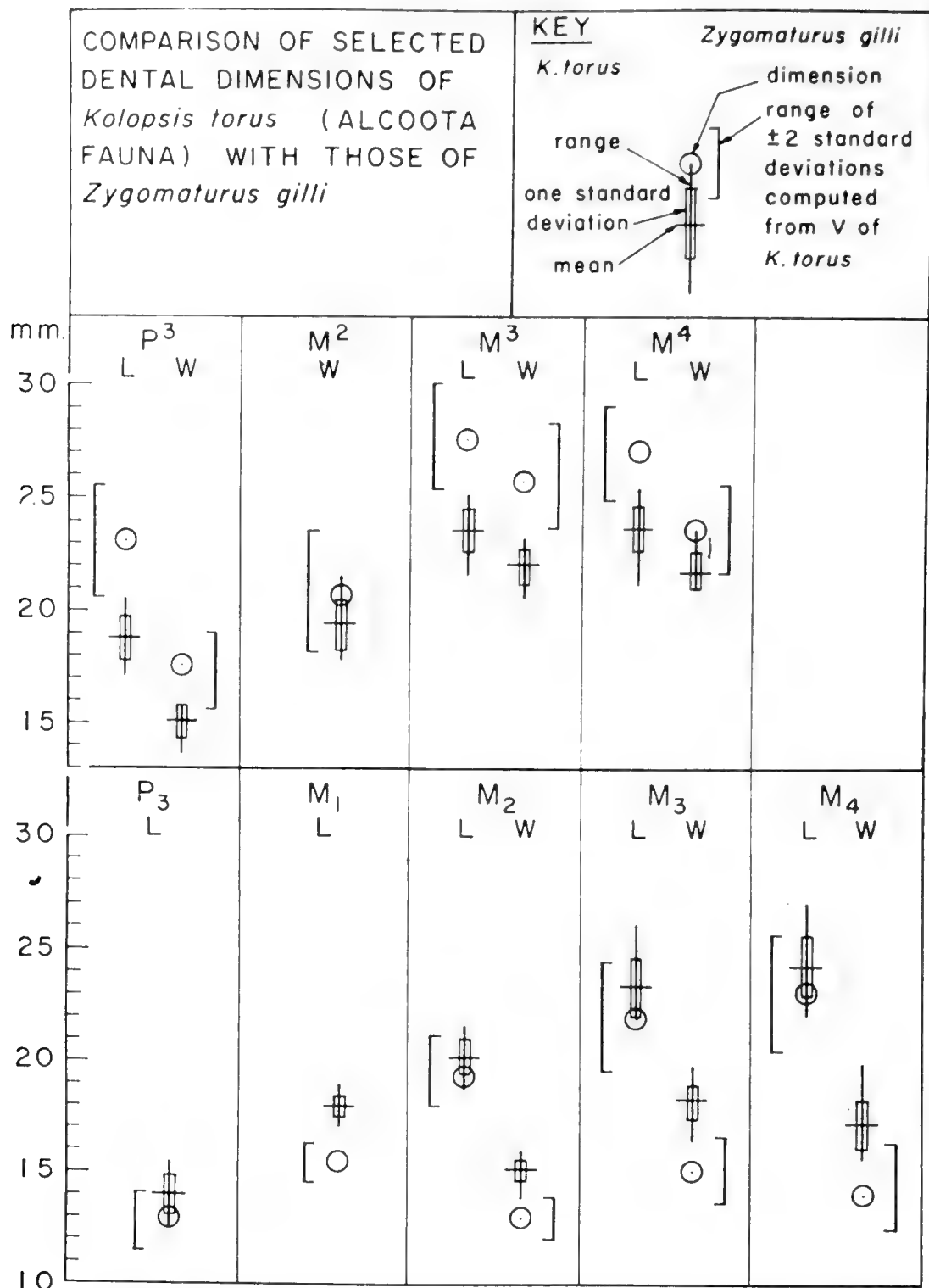
Fig. 2—Comparison of selected dental dimensions of *Kolopsis torus* (Alcoota fauna) with those of *Zygomaturus gilli* and a theoretical estimate of the range of these dimensions for a population of *Z. gilli*.

Z. keanei differs from the Beaumaris specimen in its stronger digastric process and postdigastric sulcus, anterodorsally inclined supra-symphysial surface, less bilobate basal outline of its molars, and the fact that both the protolophid and hypolophid contribute to the metalophid on M_4.

As shown in Table 1 and Fig. 2, the upper teeth of *Z. gilli* are conspicuosly larger than those of *K. torus*, except for the posterior width of M^2. The lower teeth of N.M.V. P15911A-B are generally smaller than those of *K. torus*, but overlap does occur in the lengths of P_3, M_2, M_3, and M_4.

Following procedures such as those indicated in Simpson, Roe, and Lewontin (1960), the hypothetical value of the standard deviation (s) for the population to which *Z. gilli* belongs can be computed from the coefficient of variation (V) calculated for the *K. torus* sample. These values are presented in the statistical summary below. The above procedure assumes that the dimensions observed for *Z. gilli* represent the 'mean' for its population, and that the coefficient of variation of the population would be similar to that of the closely related species, *K. torus*. Simpson, Roe, and Lewontin (1960, p. 212) indicate that over 95 per cent of all specimens in a population would theoretically fall within a range of plus or minus two standard deviations from the mean.

As shown in Fig. 2, the hypothetical range in dental dimensions of a 'population' of *Z. gilli* would completely or nearly overlap the observed ranges of analogous dimensions of the Alcoota population of *K. torus*. The fact that N.M.V. P15911A-B is too small to occlude satisfactorily with the upper teeth of *Z. gilli* is insufficient for taxonomic separation of the two groups of specimens. They could represent individuals pertaining to different parts of a 'normal' population curve of *Z. gilli*. Such a population would have approximately the same dental dimensions as those of *K. torus*. In the absence of definitive contrary evidence, and in view of its geographic and geologic proximity to the other specimens of *Z. gilli*, and because it has a similar evolutionary position, N.M.V. P15911A-B is referred to that species.

Conclusions

From the data summarized above, the mandible N.M.V. P15911A-B pertains to *Zygomaturus gilli*. Although its tooth proportions are close to *Plaisiodon*, the mandibular characters of the Beaumaris specimen are sufficiently divergent to warrant separation from that genus. The mandible of N.M.V. P15911A-B is closely similar to *Kolopsis torus* and, to a lesser degree, to *K. rotundus*. Except for its narrower tooth proportions, the Beaumaris specimen is relatively close, dentally, to *K. rotundus*. *Kolopsoides cultridens* is sufficiently divergent from the Beaumaris specimen to be excluded from further discussion.

Allowing for the dorsoventral crushing of the specimen of *Zygomaturus keanei* (late Pliocene), some of the features in which it differs from the Beaumaris mandible, e.g. the deeper pterygoid and digastric fossae and prominent digastric process and postdigastric sulcus, could be correlated with its large size. Such features are commonly found in the larger more massive Tertiary diprotodontids such as *Pyramios alcootense*, *Meniscolophus mawsoni*, and *Z. keanei*, but are not as prominently developed in some of the smaller species.

The remaining differences between *Z. keanei* and N.M.V. P15911A-B, the anterodorsal slope of the supra-symphysial surface and the somewhat less bilobate basal occlusal outline of the molars, would not preclude referral of the Beaumaris

specimen to the genus *Zygomaturus*. The high, laterally compressed, and somewhat open cross section of the proximal end of the incisor in the Beaumaris specimen differs in detail from that of *Z. keanei*, but the proportions of the incisor cross section, and the fact that the root remains open close to (if not at) the tip, is similar in both. Of the Tertiary diprotodontids surveyed, a high narrow proximal incisor cross section was also found in *Plaisiodon centralis* and *Pyramios alcootense*, the latter being a nototheriine. In both of these, however, the root is closed, and although the posterior cross section is bi-concave, it differs in detail from that in *Z. keanei* (Stirton 1967, fig. 4B), and the Beaumaris specimen.

In summary, the combination of its mandibular characters, coupled with the elongate proportions of the molars, the well developed arcuate metalophid, and laterally compressed, but open proximal cross section of the lower incisor, permit referral of N.M.V. P15911A-B to the genus *Zygomaturus*; for reasons presented previously, the specimen is assigned to *Z. gilli*.

N.M.V. P15911A-B presents a mosaic of characters. Those which are more advanced than *K. torus* are the more strongly developed and curved metalophid and asymmetrically V-shaped transverse valleys of the molars, and the flattened, essentially open posterior root of the lower incisor. The more primitive position of the Beaumaris mandible with respect to *Z. keanei* is shown in its considerably smaller size, the lack of a strong protolophid contribution to the metalophid of M_4 and possibly the less prominent development of the pterygoid and digastric fossae, and the smaller digastric process and shallower postdigastric sulcus.

The post *K. torus*—pre *Z. keanei* stage of evolution of the Beaumaris mandible thus substantiates the post Alcoota-pre Palankarinna age assignment proposed for the Beaumaris fauna, as based on evidence of the upper dentition of *Z. gilli* (Stirton, Woodburne, and Plane 1967; Stirton, Tedford and Woodburne 1968).

Tentative expanded diagnosis of Zygomaturus gilli

Referral of N.M.V. P15911A-B to *Z. gilli* allows the diagnosis of the species to be expanded beyond that given in Stirton (1967, p. 135) subject of course to future discoveries: Size much smaller than Palankarinna species, roughly similar to that of *Kolopsis torus*; mandible less robust than *Z. keanei*, with shallower pterygoid and digastric fossae; less prominent digastric process, postdigastric sulcus, and postalveolar process; supra-symphysial surface nearly horizontal; lower molars with more bilobate occlusal outline; no protolophid contribution to the metalophid on M_4.

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DESCRIPTION OF AN UPPER MIOCENE ALBATROSS FROM BEAUMARIS, VICTORIA, AUSTRALIA, AND A REVIEW OF FOSSIL DIOMEDEIDAE

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Abstract

An incomplete bill of an albatross from Upper Miocene marine sands at Beaumaris, Victoria, is shown to belong to the genus *Diomedea,* and to be distinct from all previously described species of that genus. It is described as *Diomedea thyridata* sp. nov., and its relationships with living and fossil albatrosses are discussed. The fossil record of the family Diomedeidae is reviewed, and the significance of this fossil for an understanding of the evolution of the family is demonstrated.

Introduction

The palaeontological collection of the late Dr G. B. Pritchard was purchased by the National Museum of Victoria in 1950. It included a large number of vertebrate fossils from Upper Miocene marine beds at Beaumaris, on the E. shore of Port Phillip Bay, Victoria. Most of these came from the nodule bed at the base of the Black Rock Sandstone. However, there were a few which had apparently been collected in situ from above the nodule bed, as judged by the nature of the matrix still adhering to them, and among these was the fossil described in this paper. There is no reason to doubt that the fossil was collected by Dr Pritchard from Beaumaris, but there was no information with it apart from the locality, so its exact provenance is not known. When the fossil was prepared a sample of matrix was retained, part of which was sent to Mr A. C. Collins (Honorary Micropalaeontologist) for examination. His report (dated 25.2.1967) was: 'The washed material consisted mostly of small angular quartz grains iron-stained and tending to aggregate in granules which did not break down in dilute HCl. There was some calcareous material but not a large proportion, rare glauconitic grains, and very few forams, poorly preserved and scarcely identifiable, mostly *Elphidium* sp. There is no positive evidence of age. The material is similar in lithology to other Beaumaris material in my possession, but differs in lacking the microfossil fauna. It could be from a leached horizon.'

The foraminiferal evidence is inconclusive, but there are other reasons for believing that this fossil came from the Black Rock Sandstone above the nodule bed, and these are listed below.

1. It is not likely that the bill could have survived the conditions under which the nodule bed formed. Fossils from the nodule bed are typically highly mineralized, well worn and often highly polished, whereas the albatross bill is relatively lightly mineralized, and although damaged before burial, is on the whole well preserved.

2. Scattered vertebrate remains with similar preservation and matrix are found above the nodule bed.

3. The oxidized matrix and absence of carbonate cementation support this interpretation.

The latest description of the section at Beaumaris, which includes a summary of earlier work, was given by Kenley in 1967. The sequence of marine rocks forming the lower part of the cliffs, including the nodule bed, is the type section for the Cheltenhamian stage (Singleton 1941) which is probably of late Upper Miocene age. Stirton, Woodburne and Plane (1967) place their 'Beaumaris Fauna' in the Lower Pliocene, mainly on the basis of the stage of evolution of the Diproto-dontid *Zygomaturus gilli* Stirton 1967, but this evidence is not as strong as that for a Miocene age. T. A. Darragh (pers. comm.) says: 'the Miocene age is based on the occurrence of the pelagic cephalopod *Aturia* which is restricted to the Eocene, Oligocene and Miocene in other parts of the world. This genus is absent from the younger Kalimnan stage which has been traditionally correlated with the Lower Pliocene.' It is reasonably certain then that the fossil came from the lower part of the cliffs at Beaumaris, and is therefore of Upper Miocene age.

This is the first record of the family Diomedeidae from the Tertiary of Australia, but this is not surprising since albatrosses are extremely rare as fossils. The fossil record of the family is reviewed in this paper, but it can be noted here that previously recorded occurrences are based on isolated post-cranial elements, so direct comparison between them is usually not possible. Previous records of fossil birds in Australian Tertiary marine rocks have been confined to the order Spheniciformes (penguins), and Simpson (1965) summarized their occurrence.

Acknowledgements

Systematic Description

Order PROCELLARIIFORMES Fürbringer 1888

Family DIOMEDEIDAE (Gray) 1840

Genus **Diomedea** Linnaeus 1758

Diomedea thyridata sp. nov.

Pl. 3, fig. 1; Pl. 4, figs. 2, 5.

ETYMOLOGY: Gr. *thyris, -idos* f. dim., window or small door, in allusion to the relatively small inner posterior aperture of the Antrum of Highmore.

MATERIAL: Holotype, N.M.V. P24172, G. B. Pritchard Coll.

TYPE LOCALITY: Beaumaris, Victoria, almost certainly from above the nodule bed in the Black Rock Sandstone.

AGE: Uppermost Miocene (Cheltenhamian).

DIAGNOSIS: A *Diomedea* comparable in size to the smaller living species, with a bill of the '*melanophris* group' type, distinguished from all other species by the following combination of characters: a high-crowned rounded culmenal ridge, relatively large narial apertures, a bony floor to the apertures, nasal bone behind the apertures with nearly vertical posterior border, and a width of about 10 mm, inner posterior aperture of the Antrum of Highmore wider than high and relatively small, dorsal outline of bill fairly strongly concave, nasal sulci more or less median in position, slight expansion of the nasal processes of the premaxilla behind the narial apertures.

DESCRIPTION: The fossil consists of the proximal two-thirds of the upper bill of an albatross. The strongly hooked anterior portion (the unguis) is entirely lacking, but the morphology of the preserved portion is so typical of the family that there can be no reasonable doubt that the fossil bill bore such a hook in life. The terminology used is that of Pycraft 1899, except for the addition of the term 'culmenal ridge' for the structure formed by the fusion of the nasal processes of the premaxilla.

Total length of the fossil is 68·5 mm, and comparison with living species suggests that the length of the bill in life was between 100 and 105 mm. It has a maximum width posteriorly of 19·5 mm, and when allowance is made for abrasion, this gives an estimated width in life of 22 mm. At the same level, the fossil has a maximum height of 26·2 mm. There is little evidence of any distortion during fossilization, so these dimensions are probably meaningful. The culmenal ridge is transversely rounded, and because of the near median position of the nasal sulci, is a very prominent feature of the fossil bill. It is 8·1 mm wide just anterior to the narial apertures, at which level the bill has a width of 15·8 mm. The culmenal ridge consists of the fused nasal processes of the premaxilla, and behind the narial apertures, the sutures between these and the nasal bones are just detectable on the fossil. The maximum width of the nasal processes in this area is 8·5 mm, i.e. there is a slight expansion of the nasal processes behind the narial apertures.

When viewed laterally, (Pl. 3, fig. 2) the dorsal profile is quite strongly concave and is roughly paralleled by both the nasal sulcus and ventral profile. The nasal sulcus, which lies at the contact of the nasal and maxillary processes of the premaxilla, is 2·5 mm wide, and rather wider and deeper than in related living albatrosses. The maxillary processes of the pre-maxilla are strongly-built plates, sloping steeply downwards and outwards. The sharp flanges on the ventral edges of these processes in living albatrosses are absent in the fossil, but this is certainly due to abrasion before burial. The holorhinal narial apertures lie between the processes of the premaxilla, and are bounded posteriorly by the nasal bones. They are approximately 19 mm long and have a maximum height of about 6 mm. The maxillary processes bend inwards below the apertures to form a shelf of bone which merges imperceptibly into the nasal sulcus anteriorly. This bone shelf is at least 3-4 mm wide. The depth of maxillary process below it, in the middle of the aperture, is 9·4 mm, to which can be added 1·0-1·5 mm for the missing flange at its ventral border. The flange has broken away along a line of weakness visible on the bills of living albatrosses. The measurement from the same position to the centre of the culmenal ridge is 10·3 mm. Thus the base of the narial aperture is very nearly in the midline of the bill. The minimum width of nasal bone behind the narial apertures is 10 mm, its posterior border in this area being very nearly vertical. The nasals extend onto the dorsal surface of the bill, and contact the nasal processes of the premaxilla behind the narial apertures.

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Ventrally, (Pl. 2, fig. 2) the fossil has the deep palate and slit-like premaxillary vacuity typical of the family. The latter is almost complete and is estimated to have been 41 mm in length, with a width of 2.5 mm. The vacuity separates the ventral portions of the maxillary processes of the premaxilla, but in the anterior portion of the palate these fuse to form a bony palatal roof in living albatrosses. This anterior region is only just represented on the fossil. In the vicinity of the anterior end of the premaxillary vacuity, the ventral border of the maxillary processes forms the apex of a triangular area which widens posteriorly, and faces outwards and downwards. Although considerably abraded, this area is recognizable on the fossil, and its apex could make a reference point for a rough comparison of palate widths. In the fossil the internal palate width at this point is 8.0 mm, the bill being 12.5 mm wide.

The maxillo-palatines in albatrosses are concavo-convex lamellae which are extensively fenestrated. On the palate they appear as a pair of thin processes lying between the palatines, and pointing posteriorly. This region is represented on the fossil, although it has suffered some abrasion, and in fact most of the adjacent palatine bones have been removed by erosion, allowing a view of the inner portion of the maxillo-palatine. The hollowed-out chamber which lies within the somewhat scroll-like maxillo-palatines is the Antrum of Highmore. In living albatrosses, there are generally three posterior apertures of this chamber; two lie vertically above each other close to the outer surface, while the third (normally the largest) lies internally to them. These apertures are taxonomically significant, and it is fortunate that they are partly preserved in the fossil. The inner aperture is larger, wider than it is high, and relatively small compared to those of its living relatives. The palatines are barely represented on the fossil, and give no information of diagnostic value. The ventral tip of the vomer is useful in distinguishing albatross species, but is not preserved on the fossil.

Discussion

The osteology of birds is a subject which has been relatively neglected this century when compared with the study of other vertebrate groups, and especially when compared with the voluminous literature on most other aspects of ornithology. The albatrosses have been no exception. The two principal osteological descriptions are those of Forbes (1882) and Pycraft (1899), but both are comparative descriptions of the family as a whole in relation to other Procellariiforme birds. There has apparently been no study of the osteology of the family Diomedeidae at the species level, and this has been a considerable handicap in the preparation of this paper. I have had access to skulls of the seven species which include the Australian coastline within their wintering ranges but the non-Australian species present a problem because illustrations of the living birds have the various horny plates of the ramphotheca in place, and illustrations of the skulls are not available. Very little can be deduced about their osteology, apart from gross morphology, which of course bears some relationship to the arrangement of the plates. Coues (1866) pointed out that the bills of albatrosses are diagnostic at the specific level, and described those of several species. However, his work is of limited value for the present purpose, because it is concerned with the appearance of the bill in life, and contains little information on osteology. The following discussion is therefore based mainly on comparisons with the Australian albatrosses.

1. Generic Identity of the Fossil

Two genera of living albatrosses are recognized at the present time, namely

Table 1 (rotated). Measurements of bills of Diomedeidae. All measurements in mm.

Measurement	Phoebetria fusca W 6328 Portland, V.	Phoebetria palpebrata W 6329 Portland, V.	Diomedea exulans W 6322 Portland, V.	Diomedea cauta B 705 Mewstone Rock, Tas.	B 4445 Portland, V.	Diomedea chlororhynchos B 704 Queenscliff, V.	B 4122 Brighton, S. Aust.	B 4746 Waratah Bay, V.	Diomedea thyridata sp. nov. P 24172 U Miocene Beaumaris, Vic.	Diomedea melanophris W 2673 Portland, V.	B 9678 Portland, V.	B 2455 Heard Island	B4530 Portland	Diomedea chrysostoma B 6368 Portland, V.	B 6771	B6826	W 6326
1. Length of bill	98	95	150	113	113	100	110	114	est. 105	102	98	103	99	104	96	97	98
2. Max. width at base of bill	21.3	20.5	40.5	28.4	30.2	24.5	23.7	24.2	est. 22	24.6	25.7	27.6	24.8	24.2	22.4	23.7	26.6
3. " height " " "	29.7	26.2	38.3	33.5	34.1	28.1	27.2	28.9	26.2	29.0	28.5	31.3	30.8	30.5	28.5	29.2	30.2
4. Width of culmenal ridge just anterior of narial apertures	10.0	9.7	17.4	11.5	10.2	7.4	8.1	7.8	8.1	8.7	8.6	10.0	9.2	8.8	7.4	7.8	0.0
5. Width of bill at same level	15.4	14.9	30.1	20.5	22.1	16.4	18.6	18.1	13.8	17.4	17.8	19.1	17.5	12.7	15.3	17.9	19.4
6. 4 as % of 5	65.0%	65.5%	58.0%	57.5%	46.0%	45.0%	43.5%	43.5%	51.5%	50.0%	48.0%	52.5%	52.5%	69.0%	48.5%	43.5%	47.0%
7. Max. width of nasal processes of premaxilla behind narial apertures	7.7	7.0	12.5	10.8	8.6	7.3	7.1	7.9	8.5	8.9	9.1	11.5	10.4	8.0	7.7	8.8	8.4
8. Depth of outer border of maxillary processes of premaxilla below narial apertures	6.4	6.1	13.3	15.5	15.2	12.3	11.5	12.0	est. 10.5	10.5	11.9	11.0	11.2	12.0	10.5	10.8	11.9
9. Height of bill at same level	19.3	18.6	31.6	26.8	24.9	22.9	19.4	20.8	–	22.4	23.7	23.7	22.7	22.3	21.3	21.1	23.4
10. Minimum width of nasal bone behind narial apertures	c.8	5.4	c.6	12.0	16.4	10.9	11.4	11.0	10.0	6.5	6.8	11.7	8.7	11.0	6.5	7.0	10.1
11. Approx. dimensions of narial apertures — Length	15.0	19.0	27.0	17.0	15.5	11.5	15.0	13.5	19.0	22.0	20.0	16.0	15.0	15.5	21.0	19.0	16.0
11. Approx. dimensions of narial apertures — Height	6.0	6.5	7.5	7.0	5.0	4.0	4.0	4.0	6.0	7.5	7.5	7.5	6.5	7.0	7.0	6.5	6.0
12. Length of premaxillary vacuity	39.5	32.0	47.0	42.0	43.0	42.8	51.0	47.0	41.0	47.0	37.0	46.0	40.0	40.0	39.0	42.0	39.0
13. 12 as % of 1 (bill length)	40.3%	33.5%	31.3%	37.0%	38.0%	42.6%	46.4%	45.2%	40.1%	46.0%	37.7%	44.7%	40.3%	37.5%	40.7%	43.3%	39.5%

TABLE 1

Table of measurements from a series of bills of the Diomedeidae which includes the Australian coast within their ranges. The characters used can either be directly measured on the fossil or estimated with a reasonable degree of accuracy. Only one or two representative examples have been measured of those species which have no close relationship with the fossil, but all available material of its modern relatives has been measured. All measurements in mm.

Diomedea and *Phoebetria*, (Peters 1931, pp. 41-46). Other genera have been proposed from time to time for various species of *Diomedea*, but the instability of their nomenclature is in marked contrast to the stability of *Phoebetria*. This is not surprising, because the similarities between the species of *Diomedea* are greater than their differences, while *Phoebetria* is clearly distinct. Although grouping of the species of *Diomedea* on bill characteristics is possible (see below), it is doubtful whether the use of even subgeneric names is warranted. *Phoebetria* contains two species, *P. fusca* (Hilsenberg) and *P. palpebrata* (Forster), which have in common many features which set them apart from *Diomedea*. Murphy (1936) pointed out that *Phoebetria* is distinguished by the dark plumage of adults, much larger tail, cuneate form, and the persistence of a 'primitive' character in the bill, namely a sulcus dividing the plates of the lower mandible. Before attempting to establish the generic identity of the fossil, it was necessary to ascertain whether the generic distinction between *Diomedea* and *Phoebetria* could be supported on characters of the upper bill alone. It was found that *P. fusca* and *P. palpebrata* have in common morphological features of the upper bill which clearly separate them from *Diomedea* spp. The most important of these are listed in Table 2.

TABLE 2

Osteological characters of the bill which can be used to separate the genera Diomedea *and* Phoebetria

Character	Diomedea	Phoebetria
Inner posterior aperture of Antrum of Highmore	Always present; larger than two outer apertures	Usually obsolete; if present, very small
Depth of outer border of maxillary process of pre-maxilla below middle of narial aperture	>10 mm.	<7 mm.
Width of culmenal ridge as % bill width just anterior of narial apertures	43-57%	c. 65% (i.e. relatively broad)
Nature of palate	Not as deep as in *Phoebetria* relative to palate width	Much deeper than in *Diomedea* relative to palate width

Comparison of the data in Table 1 with Table 2 clearly shows that *D. thyridata* sp. nov. differs from species of *Phoebetria* in the same features as species of *Diomedea* do, and has no close affinity with the former. On the other hand, there is no character on the fossil which cannot be at least approximately matched in some species of *Diomedea*. Its specific distinctness is based on a unique combination of characters within that genus. Furthermore the fossil belongs to one of the two main groups within *Diomedea*, as will be shown below. Clearly there could be no possible justification for the erection of a new genus.

2. Comparison with living species

The two species of *Phoebetria* are excluded from further discussion, because they can be separated from the fossil on generic characters, as shown above. Coues (1866) rejected the splitting of *Diomedea* s. l. prevalent in his time (and maintained by many other workers until well into this century), but introduced the concept of 'groups' of albatrosses based on bill characters, which I have followed

in preference to formally re-introducing the appropriate generic names as sub-genera. This must await a really detailed study of the family as a whole, but the groupings on bill characters do seem to indicate something of the relationship within the genus *Diomedea*.

(a) *D. melanophris* group

This group includes the majority of the smaller albatrosses, and is virtually confined to the S. Hemisphere at present. Two sub-groupings are possible, but these are not sharply differentiated, and the fossil shows affinities with both. More specifically it shows relationships both to *D. melanophris* Temminck (Pl. 3, fig. 3; Pl. 4, figs. 3, 6) the 'typical' member of one sub-group, and to *D. chlorohynchos* Gmelin (Pl. 3, fig. 1; Pl. 4, figs. 1, 3) which belongs to the other. The *melanophris* sub-group includes *D. chrysostoma* Forster and *D. irrorata* Salvin, and is characterized by a prominent, high-crowned culmenal ridge, large narial apertures and relatively narrow maxillary processes. The placing of *D. irrorata* here is tentative, but in describing it Salvin (1883) said 'It appears to come next to *D. melanophris* having the bill similarly constructed . . . . but the bill is much larger'. Illustrations of the living bird certainly support such an affinity, but little else can be said about it here. *D. chrysostoma* has a lower crowned culmenal ridge than either *D. melano-phris* or *D. thyridata* sp. nov., and partly bridges the gap to the *chlorohynchos* sub-group, which is characterized by expansion of the maxillary processes of the premaxilla with correspondingly low-crowned culmenal ridges. Affinities with *D. thyridata* sp. nov. are shown by the presence of a bony floor to the small narial apertures, and a relatively wide expanse of nasal bone behind them. Included in this sub-group is *D. bulleri* Rothschild, of which I have seen neither specimens nor a good illustration, but it is apparently closely related to *D. chlorohynchos* and certainly seems to have a similar bill structure. *D. cauta* Gould belongs here also, but its larger size and more robust nature of its bill distinguish it from its smaller relatives.

Basically, *D. thyridata* sp. nov. is most closely related to *D. melanophris*. Apart from the features mentioned above, it shares with that species a characteristic slight expansion of the nasal processes of the premaxilla posterior to the narial apertures, and a premaxillary vacuity of similar length. This in turn suggests a bill of similar length, because the vacuity in *D. chlorohynchos* is several millimetres longer, due to the more elongate bill. It is not unlikely that *D. thyridata* sp. nov. represented the ancestral form which gave rise to *D. melanophris* and that the affinities with *D. chlorohynchos* place it close to being the common ancestor of both. Certainly it indicates that the '*melanophris* group' as a whole has a history dating back at least to the Upper Miocene.

(b) *D. exulans* group

This includes the two largest living species, *D. exulans* Linné and *D. epomo-phora* Lesson, and *D. albatrus* Pallas. Coues (1866) also included *D. nigripes* Audubon, but this species is somewhat atypical in certain respects. The bill of *D. exulans* is readily distinguished from the fossil by its much greater size and more robust character, coupled with distinctive morphological differences, which include broad low-crowned culmental ridge, deep but wide palate, and more outward sloping maxillary processes of premaxilla. It is the only species of this group of which I have seen specimens, but illustrations of the other species show that *D. thyridata* sp. nov. has no close affinity with this group. *D. epomophora* is

closely related to *D. exulans*, but has a bill which is even broader than that of *D. exulans* (Murphy 1936). *D. albatrus* has a bill of the 'same fundamental characters' as *exulans*, according to Coues, but differs in having a much less concave dorsal outline. In fact, it is almost straight to the midpoint, where it flattens, and hardly rises to the unguis. *D. thyridata* sp. nov. has a smooth continuous curve in a fairly concave outline. *D. nigripes* has a bill which is relatively short, with an almost straight dorsal outline, reminiscent of *Phoebetria*. The dark plumage is another character shared with that genus, as is the relatively short bill, with narrower maxillary processes than in typical *Diomedea*, but the depth and robust form of the bill in *nigripes* apparently ally it to the *D. exulans* group. Figures of the bills of *D. nigripes* and *D. albatrus* given in Seebohm (1890, pp. 260-3) show these characters. *D. immutabilis* may belong to this group also, because in his description of the species Rothschild (1893) says 'This albatross belongs to the typical section of *Diomedea* as limited by Mr Salvin', and the 'typical group' was based on *D. exulans*, type species of the genus. Thus it can be seen that *D. thyridata* sp. nov. has no close relationship with this group, whereas it is clearly of '*melanophris* group' type, as shown above.

3. Comparison with fossil Diomedeidae

The fossil record of the family is very meagre indeed. There are two Lower Tertiary fossil birds which Brodkorb (1963) doubtfully referred to the Diomedeidae. The oldest of these is *Gigantornis eaglesomei* Andrews (1916) based on an incomplete sternum from the Middle Eocene Ameki Formation of the Omobialla District of S. Nigeria. The bird it belonged to was thought by Andrews to have been about twice the size of *D. exulans*. There is no certainty that *Gigantornis* was an albatross, and even if it were it is most unlikely that it had any close relationship with the genus *Diomedea*.

The other Lower Tertiary species is *Manu antiquus* Marples (1946) which was based on an incomplete furcula from the Upper Oligocene (Duntroonian) Maerawhenua Greensand from near Duntroon, N. Otago, S. Island of New Zealand. It is much more likely that this was a true albatross, as its furcula was comparable to that of *D. exulans* in some respects, being fairly close in size, though the latter 'has a slightly greater angle between the rami'. Marples concluded that the specimen differed generically from *Diomedea*, so whether a true albatross or not, it obviously bore no close relationship to *D. thyridata* sp. nov. Marples also recorded shaft fragments of an ulna and radius from the same deposit 'which might have belonged to the same or a slightly smaller species'.

There are two records of Miocene albatrosses from N. America. The first was recorded by Loye Miller in 1935 from the Upper Middle Miocene Temblor Formation at Lomita, California, U.S.A. An impression of 'the wrist and proximal bones of the hand' was referred to the Diomedeidae by Miller on the characters of the carpometacarpus and of the pollex. The specimen was 'slightly smaller than *D. nigripes* and slightly greater than *D. immutabilis*'. This would seem to suggest that the albatross from Lomita was smaller than the other N. American Miocene species, *D. californica*, which Miller described in 1962. This species was based on a distal portion of a left tarsometatarsus from the Temblor Formation at Sharktooth Hill, Kern County California. Unfortunately, comparisons were limited to *D. albatrus*, *D. exulans* and the English Pleistocene species *D. anglica* Lyddeker (1891a). He showed that the tarso-metatarsus of *D. anglica* was slightly larger than that of *D. albatrus*, although the width across the trochleae was the same in

both. That of *D. californica* was larger and stouter than either, and very much shorter than that of *D. exulans*. Comparisons of his figure with tarso-metatarsi of the albatross species available to me, but not considered by Miller, indicate that only that of *D. cauta* approaches the fossil in size and proportions. However, there is no close resemblance, since the trochleae are relatively shorter in *D. cauta*, and the shaft is narrower. The length of the bone is only about two thirds of that of Lyddeker's figure of *D. anglica*, so clearly *D. cauta* has no close affinity with *D. californica* or *D. albatrus*. On the other hand, comparison with the tarsometa-tarsus of *Macronectes giganteus* (Giant Petrel) revealed a striking similarity in appearance and proportions, and in particular in the morphology of the shaft and length of the trochleae. The principal difference is the greater width of the inner trochlea of the fossil, which is one of the features on which Miller separated the fossil from *D. albatrus*. This casts some doubt on the generic and family assignment of *D. californica*, although it should be pointed out that *Macronectes* is virtually confined to the S. Hemisphere at the present time. The giant petrels have large, strongly built bills somewhat reminiscent of those of albatrosses, but have united nostrils on the top of the bill like all members of the order Procellariiformes, other than the family *Diomedeidae*.

D. *thyridata* sp. nov. has lateral, separate nostrils, showing that this feature was present as far back as the Late Miocene at least. Even if the re-examination of the type of *D. californica* showed it to be a true *Diomedea*, the similarities to *Macronectes* are certainly interesting, and require some explanation. It is not likely that *californica* bore any close relationship to *D. thyridata* sp. nov. especially if its affinities do lie with *D. albatrus*, as Miller suggested.

There are two records of Pliocene albatross fossils, one from N. America, and one from England. The former is from the Lower Pliocene Bone Valley Formation of Pierce, Polk County, Florida, U.S.A., and was recorded by Wetmore (1943) as *D. anglica*, although this was regarded as doubtful by Brodkorb in his catalogue of 1963. The English specimen is from the Upper Pliocene Coralline Crag of Foxhall, Suffolk, England, and consists of an ulna of albatross type, tentatively referred to *D. anglica* by Lyddeker (1891b). It cannot be directly compared to the type of that species and its identity is therefore unknown.

Diomedea anglica Lyddeker (1891a) was based on a right tarsometatarsal and associated proximal phalanx of digit *iv* from the Lower Pleistocene Red Crag of Foxhall, Suffolk, and was said by its author to be intermediate in size between *D. exulans* and the smaller living species. Miller (1962) has pointed out that the tarsometatarsus is like that of *D. albatrus*, although relatively more elongated. The tarsometatarsi of *D. cauta* and *Macronectes giganteus* were compared to Lyddeker's figure of *D. anglica*, but the former is a shorter, relatively stouter bone, while the latter is more like it in proportions, but is a little shorter, and differs in morphological details. It would appear that *D. anglica* is a true *Diomedea*, and probably directly ancestral to the living *D. albatrus*, or perhaps could even be conspecific, if a sufficient range of specimens were examined. In any case, there is no obvious relationship with *D. thyridata* sp. nov.

Late Pleistocene-Early Holocene albatross fossils are presumably all of living species, and are not of any importance for this discussion.

4. Significance of *D. thyridata* sp. nov.

This is the first record of a fossil *Diomedea* from the S. Hemisphere, and the oldest undoubted record of the genus, if the *Macronectes* affinities of the slightly

older *D. californica* are sustained. *D. thyridata* sp. nov. shows that the '*melanophris* group' of *Diomedea* had evolved by the Upper Miocene, and that this predominantly Antarctic-Subantarctic group was present in the S. Hemisphere then. The '*exulans* group' has a N. Hemisphere fossil record going back to the Miocene also, if *D. californica* is a true *Diomedea*. The affinity with *Macronectes* of this fossil, and that of *D. nigripes* with the more 'primitive' *Phoebetria*, suggest that the '*exulans* group' is closer to the ancestry of albatrosses, and that the '*melanophris* group' may have evolved from it. This is highly speculative, and would need a much better fossil record for proof. It is clear that the separation of the two groups extends well back in time. Furthermore, as suggested above, *D. thyridata* sp. nov. is probably ancestral to the sub-groups within the '*melanophris* group' itself.

The partial bill from Beaumaris is also the first record of cranial material of a Tertiary albatross. It shows that the albatrosses were already essentially modern in appearance, if bill structure is any guide to this. Lateral nostrils and prominent nasal sulci demonstrate that the physiologic mechanisms for salt elimination were probably similar to those of living albatrosses. The nasal glands lie above the orbits, and their secretions pass through the nostrils and along the sulci to drip off the end of the bill. It is certain that the origins of this mechanism lie much further back in time than the late Miocene.

Finally, it can be noted that the Black-browed Albatross is a comparatively frequent visitor to Port Phillip Bay at the present time, in contrast to its more purely oceanic relatives, and the presence of remains of its Miocene ancestor at Beaumaris is therefore quite understandable. This is analagous to the situation in California where Miller (1962) noted that *D. albatrus* was much more frequently seen near shore than *D. nigripes*, and it is therefore not surprising that *D. californica* shows closer affinities to the former. It is much more likely that an albatross of habits similar to *D. melanophris* would come close enough to shore to be incorporated in shallow water sediments like those at Beaumaris.

The shoreline was not more than a few miles E., and faunal evidence suggests at least a partially enclosed bay (T. A. Darragh pers. comm.). *D. chlororhynchos* is rarely seen in Victorian waters, but is commoner further W. towards the Indian Ocean (K. G. Simpson pers. comm.). If *D. thyridata* was really ancestral to both, then obviously some kind of geographical separation would have been necessary for speciation to occur. In this connection, it is of interest to note that the breeding ranges of *D. melanophris* and *D. chlororhynchos* are mutually exclusive at the present time.

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Explanation of Plates

All figures approx. nat. size

PLATE 3

Lateral views of fossil and its living relatives

Fig. 1—*Diomedea chlororhynchos* Gmelin, B704, figured specimen, living, Queenscliff, Vict.

Fig. 2—*Diomedea thyridata* sp. nov., P24172, holotype partial bill, Black Rock Sandstone, U. Miocene, Beaumaris, Vict., G.B. Pritchard Colln.

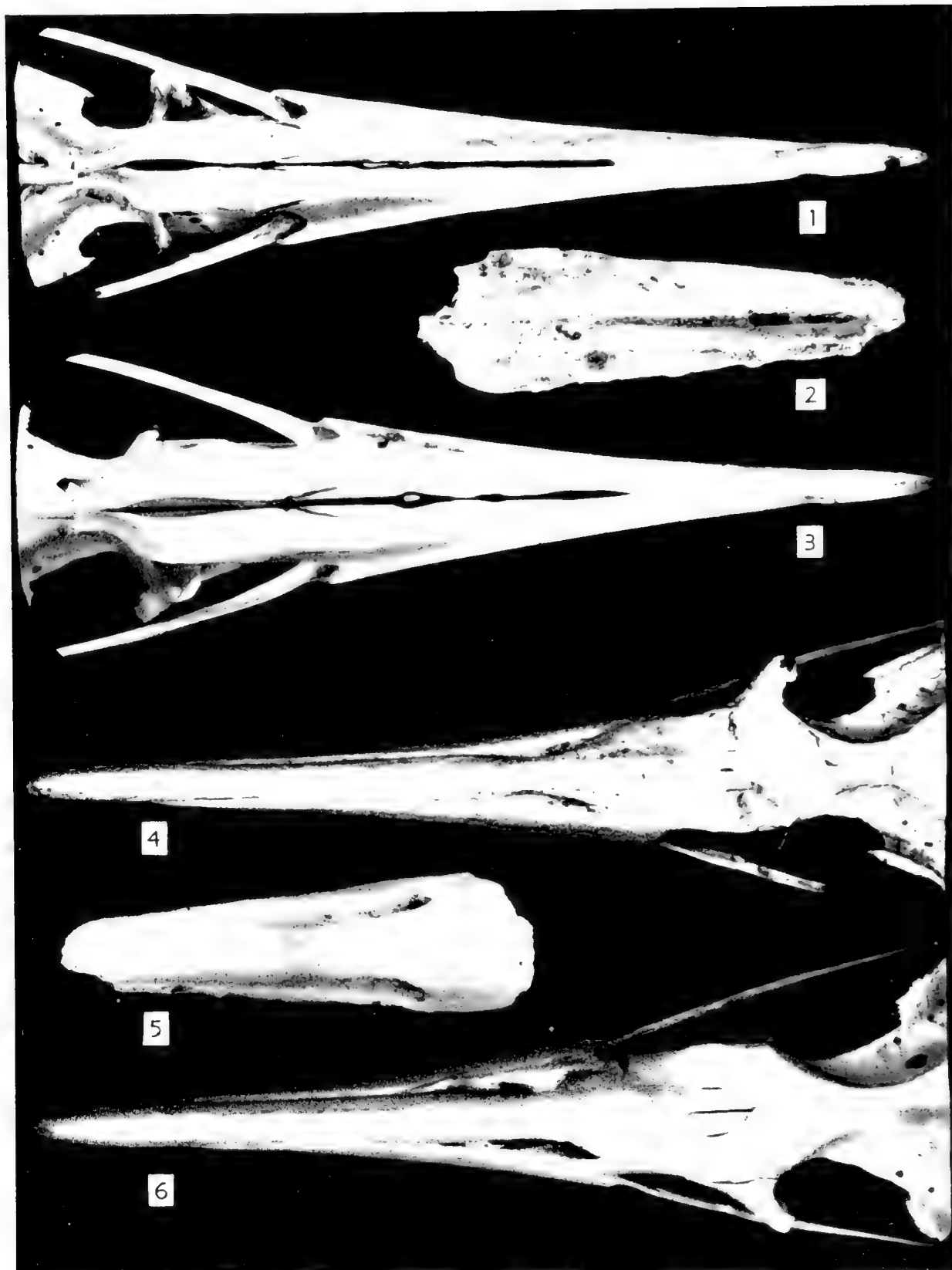Fig. 3—*Diomedea melanophris* Temminck, B9678, figured specimen, living, Portland, Vict.

PLATE 4

Ventral and dorsal views of the specimens in Plate 1

Figs. 1-3—Ventral views of B704, P24172 and B9678 respectively.

Figs. 4-6—Dorsal views of ditto.

FIVE LARGE AUSTRALITES FROM VICTORIA, AUSTRALIA, AND THEIR RELATIONSHIPS TO OTHER LARGE FORMS

By George Baker

Abstract

Fifteen of the 17 known australites with weights over 100 g have been recorded from the SW. portion of the vast Australian tektite strewnfield of 2,000,000 square miles. Only two are on record from the south-central portion (i.e. in S. Australia), and none from the E. or SE. portion. Recently, four large australites from Victoria have been noted in the National Museum of Victoria, and a fifth is privately owned, so that the distribution of the larger forms is by no means as confined as originally thought. These additional five specimens constitute the 10th, 11th, 13th, 14th and 17th largest among the 22 largest forms so far brought to scientific notice.

The largest Victorian specimen is a boat-shaped form from Port Campbell, followed by an oval core from Gymbowen, near Goroke, a round core from Lower Norton, near Horsham, then a dumbbell from Laing, and finally a round core from Lake Wallace, near Edenhope. Large australites characteristically show natural solution etch grooves (gutters) and etch pits, and usually reveal a flaked equatorial zone arising from subaerial exfoliation of the aero-thermal stress shell generated during hypervelocity passage through the earth's atmosphere.

Introduction

The recent recording of eight large specimens, each weighing over 100 g, from the SW. part of W. Australia (Baker 1961, 1962, 1963, 1966, 1967; McCall 1965), taken in conjunction with the nine large forms recorded earlier by Fenner (1955) from W. Australia (7) and S. Australia (2), makes it worthy of note that four equally large australites from Port Campbell, Gymbowen, Lower Norton, and Lake Wallace in W. Victoria, each weighing over 100 g, are lodged in the collection of the National Museum of Victoria, and a fifth, privately owned large form has been recently examined from Laing in W. Victoria. None of these specimens has been previously recorded. Their addition to those already recorded from W. Australia (15) and S. Australia (2) increases to 22 the total of large australites known among the 45,000 to 50,000 specimens so far found.

The sites of discovery of specimens weighing over 100 g are shown in Fig. 1 relative to the N. limits of the australite strewnfield. About 32 per cent occur towards the SE. portion of the strewnfield, i.e. in SW. Victoria and SE. S. Australia. The remainder occur in the SW. portion of the strewnfield, in SW. W. Australia some 900 miles distant, these two principal regions of occurrence being separated by the Great Australian Bight. The most westerly discovered large specimen, a thick-waisted dumbbell-shaped form from Cuballing, W.A. is a little over 1,350 miles distant from the most easterly discovered, a boat-shaped form from Port Campbell, Victoria. No large specimens have yet been reported from the northern portion of the australite strewnfield, i.e. from areas N. of latitude 30°S. Furthermore, no large specimens are known S. of latitude 39°S., although smaller specimens have been collected from as far S. as latitude 43°30'S. (i.e. in S. Tasmania). None has been recovered from the ocean floors or continental shelf regions S., W., or E. of the strewnfield.

From area to area within these two principal regions where large specimens have been found, and also from major region to major region, there are marked differences in the degree of preservation, some showing the effects of natural solution etching more than others, and some being more affected by abrasional weathering. This is to be expected over so vast a strewnfield over which the present climate varies significantly (40° of latitude and 26° of longitude). The area has been subjected to marked climatic changes in the immediate geological past. Furthermore, some specimens have been exposed to subaerial agents longer than others according to the times of release from the enclosing soils. The large, boat-shaped form from Port Campbell, Victoria (Pl. 5), which is the tenth heaviest of all known Australian tektites and the largest Victorian specimen, possesses the best preservation.
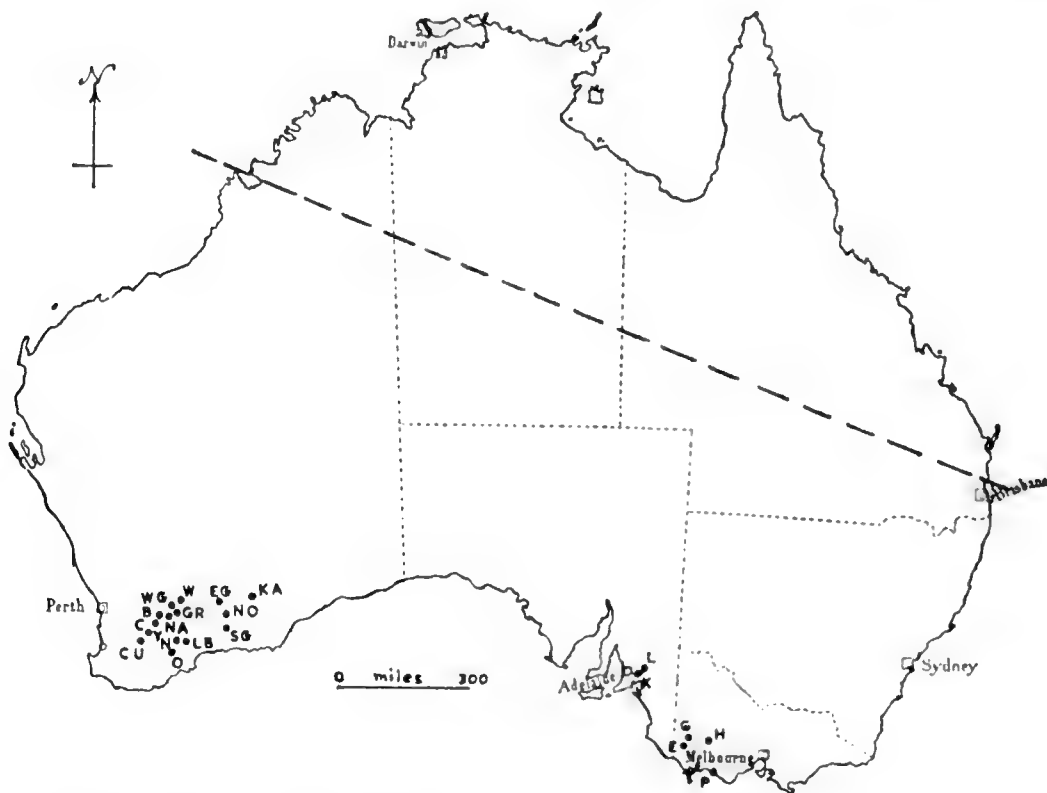

Fig. 1—Sketch map of Australia showing (broken heavy line) the N. limit of the australite strewnfield and sites of discovery in SW. Western Australia, SE. South Australia, and SW. Victoria of the 22 known australites weighing over 100 g.

KEY: B—Babakin, W.A. C—Corrigin, W.A. CU—Cuballing, W.A. E—Edenhope, V. EG—Eastern Goldfields, W.A. G—Gymbowen, V. GR—Graball, W.A. H—Horsham, V. K—Karoonda, S.A. KA—Karoni, W.A. L—Between Lowalda and Karoonda, S.A. LB—Lake Buchan (? Buchanan of earlier literature), W.A. N—Newdegate, W.A. NA—Narembeen, W.A. NO—Norseman, W.A. O—Ongerup, W.A. P—Port Campbell, V. SG—Salmon Gums, W.A. T—Laing, V. W—Warralakin, W.A. WG—Western Goldfields, W.A. Y—Lake Yealering, W.A.

Descriptions of Victorian Forms

1. *Boat-shaped form.* The large boat-shaped form (Pls. 5, 6) from Port Campbell, Victoria (Fig. 1) was found in the Sherbrook River area some three miles E. of Port Campbell township. It was presented to the National Museum of Victoria (M11402) on 2nd November 1910 by Mr A. Wishart, a local farmer. The date of presentation is approximately a quarter of a century before the author discovered the first specimen of a collection now totalling a little over 2,000 australites from the Moonlight Head—Princetown—Port Campbell—Peterborough coastal region in W. Victoria, and in which the heaviest specimen weighs approximately 56 g. Statements of having seen other large forms (round, mainly) are made from time to time by the local inhabitants, but the specimens have not been produced.

The weight of the specimen is 141·575 g, its length 86·2 mm, width 41·3 mm at the widest part (Pl. 5A), and depth 30·5 mm. It is the heaviest and largest australite for the Victorian part of the australite strewnfield. The specific gravity of this large boat-shaped form is 2·414, which is 0·017 above the average SG. value (2·397) for 573 australites (Baker 1956, p. 90) from the Port Campbell district. The width of the flaked equatorial zone (Pls. 5B, 6B) is 6 mm. This zone was produced by later spallation of the aerothermal stress shell generated on the forwardly directed surface of the australite during hypervelocity entry through the earth's atmosphere, much of the exfoliation evidently occurring as a consequence of subaerial effects brought into operation after landing on the earth's surface, although some spallation may have occurred during the final phases of atmospheric flight earthwards. In proportion to its size, this specimen has evidently lost the least amount of peripheral glass by spallation compared with other australites weighing over 100 g, and its flaked equatorial zone is proportionately the narrowest. In these respects it is closely matched by a smaller boat-shaped australite from Corop. Victoria, which weighs 88·5 gms, measures 64 mm by 35 mm by 25 mm, and is lodged in the University of Melbourne geological collection. The narrow flaked equatorial zone reveals etch grooves which cross the equatorial portion of the anterior surface and terminate abruptly at the rim separating the posterior and anterior surfaces.

Five well-defined, relatively smooth flow-swirled areas on the posterior surface of the Port Campbell large boat-shaped form (Pls. 5A, 8B) measure 49 mm by 27 mm, 21·5 mm by 15 mm, 16·5 mm by 7·5 mm, 14 mm by 9 mm, and 5 mm by 3 mm respectively. With three additional but indistinctly defined flow-swirled areas, the overall group of flow swirls occupies a little over half of the posterior surface, the remainder of which is lightly etch-pitted in places, densely pitted elsewhere, with sub-circular to oval and occasionally elliptical etch pits (Pls. 5A, 8B). The oval etch pits pass, along the trend of the flow schlieren that have become exposed by natural solution etching, into elongated, narrow gutters approximately the same depth as most of the pits (Pl. 8B).

A depressed area with relatively regular symmetry and 2 to 3 mm deep on the posterior side of the otherwise sharply defined rim (Pls. 5B, 8A) on one side of the specimen, measures 8 mm long and 5 mm wide, and is evidently a depression left by a flattened bubble after some exfoliation, rather than being an early-developed spall-mark subsequently modified by natural solution etching in moist soil. The sharply marked rim of the specimen (Pls. 5B, 6B) separates the flow-swirled and etch-pitted posterior surface from the spalled and subsequently etch-grooved anterior surface, and it delimits the zone of exfoliation of the aerothermal stress

shell for which spallation was more pronounced, leaving a more noticeable flaked zone, around the equatorial regions of the boat-shaped form.

Natural solution-etch gutters (Pl. 8A) are confined to the surface exposed after loss by spallation, and their trends have been largely determined by the very nature of the exfoliation process itself, relative to the curvature of the anterior surface. These gutters average 0·5 mm in width, range from 1 mm to nearly 15 mm in length, and are up to 0·5 mm deep. They are typically U-shaped in cross section, while longitudinally they mostly follow the general curvature of the anterior surface. Rather lighter etching of the glass forming the surface between the gutters has revealed the complex, fold-like character of the sub-surface schlieren, and the general overall trend of the schlieren is thereby shown to extend fundamentally in the direction of the longer axis. Schlieren are also well-exposed on the walls and floors of the gutters (Pl. 8A). Those on the floors represent a lower level in the sub-surface flow-line pattern than those higher up on the walls of the gutters and on the surface between the gutters. All the exposed schlieren are nevertheless part of the complex system of internal flow lines.

The radii of curvature for the posterior (R_B) and the anterior (R_F) surfaces have been determined across the width of the specimen, from enlarged silhouettes, as being $R_B = 23\cdot2$ mm, and $R_F = 23\cdot2$ mm. From graphical reconstruction, it is deduced that the forwardly directed surface during atmospheric entry, lost a maximum depth of 14·6 mm of glass by the combined effects of (a) ablational processes, (b) exfoliation of the aerothermal stress shell, and (c) some subsequent etching by subaerial processes of the surface exposed by the spallation process, provided that the original ellipsoidal form from which the ablated form was developed was biaxial and had a circular cross section normal to the long axis of the ellipsoid.

The specimen provides no evidence to indicate that a circumferential flange was developed at any stage of its aerodynamic history. This applies to all of the large forms weighing over 100 g without doubt, and in fact to all australites examined that weigh over 15 or 20 g. No flange fragments are ever found that would be large enough to fit the larger australites, and no large forms have been observed to possess flanges, remnants of flanges, nor the flange bands that result when circumferential flanges become detached by fracture. Evidently there is an optimum weight and size for australites above which circumferential flanges cannot be generated.

2. *Oval core.* A large oval core (Pl. 7A-D) from Gymbowen, near Goroke, Victoria (Fig. 1), was presented to the National Museum of Victoria (M11401) by G. T. Hause on 26th May 1911. The weight of the specimen after cleaning in an ultrasonic vibrator is 135·09 g, its length = 55·0 mm, width = 51·4 mm, and depth = 36·3 mm. The width of its well-marked flaked equatorial zone (Pl. 7B-C) ranges from 12 mm to 15 mm. The SG. was determined as 2·417. The artificial removal of a chip from towards one end of the posterior surface, evidently before lodgement in the National Museum collection, has left a conchoidal fracture surface (Pl. 7A, right-hand end) which measures 14·4 mm by 11·3 mm and shows well developed sub-concentric ripple fracture marks and a highly vitreous lustre, but no flow schlieren since they only appear after natural solution etching. Six flat-bottomed depressions on the anterior surface of the specimen (Pl. 7D) are evidently percussion produced or else represent small spall structures; they are approximately circular in outline with a diameter of 3 mm and a depth of about 0·5 mm.

The rim between the posterior surface and the flaked equatorial edge of the anterior surface is quite sharply defined (Pl. 7, B-C) and a remnant of non-spalled surface glass is left in the otherwise almost completely flaked equatorial zone (right-hand end of Pl. 7C). The flaked equatorial zone reveals a few gutters produced by natural etching (about four or five are showing in Pl. 7B-C), and these gutters trend up and down across the flaked zone. A few short solution-etch gutters on the anterior surface (left-hand side of Pl. 7D) are like those on the anterior surface of the larger boat-shaped form from Port Campbell (Pl. 6A) and resemble the stitching on a softball.

A depression on the posterior surface measures 7 mm by 6 mm (top of Pl. 7C, 7A, bottom right) and is either an original deformity or the site of a pre-existing gas bubble. The posterior surface is otherwise generally smooth (Pl. 7A), with a dull lustre, occasional scratch marks of subaerial origin, and a few etch pits up to 1 mm across. Most of these pits seem to be etched spall marks of small size and of the 'chatter-mark' type.

Radii of curvature (R_B and R_F) determined across the width and along the slightly greater length were $R_B = 36.8$ mm and $R_F = 32.1$ mm across the width, and $R_B = 42.9$ mm, $R_F = 34.3$ mm along the length. Even though there is a difference of only 3.6 mm between the width and length of the specimen, an accurate reconstruction of the primary ellipsoid from which the secondary ablated form was developed could not be guaranteed, as it can with more truly spherical primary forms, hence the calculation of the amount of glass lost from the forwardly directed surface could be grossly erroneous. On the basis that the arc of curvature across the width of the specimen is more nearly part of a circle than that provided by the arc of curvature along the greater diameter (i.e. = length) of the oval-shaped core, and with the R_F measurement for this direction being 32.1 mm, then the calculated loss of glass from the front surface along the line of the front to rear poles (i.e. the depth of ablation in the stagnation region) would be 31.4 mm. This figure would include loss of glass by subsequent exfoliation and a little further loss by natural etching, and it is almost equal to the present depth of the core (no. 11, Table 1) and appears to be excessive. On this basis, it may be that the primary form was a triaxial ellipsoid, in which event a cross section through the primary form taken normal to its length would not have been circular as it would have been if the primary form was that of a biaxial ellipsoid.

3. *Round cores*. The two large round cores, one from Lower Norton via Horsham, and one from Lake Wallace near Edenhope, show no structural nor sculptural features of significance over and above those described herein for other large forms. Their dimensions, weights, and specific gravity values are listed in Table 1. The round core from Lower Norton was found on the banks of a dam and presented to the National Museum of Victoria (E2730) on 29th August 1961 by Mrs M. Hannan. The round core from Lake Wallace was discovered about 1936 and is N.M.V. E1986.

4. *Dumbbell-shaped form*. The large dumbbell-shaped australite from Laing in W. Victoria (Pl. 9-10) was brought to notice per favour of the Assistant Director, Mr E. D. Gill. The specimen was found by Master Andrew Halford in 1966, in a low cutting some 2 ft 6 in. high, on the S. side of the Allansford-S. Ecklin road on the N. side of Buckley's Creek, Laing. The site of discovery is 1.1 miles W. of the Terang-Curdie Vale road. The specimen was partially exposed on reddish-brown soil 6-9 in. below ground level and thus within the plant root zone. It

weighs 115.752 g after cleaning, using 1:1 HCl to release iron-rich clay partially cemented in some surface pits and gutters. Its SG. was determined on a Walker's Steelyard as 2.467. This is unusually high for Victorian australites generally, but consistent results were obtained on repeating the determinations.

The form is that of a slightly distorted, thick-waisted dumbbell having one gibbosity (36 mm wide and 29.7 mm thick) a little larger than the other gibbosity (35 mm wide and 26.3 mm thick), and a distinctly marked dimple measuring 15 mm by 14 mm situated in the waist region of the posterior surface (Pl. 9A-B). Radius of curvature measurements across the widths of the gibbosities are $R_B =$ 21.2 and 21.5 mm for the smaller and larger gibbosities respectively, with $R_F =$ 18.8 mm and 26.7 mm, where $B =$ the posterior surface, and $F =$ the anterior. If cross sections through the gibbosities of the primary form were circular prior to modification, the depths of ablation in the stagnation regions (i.e. front polar regions) of the larger and smaller gibbosities were respectively 11.8 mm and 18.1 mm, without allowing for glass lost subsequently by subaerial spallation and weathering.

A flaked equatorial zone has been developed on one edge only of the specimen (Pl. 10B), and it varies in width from 10 mm where developed on the smaller gibbosity to 18 mm where produced on the larger gibbosity. A depression on the flaked equatorial zone of the waist region (Pl. 10B) measures 17 mm by 12 mm in area, and is up to 3 mm deep. It is of a somewhat similar nature to the depression on the side of the large boat-shaped form from Port Campbell (Pl. 5B), and evidently represents a somewhat compressed, elongated bubble exposed by exfoliation of the aerothermal stress shell. Its presence would weaken the glass in this zone and probably contributed to more ready spallation of the equatorial zone on the side of the tektite carrying the bubble (cf. Pls. 9B, 10B for comparison of the two edges, one non-spalled, the other spalled). Etch pits are approximately equally developed (Pls. 9-10) on all surfaces except the flaked equatorial zone which was evidently a much later exposed surface. The etch pits range in diameter from 0.25 mm to 2.0 mm. Etch gutters occur on all surfaces except that of the flaked equatorial zone, again indicating that the spallation was a relatively late event. The gutters range up to 15 mm in length, 0.75 mm in width, and 0.5 mm in depth. They are typically U-shaped in cross section. Their trends are largely across the width (i.e. approximately normal to the long axis) of the specimen on the anterior and posterior surfaces (Pls. 9A, 10A), but they take on complex patterns on the two ends (Pls. 9C, 10C) and on one side (Pl. 9B). Some of the gutters reveal outward radiating arrangements from two or three of the etch pits (Pl. 9A, top centre and right, 9B bottom left).

Internal schlieren exposed on some surfaces by etching are best seen under higher magnifications on the walls and the floors of etch pits and etch gutters, being largely normal or oblique to the trends of the gutters, but sometimes parallel to or trending more acutely to the gutter trends. Smaller etch pits are occasionally present on the floors of the gutters and even on the floors of some of the larger of the etch pits; sometimes the larger pits interrupt the trends of some of the gutters (Pl. 10A), sometimes they terminate a gutter. Where the larger diameter etch pits lie athwart the trends of the etch gutters, they are invariably more deeply etched into the glass than the gutters, sometimes being up to nearly twice as deep. Intersecting gutters with different trends are also somewhat different in depth at the points of intersection (Pl. 9B left-hand end, 9C central portions). In plan, some gutters are more or less straight (Pls. 9A, 10A, C), but some are curvilinear (Pl. 9B central por-

tion, 9C), but in the third dimension, all are slightly curved in that they follow the curved outer surfaces. The glass between the etch pits and etch gutters reveals under higher magnifications a distinct, very finely pitted 'orange-peel' effect through which flow schlieren can be only vaguely traced compared with those shown on the more lustrous walls and floors of the pits and gutters.

Aspects of Production of Surface Sculpture

The etching of different parts of the tektite to form natural solution pits, gutters, and 'feathery' schlieren lines is a function of several factors, including (a) slight variations in the chemical composition of the tektite glass from place to place, (b) variability in the strength and nature of the etchants from time to time and from place to place on the tektite surface, (c) differences in the time the etchants lie in contact with different parts of the specimen, (d) the variable nature of the curvature of the external surface and (e) whether one particular surface always remained directed upwards to be in contact with soil while buried, and exposed to atmospheric agents after soil deflation, while the other surface was always downwardly directed to and hence always in contact with the soil, or whether the tektite has been turned over, as for example by release from the soil, transportation down a slope, and reburial at a lower topographic level, or even by tipping more or less in situ during disturbance of the enveloping soil.

Further to the above factors concerned with the natural solution etching, it is known from thin section examinations under the petrological microscope that differences in the refractive index of different schlieren point to differences in chemical composition, some schlieren being richer in silica than others, and some richer in iron, hence they are liable to differential dissolution. The effects of differential dissolution can be demonstrated experimentally by immersing fractured tektites in 4 per cent hydrofluoric acid. In a matter of hours, pits, gutters, and flow schlieren can be brought out on the freshly fractured glass surfaces. These are surfaces that were smooth apart from concentric and ripple fracture patterns, and they showed a highly vitreous lustre prior to immersion in the acid. Where tektites are found, such potent acids are not available in the requisite amounts and strengths for such a rapid reaction, but soil etchants are nevertheless present and the time factor is highly favourable, for tektites have been lying in a soil environment for at least a few thousand years in the Australian strewnfield. The strength and nature of soil etchants enveloping a tektite will vary according to variations in the supply of downward percolating rain water and the circulation of subterranean solutions. Also there are variations in the nature and supply of etchants from plants. In some places the tektites lie within the root zone, while in others they are found in semi-arid to arid terrains which were much more humid in the immediate geological past. Hence all the tektite specimens are liable to have been exposed to biochemical attack by the soil biota.

As to differences in the time that etchants lie in contact with particular parts of a tektite surface, great variations can have occurred during the thousands of years that australites have lain on the earth's surface. At present, the overall effect is controlled in the first place by alternate wetting and drying of soils, more especially in the temperate regions of the strewnfield. During the drying out process, solutions are likely to lodge longer in small depressions on the tektite surface, provided the specimen lies in a favourable position. Furthermore, plant roots and fungal filaments in actual contact with the tektite could be potent factors in supplying as well as directing the attack by etchants on the glass. Once pits and gutters become

E

established, some widening and overdeepening continues. In course of time, soil constituents become cemented to their walls and floors, sometimes relatively loosely, sometimes quite firmly, mostly by secondary iron hydroxide. Even after excavation by soil deflation, most of the cemented materials remain, as in the specimen from Laing. Tektite glass not covered by cemented soil is subjected to dulling (e.g. Plate 9A) by atmospheric agents, and the lustre of such surfaces contrasts sharply with the highly vitreous lustre revealed on cleaning out the cemented soil. Evidently soil constituents remained in contact with the walls and floors of the pits and gutters all the time that differential solution was progressing, until the cementation was sufficient to protect the surface.

Notes on the 22 Large Australites

Thirteen of the large australites were listed in an earlier publication giving their weights, SG. values (where available) and dimensions (Baker 1966, Table 1). This list is re-cast (Table 1) to accommodate the nine additional large australites now reported. The discovery sites of these large specimens are shown in Fig. 1.

For dumbbells in Table 1 (nos. 5, 8, and 14) the numbers in brackets are measurements of the waist regions. For no. 1, Table 1, the number in brackets is the present length resulting from artificial fracturing. The weight of the fractured form is 238 g, while the original weight has been calculated as approximately 265 g (allowing for a relatively large piece artificially spalled off with a crowbar when the specimen was unearthed in a post hole). Some of the forms classified as round cores are slightly oval in plan aspect, but since their two diameters are only 1 or 2 mm different, this is evidently a consequence of terrestrial weathering. The size measurements in the fifth colum of Table 1 are given in the order: length, width, depth ($-$ thickness) for the elongated specimens, and in the order: diameter, depth ($=$ thickness) for forms that are round in plan.

Grouping of Large Forms according to Shape Types

Large round cores. The two Victorian specimens from Lower Norton and Lake Wallace weighing 115 92 g and 111 25 g respectively are the fourth and sixth heaviest recorded round cores. Heavier round cores have been described from Newdegate, W.A. (243 08 g, McCall 1965), Lake Yealering, W.A. (218 g, Fenner 1955, Pl. 7, 1-2), Graball, W.A. (168 28 g, Baker 1963, Pl. 1, figs. A, B), and from between Karoonda and Lowalda, S.A. (113 g, Fenner 1955, Pl. 7, 7-8).

Three other round cores weighing over 100 g have been found at Norseman, W.A. (111 g, Fenner 1955, Pl. 8, 14), at Salmon Gums, W.A. (102 37 g, Baker 1967), and on the Eastern Goldfields, W.A. (108 30 g, Baker 1967). Two large forms weighing 147 g and 116 g from Corrigin, W.A. and Lake Buchanan, W.A., are recorded (Fenner 1955) but neither the shape types nor illustrations were given for these specimens, and they have not been examined by the author.

Large oval cores. The Victorian oval core from Gymbowen, near Goroke, weighing 135 09 g (Pl. 7) is the third heaviest oval core recorded from Australia. The two heavier specimens of oval cores are from Warralakin, W.A. (265 g, Baker 1962, Pl. 5A-D), and from an unspecified locality in the W.A. Goldfields (154 3 g, Fenner 1955, Pl. 7, 5-6).

Two other oval cores weighing over 100 g have been found at Karoni, W.A. (101 g, Fenner 1955, Pl. 8, 15-16), and at Babakin, W.A. (112 9 g, Fenner 1955).

Large boat-shaped australites. The large form from the Sherbrook River area

TABLE 1

Dimensions and weights of australites exceeding 100 g

No.	Shape type	Locality	Weight (g)	Measurements (mm)	S.G.	Reference
1	Oval core	Warralakin, W.A.	Originally 265	70(65) × 62·5 × 42	2·409	Baker 1962
2	Round core	Newdegate, W.A.	243·08	58 × 52	(not given)	McCall 1965
3	Round core	Lake Yealering, W.A.	218	64 × 64·5 × 39·4	(not given)	Fenner 1955
4	Boat (abraded)	Karoonda, S.A.	208·9	82 × 46·8 × 37·9	(not given)	Fenner 1955
5	Dumbbell	Cuballing, W.A.	175·996	100 × 42(35·8) × 33·7(25)	2·435	Baker 1966
6	Round core	Graball, W.A.	168·28	57 × 34·5	2·434	Baker 1963
7	Oval core (chipped)	Western Australian Goldfields	154·3	51·5 × 48·5 × 43	(not given)	Fenner 1955
8	Dumbbell	Ongerup, W.A.	151·286	98·4 × 35·6(33·2) × 29·6(26·8)	2·460	Baker 1967
9	(not given)	Corrigin, W.A.	147	(not given)	(not given)	Fenner 1955
10	Boat	Port Campbell, V.	141·575	86·2 × 41·3 × 30·5	2·414	(this paper)
11	Oval core	Gymbowen, near Goroke, V.	135·09	55 × 51·4 × 36·3	2·417	(this paper)
12	(not given)	Lake Buchanan, W.A.	116	(not given)	(not given)	Fenner 1955
13	Round core	Lower Norton, via Horsham, V.	115·92	52 × 33	2·463	(this paper)
14	Dumbbell	Laing, V.	115·752	74·9 × 36(33·4) × 29·7(24·8)	2·467	(this paper)
15	Round core	Between Lowalda and Karoonda, S.A.	113	52 × 51·5 × 36·5	(not given)	Fenner 1955
16	Broad oval	Babakin, W.A.	112·9	52 × 46 × 37·5	(not given)	Fenner 1955
17	Round core	Lake Wallace, near Edenhope, V.	111·25	49·6 × 36·5	2·447	(this paper)
18	Round core	Norseman, W.A.	111	51·1 × 50·5 × 33·1	(not given)	Fenner 1955
19	Round core	Eastern Goldfields, W.A.	108·30	52·4 × 33	2·440	Baker 1967
20	Boat	Narembeen, W.A.	107·46	64 × 37 × 30·5	2·431	Baker 1961
21	Round core	Salmon Gums, W.A.	102·37	46·4 × 38	2·450	Baker 1967
22	Oval core	Karoni, W.A.	101	49·1 × 45·5 × 35·5	(not given)	Fenner 1955

E. of Port Campbell, Victoria, is the second largest boat-shaped australite (Pl. 5-6) known. It is a very well preserved specimen and although a little longer than the biggest boat-shaped form from Karoonda, S.A. (Table 1, 4), it is narrower and thinner. Its weight of 141·575 g is approximately 67 g less than the biggest boat-shaped form which is an abraded specimen measuring 82 mm by 46·8 mm by 37·9 mm and weighing 208·9 g (Fenner 1955, Pl. 7, 3-4).

The only other known boat-shaped form weighing over 100 g is a specimen from Narembeen, W.A. which measures 64 mm by 37 mm by 30·5 mm and weighs 107·457 g (Baker 1961, Pl. 5A-E).

Large dumbbell-shaped forms. Three large dumbbell-shaped australites each weighing over 100 g and typically possessing thick waist regions have been found at Cuballing W.A. (176 g, Baker 1966, Fig. 1, A-F), at Ongerup, W.A. (151 g, Baker 1967), and at Laing, V. (115·75 g, Table 1). These three specimens constitute the fifth, eighth, and fourteenth largest of the 22 large australites. For convenience, a grouping of these 22 large forms in four shape types is given in Table 2, along with the symbol used on the distribution map (Fig. 1), and the locality of occurrence. This reveals that six large round cores have been found in SW. Western Australia, one in S. Australia, and one in Victoria, while four large oval cores come from W. Australia and one from Victoria. One large boat-shaped form has been found in each of the three states W. Australia, S. Australia, and Victoria, and two large dumbbell-shaped forms come from W. Australia, with one from Victoria.

TABLE 2

Grouping of shape types of australites weighing over 100 g

Shape types	Symbol on Fig. 1	Locality
I. Large round cores (in order of decreasing size—N to SG)	N Y GR H L E NO EG SG	Newdegate, W.A. Lake Yealering, W.A. Graball, W.A. Lower Norton, Horsham, V. Between Lowalda and Karoonda, S.A. Lake Wallace, Edenhope, V. Norseman, W.A. Eastern Goldfields, W.A. Salmon Gums, W.A.
II. Large oval cores (in order of decreasing size—W to KA)	W WG G B KA	Warralakin, W.A. Western Goldfields, W.A. Gymbowen, V. Babakin, W.A. Karoni, W.A.
III. Large boat-shaped forms (in order of decreasing size—K to NA)	K P NA	Karoonda, S.A. Port Campbell, V. Narembeen, W.A.
IV. Large dumbbell-shaped forms (in order of decreasing size —CU to T)	CU O Γ	Cuballing, W.A. Ongerup, W.A. Laing, V.

Among these shape groupings (Table 2) of the large australites (1) no particular shape group is confined to any particular region. (2) no australite over 100 g has been brought to notice for the following shape groups: buttons, lenses, canoes, tear-

drops, discs, aberrants. (3) none of the large forms possess circumferential flanges. and (4) where surface features are not destroyed flaked equatorial zones are present.

There seems to be no significance in the fact that the known 22 largest australites occur between latitude 30°S. and 39°S., and between longitude 116°E. and 143°E. Smaller specimens are known in greater numbers (45,000 to 50,000) throughout the two million square miles of the australite strewnfield.

Acknowledgements

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Description of Plates

PLATE 5

Large boat-shaped australite from Port Campbell, V. (x 1.64.)

A. Posterior surface showing smooth, flow-swirled areas with high degree of lustre, surrounded by variously etch-pitted glass.
B. Side view (representing bottom edge of Pl. 5A) showing circular spalled area or burst bubble at the rim separating the posterior surface (uppermost) from the anterior surface.
C. End-on view (representing right-hand end of Pl. 5A) showing residual 'bung-like' character resulting from spallation. Posterior surface uppermost.

PLATE 6

Large boat-shaped australite from Port Campbell, V. (x 1.64.)

A. Anterior surface, showing solution-etch gutters, occasional flow lines, and few etch pits.
B. Side view (representing top edge of Pl. 5B) showing solution-etch gutters in the flaked equatorial zone terminating abruptly at the well-defined rim. Posterior surface uppermost.
C. End-on view (representing left-hand end of Pl. 5A, i.e. right-hand end of Pl. 6B) showing etch pits and flow swirl on posterior surface, solution-etch gutters on surface exposed by exfoliation. Posterior surface uppermost.

PLATE 7

Large oval core from Gymbowen, V. (x 1.4.)

A. Posterior surface, showing oval outline, conchoidal fracture and vitreous lustre of artificially chipped area at right-hand side, 'dimple' in surface at bottom right (Pl. 7C), and generally smooth character of surface, with few etch pits (? etched 'chatter-marks').
B. End-on view for the shorter diameter of oval specimen, showing well-developed flaked equatorial zone and some natural solution-etch gutters on surface exposed after spallation. Posterior surface uppermost.

C. Side view for the longer diameter of oval specimen, showing well-developed flaked equatorial zone except at right-hand end where some of the aerothermal stress shell remains as a partial 'indicator' of the secondary, aerodynamically shaped anterior surface developed prior to terrestrial exfoliation. Pronounced 'dimple' shown in right central region of posterior surface (uppermost).

D. Anterior surface showing six percussion spall marks (circular to ovate areas) and occasional short, natural solution-etch gutters developed on surface exposed by exfoliation and shedding of aerothermal stress shell.

PLATE 8

Enlarged photographs of portions of large boat-shaped australite from Port Campbell, V.

A. Depression interrupting the sharp rim that separates pitted and flow-swirled posterior surface (uppermost) from flaked and subsequently grooved equatorial zone and anterior surface (lowermost) (x 5.2).

B. 'Contorted' contact zone of two flow-swirled areas on the posterior surface, showing flow schlieren in the smoother flow-swirled areas and etch pits of elongated to short gutter-like character between the two flow swirls (x 5.5).

PLATE 9

Large dumbbell-shaped australite from Laing, V. (x 1.65.)

A. Posterior surface showing marked waist constriction on one side only of specimen and 'dimple' in centre (cf. 'dimple' on posterior surface of oval core shown in Pl. 7A); narrow etch gutters trend partly across width of specimen, while etch pits are sporadically distributed.

B. Side view (representing lower edge of Pl. 9A) showing constricted waist region, edge-on view of 'dimple' in Pl. 9A, and etch gutters trending in several directions (Posterior surface uppermost).

C. End-on view (representing left-hand end of Pl. 9A-B) showing straight and curvilinear etch gutters sometimes intersecting, and a few scattered etch pits.

PLATE 10

Large dumbbell-shaped australite from Laing, V. (x 1.65.)

A. Anterior surface showing etch gutters extending partly across width of specimen, and etch pits sporadically distributed.

B. Side view (representing bottom edge of Pl. 10A) showing relatively smooth-surfaced flaked equatorial zone with depression resulting from exposure on spallation of a compressed, elongated bubble. Fine flow lines representing internal flow schlieren brought out by natural solution-etching of surface exposed by spallation, can be detected on bubble walls and parts of smooth flaked equatorial zone.

C. End-on view (representing left-hand end of Pl. 10B, right-hand end of Pl. 10A) showing slightly deeper etch gutters trending mainly from left to right, and a few scattered etch pits.
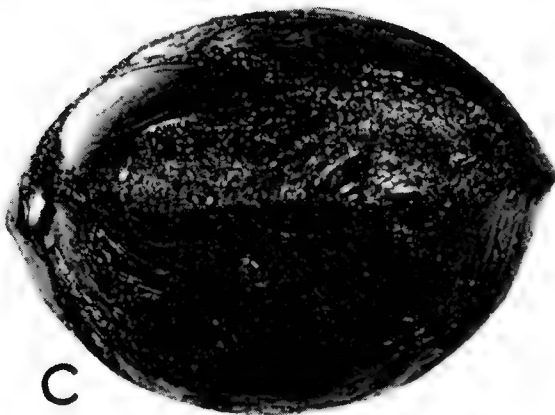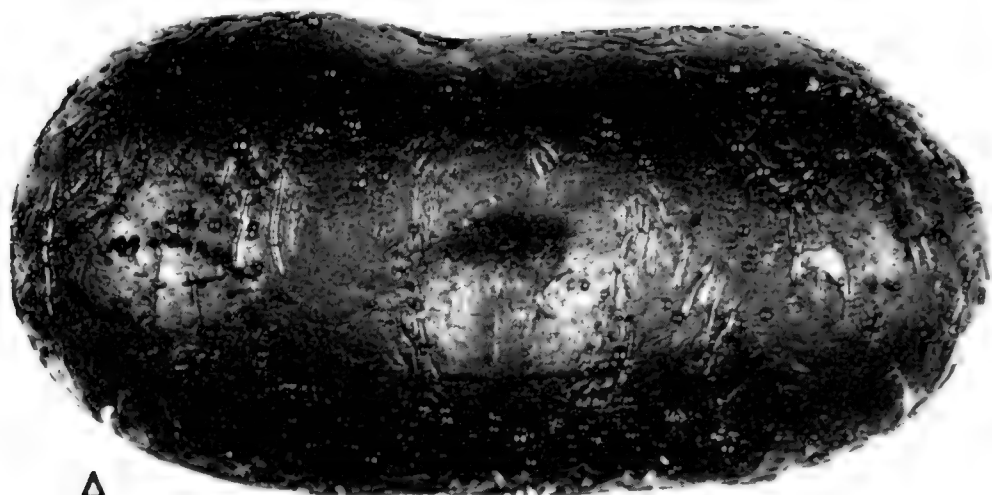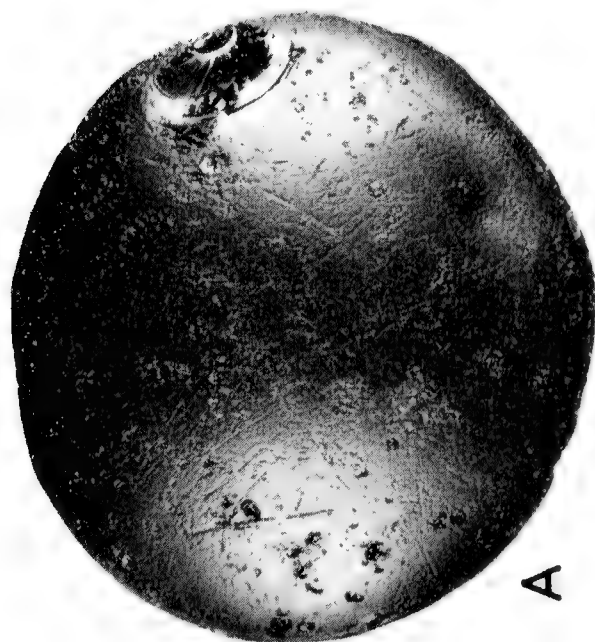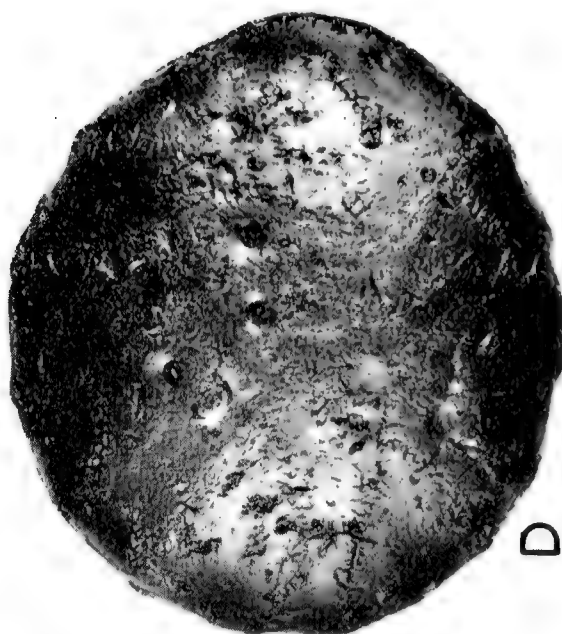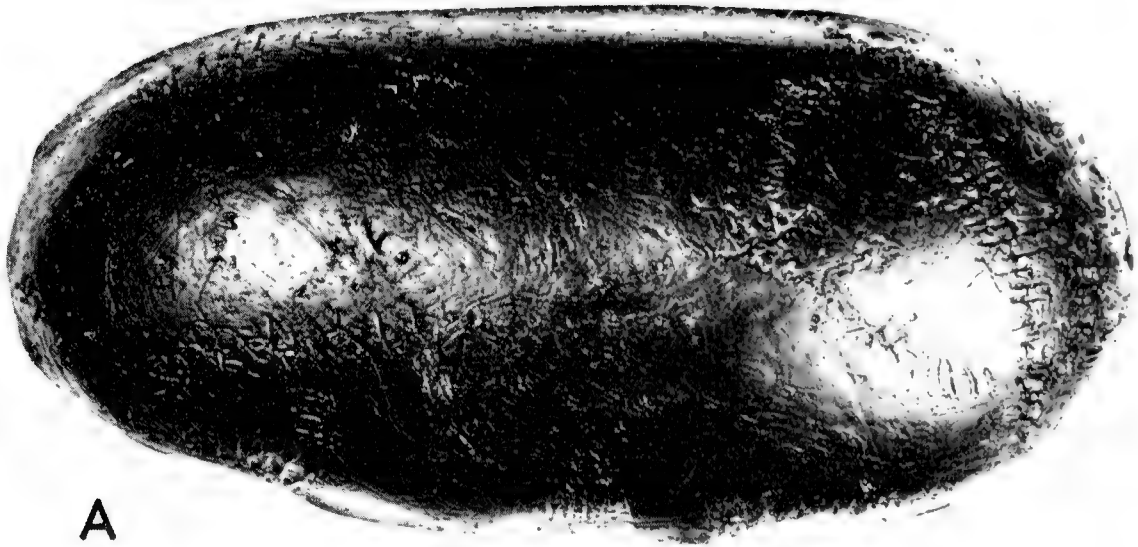
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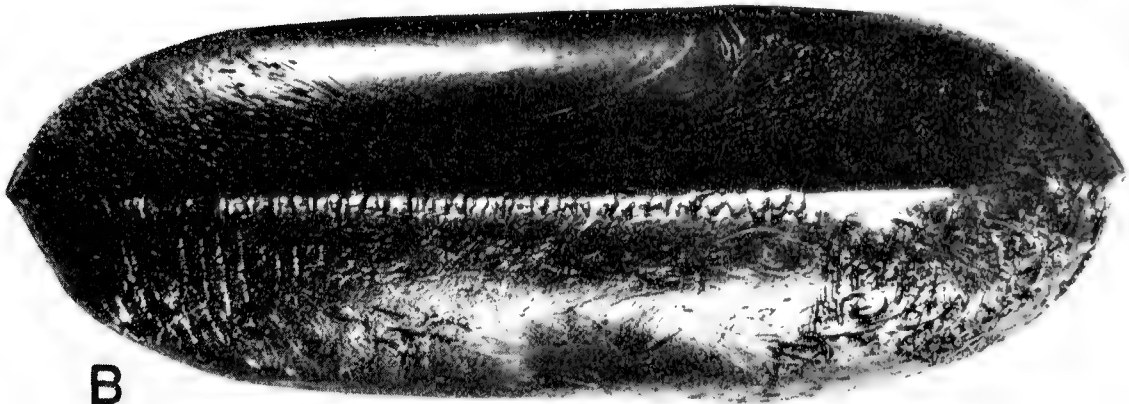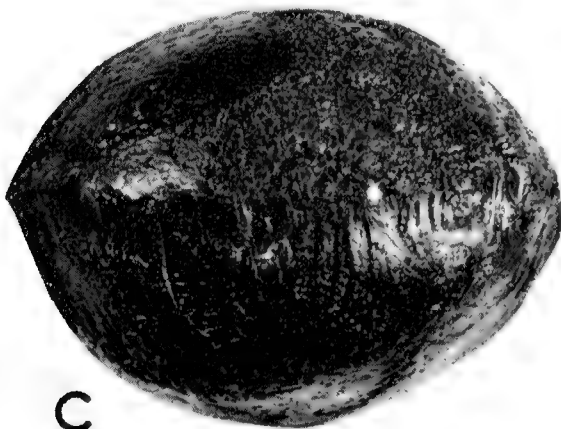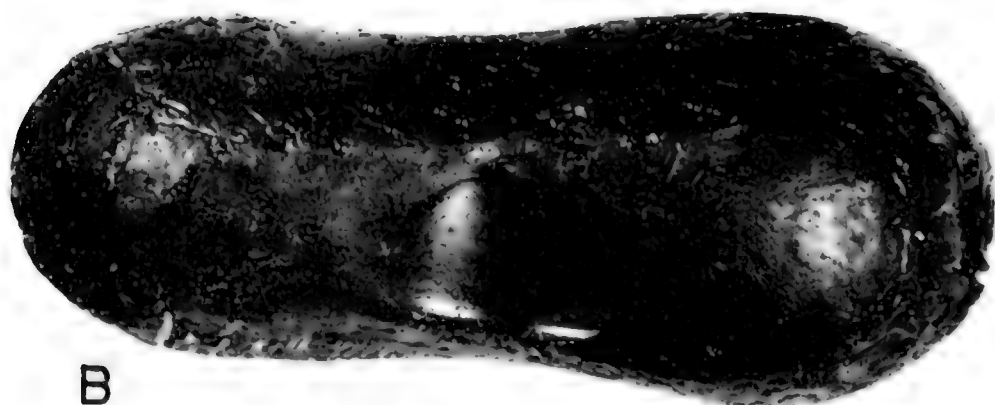
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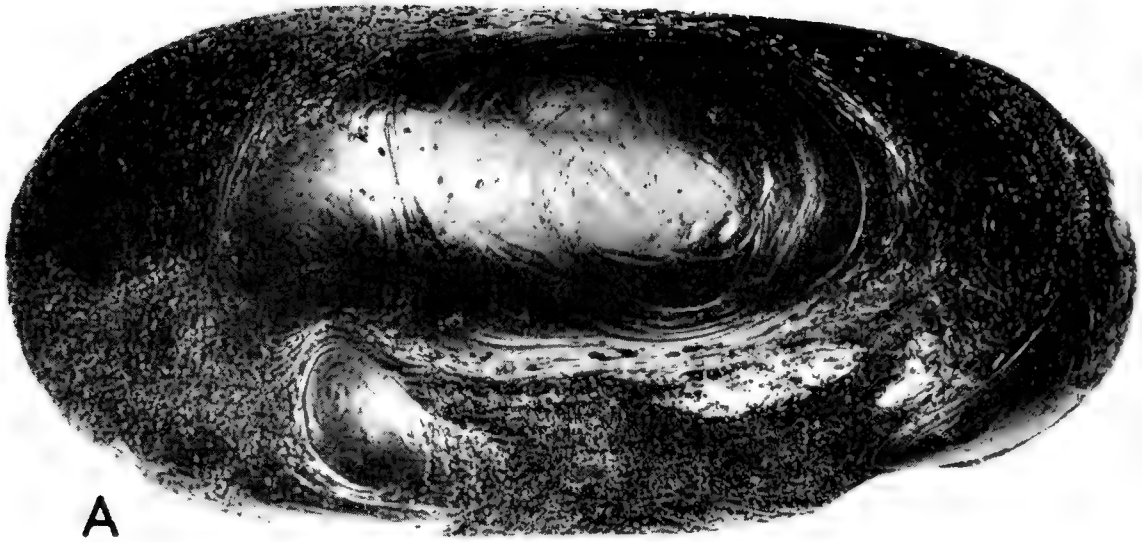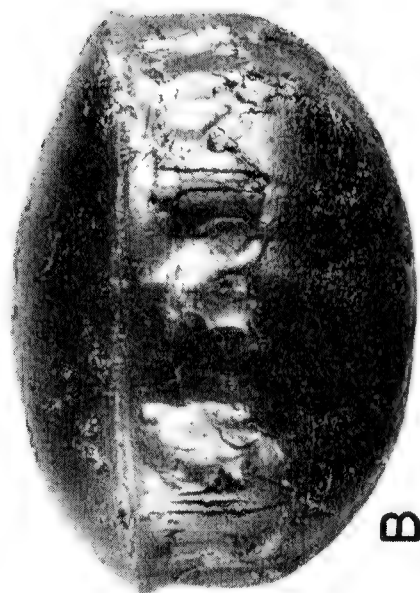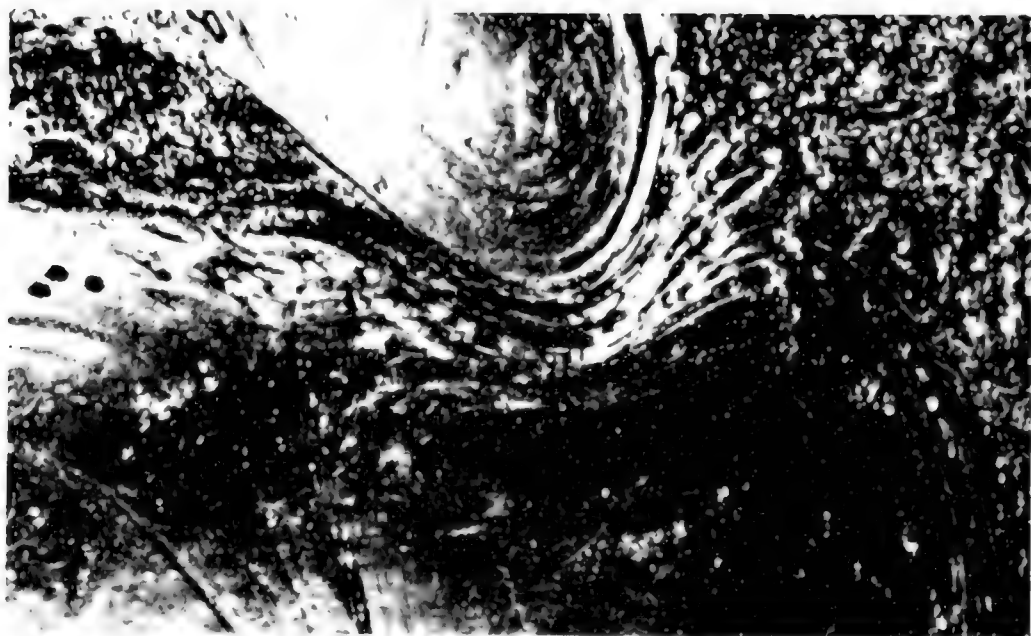
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AUSTRALITES FROM MULKA, LAKE EYRE REGION, SOUTH AUSTRALIA

By George Baker

Introduction

Two hundred and seventy-five specimens of markedly worn to severely worn australites from the Mulka district, via Marree, Lake Eyre region, S. Australia, have been examined in detail, and their weights and specific gravity values determined for comparison with statistically significant numbers of similar determinations for australites from other concentration centres in widely separated regions of the Australian tektite strewnfield. In addition, 414 severely worn specimens from the same area have been examined but not weighed.

Marree is approximately 25 miles from the SE. end of Lake Eyre, and is situated on the Adelaide-Oodnadatta railway line at long. 138°19′E. and lat. 29°48′S. The australies from Mulka, 130 miles NNE. from Marree, along the Birdsville stock route, come from a region of low relief and scant rainfall. The specimens have been subjected to such a degree of desert erosion that they have lost virtually all of their pre-existing surface sculpture patterns and much of their original shape and structure. Many of the specimens show the lacquer-like lustre called 'desert varnish'.

The 275 specimens for which specific gravity values have been determined are from three separate collections (1) S. R. Mitchell collection (60 specimens in N.M.V., reg. nos. E3133-3191), (2) R. D. Croll collection (51 specimens), and (3) University of Melbourne geological collection (164 specimens). All were obtained in 1930 from Mr George Aiston of Mulka, who collected them on surfaces bared by sand drift during a particularly dry period. Many were found on or around aboriginal camp sites, and have come to be regarded by some as 'magic-stones' because of aboriginal beliefs in their curative and lethal powers; no particular specimen, however, can be definitely proved to have been in use as a 'magic-stone'.

The author is indebted to the late Mr S. R. Mitchell of Frankston, Vict. to Mr R. D. Croll, of Balwyn, Vict. and to Mr Alfred A. Baker of the Geology Department, University of Melbourne, for making available the australites from Mulka for examination. The 414 non-weighed australites were inspected in the National Museum of Victoria, by courtesy of the Director, Mr J. McNally; 264 of these specimens, all with the same register number (11701), were purchased from Mr Aiston in 1935. The remaining 150 (nos. E2800-E2854, E2858-E2952) constituted part of the ethnological collection of the late Mr H. R. Balfour of Toorak, Vict., which was left to the National Museum in 1962.

Of the total of 689 australites from Mulka in the five collections examined, the better of the generally poorly preserved specimens became lodged in the Mitchell and Croll collections, and it is these only that have been used for purposes of illustration in this paper (Pls. 11-15).

Among the australites listed in private collections by Fenner (1935), 20 specimens are in the possession of Mr Aiston, and Fenner states (1935, p. 127) that

Aiston reported having 'collected and distributed many hundreds, perhaps thousands' of australites. The evidence of other collections bears this out, according to Fenner.

Proportions of shape types

The shape types of the 275 weighed australites from Mulka are listed in Table 1, and 111 of the specimens are shown in Pls. 11-15 . All are worn, some being much more eroded than others, largely from sand blasting by wind-borne sand under arid conditions, but also by other subaerial agents. Some specimens were fractured early, and subsequently worn, while some worn specimens reveal evidence of recent fragmentation which has exposed relatively fresh conchoidal fracture surfaces with secondary ripple fracture patterns and vitreous lustre. Specimens with evidence of controlled pressure flaking (Pl. 15, figs. 17-21) were prepared by aborigines.

As a consequence of relatively severe erosion, circumferential flange structures have been much chipped (Pl. 11, figs. 2-10) or completely removed. Most specimens have had the flow ridge patterns either completely erased, or so worn down that only a few reveal indistinct remnants (Pl. 11, figs. 2b, 3b, 4b, 7b, 10b, 22b). The sculpture patterns represented are entirely of tertiary origin, due to terrestrial erosion exposing and etching inner portions of these tektite glass bodies (e.g. Pl. 12, figs. 9a, b), after removal of pre-existing surfaces.

Based on the better preserved of the worn specimens and long experience, it has been possible to arrive at the grouping of specimens into the shape categories set out in Table 1 and arranged in Pls 11-15. A few of the worst weathered and fractured specimens were not readily classifiable, and discrimination between the remnant cores of certain oval-shaped and boat-shaped specimens from Mulka (e.g. Pl. 12, figs. 5a, b, compared with Pl. 13, figs. 11a, b), had to be based on an assessment of the nature of the equatorial zone fracturing and the overall degree of erosion of each specimen, for better preserved boat-shaped forms have approximately parallel longer edges (cf. Pl. 13, figs. 13-15).

The proportions of the shape types are listed in Table 1, along with the range in weight, average weight, range in specific gravity and average specific gravity values for each shape group. In view of the degree of wear by natural processes, the weights of individual specimens are now much less than the original weights, hence those in Table 1 are minimal values.

The total weight of the specimens listed in Table 1 is 1,135 58 g, and the average weight of just over 4 g, is 1 5 times as great as the average weight (2 734 g) of 212 nearly complete to complete forms of Port Campbell australites (Baker 1956, p. 83).

After careful cleaning, each specimen was separately weighed in air and in deionized water ($T = 21.4°C$) to the nearest 0 0005 g for determination of the specific gravity values. The results were checked and re-checked, particularly for those specimens yielding the higher and lower values. The average S.G. values determined for the various shape groups show a range (Table 1) from 2 402 to 2 455, excluding the hollow forms which have an average specific gravity of 2 060.

The differences in the average S.G. point to compositional variations among the various shape groups, and since the S.G. of tektite glass varies sympathetically with SiO_2 content, the flanged ovals are evidently the more siliceous shape types among the groups of australites from Mulka. These are followed by small oval cores, larger oval cores, aberrant 'nut-like' forms, canoes, teardrops, boats with rims and/or flange remnants, button cores and 'lenses', larger ovals, boat-shaped

TABLE 1

Shape grouping of worn australites from Mulka, S. Australia, based on the Mitchell, Croll, and Melbourne University collections

Shape type	Number of specimens	Range in weight (g)	Average weight (g)	Range in specific gravity	Average specific gravity	Percentage of shape types in combined collections	Plate and figure number
Buttons with flange remnants	26	1·190 to 5·639	3·066	2·383 to 2·486	2·439	9·5	11, 1-10
Flange fragment	1	—	0·238	—	2·428	0·4	11, 11
Button cores and 'lenses'	45	0·507 to 3·273	1·736	2·378 to 2·466	2·426	16·4	11, 12-21
Ovals with flange remnants	3	3·018 to 5·300	3·882	2·372 to 2·435	2·402	1·1	11, 22-23
Small ovals (no flange)	23	0·463 to 4·406	1·565	2·379 to 2·457	2·420	8·4	11, 24-30, and 12, 1-4
Large ovals (no flange)	2	5·007 to 19·494	12·250	2·414 to 2·441	2·428	0·7	12, 5-6
Round cores	27	1·438 to 22·645	7·158	2·397 to 2·476	2·436	9·8	12, 8-15
Oval cores	15	1·487 to 20·450	8·072	2·374 to 2·463	2·421	5·4	12, 16-18
Conical cores	6	0·565 to 7·558	3·192	2·426 to 2·460	2·447	2·2	12, 19-20
Core fragments	6	1·353 to 4·176	2·603	2·378 to 2·459	2·434	2·2	12, 21-23
Boats with rims and/or flange fragments	5	1·291 to 3·781	2·449	2·404 to 2·442	2·425	1·8	13, 1 and 3
Boat cores	55	0·983 to 22·493	5·858	2·365 to 2·474	2·430	20·0	13, 2, 4-15
Hollow forms	5	2·090 to 5·811	3·361	1·509 to 2·347	2·060	1·8	15, 1
Dumbbells, 'peanuts, and 'ladle-like' forms	27	0·894 to 8·698	4·149	2·371 to 2·474	2·431	9·8	14, 1-18
Canoes	3	1·517 to 2·674	2·005	2·400 to 2·447	2·423	1·1	14, 20-22
Teardrops	13	0·491 to 7·033	2·885	2·381 to 2·459	2·424	4·7	15, 1-10
Aberrant 'pod-like' form	1	—	5·648	—	2·431	0·4	14, 19
Aberrant 'nut-like' forms	5	1·748 to 4·974	2·775	2·401 to 2·438	2·422	1·8	15, 11-14
Nondescript fragments	2	2·023 to 2·816	2·420	2·411 to 2·437	2·424	0·7	15, 15-16
Aboriginal flakes	5	0·985 to 11·755	5·659	2·385 to 2·557	2·455	1·8	15, 17-21
TOTALS	275	0·463 to 22·645	4·129	2·365* to 2·557	2·430*	100·0	

* Excluding specimens containing internal cavities significantly affecting the specific gravity values. If the hollow specimens are included, the range in specific gravity becomes 1·509 to 2·557.

cores, dumbbells, 'peanuts' and 'ladle-like' forms, aberrant 'pod-like' form, core fragments, round cores, buttons, and finally the conical cores, in that order (aboriginal flakes omitted because from various shape groups).

From the silica—S.G. curve for tektites (Baker 1959a, p. 56), the small ovals, with the lowest average specific gravity, have a silica content of approximately 75 per cent, while the conical cores, with the highest specific gravity, have a silica content of approximately 71 per cent. The round (in plan aspect) and elongated forms of Mulka australites reveal differences in average weights, average S.G. values, and in the proportions of these two major shape groups. These relationships are shown in Table 2.

TABLE 2

Comparison of proportions, average weights, and average S.G. values of round and elongated australites from Mulka

	Number of specimens	Per cent (based on three collections)	Average weight (g)	Average S.G.
Round forms	107[a]	39	3·528	2·434
Elongated forms	168[b]	61	4·500	2·427

[a] 14 Mitchell coll., 17 Croll coll., 76 Melbourne University coll.

[b] 46 Mitchell coll., 34 Croll coll., 88 Melbourne University coll.

The round forms, having a lower average weight (Table 2), have the slightly higher average S.G. value for the Mulka australite concentration centre (excluding the obviously hollow specimens of specific gravity less than 2·350). In terms of silica content, the difference between the two average S.G. values indicates that the elongated forms are approximately 1 per cent richer in silica than the round forms.

Another feature of note is the dominance of elongate forms relative to round forms (Table 2). The reverse has been noted for 571 well-preserved specimens from Port Campbell (Baker 1955b), where 71 per cent of the australites are round forms, and 29 per cent are elongated forms. There are thus 1·6 times as many elongated as round forms at Mulka, and 2·4 times as many round forms as elongated forms at Port Campbell. This is regarded as a fundamental difference between these two australite concentration centres, and is not to be interpreted in terms of 'sampling errors' (i.e. involving differential collecting) or in terms of difference in degree of erosion (which is principally desert erosion at Mulka, and temperate zone erosion at Port Campbell). Different proportions of round and elongate australites occur within these two widely separated concentration centres, because different proportions were precipitated from the one australite shower at the time of infall. The shape populations have not been affected by the activities of aboriginal man.

Whereas only 13 per cent of the Mulka australites reveal flange remnants, 63 per cent of the australites collected by the author from the Port Campbell district are flanged. Furthermore, flanged specimens usually possess a greater volume of preserved flange glass at Port Campbell compared with Mulka. In terms of numbers only, the fact that there are nearly five times as many flanged specimens recovered from Port Campbell is a true reflection of the less severe erosion of tektite glass there, for it is doubtful that detached flange fragments (Pl. 11, fig. 11) were largely overlooked by collectors in the Mulka concentration centre. The actual volume of flange glass preserved in the Port Campbell concentration centre is more nearly 20 or 30 times as great as that at Mulka.

Distribution of S.G. values

The frequency distribution of 271 of the 275 S.G. determinations made of the Mulka australites is shown in Fig. 1, where the mode of distribution is 2·44. Four values for hollow forms, ranging from 1·509 to 2·286, are not plotted. The arithmetic mean is 2·433, but the bias in distribution is towards the higher S.G. values, as evidenced from Fig. 1, where 162 values are 2·43 and over, and 109 values are under 2·43.
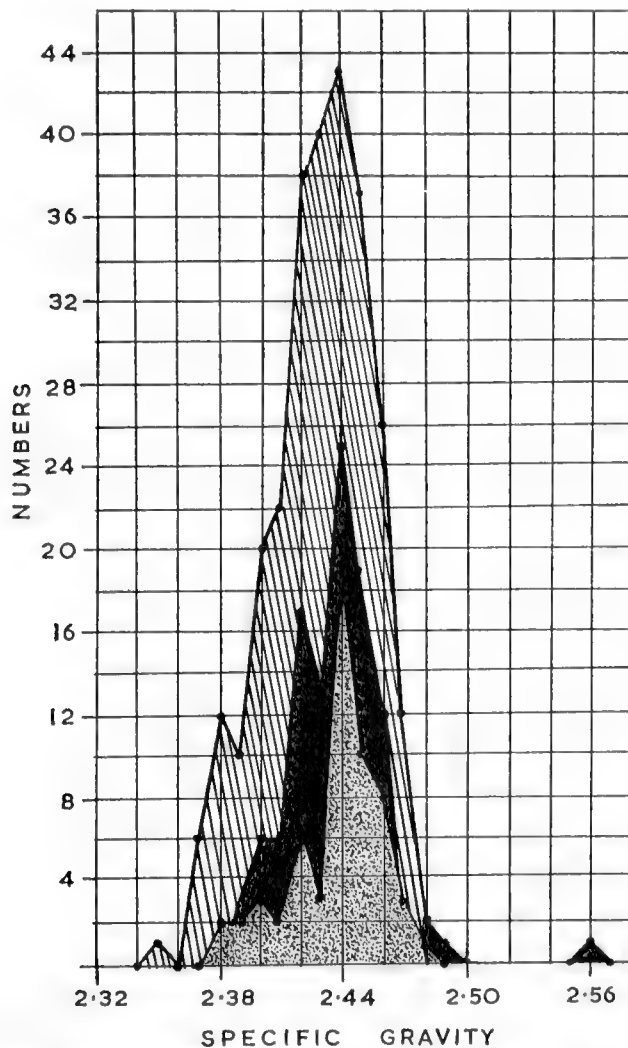

Fig. 1—Frequency polygon showing distribution of S.G. values for 271 australites from Mulka.
The S.G. values for specimens in the Mitchell coll. are represented by the stippled area, those in the Croll coll. by solid black, and those in the Melbourne University coll. by diagonal lines.

The average S.G. of approximately 1,125 g of australite tektite glass from Mulka, represented by 271 specimens (four hollow forms excluded), is approxi-

mately 2·44. By way of contrast, the average S.G. is 2·397 for a total of nearly 800 g of australite glass represented by 555 specimens from Port Campbell (Baker and Forster 1943). The difference of about 0·04 between these two averages is quite significant in terms of variation in chemical composition, inasmuch as the effects of internal cavities in each separate australite population has been minimized, as far as practicable, by not utilizing individual S.G. values under 2·350 in calculating the averages.

From the S.G.—silica curve for tektites (Baker 1959a, p. 56), the difference in the average S.G. values is found to represent nearly 4 per cent less SiO_2 in Mulka, compared with Port Campbell tektite glass. Inasmuch as (a) secondarily formed flange glass is more dominantly preserved in the Port Campbell region, and (b) flange glass generally has a lower average specific gravity value than core glass in australites, thus being more siliceous, this may partially explain the overall lower S.G. values at Port Campbell relative to Mulka (800 miles NNW.). Apart from this, there is a distinct difference in chemical composition between the two concentration centres, as evidenced by 126 core specimens from Port Campbell having a lower average S.G. value (2·408) than 156 core specimens from Mulka (average S.G. = 2·429).

Hollow forms

S.G. determinations have revealed that five of the 275 weighed australites from Mulka possess internal cavities that are not connected to the external surfaces by narrow channelways or fine capillaries. All are differently shaped forms in which the internal cavities are sufficiently large to significantly lower the S.G. value of each well below the average (2·44) for australite glass from Mulka, as shown in Table 3, where the specimens are listed according to an order of increasing S.G.

TABLE 3

Hollow australite shape types from Mulka having S.G. values significantly lower than the average of 2·44 for the tektite glass.

Shape type	S.G. value	Weight in g
1. Ball-like (button) form*	1·509	3·564
2. Lenticular form (button core)*	1·900	2·090
3. Teardrop†	2·259	3·134
4. Oval core*	2·286	2·204
5. Oval*	2·347	5·811
AVERAGE	2·060	3·361

* Melbourne University coll.
† Mitchell coll.

The total weight of these five specimens is 16·803 g.

Variability in S.G. of the five hollow forms (Table 3) can be detected in some of the specimens as due to enclosed cavities of various sizes. This is determined by holding such specimens up to a strong source of illumination, when the translucency of the australite glass in thicker parts away from the edges of the specimens, reveals the presence of a sizable internal cavity in each form. The specimens with the higher S.G. values of 2·286 and 2·347 respectively (Table 3) did not reveal the property of translucency in the thicker parts of the specimens, hence (a) the internal cavity is much smaller than in the forms with lower S.G., or (b) the absence of detectable translucency, taken in conjunction with the relatively low

S.G., indicates the presence of a number of smaller cavities scattered through the interior of the glass.

A unique specimen is the hollow ball-like form (No. 1 in Table 3), which has the largest internal cavity of all these hollow specimens. It shows remnants of a circumferential flange structure, and evidently represents a worn, distended australite button. Its external dimensions are 19 mm by 14 mm, and when held to a strong light source, the internal cavity can be approximately estimated as just under 14 mm in diameter, so that parts of the walls must be relatively thin. The specimen is lodged in the Melbourne University coll. (2685). It was purchased from Mr G. Aiston (who collected it), and later presented to Mr G. A. Ampt by Mr R. H. Croll with a view to having the pressure and composition of the gas in the internal cavity determined. This was not accomplished, and the specimen was ultimately lodged by Mr Ampt in the Melbourne University coll. in March 1934. This hollow form is only one third the size of the sliced, perfectly developed hollow australite from Horsham, Vict. (Baker 1961c). In external appearance it resembles the solid ball-like form shown in Pl. 12, figs. 7a, b, but is 2·5 mm larger.

S.G. determinations of some of the 264 Mulka specimens obtained from Mr Aiston by the National Museum of Victoria were made by Dr Dean R. Chapman and Mr Howard K. Larson of the U.S. National Aeronautics and Space Administration during their visit to Melbourne in December 1962. This revealed that two specimens were hollow, one a worn oval form, and the other a worn cylindrical form with tapered ends. On holding these specimens to a strong source of light, one of them revealed distinct, the other faint translucency. The oval form, measuring 16·1 mm long, 15·0 mm wide and 11·2 mm thick, and weighing 2·262 g, has a S.G. of 2·072. The cylindrical form, measuring 19·4 mm long, 10·8 mm wide and 10·0 mm thick, and weighing 2·433 g, has a S.G. of 2·255. Taken in conjunction with the five hollow forms listed in Table 3, the average S.G. for the seven hollow forms is 2·090 and the average weight is 3·071 g. The internal cavity in the oval form is 4 to 5 mm across and situated nearer the posterior surface. The smaller internal cavity in the cylindrical form is very close to the posterior surface.

Relationships of the Mulka concentration centre

The average S.G. of the Mulka australites fits satisfactorily into the scheme of provincial distribution of australites according to chemical composition as reflected by the trend of increasing average S.G. from SE. to NW. across the strewnfield (Summers 1909, Baker and Forster 1943). This trend is shown in Table 4 and plotted in Fig. 2, where it is seen that Mulka occupies an approximately central position relative to (a) spatial occurrence, and (b) the average S.G. range. Centres of concentration from which statistically significant numbers of S.G. determinations have been made, and the regions in which they occur, are listed in Table 4 in order of increasing S.G. The total approximate weight of the specimens listed in Table 4 is 7,000 g.

A further 185 S.G. values are available in addition to those in Table 4, but they are from approximately 40 widely scattered localities each with one to nine determinations. These have not been considered in Fig. 2, and are not included in Table 4. Only centres with over 20 determinations are included, except for Balmoral and Peake Station (Table 4), which are relatively near to other concentration centres.

Since the publication 20 years ago of considerable numbers of australite S.G. determinations, scattered parts in the Australian strewnfield (Baker and Forster

TABLE 4

Cross-continent trends of australite S.G., based on average values for statistically significant populations occurring in nine major regions

	Region	Combined concentration centres	Number of S.G. determinations	Average S.G.
A.	S. coast of W. Victoria	Port Campbell Nirranda	573 ⎫ 366 ⎭ 939	2·402

B.	Central part of W. Victoria	Harrow
		Telangatuk E.—Kanagulk—
		   Toolondo
		Nurrabiel
		Balmoral
		Caramut—Kaniva—Mt.
		   William—and other W.
		   Victoria specimens
			35 ⎫
			48 ⎪
			34 ⎬ 163
			14 ⎪
			34 ⎭
				2·411

C.	E. part of S. Australia	Oakvale	24	2·417
D.	Lake Eyre, NE. part of S. Australia	Mulka William Creek Peake Station	271 ⎫ 96 ⎬ 379 12 ⎭	2·430
E.	SW. part of S. Australia	Ooldea	28	2·434
F.	S. part of N. Territory	Charlotte Waters	29	2·439
G.	SE. part of W. Australia	Transcontinental Railway Line	24	2·441
H.	S.-Central part of W. Australia	Coolgardie—Bulong—Kalgoorlie—Norseman	52	2·443
I.	E.-Central part of W. Australia	Wingellina	135	2·460
			TOTAL = 1,773 determinations of specimens	Grand Average = 2·416

1943), many additional determinations have been made. In Table 4, 862 such are included, viz:

(a) those from Nirranda (Baker 1956), Harrow (Baker 1955a), Nurrabiel (Baker 1967), and Wingellina (Baker 1961b)

(b) most of those from Telangatuk E.—Kanagulk—Toolondo (Baker 1959b)

(c) a further 111 from Mulka

(d) several additional values for Port Campbell (Baker 1944, 1946, 1961a, 1962).

The additional values substantiate the trends established from the earlier S.G. values (Summers 1909, Baker and Forster 1943). There are other concentration centres of australites in the Australian strewnfield, but statistically significant num-

bers of S.G. determinations have yet to be made. The positions of the major regions and the average S.G. values for the concentration centres within those regions are shown in Fig. 2.
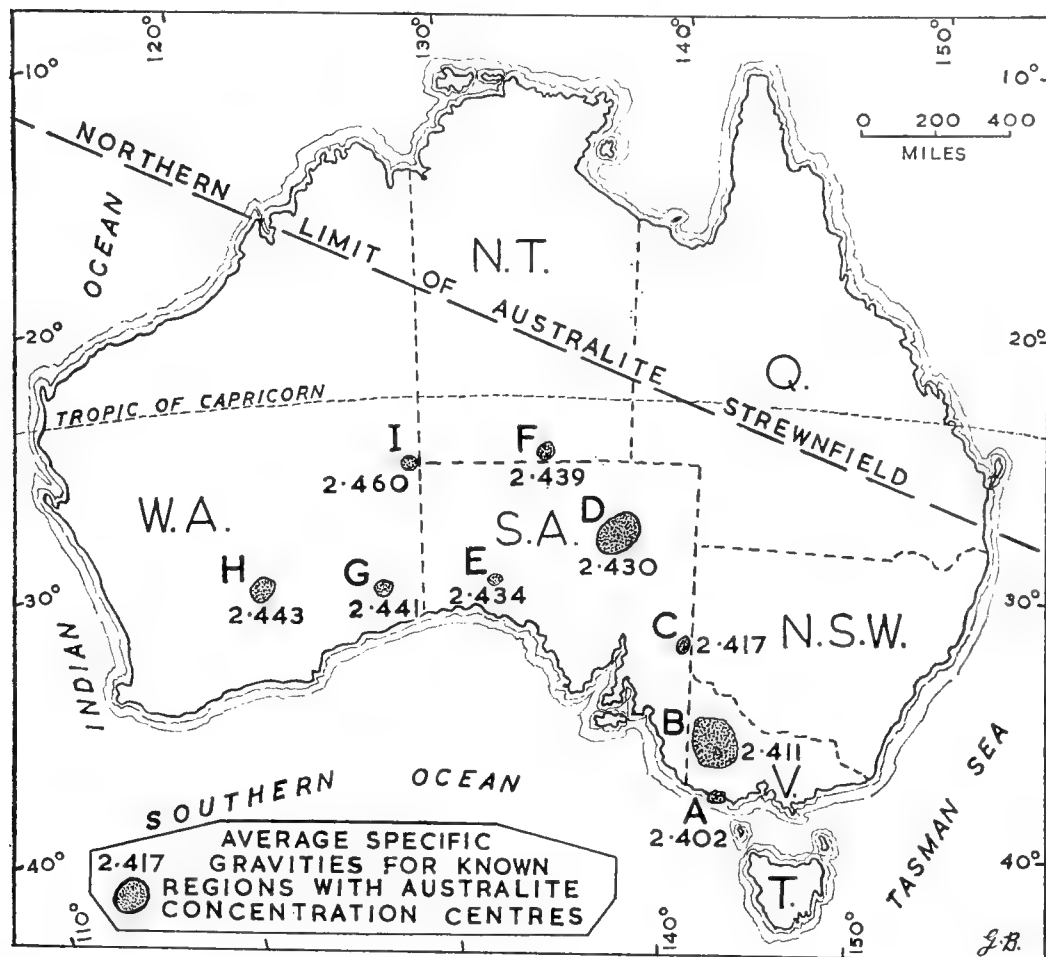

FIG. 2—Sketch map of Australia showing increase from SE. to NW. of average australite S.G. values in the concentration centres of nine widely separated regions.

A. Port Campbell—Nirranda region 939.
B. Horsham—Nurrabiel—Harrow—Telangatuk E.—Kanagulk—Toolondo—Balmoral—Caramut—Kaniva—Mt. William region 163.
C. Oakvale Station region 24.
D. Mulka—William Creek—Peake Station region 379.
E. Ooldea region 28.
F. Charlotte Waters region 29.
G. Transcontinental Line region 24.
H. Coolgardie—Bulong—Kalgoorlie—Norseman region 52.
I. Wingellina region 135.

The difference between the end members of these statistically significant average S.G. values points to a difference of some 5 to 6 per cent of SiO_2 in the average silica contents as deduced from the S.G. values. Differences in the silica contents of analyzed australites range up to approximately 11 per cent, but these are single determinations only, some of which were made about 100 years ago.

It should be noted that the known australite strewnfield extends for a further 400 miles to the SE. and a further 700 miles to the NW. The distance included between the end members of the regions shown in Fig. 2, i.e. from Port Campbell-Nirranda region in the SE., to the Wingellina region in the NW., is approximately 1,250 miles. The full range of silica variation is unlikely to be represented by the limits shown in Fig. 2. It is not yet known how much further the strewnfield extends into the Tasman Sea and Indian Ocean, so the range in silica content of end-member australites may be significantly greater than is indicated by the presently determined average S.G. values.

The distinct trend of decrease in silica content to the NW. across the continent is not consonant with the random variability in the composition of surficial geological formations. So marked a chemical distribution is not explicable in terms of the fusion of terrestrial substances. No known terrestrial process could produce such a chemical gradient. Resort is therefore made to an extraterrestrial means of distribution as adequate for producing a chemical gradient in australites across 2,500 miles of the continent. Such a gradient also calls for only one shower of australites (Baker and Forster 1943), and the fact that some specimens 'look older' than others is purely an expression of different degrees of erosion.

Special forms

Although the Mulka australites, because of their setting in an arid milieu, are relatively worn compared with specimens recovered from the more temperate regions of the strewnfield, they are in a better state of preservation than many specimens from other arid regions such as Wingellina, W.A. (Baker 1961b), Norseman, Kalgoorlie, Coolgardie and Bulong, W.A. Among them are two types of which sufficient shape and structure remain to indicate rather unusual shapes hitherto not figured in the literature. The posterior surface and side aspect of a canoe-shaped form is shown in Pl. 14, figs. 20a, b, and an enlarged silhouette tracing of the plan aspect and end-elevation are shown in Fig. 3, nos. 1, 2.

The posterior and anterior surfaces of a ridged 'nut-like' aberrant type are illustrated by two specimens shown in Pl. 15, figs. 11a, b, and 12a, b, while enlarged silhouette tracings of the end-elevations are shown in Fig. 3, nos. 3, 5, and the side-elevation of the smaller of the two specimens is shown in Fig. 3, no. 4. Two other rather more worn specimens allied to the distinctly ridged 'nut-like' forms are shown in Pl. 15, figs. 13a, b and 14a, b, but the ridges are practically all removed by weathering.

The worn canoe-shaped australite (Pl. 14, figs. 20a, b and Fig. 3, nos. 1, 2) is unusual in that it provides evidence of a type resembling Fenner's (1934 fig. 2) postulated primary form with two constrictions separating tear-shaped extremities from a larger elongated central core. All other known canoe-shaped australites reveal tapering ends (in plan) that are curved backwards (in side-elevation). This australite is the only known specimen in which the extremities spread out again beyond the two waist-like constrictions. The extremities also recurve backwards towards the posterior surface of the specimen (Pl. 14, fig. 20b), and reveal some thickening of the worn, broken ends. The radii of curvature of the posterior (R_B)
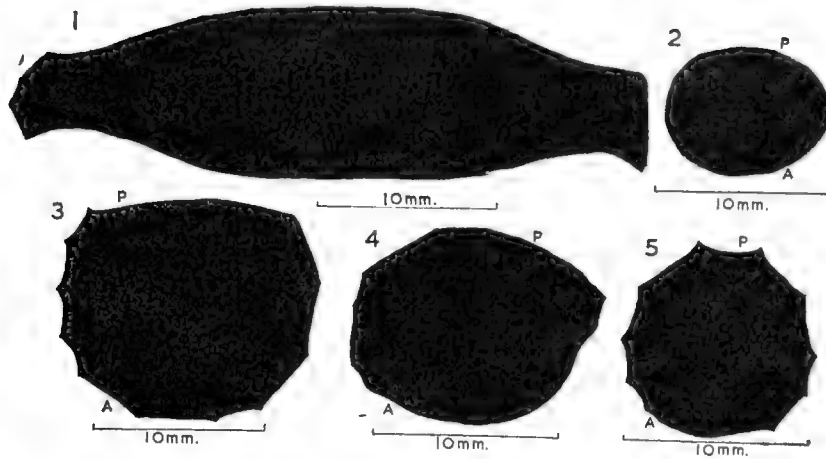
Fig. 3—Outline shapes of canoe-shaped and 'nut-like' australites from Mulka traced from enlarged silhouettes. P = posterior surface. A = anterior surface.

1. Plan aspect of canoe-shaped form showing a constricted 'waist' near each extremity (Pl. 14, fig. 20a).
2. End-elevation of canoe-shaped form depicted in no. 1 (above), showing lenticular outline comparable to a section taken normal to the long axis through its thickest portion.
3. End-elevation of 'nut-like' australite showing cross-sectional aspect of the longitudinal flow ridges revealed in Pl. 15, fig. 11b. The side-elevation silhouette reveals a small incipient flange-like process on one edge, just discernible on the posterior surface, near the top pointed extremity in Pl. 15, fig. 11a.
4. Side-elevation of smaller 'nut-like' form shown in Pl. 15, figs. 12a, b.
5. End-elevation of smaller 'nut-like' australite depicted in no. 4 (above), showing fewer flow ridge crests than the larger form in Fig. 3, no. 3.

and anterior (R_F) surfaces of this form are numerically equal, and the two arcs of curvature intersect in such a manner that the short cross section through the specimen is that of a bilaterally symmetrical lens (Fig. 3, no. 2).

Unless rounded by erosion, as in some specimens (e.g. Pl. 15, figs. 13, 14), the 'nut-like' type of australite has tapered ends and shows distinct longitudinal flow ridges that converge towards the pointed extremities (Pl. 15, fig. 11b). The specimen is evidently an entity in itself, and not a result of a peculiar type of fracturing. Comparable longitudinal flow ridges are infrequently revealed on more elongated australites like the 'pod-shaped' aberrant form illustrated in Pl. 14, figs. 19a, b. It seems possible that the 'nut-like' forms may have had a shape parentage linked with that of the 'pod-like' forms with tapered ends, and a similar secondary, but independent, atmospheric flight-shaping history.

The secondary shaping effects of such types, and their behaviour on aerodynamic heat treatment during ultrasupersonic transit through the earth's atmosphere, are debatable. Close examination of the better preserved specimens (Pl. 15, figs. 11a, b), reveals the possibility that the more extensive, slightly convex surface free from longitudinal flow ridges (Pl. 15, fig. 11a) and surface marked P in Fig. 3, no. 3, is most likely the posterior surface. The posterior surfaces of australites remained directed back along the flight path during aerodynamically stable orientation whilst high speeds of entry prevailed. For longitudinal flow ridges (of the pattern shown) to be developed from thin films of secondary melt glass (periodically

produced by aerodynamical heating), it appears that the specimen would have to possess a rocking motion through the earth's atmosphere with the axis of sway passing through the pointed ends. This would be a rare and most unusual type of motion (Baker 1958).

The distribution of the longitudinal flow ridges over the anterior surfaces of the ridged 'nut-like' australites is shown by the sectional aspects through their crests in Fig. 3, nos. 3, 5. The sharpness of the crests of the ridges is over-emphasized in Fig. 3 for the purposes of illustration, and it is possible that in Fig. 3, no. 5, the specimen should have been rotated to make one surface (designated A) the posterior surface, and the other (designated P) the anterior surface. This specimen did not possess a sculpture pattern that would ordinarily provide evidence diagnostic of the posterior surface. The larger form shown in Fig. 3, no. 3 reveals the presence of an odd number (11) of longitudinal flow ridges, whilst the smaller form represented in Fig. 3, no. 5 shows an even number (10). The intervening flow troughs are slightly variable in width on the same specimen, but are rather more symmetrically disposed on the smaller one. Only half the number of flow ridges show up in the silhouette representing the side-elevation (Fig. 3, no. 4) of the smaller 'nut-like' form, and the position and distribution of the ridges in the flow pattern are not as clearly displayed. The ridges are undoubtedly remnants of a pre-existing flow pattern, and not peculiarities of terrestrial fracturing and erosion. Weathering removes them in course of time, as evidenced by the remnant 'stumps' of two longitudinal flow ridges still extant on the specimen depicted in Pl. 15, fig. 14b, and their complete erasure from another much worn 'nut-like' form shown in Pl. 15, fig. 13b. An indication that these 'nut-like' forms developed circumferential flanges, is provided by the small remnant of a flange structure on one of the specimens (Pl. 15, fig. 11a, top of photograph).

Normal forms

All of the other 270 australites from Mulka listed in Table 1 have the typical shapes characteristic of Australian tektites, but they are variously chipped, flaked, etched and worn. Features of interest are included in the descriptions of Pl. 11-15. Certain grooves and markings on some of the specimens (e.g. Pl. 11, figs. 12, 18; Pl. 13, figs. 3-4, 8, 11-12) are due to differential solution-etching effects (Baker 1961d), and are not the work of aborigines as sometimes suggested. Specimens definitely flaked and probably used as stone implements are illustrated in Pl. 15, figs. 17-21.

Variations in the sizes of the gibbosities and in the thicknesses of the waist regions of the dumbbell-shaped forms are evident in Pl. 14, figs. 1-18. Among the group of dumbbell-shaped forms, the aberrant 'peanut-like' forms were evidently subjected to considerably less ablation during high speed aerodynamic entry, for their end-elevations are approximately circular in outline, and their plan aspects and side-elevations are very similar. However, they have been worn smooth (Pl. 14, figs. 15a, b) by subaerial agencies.

Variations in the size and shape of the gibbosity in the teardrop-shaped forms, and variations in the degree of attenuation, amount of recurvature, and amount of tail-portion preserved after erosion, are shown in Pl. 15, figs. 1-10. Surface bubble craters are exposed in the tail regions of the posterior surfaces of two of the teardrop-shaped specimens (Pl. 15, figs. 8a, 10a).

The best preserved specimen, a complete flanged button illustrated in Pl. 11, figs. 1a, b, reveals so much better shape and structural characteristics compared

with the rest of the specimens from Mulka, that it is likely to have come from a more temperate zone where the state of preservation is usually much better. It is in the collection of the late Mr S. R. Mitchell who acquired the 60 Mulka australites from Mr George Aiston 33 years ago. Mr Mitchell agreed that this specimen could be an extra-Mulka specimen that had become accidentally incorporated, but he was unable to suggest its origin. This complete flanged button, with excellently preserved sculpture patterns and well-developed secondary shape, is retained among the illustrations herein, in order to provide a contrast with the poorly preserved to severely weathered australites (Pls. 11 to 15) definitely known to have come from the Mulka district. The specimen measures $23 \cdot 5$ mm in diameter, $9 \cdot 8$ mm in thickness, and the width of its complete circumferential flange is 4 mm. It weighs $5 \cdot 639$ g, and has a S.G. value of $2 \cdot 437$ (T $H_2O = 21 \cdot 4°C$.). The radius of curvature of the posterior surface (R_B) is $12 \cdot 71$ mm, and of the anterior surface (R_F) $13 \cdot 28$ mm. The original spherical (or near-spherical) form measuring $25 \cdot 4$ mm in diameter was ablated for a depth of $15 \cdot 6$ mm. This means that the original front polar regions of the primary spherical form migrated under aerodynamical heating to beyond the position of the original centre of the primary form before the process of ablation was arrested.

Silhouette tracings were made of all specimens in the Mitchell collection, and of some in the Croll collection. Radii of curvature of the posterior (R_B) and anterior (R_F) surfaces were determined graphically from these silhouettes (Baker 1955b) for several of the flanged buttons and button cores in these two collections. The details of these determinations are not presented because of the advanced state of weathering of the specimens. The results from the measurement of such worn specimens yield values over the true radius of curvature of the original posterior surface (R_B), so that the diameters of the original spherical forms, and the depths of aerodynamic ablation in the stagnation point regions, give greater values than for well preserved forms of comparable size (Table 5).

Some of the characteristics of the flanged buttons from Mulka are compared in Table 5 with those of the much better preserved specimens from Port Campbell (Baker 1962a).

TABLE 5

Comparison of some characteristics of flanged buttons from Mulka and Port Campbell

	Mulka	Port Campbell
Number of flanged australite buttons	10*	23
Average weight	$3 \cdot 614$ g	$5 \cdot 297$ g
Average S.G.	$2 \cdot 449$	$2 \cdot 402$
Average diameter	$20 \cdot 7$ mm	$22 \cdot 5$ mm
Average depth ($=$ thickness)	$9 \cdot 3$ mm	$10 \cdot 5$ mm
Average width of flange	$2 \cdot 5$ mm	$3 \cdot 5$ mm
Average R_B	$10 \cdot 30$ mm (range $= 8 \cdot 0$ to $12 \cdot 7$ mm)	$10 \cdot 10$ mm
Average R_F	$11 \cdot 00$ mm (range $= 9 \cdot 8$ to $11 \cdot 7$ mm)	$12 \cdot 10$ mm
Average diameter of primary form	$20 \cdot 6$ mm	$20 \cdot 1$ mm
Average depth of ablation	$11 \cdot 2$ mm (range $= 5 \cdot 5$ to $16 \cdot 5$ mm)	$9 \cdot 5$ mm

* 7 from Mitchell coll., 3 from Croll coll.

In Table 5, the lower values for the averages of the weight, diameter, depth, flange width, and R_F of the Mulka australites are largely a result of the chipped and eroded character of the specimens. Weathering effects have increased the calculated average values for R_B, and hence also the values for the diameter of the primary spherical form, and the depth of ablation. Because the Mulka specimens are so worn, further calculations such as the average volume loss by ablation and the average volume of the circumferential flange were not carried out. The values of these average volumes for the 23 excellently preserved Port Campbell flanged australite buttons are 44·9 per cent average volume loss by ablation of the primary form, and 15·3 per cent average volume of the circumferential flange (Baker 1962a).

The higher average S.G. value for the flanged buttons from Mulka is significantly so much greater that the increase cannot be attributed *in toto* to the larger volume and the better state of preservation of the Port Campbell specimens.

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Explanation of Plates

PLATE 11

Mulka Australites

In all plates a = posterior surfaces, b = anterior surfaces (x 0.87).

1. Relatively well-preserved australite button showing circumferential flange and flow-lined posterior surface (1a), and anterior surface (1b) with concentric flow ridges.
2-10. Worn australite buttons with chipped flanges and solution-etched surfaces. 8a shows a worn bubble crater.

11. Worn flange fragment.

12-21. Severely worn cores of australite buttons, some with minute remnants of flanges. 12 reveals a deep solution groove, 15a shows a worn bubble crater.

22. Worn oval with circumferential flange (22a) and traces of flow ridges (22b).

23. Worn oval with chipped circumferential flange (23a).

24-30. Worn ovals.

(1-7, 12, 23-27 Mitchell collection; 8-11, 13-22, 28-30 Croll collection.)

PLATE 12

11b, is an oblique side view, and 14b, 18b, 19b, 20a are side views (x 0.87).

1-7. Worn ovals with flanges all removed by erosion. 1b shows a chipped anterior surface, 7 is a slightly oval ball-like form, 5a shows V-shaped (in sectional aspect) solution-etch grooves. The small bubble crater in 3a is 1·1 mm deep, 4b shows the remnants of a broken hollow form (top edge), the walls of which are much dulled and worn.

8-15. Worn round cores. Schlieren (i.e. flow streaks) on 8a and 10a are in the form of flow swirls, 9 is the 'indicator' type showing still attached remnants of the outer edge of the form, 11 is abraded and pitted.

16-18. Worn oval cores. 18a shows a worn bubble crater, 18b shows the worn nature of the flaked equatorial zone.

19-20. Worn conical cores.

21-23. Worn, irregular fragments of cores.

(1-4, 7, 12-15, 17, 21 Croll collection; 5, 6, 8-11, 16, 18-20, 22, 23 Mitchell collection).

PLATE 13

(x 0.87.)

1-15. Worn boat-shaped forms and boat cores. No. 1a shows remnants of the circumferential flange along the parallel longer sides of a broader form, 3-4 show deep solution grooves, 6 shows a fractured edge (left-hand side), 8a has a large, shallow crater 0·8 mm deep, 12a shows a cluster of short solution grooves, and 13-15 are smoothed by wear.

(1, 3-4, 7, 10-15 Mitchell collection; 2, 5-6, 8-9 Croll collection.)

PLATE 14

20b is a side view (x 0.87).

1-18. Worn dumbbell-shaped forms. 4 shows a slender waist, 5, 9, 14 show thick waists. 15-16 are 'peanut-like' forms, with rounded extremities in 15 and pointed extremities in the rather less weathered specimen 16. 17-18 are 'ladle-like' forms with gibbosities of different size at opposed extremities on each specimen. A flange remnant is visible along one side (right-hand side) in 1a, and is the same width in the waist region as around the gibbosities. 8 shows broader gibbosities relative to the width of the waist region, compared with other dumbbell-shaped forms. 13b shows flaked ends.

19. Worn aberrant form, cylindrical, 'pod-like' with tapered ends and indistinct longitudinal ridges on all surfaces.

20-22. Worn canoe-shaped forms. 20 shows 'splayed-out' extremities and flow streaks (brought out by natural solution-etching) trending parallel with the outline of the form.

(1-4, 9-16, 18, 20-22 Mitchell collection; 5-8, 17, 19 Croll collection.)

PLATE 15

5-6 are reversed, 17-21 are mainly fracture surfaces (x 0.87).

1-10. Worn tear-drop-shaped forms. 1 has the low S.G. of 2·259, 6 is smoothed by abrasion, 8, 10 show bubble craters 1·4 and 1·6 mm deep respectively, 10a reveals portion of a flaked equatorial zone.

11-14. Worn 'nut-like' forms. 11 shows pointed extremities and has longitudinal flow ridges relatively well-preserved, 12-14 show indistinct longitudinal flow ridges. These forms are approximately circular in end-elevation. 13, 14 are much more worn than 11, 12.

15-16. Worn, nondescript fragments.

17-21. Aboriginal flakes showing fresher fracture surfaces of artificial origin, and remnants of the worn outside surfaces. The conchoidal and subsidiary ripple fracture patterns of the glass are shown by several photographs. 19 is flaked from a round or slightly oval australite, 18, 20-21 are from distinctly oval- or boat-shaped forms.

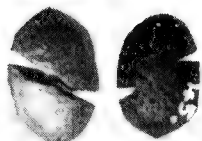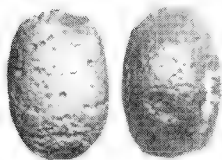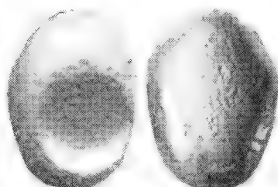(1-6, 11-12, 17 Mitchell collection; 7-10, 13-16, 18-21 Croll collection.)
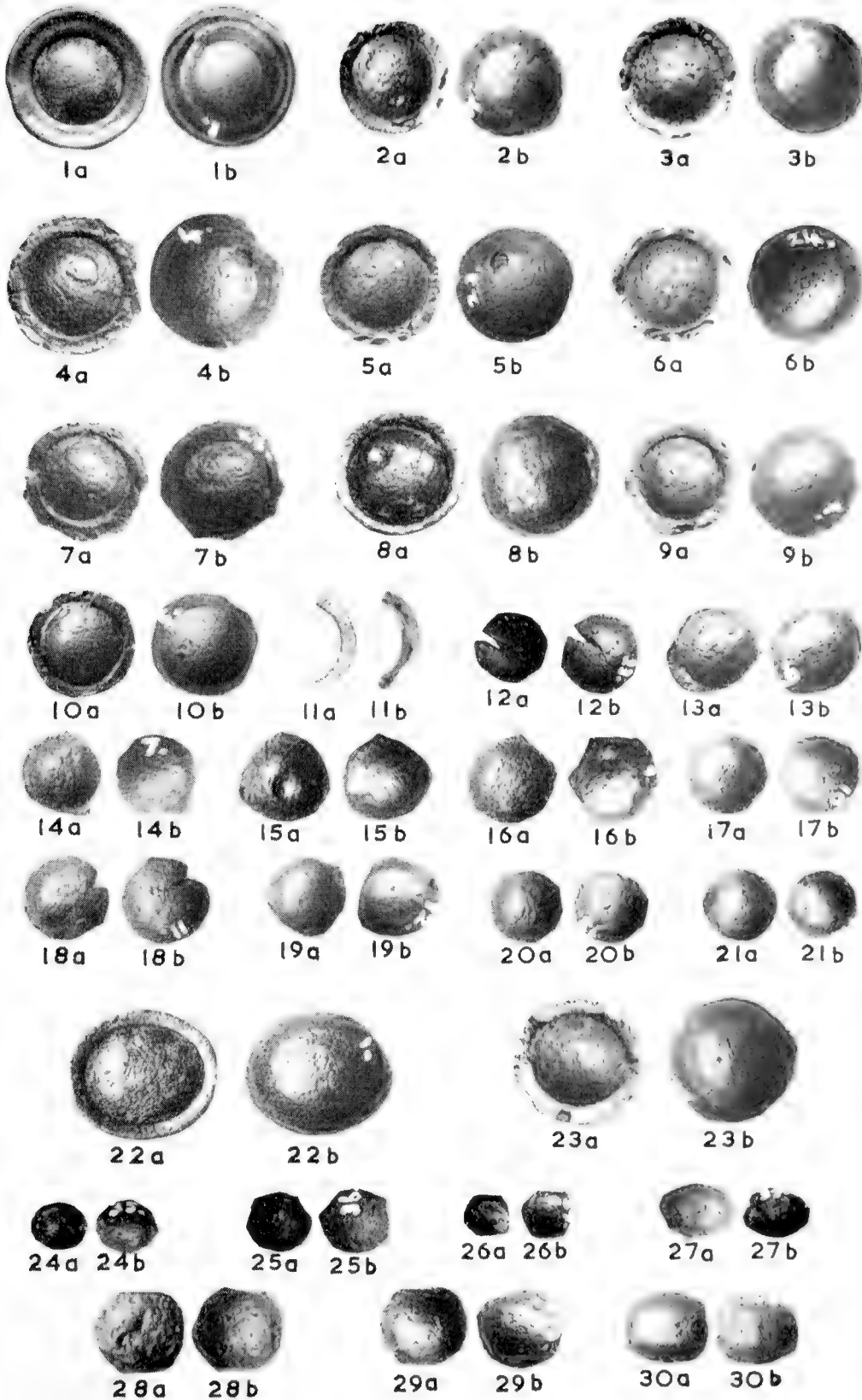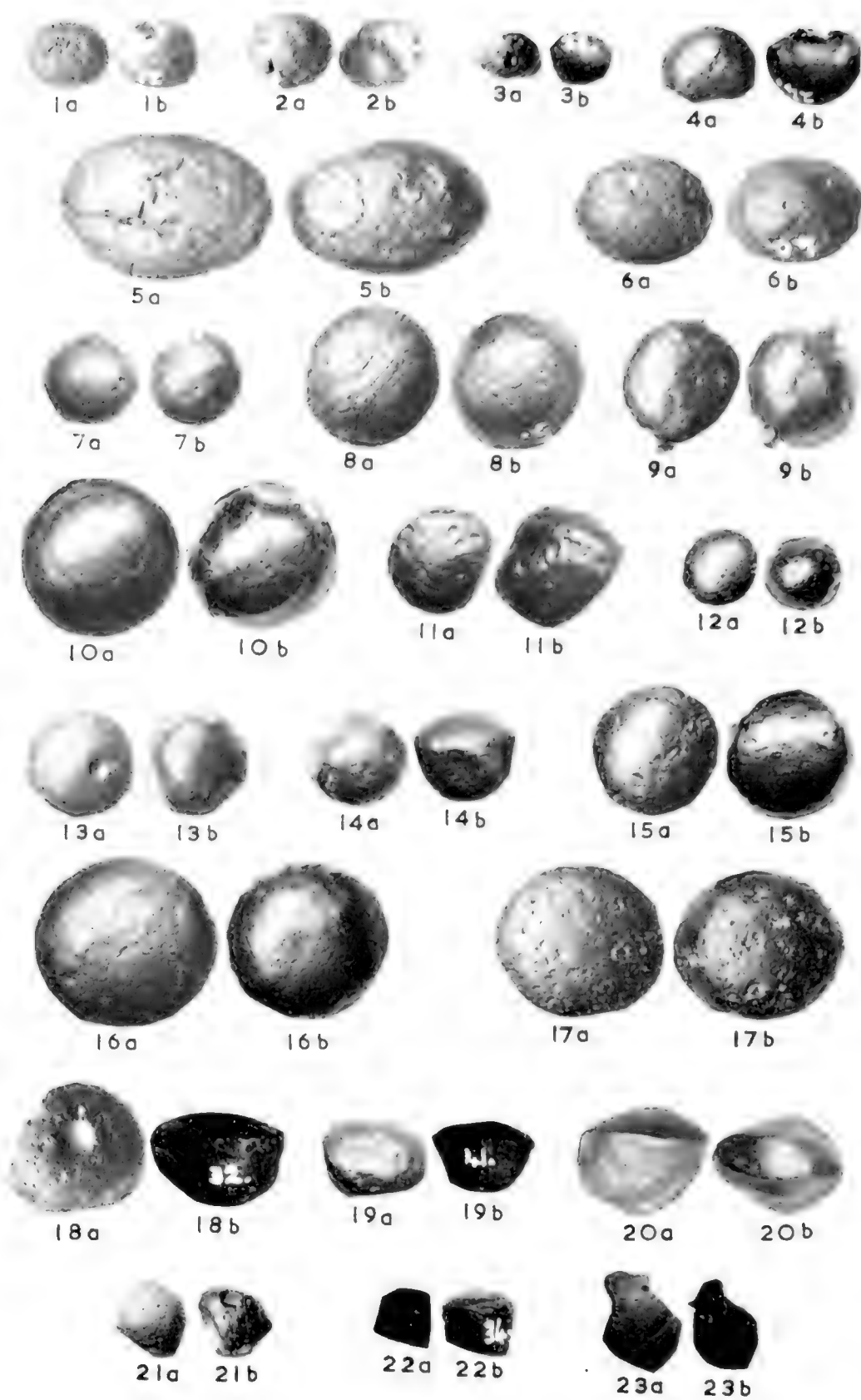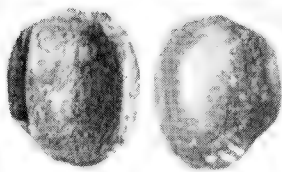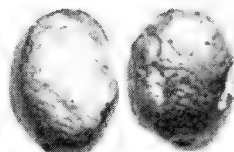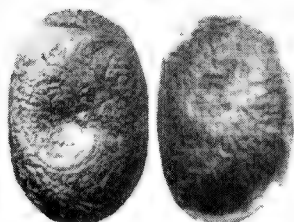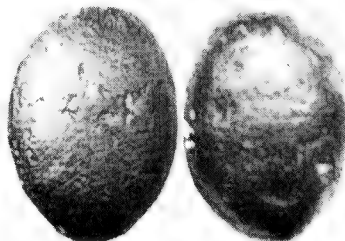
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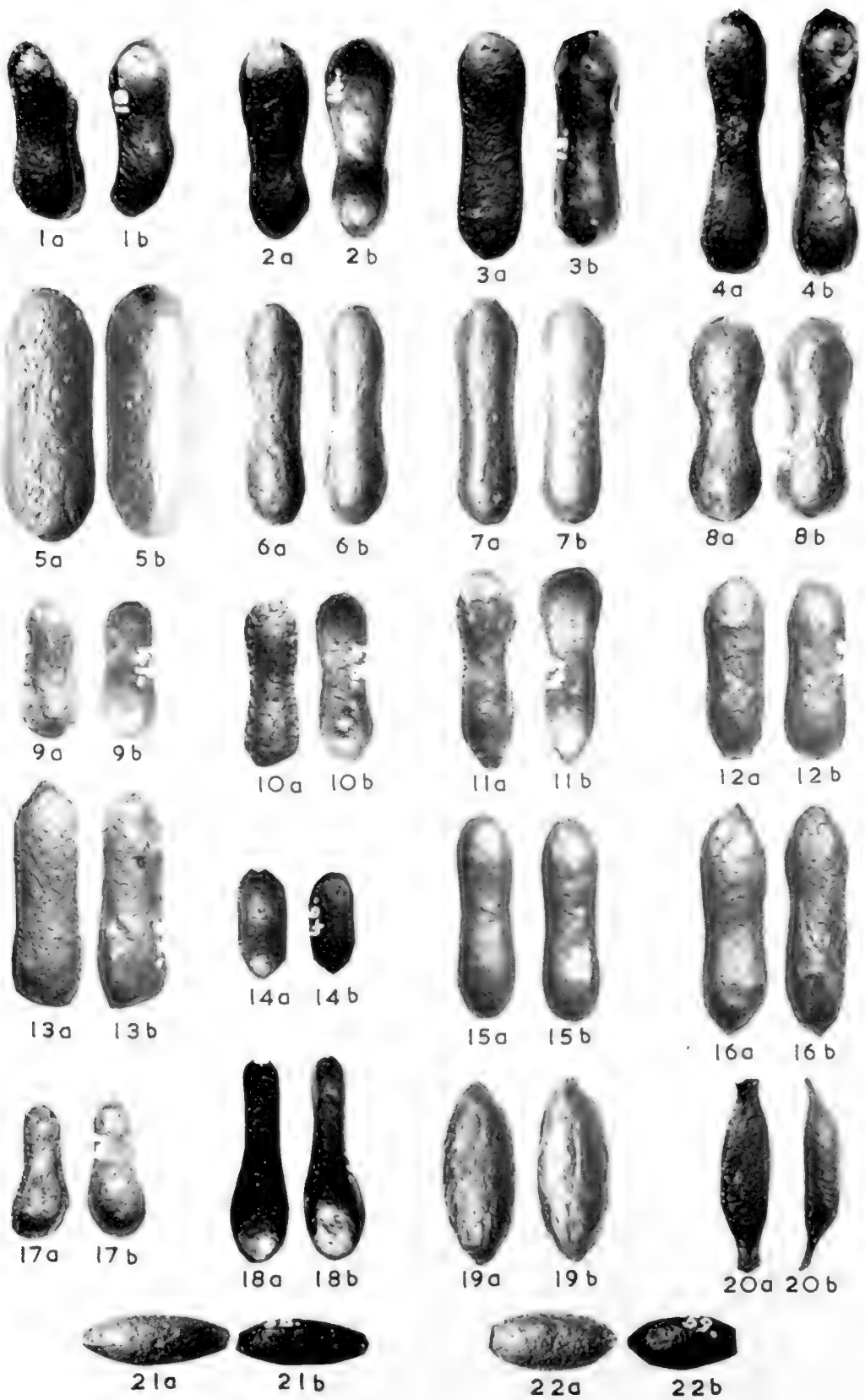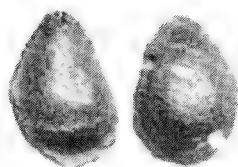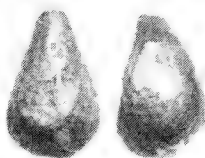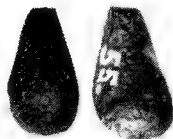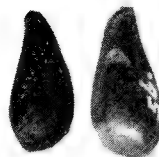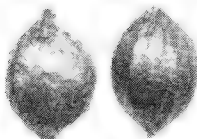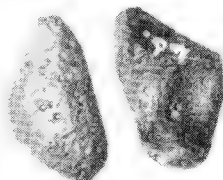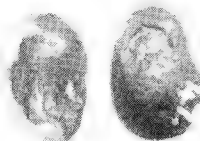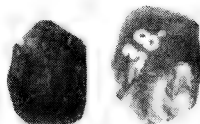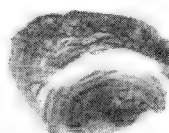
RADIOCARBON DATE FOR ABORIGINAL REMAINS AT MAROONA, VICTORIA, AUSTRALIA

By Edmund D. Gill

Assistant Director

Abstract

The organic fraction of aboriginal skeletal fragments from Maroona, Victoria, gave a radiocarbon age in 8th cent. AD.

Introduction

A radiocarbon date of 1190 ± 90 years B.P. (GaK-1059) has been obtained for aboriginal skeletal fragments from Maroona, 9 miles S. of Ararat, Victoria. The site is a sand and gravel quarry operated by the Shire of Ararat, and is in the Parish of Kiora (No section, C.A. 15A). It is reached by travelling 9 miles S. from Ararat to Maroona, then about 1 mile W. to the property owned by Gleeson Brothers. The quarry is on the S. side of the road opposite Mr R. Gellie's homestead. This area has been geologically mapped by the Mines Department of Victoria as can be seen in their map of the Langi Logan Lead System (Hunter 1909). The sand pit is on the left bank of a creek which flows into the Hopkins River. The quarry reveals horizontally bedded sand and gravel which is very poorly sorted and with current bedding. Most of the rock is rather angular granitic detritus. There are also some pebbles of milky quartz up to two inches in diameter, some buckshot gravel, a few pieces of non-magnetic iron oxide, and a few pieces of mica schist; one piece of granite was seen. Thus the sand and gravel came mostly from the granites to the north, with minor contributions from bedrock and basalt. Where tested with acid, no sign of carbonates was found. The coarseness of the sediments and the current bedding show that the deposits were laid down by rapidly moving waters, and probably do not represent a very long period of sedimentation.

An imperfect but fairly well preserved calvaria (Maroona 1) was brought to the National Museum by Mrs Margaret Smith for her father Mr T. N. Muntz, engineer to the Shire of Ararat. A site was indicated by the Shire engineers in the SE. corner of the quarry where the imperfect cranium was found at a depth 'between four and five feet' by the bulldozer excavating sand and gravel. On the NW. side of the pit another locality was shown where, at a depth 'between six and seven feet', the bulldozer removed a skeleton. Fragments of this skeleton were collected by me and used for the radiocarbon dating. It was not possible to determine whether the remains had been stratified or had reached their position by some other means. Mr Muntz kindly donated all the specimens found to the National Museum. Their preservation is similar.

Stratigraphy

The fluviatile sediments in which the quarry is excavated present the following succession:

0-3 in. Light brownish grey top soil (10 YR 6/2).
3-21 in. Light reddish-brown sandy gravel ((5 YR 6/4).

21-70 in. Yellow (10 YR 7/6) sandy gravel, not strongly compacted.
70-76 in.¹ Strong brown very compact (over 1 ton per sq. ft) sand of variable colour, but chiefly 7.5 YR 5/6, with some off-white patches.

The colour references are to the Munsell Chart.

After investigating the site, I believe that all that can be said with certainty is that these skeletal remains came from the five feet of yellow sandy gravel from 21 in. to 70 in. from surface in the quarry described. As the radiocarbon dating was carried out on the organic fraction of these bones (not on the carbonate), the result may be considered reliable. The date is on the bones of Maroona II.

Anatomy

Professor L. J. Ray of the Department of Anatomy, University of Melbourne, kindly examined the bones. These have been determined as follows:

Maroona I. Calvaria with heavy supraorbital ridges (N.M.V. X72,227). The facial bones and the mandible are absent, although some of the fragments collected could belong to this specimen. The post-cranial bones include a hip bone which is male. The age of the individual is estimated to have been 45 ± 5 years (Pl. 16, fig. 2).

Maroona II. Calotte, probably of a female, whose age is estimated to have been 55 years or more (N.M.V. X72,236).

Maroona III A right third molar tooth showing relatively light attrition was found. The wear is so light, especially for an aborigine, that it is judged to belong to a person much younger than Maroona I or II. However, the tooth is much more worn on the left side and so without the upper jaw to show the position of wear, one cannot be certain, but this tooth may represent a third individual.

Dating

When examining a range of aboriginal skeletal material in the National Museum, I was struck by the fact that, according to the labels, two mutually exclusive periods of time are represented, viz. (1) fossils many thousands of years old, and (2) recent burials. Believing that bones of the intervening period must be available, it was decided to date by radiocarbon a few skeletons in order to discover if this were so. The first test was on the Mitiamo Skeleton from N. Victoria (GaK-703) which gave a date of approximately 5540 years (Gill 1967). The second test was made on bone fragments from Maroona which gave an age of about 1190 years. These assays indicate that the aboriginal bones which formerly were regarded as recent burials may well cover a considerable period of time. Aboriginal bones from Keera Station west of Mildura that once would have been regarded as 'recent burials' have given radiocarbon ages of 4170-5900 y. B.P. Examination of 'recent' bones shows a range in preservation which is greater than would be expected simply by reason of the fact that the bones have been buried under different climatic conditions and in different substrates.

Mortar

The bulldozer excavated a large basalt mortar (Reg. No. X72, 228) from near Maroona II. This is a good example of this type of artifact, and has two deep depressions, one on each of two opposite sides of the piece of basalt. As the mortar was found in association with the dated skeleton, it may well be of approximately the

same age. Basalt is available in the nearby countryside, so the piece of rock need not have been brought very far. It measures approximately $5\frac{1}{2}'' \times 7'' \times 4\frac{1}{2}''$, and weighs 12 lbs 6oz. (Pl. 16, fig. 1).

Conclusions

About 1200 years ago an adult aboriginal, probably a woman, lived in the Maroona district of Victoria. Part of the territory of these people was the flood plain of the stream which flows into the Hopkins River, a good place for food gathering. The only direct cultural evidence is the double mortar which was found associated with the dated skeleton. Judging by the deep depressions in this piece of basalt, the stone had been in use for a long time, presumably for milling grass seeds and pounding roots. Search failed to reveal any other evidences of aboriginal occupation.

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Explanation of Plate

PLATE 16

Basalt mortar and aboriginal calvaria from Maroona, Victoria.

CATALOGUE OF BALDWIN SPENCER EARTHWORM TYPES IN THE NATIONAL MUSEUM OF VICTORIA, AUSTRALIA

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and B. J. Smith

Curator of Invertebrates

Abstract

W. Baldwin Spencer described 96 new species, one subspecies and two varieties of earthworms between 1892 and 1900. His earthworm collection was donated to the National Museum of Victoria in 1916. The species are catalogued with the number and condition of the type specimens, the locality, reference, previously unpublished Spencer serial numbers and habitat data. Lectotypes for 45 species are designated.

Introduction

Between 1892 and 1900 Professor (later Sir) W. Baldwin Spencer, Professor of Biology at the University of Melbourne, and later Director of the National Museum of Victoria, described 96 new species, one subspecies and two varieties of earthworms from Victoria, Tasmania and Queensland. He also amassed a large collection of Australian earthworms in the Zoology Department at the University. This collection was donated by Spencer to the National Museum on 23 March 1916. As a recent search in that department and in other Museum collections in Australia failed to reveal any Spencer earthworm material, it is concluded that the entire collection was donated at this time. Before the present study, the types of 41 species were known, including those of four species questionably so. A complete cataloguing of the Spencer earthworm collection was undertaken to locate all probable type material, to document it, and to assess its value for future study. Spencer's original notes, with an unpublished key to his specimen numbering system, were located in the Museum archives and these gave an accurate guide as to which specimens were used in the descriptions of his species. As a result, the type specimens of 41 species previously so labelled have been confirmed as types, including the questioned type specimens of four species. In addition, type material of a further 28 species has been found. Of the 69 species for which type material exists, 15 are represented by material in such poor condition that all further work on it is impossible. Type specimens of the 30 remaining species are presumed lost. All material has been transferred to fresh 70 per cent alcohol.

The original generic names are used, arranged alphabetically, and under each genus the specific names are so arranged. In the original descriptions, Spencer did not designate types. He gave exact localities and habitats, both in his papers and on his labels, and these were of considerable assistance in identifying type material. However, the principal means used was the series of numbers included with each specimen. The catalogue also includes specimens determined by Spencer, but which had not been collected at the time his papers were written, or were present but not used in the preparation of those papers. If the Spencer number with a specimen shows it to have been used in the type description, plus the agreement of the type

locality, collector's name, date of collection, and species name all in Spencer's handwriting, the specimen is accepted as type material. As no primary types were designated by Spencer, all such specimens are syntypes. A lectotype has been chosen from the syntypes when (a) In good or reasonable condition, (b) Complete (dissected, when available), (c) Documentation adequate. Lectotypes have been separated from paralectotypes. When none of the type material complies with the above criteria the series is left as syntypes.

The condition of the specimens is defined as follows:

Good—suitable for detailed study, including dissection

Reasonable—probably suitable as above

Fair—doubtfully suitable for detailed study and of limited use for dissection

Poor—little use for study

Bad—no use for study

Details are given of specimens other than types, but identified by Spencer. Unless otherwise stated, the specimens were collected by Spencer. Page numbers given with the Spencer number or in brackets in the text in the catalogue refer to the pages in Spencer's notes. The abbreviations for States are as follows: Vict. = Victoria, Tasm. = Tasmania, Qd. = Queensland.

Genus **Cryptodrilus** Fletcher, 1886
Cryptodrilus campestris Spencer, 1895

Proc. Roy. Soc. Vict. 7: 39, figs. 13-15.

SYNTYPES: G48, a dissected entire worm, four complete specimens and one fragment. Poor (shrivelled).

LOCALITY: Parattah, Tasm., in damp earth under logs, collected February 1893.

SPENCER NUMBER: C sp 6 T (p. 8).

Cryptodrilus cooraniensis Spencer, 1900

Proc. Roy. Soc. Vict. 13: 42-43, figs. 34-36.

SYNTYPES: G43, one complete specimen, questionably a syntype. Reasonable. G44, a dissected entire specimen and a number of fragments. Bad. G45, specimen completely fragmented. Bad.

LOCALITY: Cooran, Qd., collected October 1891.

SPENCER NUMBER: G43, Peri sp 8 ? (Not listed in Spencer notes). G44, C sp 4 Q; G45, C sp 8 Q (p. 7).

NOTES: None has been previously recognized as type material. G44 was used in MS preparation (p. 7). The remaining specimens are included here as they were collected at the same time and in the same locality. While G45 appears to have been used in MS preparation there is no indication that G43 was. The latter assumes importance as it is the only original specimen in reasonable condition. Unfortunately its position is ambiguous as the number is not recorded in the Spencer notes whereas a similar number, Peri sp 8 Q, does appear under the genus *Diporochaeta* (p. 28).

Cryptodrilus dubius Spencer, 1892

Proc. Roy. Soc. Vict. 4: 136-137, figs. 13-15, 67.

LECTOTYPE: G35, an entire specimen. Length in spirit 108 mm. Good.

PARALECTOTYPES: G1434, three entire specimens and three fragments formerly included with G35. Good.

LOCALITY: Vict., given on an original label. Spencer writes (p. 137) 'This probably comes from Croajingolong but the distinct locality other than Victoria is not noted'. It appears that Spencer did not collect the specimens. The types of three other species were collected at Croajingolong in January 1889, during an expedition of the Field Naturalists' Club of Victoria. Perhaps Spencer had reason to believe that these specimens were collected on the same expedition.

SPENCER NUMBER: C sp ? 5 (p. 7).

NOTES: Specimens G35 were previously recorded as type material although the original label (C sp ? 5) is now missing. The label is not located with any other specimen in the collection and is probably correctly identified with G35.

Cryptodrilus ellisii Spencer, 1895

Proc. Roy. Soc. Vict. 7: 42-43, figs. 22-24.

SYNTYPES: G32, four dissected entire specimens and two complete specimens. Poor. G33, specimens missing from collection, presumed lost.

LOCALITY: Dee Bridge, Tasm., under logs and stones, collected January 1893.

SPENCER NUMBER: C sp 9 T and C sp 10 T (p. 8).

NOTES: The National Museum label records specimens G32 as questionably type material. This doubt probably arose from the date of collection on the museum filing card 'Jan. 1895', coupled with the fact that the type description was read in March, 1894, and published in January, 1895. An original label (which appears to be by Spencer) shows the date poorly written but probably 'Jan. /93'. This date would be consistent with Spencer's collecting trip 'early part of 1893' (p. 33). It is suggested here that the correct date is 1893, that the 3 has previously been misread as a 5, and that these specimens are types. Specimens G33 are types not previously recognized as such but are now missing. They have been lost since coming to the museum as a filing card notes that five specimens were in the jar.

Cryptodrilus frenchi Spencer, 1892

Proc. Roy. Soc. Vict. 4: 135-136, figs. 10-12, 66.

TYPE SPECIMENS: Not present in National Museum, presumed lost.

LOCALITY: Croajingolong, E. Gippsland, Vict.

SPENCER NUMBER: C sp ? a (p. 7).

Cryptodrilus gippslandicus Spencer, 1892

Proc. Roy. Soc. Vict. 4: 132-133, figs. 1-3, 63.

LECTOTYPE: G57, a dissected entire specimen. Length in spirit 90 mm. Reasonable.

PARALECTOTYPES: G1405, two complete specimens and two fragments, one of which has been dissected. These were formerly included with G57. Reasonable.

LOCALITY: Croajingolong, E. Gippsland, Vict. The specimens were collected January 1889.

SPENCER NUMBER: C sp ? 3 (p. 7).

Cryptodrilus hobartensis Spencer, 1895

Proc. Roy. Soc. Vict. 7: 37-38, figs. 10-12.

LECTOTYPE: G50, a complete, undissected specimen. Length in spirit 28 mm. Reasonable.

PARALECTOTYPES: G49, a dissected entire specimen, seven complete specimens and five fragments. Poor to fair (dried). G51, four complete specimens, one partly dissected. Fair (dried).

LOCALITY: G49, Mt Wellington, Tasm., collected by A. Morton, July 1892. G50 and G51, Parattah, Tasm., G50, January 1893 and G51, February 1893.

SPENCER NUMBER: C sp 5 T (p. 8). All three jars bear this code number.

NOTES: None has been previously recognized as type material.

Cryptodrilus insularis Spencer, 1895

Proc. Roy. Soc. Vict. 7: 41-42, figs. 19-21.

LECTOTYPE: G39, a complete undissected specimen. Length in spirit 26 mm. Good.

PARALECTOTYPES: None.

LOCALITY: Parratah, Tasm., collected February 1893.

SPENCER NUMBER: C sp 8 T (p. 8).

NOTE: The specimen has not been previously recognized as type material.

Cryptodrilus intermedius Spencer, 1892

Proc. Roy. Soc. Vict. 4: 133-134, figs. 4-6, 64.

LECTOTYPE: G58, a dissected entire specimen. Length in spirit 100 mm. Reasonable.

PARALECTOTYPES: G1406, seven complete specimens formerly included with G58. Reasonable.

LOCALITY: S. Warragul, Vict. collected by W. Mann, July 1891.

SPENCER NUMBER: C sp ? 12 (p. 7).

OTHER SPECIMENS: G86 contains 10 complete specimens and a fragment, from the type locality dated July 1892, and found 'In black, very heavy swamp soil, about 12 inches down'. Their condition is fair but several are fragmenting badly. These specimens were found after the original paper was read and so were not used therein. However, they are listed in the Spencer Notes (p. 7) as 'MSS', perhaps in error. Their number is C sp ? 11. G72 is questionably referred to this species. There are two specimens thought to be different forms or at different stages. There is no included data and their condition is reasonable.

Cryptodrilus irregularis Spencer, 1895

Proc. Roy. Soc. Vict. 7: 34-35, figs. 1-3.

LECTOTYPE: G46, a dissected entire specimen. Length in spirit 145 mm. Reasonable.

PARALECTOTYPES: None, although the description suggests that more than one specimen was found.

LOCALITY: Table Cape, Tasm., found under logs, no date.

SPENCER NUMBER: C sp 1 T (p. 8).

Cryptodrilus lucasi Spencer, 1892

Proc. Roy. Soc. Vict. 4: 143, figs. 28-30, 72.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: Goulburn River, Tallarook, Vict., collected by A. H. S. Lucas, no date.

SPENCER NUMBER: C sp ? V (p. 7).

OTHER SPECIMENS: G84 is the only representative of this species in the collection. It contains two fragments in fair condition, without record of locality, date or collector.

Cryptodrilus macedonensis Spencer, 1892

Proc. Roy. Soc. Vict. 4: 138-139, figs. 16-18, 68.

LECTOTYPE: G47, an undissected complete specimen. Length in spirit 56 mm. Reasonable.

PARALECTOTYPES: G1407, four fragments formerly included with G47. Reasonable.

LOCALITY: Mt Macedon, Vict., collected by H. R. Hogg and Spencer in June 1891.

SPENCER NUMBER: C sp ? 6 (p. 7).

Cryptodrilus minor Spencer, 1892

Proc. Roy. Soc. Vict. 4: 144, figs. 31-33, 73.

LECTOTYPE: G56, a dissected entire specimen. Length in spirit 110 mm. Reasonable.

PARALECTOTYPES: G1435, two complete specimens and two fragments formerly included with G56. Reasonable.

LOCALITY: Ellinbank, South Warragul, Vict., collected by W. Mann in August 1891.

SPENCER NUMBER: C sp ? 14 (p. 7).

Cryptodrilus mortoni Spencer, 1895

Proc. Roy. Soc. Vict. 7: 36-37, figs. 7-9.

SYNTYPE: G83, one entire dissected specimen. Poor to fair (dried).

LOCALITY: Dee Bridge and Mount Wellington, Tasm., under logs and stones. G83 was collected by A. Morton in 1892, the locality being recorded as 'Tasmania'.

SPENCER NUMBER: C sp 4 T (p. 8).

NOTES: The specimen has not been previously recognized as type material.

Cryptodrilus narrensis Spencer, 1892

Proc. Roy. Soc. Vict. 4: 142, figs. 25-27, 71.

SYNTYPES: G53, dissected entire specimen and two complete undissected specimens. Poor.

LOCALITY: Narre Warren, Vict., very abundant under logs in wet weather, collected by C. French and Spencer, no date.

SPENCER NUMBER: C sp ? 15a (p. 7).

NOTES: There is no label recording presentation to the National Museum as part of the Spencer Collection, but other labels agree in form and writing with those of this collection. The Spencer Notes also refer to specimens registered as 'C sp ? Narrewarren' which it appears were used with the above specimens to prepare the type description. There are no specimens with this label.

Cryptodrilus officeri Spencer, 1895

Proc. Roy. Soc. Vict. 7: 44-45, figs. 28-30.

TYPE SPECIMENS: G80 is recorded on a catalogue card as having four specimens. However, the jar is now empty and the specimens are presumed lost.

LOCALITY: King River Valley, Tasm., collected by C. S. Officer in January 1894.

SPENCER NUMBER: C sp X 4 King R T (p. 8).

Cryptodrilus polynephricus Spencer, 1895

Proc. Roy. Soc. Vict. 7: 35-36, figs. 4-6.

LECTOTYPE: G41, a dissected entire specimen. Length in spirit 97 mm. Reasonable.

PARALECTOTYPE: G1436, four complete specimens formerly included with G41. Reasonable. G40, one entire dissected specimen. Bad (dried).

LOCALITY: Mt Wellington, Tasm. G41 was collected by A. Morton in July 1892. The type locality is extended by Spencer to include Hobart and Parattah. G40 contains two labels stating the localities as Mt Wellington by A. Morton in February 1892 and Parattah 1892.

SPENCER NUMBER: G40 and G41 both contain the same number, C sp 3 T (p. 8).

NOTES: The specimens were not previously recognized as type material. G40 includes two Spencer labels: C/sp 3 T — Parattah Feb./'92 and C sp 3 T (Mt Wellington) AM/'92.

Cryptodrilus queenslandica Spencer, 1900

Proc. Roy. Soc. Vict. 13: 41-42, figs. 31-33.

LECTOTYPE: G593, a dissected entire specimen. Length in spirit 270 mm. Reasonable.

PARALECTOTYPES: G1448, two complete dissected specimens, six complete specimens and six fragments, formerly included with G593. Reasonable. G68, five complete specimens and five fragments. Poor. G69, 11 complete specimens and two fragments. Fair. G70, one complete specimen. Fair.

LOCALITY: G593, Dundergan, near Maryborough, Qd., collected by P. R. A. O'Brien, no date. G68 was collected at Toowoomba, Qd., by D. Le Souef in October 1891. G69 was collected at Jandina, Qd., and G70 was collected at 'Scrub behind Gayndah', Qd., also in October 1891 presumably by D. Le Souef.

SPENCER NUMBERS: G593, Mega 1 X Q (p. 7). G68, G69 and G70, all under Crypto sp ? 5 Q (p. 7).

NOTES: The specimens have not previously been recognized as type material. G68, G69 and G70 are included with the type material as they are noted in Spencer's Notes (p. 7) as C sp ? 5 Q in MSS.

OTHER SPECIMENS: G79, Spencer number C sp 5 Q, is referred to as not in MSS (p. 10). It was found at Cooran, Qd., in October 1891 and contains two fragments in fair condition.

Cryptodrilus shephardi Spencer, 1900

Proc. Roy. Soc. Vict. 13: 40-41, figs. 28-30.

LECTOTYPE: G34, a dissected entire specimen. Length in spirit 157 mm. Reasonable.

PARALECTOTYPES: G1409, two complete specimens formerly included with G34. Reasonable.

LOCALITY: Horsham, Vict., collected by J. Shephard in October 1892.

SPENCER NUMBER: C sp la V (p. 7).

OTHER SPECIMENS: One jar, G74, from which the specimen is missing, bears the same Spencer number as the type material. It contained one specimen collected by D. Le Soeuf on 3/10/1892 at 'Mallee district in Dimboola, Victoria'. Although it would appear to have been included in the MSS, the type description does not refer to this collector or date.

Cryptodrilus tanjilensis Spencer, 1892

Proc. Roy. Soc. Vict. 4: 134-135, figs. 7-9, 65.

LECTOTYPE: G54, a dissected entire specimen. Length in spirit 160 mm. Good.

PARALECTOTYPES: G55, one dissected entire specimen, one complete specimen and one fragment. Reasonable to good.

LOCALITY: Tanjil Track, near the source of the Yarra River, Vict., collected November 1890.

SPENCER NUMBERS: G54, C sp 2 (p. 7). G55, C sp 9 (= sp 1). See note below.

NOTES: G54 was previously known to be type material. Other specimens apparently used in the MSS were 'C sp ? 9' and 'C sp 5a V' (p. 7). Much of the '5' in the latter number is missing but the remains suggest '5'. No specimens bearing either number are in the collection now. Another jar, G55, which is considered here to contain paralectotypes bears the label C sp 9 (= sp 1). It is possible that this is the missing specimen C sp ? 9. Whether this is so or not, the material appears to have been collected by Spencer at the type locality and was identified by him.

Cryptodrilus tesselatus Spencer 1892

Proc. Roy. Soc. Vict. 7: 40-41, figs. 16-18.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: Mount Olympus, Lake St. Clair, Tasm.

SPENCER NUMBER: C sp 7 T (p. 8).

Cryptodrilus victoriae Spencer, 1892

Proc. Roy. Soc. Vict. 4: 139-140, figs. 19-21, 69.

LECTOTYPE: G36, a large dissected entire specimen. Length in spirit 102 mm. Reasonable.

PARALECTOTYPES: G1410, a small complete specimen formerly included with G36. Reasonable.

LOCALITY: Warburton, Yarra Valley, Vict., collected by Dendy, no date.

SPENCER NUMBER: C sp ? 1 (p. 7).

OTHER SPECIMENS: Two jars in the collection are not considered to contain type specimens as their locality differs from that published, but the dates of collection are later. Some confusion is caused by Spencer's notes implying that they were used in the MSS. The specimens concerned are G71 (C sp 2X) which contains one entire dissected specimen, five complete specimens and three fragments in reasonable condition, and G73 (C sp X3) which contains two complete specimens in good condition. The former were collected at Mt Baw Baw in 1893 by Frost, and the latter were collected at Mount Arnold (collector unknown) in 1894. The Mount Arnold specimens have with them a note in Spencer's handwriting which does not appear to have been published previously. It is quoted here in full, but two words could not be read and three are questionable. 'Mt Arnold, Victoria near Marysville. Under and in rotten logs, length crawling 5¾ inches, setae . . . ., dorsal surface purplish *brown* (?) getting gradually lighter as pass back, ventral surface reddish in front of clitellum dull flesh colour behind. *Moves* (?) body about *like* (?) a perichaete when irritated. Clitellum not distinguishable when alive. Setae visible as white spots, body round not angular, male opening pink accessory in front of and behind. Accessory visible in living as white glandular eclipse with darker centre.

b. c. (Body cavity?) fluid white in spirit.'

Cryptodrilus victoriae var. a Spencer, 1892

Proc. Roy. Soc. Vict. 4: 140, not figured.

TYPE SPECIMENS OF VARIETY: G37, a dissected entire specimen and a long, median, post-clitellar fragment. Reasonable.

LOCALITY: Tanjil Track, Thompson Valley, Vict., collected November 1891.

SPENCER NUMBER: C sp ? 10 (p. 7).

NOTES: This may be a subspecies but must await revision to elucidate its status.

Cryptodrilus victoriae var b Spencer, 1892

Proc. Roy. Soc. Vict. 4: 140, not figured.

TYPE SPECIMENS OF VARIETY: G38, a dissected entire specimen and a long, median, post-clitellar fragment. Reasonable.

LOCALITY: Vict., 'exact locality not known'. This suggests that Spencer was not the collector, no date.

SPENCER NUMBER: C sp ? 7 V (p. 7).

NOTES: This may be a subspecies but must await revision to elucidate its status.

Cryptodrilus wellingtonensis Spencer, 1895

Proc. Roy. Soc. Vict. 7: 43-44, figs. 25-27.

SYNTYPE: G75, one entire dissected specimen. Poor (hardened).

LOCALITY: Hobart, Tasm. The specimen was collected by A. Morton in August 1892. The type description specifies Mt Wellington as the locality, while the label in Spencer's handwriting refers to Hobart.

SPENCER NUMBER: C sp 11 T (p. 8).

NOTES: G75 has not been previously recognized as type material. In the same

jar as the specimen is an unattached metal tag bearing the number 'TMS 1048'. Its significance is not known.

Cryptodrilus willsiensis Spencer, 1892

Proc. Roy. Soc. Vict. 4: 140-141, figs. 22-24, 70.

SYNTYPES: G52, five fragments, four of which have been dissected. Reasonable.

LOCALITY: Mt Wills, Vict., collected by T. Lidgey, no date.

SPENCER NUMBER: C sp 16 a ? (p. 7). The original Spencer label is no longer with the specimen.

Genus **Digaster** Perrier, 1872

Digaster brunneus Spencer, 1900

Proc. Roy. Soc. Vict. 13: 66, figs. 103-105.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: Gayndah, Qd., no collector or date.

SPENCER NUMBER: D sp 3 Q (p. 13).

Digaster gayndahensis Spencer, 1900

Proc. Roy. Soc. Vict. 13: 67, figs. 106-108.
Rec. Aust. Mus. 26: 96-98, figs. 3A-B.

LECTOTYPE: G99, a dissected entire specimen. Length in spirit 65 mm. Reasonable.

PARALECTOTYPE: G1449, a small dissected entire specimen formerly included with G99. Reasonable.

LOCALITY: From scrub behind Gayndah, Qd., collected in October 1891.

SPENCER NUMBER: Digaster sp ? 1 Q (p. 13), G99). D sp ? 2 Q (p. 13).

NOTES: Jamieson (1963) worked with these specimens and noted 'the dissected specimen is the holotype and the undissected specimen a paratype'. However, as Spencer did not designate a primary type, no *holotype* can exist. In his notes Spencer records both 'Digaster sp ? 1 Q' and 'Digaster sp ? 2 Q' as being this species. G100 bears the Spencer number 'Digaster sp ? 2 Q' but Jamieson records G100 as the type of *Digaster minor* (see below) and records a Spencer number of 'Digaster sp. 2 Q'. The Spencer notes were not available to him and it is likely that he overlooked or did not know the significance of the question mark in the number. In the Spencer notes (p. 13) the number for *D. minor* is M sp 2 Q. Specimens with this number are not present in the collection. Jamieson assumes G100 to be type material of *D. minor* and uses it to extend the type description and reinforce it as a separate species. In view of the newly rediscovered Spencer notes, this must now be doubted and G100 be considered as the questionably syntype material of *Digaster gayndahensis*.

Digaster minor Spencer, 1900

Proc. Roy. Soc. Vict. 13: 65-66, figs. 100-102.
Rec. Aust. Mus. 26: 105-106, fig. 6.

TYPE SPECIMEN: None present. Jamieson records G100 as type material of this species but it is now considered the type material of *Digaster gayndahensis* (see above).

LOCALITY: Gayndah, Qd., no date or collector.

SPENCER NUMBER: M sp 2 Q (p. 13). G100 *Digaster* sp ? 2 Q.

Genus **Diplotrema** Spencer, 1900
Diplotrema fragilis Spencer, 1900

Proc. Roy. Soc. Vict. 13: 31-32, figs. 4-6.

SYNTYPES: G31, two complete specimens and two fragments. Fair. G101, three complete specimens. Fair.

LOCALITY: G31, Gayndah, Qd., collected September 1891. G101, Cooran, Qd., collected October 1891.

SPENCER NUMBER: G31, Crypto sp 6 Q (p. 7). G101, C ? sp ? 6 Q (p. 15).

NOTES: The specimens were not previously known as type material.

Genus **Diporochaeta** Beddard, 1890
Diporochaeta arnoldi Spencer, 1900

Proc. Roy. Soc. Vict. 13: 61-62, figs. 88-90.

LECTOTYPE: G203, a dissected entire specimen. Length in spirit 60 mm. Reasonable.

PARALECTOTYPES: G1411, seven complete specimens formerly included with G203. Reasonable.

LOCALITY: Mt Arnold near Marysville, Vict., under logs and sheets of bark in a small swamp. Collected February 1894.

SPENCER NUMBER: Peri sp X 5 (p. 29).

NOTES: An original descriptive note is included with the lectotype: 'Mt Arnold, near Marysville, Victoria. Length 3 ins. dull purplish brown dorsally, darker anteriorly. Clitellum dull yellow-brown. Setae fairly clear. Dirty dark flesh colour ventrally, extent shows through. Under log. Male pore visible as slit on papilla with 2 other papillae to outer side. b.c. fluid white. Feb./94.'

Diporochaeta davallia Spencer, 1900

Proc. Roy. Soc. Vict. 13: 52-53, figs. 61-63.

LECTOTYPE: G121, a dissected entire specimen. Length in spirit 200 mm. Reasonable.

PARALECTOTYPE: G1412, one complete specimen and one posterior fragment formerly included with G121. Reasonable.

LOCALITY: Fern Tree Gully, Vict., no date.

SPENCER NUMBER: 'c' or 'Diprochaeta c Fern Tree Gully' (p. 16).

OTHER SPECIMENS: G587 contains one dissected specimen in reasonable condition, but without information.

Diporochaeta euzona Spencer, 1900

Proc. Roy. Soc. Vict. 13: 55-56, figs. 70-72.

LECTOTYPE: G120, a dissected entire specimen. Length in spirit 160 mm. Reasonable.

PARALECTOTYPES: None, but the type description suggests that more than one specimen was collected.

LOCALITY: Warrandyte, Vict., collected by C. M. Maplestone, no date.

SPENCER NUMBER: 3° (p. 16).

Diporochaeta frosti Spencer, 1900

Proc. Roy. Soc. Vict. 13: 62-63, figs. 91-93.

LECTOTYPE: G117, a dissected, entire specimen. Length in spirit 45 mm. Reasonable.

PARALECTOTYPES: None.

LOCALITY: Mt Baw Baw, Vict., collected by C. Frost in January 1893.

SPENCER NUMBER: Peri sp X 8 (p. 16).

NOTES: The specimen has not previously been recognized as type material.

Diporochaeta grandis Spencer, 1900

Proc. Roy. Soc. Vict. 13: 63-64, figs. 94-96.

TYPE SPECIMENS: None, presumed lost.

LOCALITY: Upper Endeavour River, Qd., collected by C. French and D. Le Soeuf, no date.

SPENCER NUMBER: Not known.

OTHER SPECIMENS: G184 records material collected at Cairns, Qd., and donated to the National Museum 24 April 1909. This material is now missing and presumed lost.

Diporochaeta lindti Spencer, 1900

Proc. Roy. Soc. Vict. 13: 54-55, figs. 67-69.

TYPE SPECIMENS: None, presumed lost.

LOCALITY: Black Spur, Vict., found under logs at 2,000 ft, no date.

SPENCER NUMBER: Peri sp a (p. 16).

Diporochaeta manni Spencer, 1900

Proc. Roy. Soc. Vict. 13: 60-61, figs. 85-87.

LECTOTYPE: G118, a dissected entire specimen. Length in spirit 74 mm. Reasonable.

PARALECTOTYPES: G1423, five complete specimens and three fragments formerly included with G118. Reasonable.

LOCALITY: S. Warragul, Vict., collected near a creek in black alluvial soil by W. Mann, July 1892.

SPENCER NUMBER: Peri sp X 10 (p. 29).

NOTES: The specimens have not previously been recognized as type material.

Diporochaeta maplestoni Spencer, 1900

Proc. Roy. Soc. Vict. 13: 64-65, figs. 97-99.

SYNTYPES: G122, several fragments, probably no longer determinable. Bad.

LOCALITY: Warrandyte, Vict., collected by C. M. Maplestone, no date.

SPENCER NUMBER: 1° Warrandyte (p. 16).

NOTES: The specimens were questionably regarded as type material but are now considered original type material.

Diporochaeta mediocincta Spencer, 1900

Proc. Roy. Soc. Vict. 13: 53-54, figs. 64-66.

LECTOTYPE: G124, a dissected entire specimen. Length in spirit 55 mm. Reasonable.

PARALECTOTYPES: None, although the description suggests more than one specimen was found.

LOCALITY: S. Warragul, Vict., collected by W. Mann, July 1892.

SPENCER NUMBER: Peri sp 1 a V (pp. 16, 29).

Diporochaeta nemoralis Spencer, 1900

Proc. Roy. Soc. Vict. 13: 59-60, figs. 82-84.

TYPE SPECIMENS: None, presumed lost.

LOCALITY: Neerim, Vict., found under logs in the eucalypt forests, no date.

SPENCER NUMBER: Peri sp X 13 (pp. 16, 29).

Diporochaeta notabilis Spencer, 1900

Proc. Roy. Soc. Vict. 13: 57-58, figs. 76-78.

TYPE SPECIMENS: None, presumed lost.

LOCALITY: Dimboola, Vict., no date.

SPENCER NUMBER: Peri sp 2 a V (pp. 16, 29).

Diporochaeta richardi Spencer, 1900

Proc. Roy. Soc. Vict. 13: 58-59, figs. 79-81.

LECTOTYPE: G220, a dissected entire specimen. Length in spirit 93 mm. Reasonable.

PARALECTOTYPE: G1413, one complete specimen formerly included with G220. Reasonable.

LOCALITY: Loch, Vict., collected July 1891.

SPENCER NUMBER: Peri sp 13 (pp. 16, 29).

Diporochaeta telopea Spencer, 1900

Proc. Roy. Soc. Vict. 13: 56-57, figs. 73-75.

TYPE SPECIMENS: G119, not present, presumed lost.

LOCALITY: Waratah Bay, Vict., collected by W. Mann, January 1891.

SPENCER NUMBER: Peri sp ? 34 (pp. 16, 29).

NOTES: A filing card indicates that a single specimen, known to be the type, was in the National Museum under G119.

Genus Fletcherodrilus Michaelson, 1891
Fletcherodrilus unicus major Spencer, 1900

Proc. Roy. Soc. Vict. 13: 44, (no fig.).

LECTOTYPE: G116, a dissected entire specimen. Length in spirit 215 mm. Reasonable.

PARALECTOTYPES: G1437, two dissected entire specimens and two fragments, formerly included with G116. Reasonable.

LOCALITY: Gayndah, Qd., collected from cedar scrub October 1891.

SPENCER NUMBER: Crypto sp 1 Q (p. 9).

OTHER SPECIMENS: G115 contains one dissected fragment, two entire specimens and five fragments in good condition from 'Queensland'.

Genus **Megascolex** Templeton, 1844

Megascolex andersoni Spencer, 1900

Proc. Roy. Soc. Vict. 13: 44-45, figs. 37-39.

LECTOTYPE: G105, a dissected entire specimen. Length in spirit 110 mm. Reasonable.

PARALECTOTYPES: G1414, five complete specimens, formerly included with G105. Reasonable.

LOCALITY: Gerangamete, Vict., no date. The original label reads 'Kerangamete'.

SPENCER NUMBER: Peri sp X 11 (pp. 22, 29).

Megascolex fardyi Spencer, 1900

Proc. Roy. Soc. Vict. 13: 46-47, figs. 43-45.

SYNTYPES: G107, three complete specimens. Reasonable.

LOCALITY: Heathcote Range, Vict., collected at 900 ft by T. Lidgey, no date.

SPENCER NUMBER: Peri sp 1 X (pp. 22, 29).

NOTES: These are not the type specimens of the MSS as the latter were collected at Heathcote by J. H. Fardy and Spencer. However, it is reasonable to assume they are syntypes as they are from the type locality, identified by Spencer and the Spencer Number agrees with that of the original material. The latter appears to be lost as there is no record of it in the National Museum.

Megascolex illidgei Spencer, 1900

Proc. Roy. Soc. Vict. 13: 50-51, figs. 58-60.

SYNTYPE: G110, one entire specimen. Reasonable.

LOCALITY: Gayndah, Qd., collected on September 23 1891. The type description records Cooran, Qd., as the locality.

SPENCER NUMBER: Peri s ? Q (pp. 22, 29).

NOTES: This specimen has not previously been recognized as a type and is recorded here as a questionable type material because of the locality.

Megascolex larpentensis, 1900

Proc. Roy. Soc. Vict. 13: 45-46, figs. 40-42.

LECTOTYPE: G106, a dissected entire specimen. Length in spirit 55 mm. Reasonable.

PARALECTOTYPES: G1415, five complete specimens, formerly included with G106. Reasonable.

LOCALITY: Gerangamete, Vict., collected by R. Anderson in June 1894. The original label is spelt 'Kerangamete'.

SPENCER NUMBER: Peri sp X 12 (pp. 22, 29).

NOTES: The museum filing card notes '8 specs' which suggest that some of the material has been lost.

Megascolex lobulatus Spencer, 1900

Proc. Roy. Soc. Vict. 13: 48-49, figs. 52-54.

LECTOTYPE: G229, one dissected specimen in two parts. Length in spirit 45 mm. Reasonable.

PARALECTOTYPES: G1432, nine complete specimens and two fragments formerly included with G229. Reasonable.

LOCALITY: Nar-Nar-Goon, Vict., collected by H. Giles in October 1892.

SPENCER NUMBER: Peri sp X 6 (pp. 22, 29).

NOTES: The specimens have not previously been recognized as type material.

Megascolex minor Spencer, 1900

Proc. Roy. Soc. Vict. 13: 49-50, figs. 55-57.

SYNTYPES: G103, seven complete specimens and one fragment. Poor (dried). G104, Several fragments. Poor (fragmented).

LOCALITY: Cooran, Qd., collected in October 1891.

SPENCER NUMBER: Peri sp 3 Q (p. 29). Both sets of specimens bear the same number and information.

NOTES: The specimens have not previously been recognized as type material. Further type material 'Peri sp 7 Q' has not been found in the National Museum and is presumed lost. The filing card for G103 records '14 specs'. The whereabouts of the missing specimens is not known, but are presumably also lost. The number originally present in G104 was three, which are now indeterminable.

OTHER SPECIMENS: G102 contains two poor specimens bearing the Spencer number 'Peri sp 3 ? Q', collected from Gayndah in 1891.

Megascolex montanus Spencer, 1900

Proc. Roy. Soc. Vict. 13: 48, figs. 49-51.

LECTOTYPE: G109, a dissected anterior fragment and a dissected posterior fragment, which appear to be from the same specimen. Reasonable.

PARALECTOTYPE: G1416, one complete specimen, formerly included with G109. Reasonable.

LOCALITY: Mount Baw Baw, Vict., collected by C. Frost in January 1893.

SPENCER NUMBER: Peri sp X 7 (pp. 22, 29).

Megascolex pritchardi Spencer, 1900

Proc. Roy. Soc. Vict. 13: 47, figs. 46-48.

LECTOTYPE: G108, a dissected entire specimen. Length in spirit 58 mm. Reasonable.

PARALECTOTYPES: G1417, six complete specimens and a short fragment formerly included with G108. Reasonable.

LOCALITY: Mornington, Vict. An original label notes the locality as 'Mornington?'. The specimens were collected by G. B. Pritchard in 1892.

SPENCER NUMBER: Peri sp X 2 (pp. 22, 29).

NOTES: The museum filing card notes '11 specs' which suggests that some of the material has been lost.

Megascolex terangiensis Spencer, 1900

Proc. Roy. Soc. Vict. 13: 51-52, (not figured).

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: Terang, Vict., no date.

SPENCER NUMBER: Peri sp ? 33 (p. 29).

Genus **Megascolides** McCoy, 1878

Megascolides attenuatus Spencer, 1892

Proc. Roy. Soc. Vict. 4: 155, figs. 61-62, 82.

LECTOTYPE: G176, an undissected specimen. Length in spirit 128 mm. Good.

PARALECTOTYPES: G1438, two dissected specimens, one complete specimen and eight fragments, formerly included with G176. Fair to good.

LOCALITY: Warragul, Vict., collected on 22nd April 1888 'from gullies some distance underground and found with other species of *Megascolides*'.

SPENCER NUMBER: Mega sp ? 8 (p. 23).

NOTES: The Spencer number is not with the specimen nor is it with any other specimen in the collection. A label in Spencer's hand-writing bears the name.

Megacolides bassanus Spencer, 1895

Proc. Roy. Soc. Vict. 7: 46-47, figs. 34-36.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: King Island, Bass Strait, Tasm., no date.

SPENCER NUMBER: Mega sp ? 3-2 (p. 23).

Megascolides cameroni Spencer, 1892

Proc. Roy. Soc. Vic. 4: 144-145, figs. 34-36, 74.

LECTOTYPE: G167, an undissected entire specimen. Length in spirit 215 mm. Good.

PARALECTOTYPES: G1439, six dissected fragments which may be from a single specimen and one complete specimen, formerly included with G167. Good.

LOCALITY: Croajingolong, Vict., collected in January 1889.

SPENCER NUMBER: Mega sp ? (1) (p. 23).

NOTES: A label in the jar indicates type material. This is over-looked on the filing card.

Megascolides diaphanus Spencer, 1900

Proc. Roy. Soc. Vict. 13: 32-34, figs. 7-9.

SYNTYPES: G179, two complete worms and several fragments, some of which have been dissected. Fair.

LOCALITY: West Dimboola, Vict., near Mission Station. The specimens were probably collected in October 1892. The type description (p. 34) notes locality thus: 'Near to the Ebeneezer Mission Station, Mallee District, Victoria. Found in very moist earth on flats close to the River Wimmera . . . . The Flats on which the worm was found are liable to be flooded at rainy seasons but at other times perfectly dry', while the label in Spencer's writing notes the locality: 'Smaller worms

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from side of pool near station (Dimboola) many of them from mud under the water, all in damp clayey earth'.

SPENCER NUMBER: C sp 4a V (p. 7). Missing from the jar.

Megascolides eucalypti Spencer, 1900

Proc. Roy. Soc. Vict. 13: 35-36, figs. 13-15.

LECTOTYPE: G185, a dissected entire specimen. Length in spirit 140 mm. Reasonable.

PARALECTOTYPES: G1440, three dissected specimens, eight complete specimens and one long fragment, formerly included with G185. Reasonable.

LOCALITY: Noojee, South Warragul, Vict., no date.

SPENCER NUMBER: Mega sp XI (p. 23).

NOTES: The specimens have not been previously recorded as type material.

Megascolides hulmei Spencer, 1892

Proc. Roy. Soc. Vict. 4: 147-148, figs. 40-42, 76.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: Dandenong Ranges, Vict., collected by J. Hulme, no date.

SPENCER NUMBER: Mega sp ? 7 (p. 23).

OTHER SPECIMENS: G165, collected by C. Pioneer in 1891, is also missing and is presumed lost. Although it had been given the same Spencer number as the type, it is not type material as its locality is recorded as Victoria, and the collector differs.

Megascolides incertus Spencer, 1892

Proc. Roy. Soc. Vict. 4: 151-152, figs. 52-54, 80.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: Vict., exact locality not known.

SPENCER NUMBER: Not known.

OTHER SPECIMENS: G174 contains many specimens. The condition is poor as the specimens are generally fragmenting. There is no further information available. This could be type material. G175, one dissected specimen and two entire specimens from Black Spur, Vict., collected October 1895. This is in good condition but could not be type material.

Megascolides insignis Spencer, 1892

Proc. Roy. Soc. Vict. 4: 146-147, figs. 37-39, 75.

SYNTYPES: G166, two dissected specimens, two entire specimens and two fragments. Reasonable.

LOCALITY: (From the type description) Dandenong Ranges, Vict., collected by J. Hulme, no date. Specimens G166 were collected by C. Pioneer on 30 October 1890, the locality being given as 'Victoria'.

SPENCER NUMBER: Mega sp ? 3 (p. 23).

NOTES: No specimens have been previously recognized as type material. Specimens G166 were not collected by Hulme and may not have come from the Dandenong Ranges, but they have been identified by Spencer and appear to have been

considered in the preparation of the MSS as they bear the appropriate Spencer number.

Megascolides manni Spencer, 1892

Proc. Roy. Soc. Vict. 4: 149-150, figs. 46-48, 78.

LECTOTYPE: G158, a dissected entire specimen. Length in spirit 250 mm. Good.

PARALECTOTYPES: G1441, a dissected entire specimen, one complete specimen and one fragment, formerly included with G158. Good.

LOCALITY: S. Warragul, Vict., collected by W. Mann in July 1891.

SPENCER NUMBER: Mega sp ? 13 (p. 23).

Megascolides manni variabilis Spencer, 1892

Reference: as for stem species.

SYNTYPES: G163, a number of fragments. Bad (hardened, shrivelled, black fragments).

LOCALITY: S. Warragul, Vict., collected by W. Mann, July 1891.

SPENCER NUMBER: Mega sp ? 12 (p. 23).

OTHER SPECIMENS: G164, collected in S. Warragul, Vict., by W. Mann in July 1892; contains 15 complete specimens and four fragments.

Megascolides obscurus Spencer, 1892

Proc. Roy. Soc. Vict. 4: 148-149, figs. 43-45, 77.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: Dandenong Ranges, Vict., collected by J. Hulme, no date.

SPENCER NUMBER: Mega sp ? 4 (p. 23).

Megascolides punctatus Spencer, 1900

Proc. Roy. Soc. Vict. 13: 37-38, figs. 19-21.

LECTOTYPE: G180, an undissected entire specimen. Length in spirit 145 mm. Good.

PARALECTOTYPES: G1442, two dissected entire specimens, eight complete specimens and three fragments, formerly included with G180. Reasonable to good.

LOCALITY: Warrandyte, Vict., no date.

SPENCER NUMBER: Mega 2° (p. 23).

Megascolides roseus Spencer, 1892

Proc. Roy. Soc. Vict. 4: 153-154, figs. 58-60, 81.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: Warragul, Vict., found by Spencer about one foot underground, no date.

SPENCER NUMBER: Mega sp 8a (p. 23).

Megascolides simsoni Spencer, 1895

Proc. Roy. Soc. Vict. 7: 45-46, figs. 31-33.

LECTOTYPE: G182, an entire undissected specimen. Length in spirit 45 mm. Good.

PARALECTOTYPES: None present.

LOCALITY: Launceston, Tas., collected by A. Simson in February 1892.

SPENCER NUMBERS: Mega sp 1 Tas., C sp 2 Tas. (p. 23).

NOTES: The specimen has not previously been recognized as a type but bears the Spencer number C sp 2 Tas.

Megascolides sinuosus Spencer, 1892

Proc. Roy. Soc. Vict. 4: 152-153, figs. 55-57.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: Dandenong Ranges, Vict., collected by J. Hulme, no date.

SPENCER NUMBER: Mega sp ? 6 (p. 23).

OTHER SPECIMENS: G177 contains one specimen and numerous fragments in very bad condition. They were collected by C. Pioneer in October 1890 and bear the Spencer number of the type material. They could therefore have been considered in preparation of MSS but no locality is recorded.

Megascolides steeli Spencer, 1900

Proc. Roy. Soc. Vict. 13: 34-35, figs. 10-12.

LECTOTYPE: G168, an entire, dissected specimen. Length in spirit 125 mm. Reasonable.

PARALECTOTYPES: G1418, two fragments, formerly included with G168. Reasonable.

LOCALITY: Warragul, Vict., collected by T. Steel in April 1892.

SPENCER NUMBER: Mega sp la V (p. 23).

Megascolides tisdalli Spencer, 1900

Proc. Roy. Soc. Vict. 13: 36-37, figs. 16-18.

LECTOTYPE: G178, an entire dissected specimen. Length in spirit 85 mm. Reasonable.

PARALECTOTYPES: None present.

LOCALITY: Walhalla, Vict., collected by H. R. Hogg in July 1892.

SPENCER NUMBER: C sp 2a V (pp. 7, 23).

NOTES: The filing card refers to 'specs.'. Any other specimens that may have been present are now missing. The position of the gizzard is incorrectly noted in the text (p. 37) due to a misprint. Fig. 17 is correct in this respect.

Megascolides victoriensis Spencer, 1892

Proc. Roy. Soc. Vict. 4: 151, figs. 49-51, 79.

SYNTYPES: G181, many fragments. Very bad.

LOCALITY: Vict., collector unknown, January 1890. Spencer wrote: 'Victoria (Locality?)' and 'Left at Uni. at time of A.A.A.S. Jan./90'.

SPENCER NUMBER: Mega sp 11a (p. 23).

Megascolides volvens Spencer, 1900

Proc. Roy. Soc. Vict. 13: 39-40, figs. 25-27.

SYNTYPES: G590, three complete specimens. Bad. (dried).

LOCALITY: (From description) River Yarra, Vict., collected by C. Frost, no date. G590, Yarra Track, Vict., collected by E. Anderson, no date.

SPENCER NUMBER: C 3a V (pp. 7, 23).

Megascolides warragulensis Spencer, 1900
Proc. Roy. Soc. Vict. 13: 38-39, figs. 22-24.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: S. Warragul, Vict., no date.

SPENCER NUMBER: Mega sp X2 (p. 23).

Genus Perichaeta Schmarda, 1861
Perichaeta alsophila Spencer, 1893
Proc. Roy. Soc. Vict. 5: 17-19, figs. 10-12.

SYNTYPES: G291, one dissected entire specimen, two complete specimens and two fragments. Poor (hardened and shrivelled).

LOCALITY: Fern Tree Gully, Vict., collected March 1892.

SPENCER NUMBER: Peri sp 32 (p. 28).

Perichaeta copelandi Spencer, 1893
Proc. Roy. Soc. Vict. 5: 2-3, figs. 52-54, 76.

LECTOTYPE: G186, a dissected entire specimen. Length in spirit 83 mm. Good.

PARALECTOTYPES: G1443, two dissected entire specimens, two complete specimens and two fragments, formerly included with G186. Good. G187, three complete specimens and one fragment. Good. G188, three complete specimens and three fragments. Reasonable. G189, one large undissected specimen. Reasonable. G190, three fragments, one dissected. Reasonable.

LOCALITY: Warragul Dist., Vict. G187 collected Warragul, no date; G188 collected Warragul (?), no date; G189 collected Warragul, September 1892; G190 collected Loch, S. Gippsland, July 1891; G186 collected Ellinbank, S. Warragul, July 1891; G186 collected by W. Mann; the remainder are assumed to have been collected by Spencer.

SPENCER NUMBERS: Peri sp? 6 = G190, Peri sp? 8 = G186, Peri sp? 15 = G187 and G188 (p. 28). No number is included with G189.

NOTES: None of the material has been previously recognized as type material. Four jars bear Spencer numbers which suggest that they have been used in the preparation of the MSS. Three specimens are questionable types because of the locality. G189, while not having a Spencer number (probably lost), was collected from the type locality, identified by Spencer and has (included in the jar) the following note by Spencer: 'Dorsal surface purple. Clitellum pink, very distinct. Ventral surface dull cream. Setae distinct, especially in front of clitellum as white spots. Length crawling, 8 inches, width ¼ inch.'

OTHER SPECIMENS: G192 includes two complete specimens and two fragments collected in the type locality, no date or collector being recorded. G191 contains one specimen and a fragment with no locality, date or collector. G206 contains one dissected specimen from S. Warragul, no date or collector recorded.

Perichaeta dendyi Spencer, 1893

Proc. Roy. Soc. Vict. 5: 12-13, figs. 49-51, 77.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: Healesville, Vict., collected by A. Dendy, no date.

SPENCER NUMBER: P sp ? 20 (p. 28).

Perichaeta dicksonia Spencer, 1893

Proc. Roy. Soc. Vict. 5: 16-17, figs. 7-9.

SYNTYPE: G221, one dissected anterior fragment. Poor (badly hardened).

LOCALITY: G221 was collected from Dandenong by Hill on March 9th, 1892. The type locality is Fern Tree Gully, under logs, no date or collector recorded.

SPENCER NUMBER: P sp 31 ? (p. 28). This number is not with specimen G221 nor has it been found with any other specimen in the collection.

Perichaeta dilwynnia Spencer, 1895

Proc. Roy. Soc. Vict. 7: 50-51, figs. 46-48.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: Dee Bridge, Tasm., no date.

SPENCER NUMBER: P sp 4 T (p. 27).

Perichaeta dubia Spencer, 1893

Proc. Roy. Soc. Vict. 5: 14-15, figs. 46-48, 67.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: S. Warragul, Vict., collected by W. Mann, no date.

SPENCER NUMBER: Peri sp ? 18 (p. 28).

Perichaeta fielderi Spencer, 1893

Proc. Roy. Soc. Vict. 5: 19-20, figs. 19-21, 64.

LECTOTYPE: G224, a dissected entire specimen. Length in spirit 100 mm. Good.

PARALECTOTYPES: G1444, two dissected specimens and one fragment, formerly included with G224. Good. G222, two complete specimens. Good. G223, two complete specimens and nine fragments. Good. G225, three dissected entire specimens, 18 complete specimens and 11 fragments. Good.

LOCALITY: Spencer named three localities, all in the same general area of Victoria:

1. Fern Tree Gully, collected by W. Fielder and W. Mann, May 1891 (G224).
2. Narre Warren, collected July 1891 (G223, G225), also by C. French and Spencer.
3. Sassafras Gully, collected by J. Shephard, November 1891 (G222).

SPENCER NUMBER: Peri sp 3, Peri sp ? 9 (p. 28). G224 bears the number 'Peri sp ? 3' which is probably synonymous with 'Peri sp 3' while the number with G225 is now missing. G222 and G223 have no Spencer number.

NOTES: The specimens have not previously been regarded as type material. There is slight doubt in one, due to '?' in the Spencer number and in the others due to the absence of Spencer numbers. Spencer is known to have collected type material from Narre Warren at about the time recorded, and Shephard from Sassafras Gully. It is probable that this is the missing material 'Peri sp ? 9'.

OTHER SPECIMENS: G226 has two entire dissected specimens, two whole specimens and a fragment. They are in reasonable condition and were collected by Hennell in July 1892 at Dandenong Creek, Vict. G227 contains one entire dissected specimen and seven fragments with no data.

Perichaeta frenchii Spencer, 1893

Proc. Roy. Soc. Vict. 5: 9-10, figs. 31-33, 79.

LECTOTYPE: G210, one dissected entire specimen. Length in spirit 70 mm. Reasonable.

PARALECTOTYPES: G212, one dissected entire specimen, 15 complete specimens and seven fragments. Poor. G1445, one entire dissected specimen, six complete specimens and 11 fragments, formerly included with 210. Reasonable.

LOCALITY: The type locality is given as Loch, S. Gippsland, the collector is assumed to be Spencer, no date recorded; Narre Warren, collectors Spencer and C. French, no date; Waratah Bay, collector Mann, no date. Localities of specimens in the collection are as follows: G212 Loch, S. Gippsland, Vict., collected July 1891; G210 Narre Warren, S. Gippsland, Vict., collected July 1892.

SPENCER NUMBER: Peri sp ? 21 (p. 28). G212 bears this number. G210 has the number 'Peri sp? 17 Narre Warren', not recorded in the Spencer notes as 'in MSS'.

NOTES: The specimens have not previously been known to be type material. While the Spencer notes suggest that G212 was the material used (at least in part) for preparation of the MSS, it would appear reasonable, from the broad type locality, that he also made use of the material in G210. The latter specimens assume some importance as they were collected and identified by Spencer from the type locality, and they are the only remaining material in reasonable condition from this locality.

OTHER SPECIMENS: G209 contains one specimen in reasonable condition from Gembrook, Vict., collected by D. le Souef, March 1892. G213 contains several specimens in very bad condition, and said to be immature, but no other data is included.

Perichaeta frosti Spencer, 1893

Proc. Roy. Soc. Vict. 5: 20-21, figs. 13-15, 71.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: Croajingolong, E. Gippsland, Vict., no date.

SPENCER NUMBER: Peri sp ? 4 (p. 28).

Perichaeta goonmurk Spencer, 1893

Proc. Roy. Soc. Vict. 5: 21-23, figs. 16-18.

LECTOTYPE: G228, a dissected entire specimen. Length in spirit 95 mm. Reasonable.

PARALECTYPES: G1421, one complete specimen and one fragment formerly included with G228. Reasonable.

LOCALITY: The description notes: 'Locality Croajingolong, Vict. Under logs at head of gully, elevation about 3500 feet'. Collected January 1889.

SPENCER NUMBER: Peri sp ? 2 (p. 28).

Perichaeta hallii Spencer, 1893

Proc. Roy. Soc. Vict. 5: 7-8, figs. 40-42, 69.

SYNTYPE: G205, one specimen. Very bad.

LOCALITY: Mt Barker, near Castlemaine, Vict., collected by T. S. Hall, no date.

SPENCER NUMBER: Peri sp ? 32 (p. 28).

NOTES: The museum filing card records '4? specs'. If there were four, three of the specimens are now lost.

OTHER SPECIMENS: G201 contains two entire dissected specimens and four complete specimens in reasonable condition collected at Derrinal, Vict., collector and date unknown. G202 contains one entire dissected specimen and eight complete specimens collected at Big Hill, W. Bendigo, Vict., by Spencer (?) August 1892. They are in good condition. G204 contains a fragmented specimen collected at Maldon, Vict., by D. le Soeuf. The Spencer number is 'Peri sp ? 33' but the specimen is of little value.

Perichaeta hoggii Spencer, 1893

Proc. Roy. Soc. Vict. 5: 6-7, figs. 28-30, 80.

LECTOTYPE: G199, a dissected entire specimen. Length in spirit 95 mm. Good.

PARALECTOTYPES: G1446, eight complete specimens formerly included with G199. Good. G198, 11 complete specimens and three fragments. Reasonable. G200, one dissected entire specimen and four complete specimens. Reasonable.

LOCALITY: G198 and G199 were collected from Mt. Macedon, Vict., by Spencer and H. R. Hogg, June 1891. G200 were collected from Healesville, Vict., by Dendy in January-February 1892. The type material was collected by Dendy but it is not certain that this is the same as specimens in G200.

SPENCER NUMBER: Peri sp ? 29 (= G198 and G199), Peri sp ? 19 (= Healesville specimens ?) (p. 28), Peri sp ? 26 (= G200) (Not listed).

NOTES: The specimens have not been previously recognized as type material. Healesville material bearing either of the above Spencer numbers recorded for the MSS is no longer in the collection and is presumed lost. However G200 bearing the number 'Peri sp ? 26' is included here as type material because it was obtained by the original collector in the same locality about the same time.

Perichaeta irregularis Spencer, 1895

Proc. Roy. Soc. Vict. 7: 53-54, figs. 52-54.

LECTOTYPE: G288, a dissected entire specimen. Length in spirit 90 mm. Reasonable.

PARALECTOTYPES: None present.

LOCALITY: King River, Tasm., collected by C. G. Officer in January 1894.

SPENCER NUMBER: Peri sp. X 15 (p. 28).

Perichaeta lateralis Spencer, 1893

Proc. Roy. Soc. Vict. 5: 11-12,, figs. 55-58.

LECTOTYPE: G214, a dissected entire specimen. Length in spirit 80 mm. Good.

PARALECTOTYPES: G1424, nine complete specimens and one fragment, formerly included with G214. Good.

LOCALITY: Castlemaine, Vict., collected by T. S. Hall, no date. Spencer records a second syntype locality—Goulburn Valley, Tallarook, collector A. H. S. Lucas, no date.

SPENCER NUMBER: Peri sp 12 ? (p. 28). Specimens G214 have the Spencer number 'Peri sp 12' which is not recorded in the notes.

NOTES: There is some doubt that these specimens are the original types, although the Spencer number may be an error. They were collected by the original collector in the type locality and identified by Spencer.

OTHER SPECIMENS: G215 contains one dissected entire specimen and three complete specimens in good condition collected at Mt Barker, Castlemaine, Vict., by T. S. Hall, no date or Spencer number recorded.

Perichaeta lochensis Spencer, 1893

Proc. Roy. Soc. Vict. 5: 13-14, figs. 1-3.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: Loch, S. Gippsland, Vict., collected by Spencer, no date.

SPENCER NUMBER: Peri sp ? 28 (p. 28).

Perichaeta moroea Spencer, 1895

Proc. Roy. Soc. Vict. 7: 49, figs. 40-42.

SYNTYPE: G292, one dissected entire specimen. Poor (hardened).

LOCALITY: Lake St Clair district, Tasm., collected January 1893.

SPENCER NUMBER: P sp 2 T (p. 27).

Perichaeta obscura Spencer, 1893

Proc. Roy. Soc. Vict. 5: 3-5, figs. 4-6, 70.

LECTOTYPE: G195, a dissected entire specimen. Length in spirit 68 mm. Good.

PARALECTOTYPES: G1447, one entire specimen and two fragments, formerly included with G195. Good. G196, eight complete specimens and three fragments. Good. G197, one complete specimen. Good.

LOCALITY: Warragul, Vict. The specimens G195 were collected by Spencer, (no date), G196 collected February 1892, and G197 collected S. Warragul by W. Mann, 1892.

SPENCER NUMBER: Peri sp ? 22 (p. 28).

NOTES: The specimens have not been previously known as type material.

Perichaeta richea Spencer, 1895

Proc. Roy. Soc. Vict. 7: 49-50, figs. 43-45.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: Mt Olympus, Tasm., collected under logs in a beech forest, no date.

SPENCER NUMBER: P sp 3 T (p. 27).

Perichaeta rubra Spencer, 1893

Proc. Roy. Soc. Vict. 5: 8-9, figs. 25-27.

SYNTYPES: G207, one dissected entire specimen, two complete specimens and two fragments. Reasonable.

LOCALITY: Tallarook, Vict., collected by A. H. S. Lucas. G207 does not include the original label with collector's name.

SPENCER NUMBER: Peri sp V (p. 28). This number is not with specimen G207, nor is it with any other specimen in the collection.

NOTES: This is questionable type material. The original label (including collector and Spencer number) is no longer with the specimens. While there is reasonable probability that this is the original type material, it cannot be considered certain in the absence of the original label.

OTHER SPECIMENS: G208 contains two complete specimens and two fragments in reasonable condition, collected by W. Shephard in October 1892.

Perichaeta scolecoidea Spencer, 1895

Proc. Roy. Soc. Vict. 7: 51-52, figs. 49-51.

LECTOTYPE: G290, a dissected entire specimen. Length in spirit 28 mm. Reasonable.

PARALECTOTYPES: G1422, two complete specimens formerly included with G290. Reasonable.

LOCALITY: King River Valley, Tasm., collected by C. G. Officer, January 1894, and recorded as being very abundant.

SPENCER NUMBER: P sp X 14 T (p. 28).

Perichaeta steelii Spencer, 1893

Proc. Roy. Soc. Vict. 5: 10-11, figs. 37-39.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: Woodend, Vict., collected by T. Steel, no date.

SPENCER NUMBER: Peri sp 33 (p. 28).

Perichaeta sylvatica Spencer, 1893

Proc. Roy. Soc. Vict. 5: 5-6, figs. 34-36, 38.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: Fern Tree Gully, Vict., no date.

SPENCER NUMBER: Peri sp ? 30 (p. 28).

Perichaeta tanjilensis Spencer, 1893

Proc. Roy. Soc. Vict. 5: 24-25, not figured.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: Four Victorian localities are given: Gembrook, Fern Tree Gully, Dandenong, and Tanjil Track (Warburton).

SPENCER NUMBER: Peri 5°, Peri sp ? 5?, Peri sp? 10 (p. 28).

OTHER SPECIMENS: G235 contains a single specimen in near liquid condition, collected Tanjil Track, July 1891. The label bearing the Spencer number is missing from the jar; probably a syntype but its condition is so bad that it is of little scientific value.

Perichaeta tasmanica Spencer, 1895

Proc. Roy. Soc. Vict. 7: 47-48, figs. 37-39.

SYNTYPES: G289, two dissected specimens, three complete specimens and one

fragment. Poor (hardened, although the dissected specimens are slightly better than the others).

LOCALITY: Emu Bay, Tasm., collected January 1892.

SPENCER NUMBER: P sp 1 T (p. 27).

Perichaeta walhallae Spencer, 1893

Proc. Roy. Soc. Vict. 5: 15-16, figs. 43-45, 66.

TYPE SPECIMENS: Not present, presumed lost.

LOCALITY: Walhalla, Vict. The single mature specimen was collected by Dendy, no date.

SPENCER NUMBER: Peri sp ? 36 (p. 28).

Perichaeta yarraensis Spencer, 1893

Proc. Roy. Soc. Vict. 5: 23-24, figs. 61-63, 74.

LECTOTYPES G232, a dissected entire specimen. Length in spirit 130 mm. Good.

PARALECTOTYPES: G1426, two complete juvenile specimens, formerly included with G232. Poor (hardened).

LOCALITY: Warburton, Vict. G232 was collected by A. Dendy, no date. Other syntype localities are Tanjil Track near Woods Point and Warragul in Victoria. Specimens from the last two localities are presumed lost.

SPENCER NUMBER: Peri sp ? 7 (= G232), Peri sp ?16, Peri sp ? 1, (p. 28).

NOTES: The specimens were not previously recognized as type material. Although Dendy is not mentioned as collector in the original description the presence of the correct Spencer number is taken as an indication that they were used in the preparation of the MSS.

OTHER SPECIMENS: G233 bears a number indicating that the material was used in the preparation of the MSS (Peri sp ? 16). However, it is not type material as Spencer points out that these specimens differ from the type. He regarded the material as questionable subspecies. G230 contains an entire, dissected specimen and a complete specimen in good condition collected at Fern Tree Gully, March 1892. G231 contains a dried specimen in fair condition collected at Dandenong, June 1892. G234 contains a complete specimen in good condition collected by J. Shephard, November 1891.

Genus Trichaeta Spencer, 1900

Trichaeta australis Spencer, 1900

Proc. Roy. Soc. Vict. 13: 30-31, figs. 1-3.

SYNTYPES: G131, three complete specimens and two dissected specimens. Poor (hardened).

LOCALITY: Narre Warren, Vict. The type material was collected from under logs in damp soil. A note on the filing card for specimen G131 states 'This appears to be a figured specimen but has no locality—is probably the type specimen'.

SPENCER NUMBER: Sp ? 6 a or Peri sp ? 6 a (p. 29).

NOTES: This material has previously been regarded as questionable type material. The Spencer label with the specimens reads 'Peri ? sp ? 6a'. While this differs

from those noted above, the specimens were identified by Spencer. Absence of locality is a more serious difficulty.

Acknowledgements

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THE SPAWN AND EARLY LIFE HISTORY OF *CACOZELIANA GRANARIA* (KIENER 1842) (GASTROPODA: CERITHIIDAE)

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Abstract

The spawn of *C. granaria* is described, recording for the first time that of an Australian cerithid. It resembles the egg masses of the N. hemisphere species so far recorded in consisting of a gelatinous thread containing encapsulated eggs which hatch as planktotrophic veligers. It follows the pattern of *Bittium reticulatum* in being deposited as a flat coil but differs from it in being coiled in a clockwise direction.

Introduction

Although many members of the Cerithiidae inhabit Australian waters there are no known records of their reproduction or early life histories (Anderson 1960). Some N. hemisphere species have been examined, namely the Hawaiian *Clava obeliscus* (Ostergaard 1950), the Bermudian *Cerithium ferruginum* (Lebour 1945), the Jamaican *Cerithium algicola* (Davis 1967), the Mediterranean *C. vulgatum* (Lo Bianco 1888) and the British *Bittium reticulatum* (Lebour 1936) all of which lay their eggs in gelatinous tubes, or strings, attached to a substratum, either as a tangled mass or a flat coil. The eggs of all five species hatch as planktotrophic veligers.

The present study was undertaken as part of a project designed to discover whether this mode of reproduction pertains to Australian species and is perhaps indicative of a typical pattern for the family.

Genus **Cacozeliana** Strand

Cacozeliana granaria (Kiener)

Cerithium granarium Kiener, 1842. *Coq. Viv.,* p. 72, Pl. 19, fig. 5.

The 'Granulated Creeper', *Cacozeliana granaria*, is a small but common cerithid occurring along the coasts of New South Wales, Victoria, Tasmania, S. Australia and S. Western Australia. The shell is elongated with many whorls, a short, wide anterior canal and a brown, horny, paucispiral operculum. The whorls are ornamented with spiral, tuberculate ribs, and the colour varies through brown, red-brown, and cream with or without maculations. It may reach up to 20 mm in length.

The body of the animal is basically translucent scattered with opaque white flecks; dark markings occur on the 'snout', tentacles and upper part of the foot, and there is a black eyespot at the base of each tentacle.

The species lives mostly in shallow water on sand banks where there is a growth of algae, or in rock pools on reefs in the intertidal zone. As far as is known they are general detritus feeders.

Material and Methods

Three specimens, averaging 12 mm in length, were collected from rock pools

on the ocean reef at Flinders, Victoria, in November 1964, and transferred to a four-gallon glass home aquarium equipped with a filter and containing sand, stones, sea-bed debris, 'lettuce weed', (*Ulva lactuca*), and some other molluscs whose spawning habits were known.

Five days later (1/12/64) one of the specimens crawled up the front wall of the aquarium and began to spawn. The animal worked continuously for six hours extruding a gelatinous, egg-packed thread which it attached to the glass in a flat
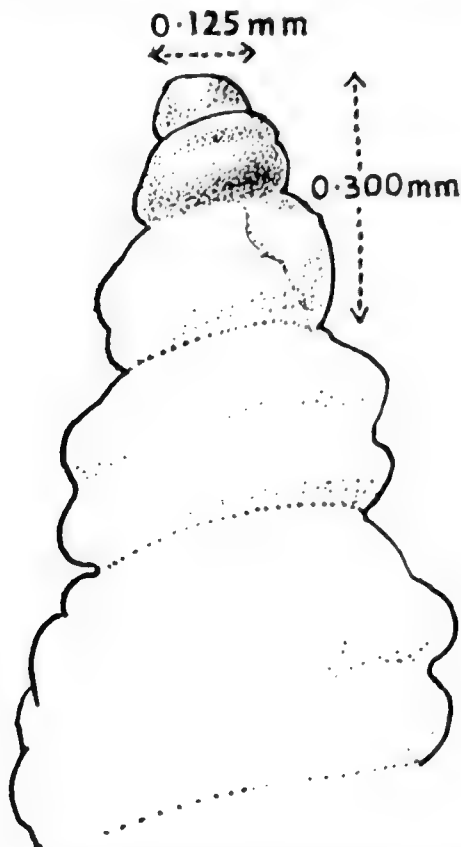

Fig. 1—*C. granaria*. Apex of juvenile specimen showing the smooth, rounded whorls of the larval shell.

coil. Progressing in a clockwise direction it placed the thread closely beside that already laid down, constantly changing the position of its foot and body generally in order to maintain the spiral pattern. Throughout the whole procedure the animal's radula could be seen rasping the glass as it pushed forward presumably preparing the surface (substratum) for the attachment of the thread.

The Spawn

The egg-mass (Pl. 17) when completed, was roughly circular in shape and measured 20 mm at its widest diameter. The gelatinous thread composing it was wound in a tight, flat spiral attached to the substratum and was packed with irregu-

larly spaced encapsulated eggs. It was transparent, with an average diameter of 0·5 mm, and was coiled in a clockwise direction thus providing an interesting contrast to the anti-clockwise spiral described by Lebour for *Bittium reticulatum*.

An examination of the contents of the aqquarium (stones, old shells etc.) revealed a similarly coiled gelatinous egg-mass on the inner surface of an empty mussel valve, and a specimen collected in April 1966 spawned in the same manner in a glass dish. In each case the egg mass was similar in detail to that described above. The eggs were white, spherical and averaged 0·085 mm across, each being contained within a spherical, transparent covering, or envelope, 0·100-0·125 mm in diameter.

Development

Within a few hours, at a water temperature of 15·5°C (60°F), the eggs began to cleave, those in the centre of the coil reaching the 4-cell stage before those towards the outside had commenced to divide. A solid gastrula was formed in 48 hours and within another 48 hours an early veliger was rotating within the egg envelope. After 8 or 9 days the veliger emerged from the envelope and dissolving gelatinous thread, and entered the water. Except for two black eye spots the veliger is colourless with small rounded velum lobes. Its shell is horn-coloured and averages 0·125 mm across. Some of the veligers were maintained in a small jar of sea-water and many continued to swim for up to 10 weeks, during which no apparent changes in growth were detected.

An examination of the apex of adult shells indicates that the embryonic shell grows during its planktonic life to $2\frac{1}{2}$ whorls before settling and changing to the adult type of shell sculpture. Figure 1 shows the early whorls to be transparent and smooth (presumably the larval shell) followed by the sculptured whorls of the post-larval shell, with a definite line of demarcation between the two. From this it may be assumed that the free-swimming veliger of *C. granaria* spends a considerable time as a constituent of the plankton, and that this may be a contributory factor to the widespread distribution of the species.

Three juvenile specimens showing larval whorls have been placed in the National Museum collection (F26387); also sample of veliger shell (F26388).

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PLATE 17

C. granaria depositing an egg-ribbon on the glass wall of an aquarium. The displacement of the thread was caused by a nassarid which crawled on to the egg mass and disturbed the spawning cerithid, x 5.