G. Baker, M.Sc.

MEMOIRS

OF THE

NATIONAL MUSEUM OF VICTORIA

MELBOURNE

(World List abbrev. Mem. Nat. Mus. Vic.)

No. 14, Part II

Issued June, 1946

R. T. M. PESCOTT, M.Agr.Sc., F.R.E.S.
DIRECTOR

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Mem. Nat. Mus. Vict., 14, Pt. 2, 1946.

SOME UNUSUAL SHAPES AND FEATURES OF AUSTRALITES (TEKTITES).

By George Baker, M.Sc.,
Geological Department, Melbourne University.

Plates VI-XIV.

(Received for publication 6th June, 1944)

Some rare types of australites, differing from the common forms in shapes and surface structures are recorded in this paper. Twenty-nine were selected from 880 specimens collected by myself and friends near the Sherbrook River, a few miles east of Port Campbell (Baker, 1937), and two from a collection of Western Australian specimens in the Geological Department, Melbourne University.

Their weights, specific gravities and dimensions are set out in Table I (see page 51). In the diameter column, figures not bracketed refer to external diameters of flanges, bracketed figures to internal diameters.

Plate VI

Fig. 1. An oval, traylike form without a central core; the lightest complete and unweathered australite on record. The flat anterior surface curves at the edges, and the posterior surface is slightly concave; both surfaces have strongly marked, contorted flow lines, and a bubble cavity, 1 mm. across, forms a small hole through the specimen. Locality: Six miles east of Port Campbell.

Fig. 2. An oval, platelike australite with flat posterior surface, slightly concave anterior surface, and small core 2 × 3 mm., surrounded by minute, elliptical bubble pits. The few flow lines are confined to the posterior surface. Locality: Three and a quarter miles east of Port Campbell.

Figs. 3A and 3B. Side and posterior aspects of a bowl-shaped form (Baker, 1940) with a smooth rounded lip, a small core with flow lines at the base of the bowl, and numerous minute bubble pits on both surfaces; the walls of the bowl slope uniformly down to the core, which is not visible in the photograph. Locality: One and a half miles east of track to Loch Ard Gorge.

Plate VII

Fig. 4. An elongated form, canoe-shaped in side aspect. The flange, which is developed on one side (left-hand side in fig. 4) and partly along one end, arises at an angle of 80° from the core; it is thin and its

anterior surface is flow-ridged. A highly contorted flow-line pattern occurs on the posterior surface of the core, a concentric flow-line pattern on the flange. The shape does not appear to be due to fracturing. Fenner (1940, p. 316) described a somewhat comparable form with a flange on one side only as resembling a Cornish pasty. Locality: East of Deany Steps, 1¼ miles east of Port Campbell.

Fig. 5. An irregular oval, with a flat, bubble-pitted posterior surface on which is a curious fleur-de-lys-shaped depression, less bubble-pitted and more flow-lined than the rest of the posterior surface; this depression has probably resulted from the bursting of coalesced, larger bubbles. The anterior surface is smooth and flow-ridged. Locality: Half a mile east of Sherbrook River.

Figs. 6A and 6B. Side and posterior surfaces of a form with strongly marked flow lines trending towards a small flange at the right-hand end of the posterior surface. Bubble pits elongated parallel to the flow lines; flange thin. Anterior surface (bottom of fig. 6A) carries circular bubble pits, crinkly and irregular flow ridges, and occasional flow lines simulating symmetrical compression folds. Locality: Near Gravel Point, 3 miles east of Port Campbell.

Plate VIII

Figs. 7A and 7B. Anterior surface and end-on aspect of a curious form which appears to have been squeezed at one end. The ragged outline of the top end (fig. 7A) results from erosion of the thin edge. Outstanding features are a fingernail-like impression on the posterior surface and opposite this, on the anterior surface, a constricted, elevated, flange-like structure (bottom of fig. 7A). Most flow ridges and flow lines on the anterior surface are parallel to edges. Locality: Broken Head, 4 miles east of Port Campbell.

Fig. 8. Posterior surface of an elongated, very thin, traylike form with prominent, elongated bubble marks coalescing on the posterior surface; there is no defined core or flange. Occasional small bubble pits and flow lines on anterior and posterior surfaces; the flow lines frequently conform to the shapes of the larger bubble cavities, but some trend across them. The base of one bubble cavity has worn away, leaving a hole through the specimen. Locality: South side of Great Ocean Road, 3½ miles east of Port Campbell.

Plate IX

Figs. 9A and 9B. Posterior and side aspects of a pear-shaped form. Molten glass from the anterior surface has flowed over part of the bubble-pitted equatorial portions of the posterior surface; the prominent groove in it was probably formed by escaping gas. A small flange subsequently developed along the tapering sides of the australite. On the anterior surface (fig. 9B) wrinkled flow ridges are prominent, and on the posterior surface, bubble pits elongated parallel to the long axis pass into shallow flow grooves at the tapered end. Locality: West of Port Campbell.

Figs. 10A and 10B. Posterior surface and side aspect of a ladlelike form from which part of the narrow end has broken away. On the posterior

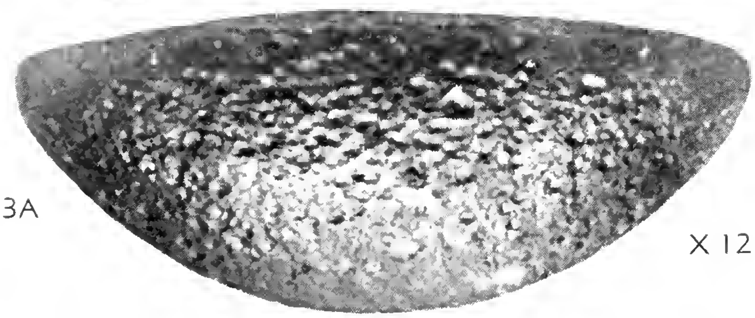
1

X 10·4

2

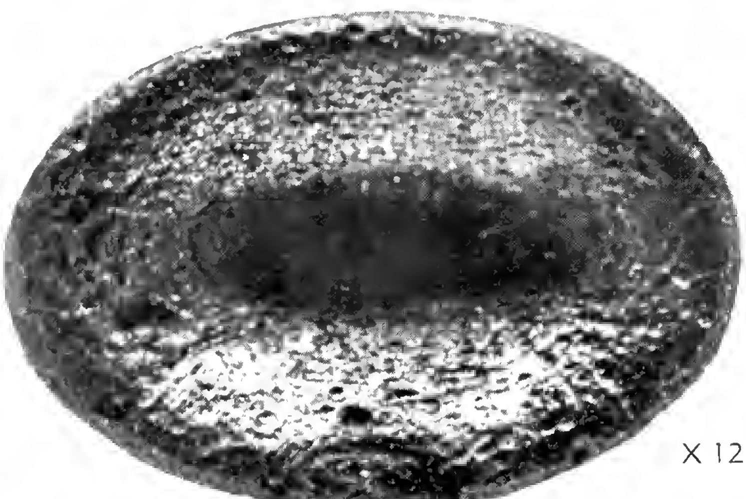
X 6·5

3A



X 12

3B



X 12

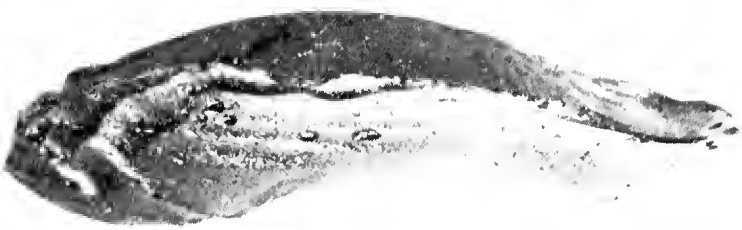
4

X 7·5

5

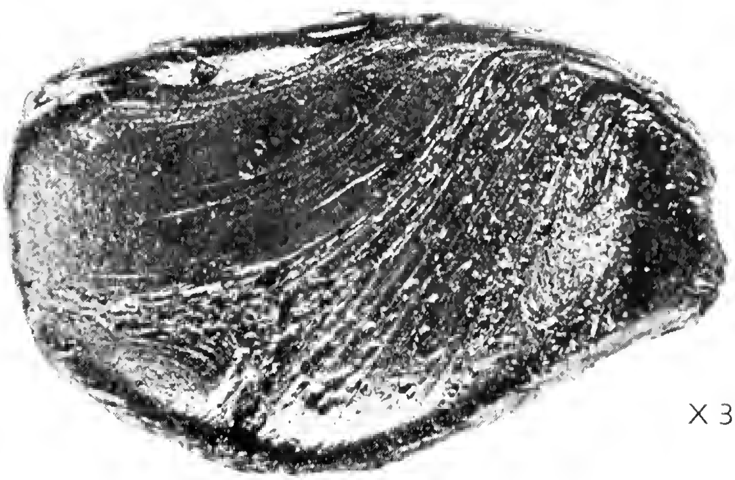
X 5·5

6A



X 3·2

6B



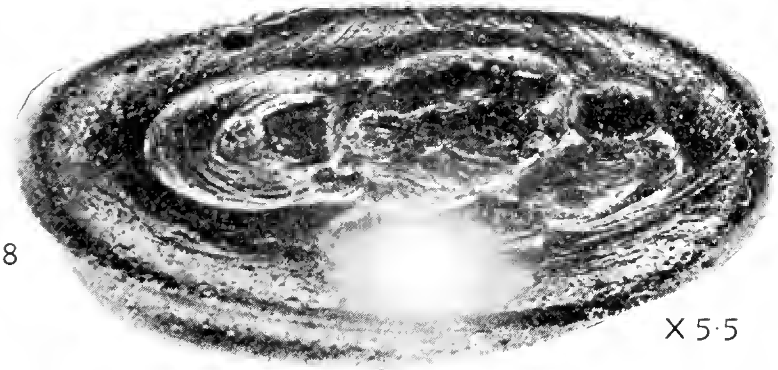
X 3·2

7A

X 5

7B

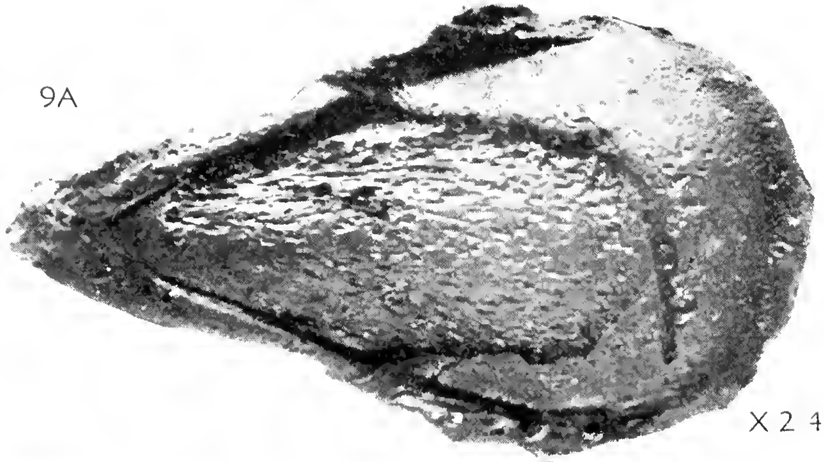
X 5



8

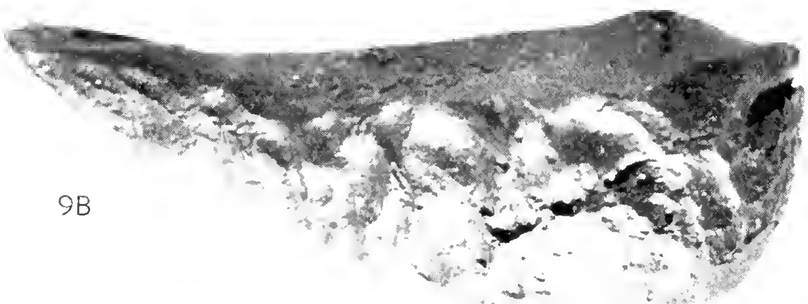
X 5·5

9A



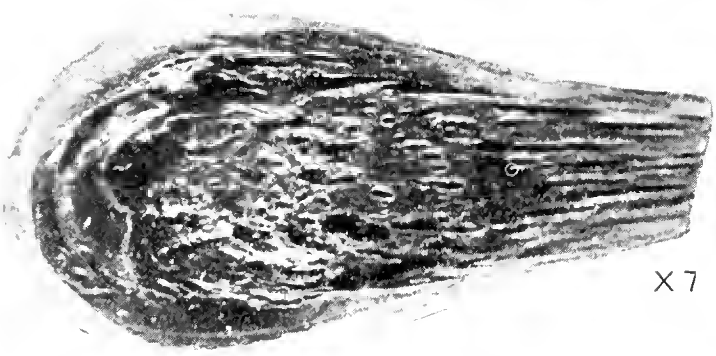
X 2·4

9B



X 2·4

10A

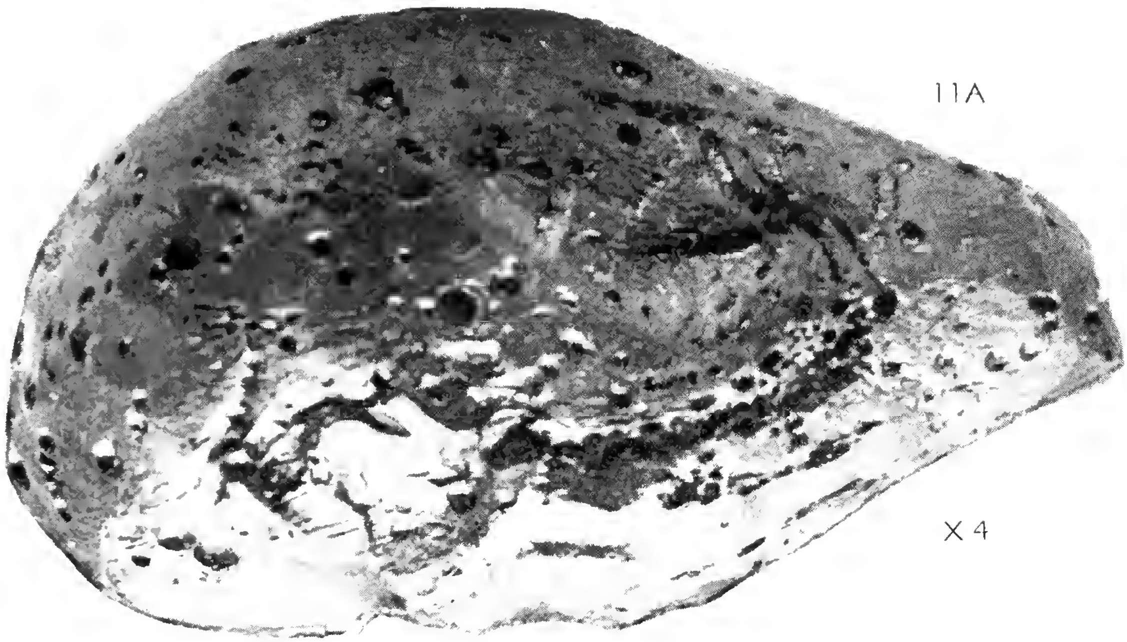


X 7

10B

X 7

11A

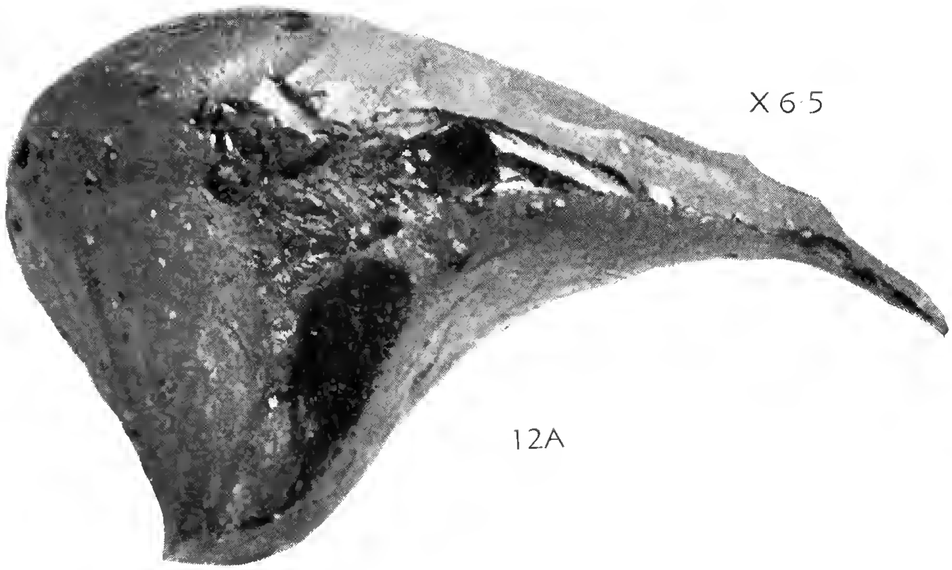


X 4

11B

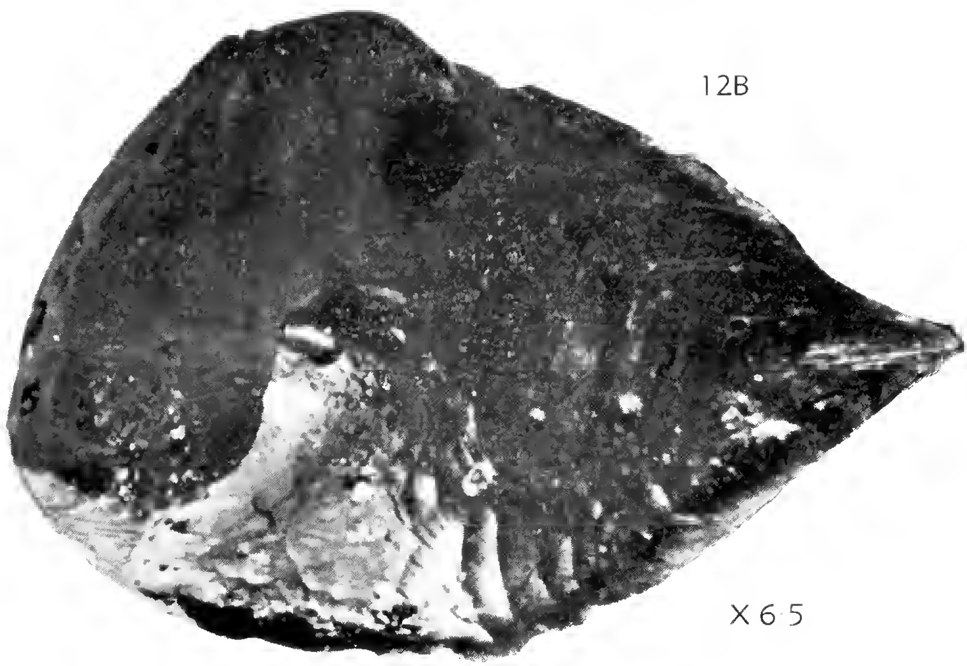
X 4

X 6·5



12A

12B



X 6·5

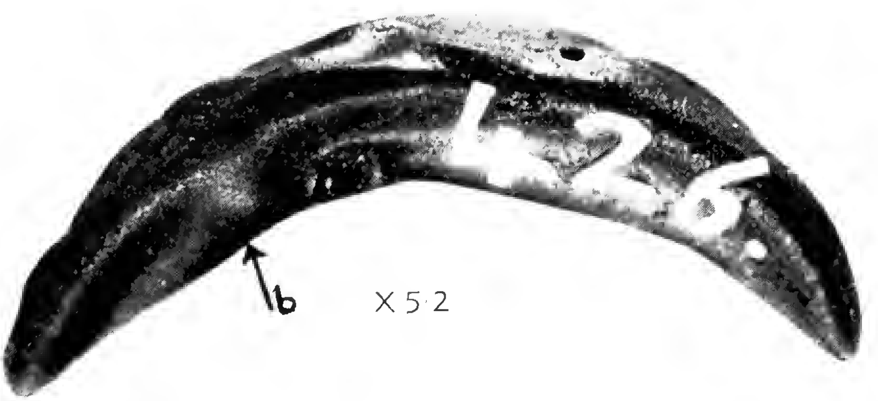
13

X 3

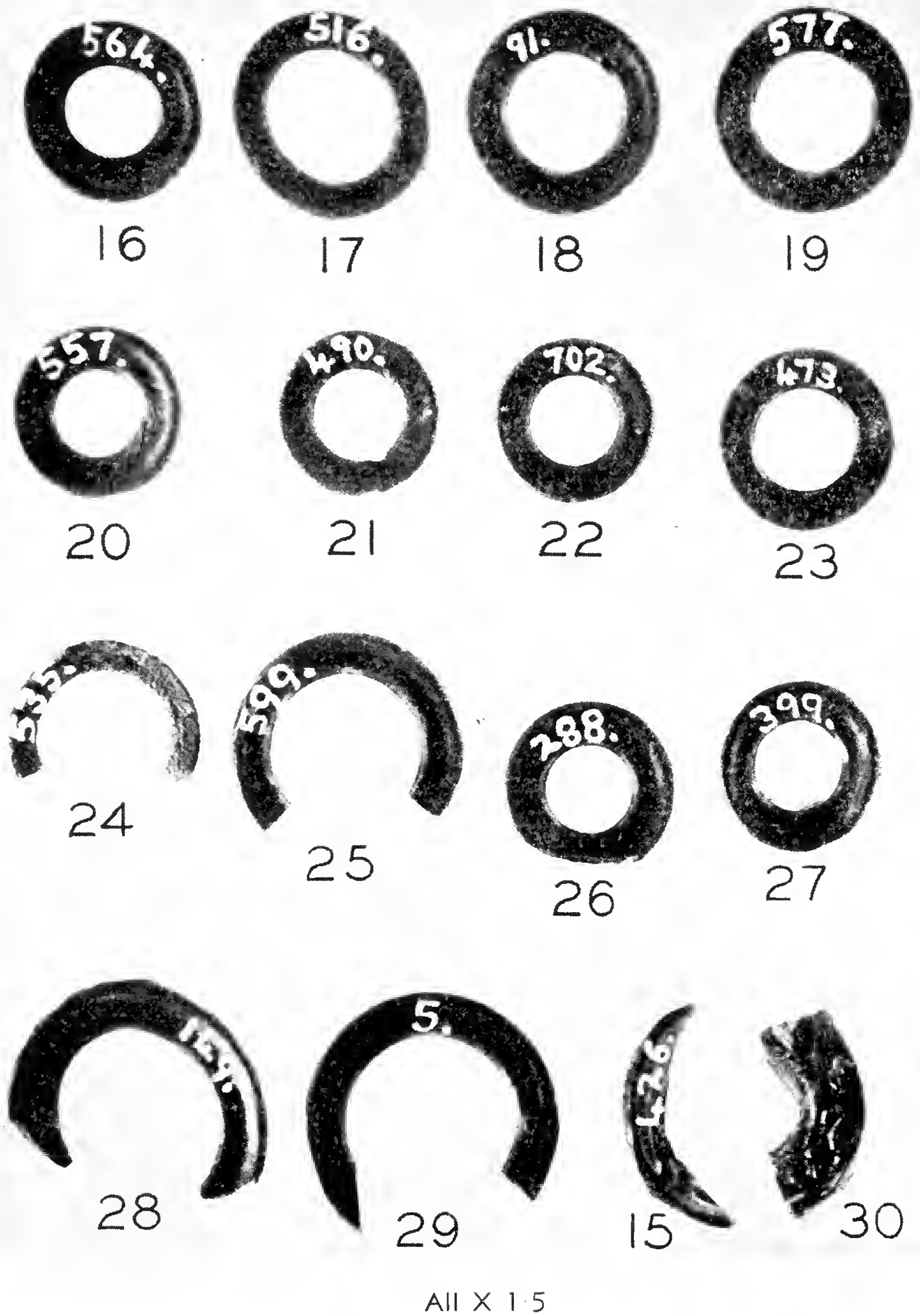
14

X 4·4

15



X 5·2



All X 1·5

31A X 3·5

31B NAT. SIZE

surface, bubble pits are elongated and drawn out at the narrow end into flow grooves (fig. 10A). The anterior surface has one prominent flow ridge (fig. 10B), and numerous flow lines simulating an isoclinal fold, some of which terminate sharply against the flow ridge on one side but pass through it on the opposite side. Locality: A quarter of a mile north-east of Port Campbell Sports Ground.

Plate X

Figs. 11A and 11B. A pear--shaped form comparable with Fenner's (1934) "air bombs." A few large bubble pits and flow lines occur on the posterior surface (top of fig. 11A) and a lesser number on the anterior surface (fig. 11B). At the narrow end are occasional flow grooves. Flaked areas on the anterior surface (fig. 11B) suggest some plucking away of glass during flight. Locality: Near Baker's Oven Rock, 3¼ miles east of Port Campbell.

Plate XI

Figs. 12A and 12B. A cusp-shaped form (fig. 12A) teardroplike when viewed from above (fig. 12B). On the anterior surface are flow ridges at right angles to the long axis (top of fig. 12A) which become crinkled towards the narrow end. Few bubble pits; deep bubble crater on posterior surface (dark area at top of fig. 12B). On the posterior surface are flow lines, small flow ridges (normally typical of anterior surfaces) and short, reticulating flow grooves; the flow lines trend towards the two drawn--out portions (fig 12A). The edges are turned slightly back towards the posterior surface, indicating an early stage in flange formation. Locality: Near Twelve Apostle rock stacks, 6 miles east of Port Campbell.

Plate XII

Fig. 13. A club-shaped australite with a somewhat polished surface, a few flow lines and small bubble pits; occasional wrinkled flow ridges on the head of the club. Length of shaft 24 mm.; thickness 7 to 8 mm.; width of the head 11 to 15 mm. at the widest end. The top portion, carrying remnants of flow ridges, is part of the original anterior surface. Locality: Near Kurnalpi, north-east Coolgardie Goldfield, Western Australia.

Fig. 14. Another club-shaped australite; surface dull and carrying numerous small marks like percussion figures. Flow lines and flow grooves are conspicuous on the sides of the head near the shaft, but there are very few bubble pits. Shaft 10 mm. long and from 4 to 5 mm. thick; the head is 7 mm. thick and 11 mm. wide. Locality: Kalgoorlie district, Western Australia.

The shape of these two club-like forms has been determined by abrasion, and the shape of the head of the Kurnalpi specimen has been partly determined by deep flow grooves. The position, shape and length of the shaft of the Kalgoorlie specimen has been determined by flow grooves and flow lines parallel to and adjoining the outer edges. It appears to have been originally boat-shaped and to have been reduced to its present shape by selective flaking and abrasion.

Fig. 15. (Plates XII and XIII.) A fragment, approximately one third of a flange; on the posterior surface is a gas blister, $1\frac{1}{2}$ mm. across, marked *b* in fig. 15, Plate XII, an unusual feature on flanges. The thin glass film covering this bubble has been distended by the enclosed gas. No similar bubbles have been noted in other flanges examined, although larger bubbles are not uncommon in cores. Most bubbles in flanges have burst and are represented by small pits or craters (see fig. 15, Plate XII). Locality: Near Sentinel Rock, $1\frac{1}{2}$ miles east of Port Campbell.

Plate XIII

Figs. 16 to 30. Posterior surfaces of flanges detached from the cores of button-shaped or oval (figs. 17, 28) australites by clean natural fractures.

The posterior surfaces are smooth, except for occasional small bubble craters, but fine concentric flow lines can be observed under higher magnifications. The anterior surfaces are usually flow-ridged. Few examples of such complete flanges have been recorded in the extensive literature on australites.

One fragment of a thin flat-topped flange (fig. 24), is exceptional in having both the posterior and the anterior surfaces rough.

Fig. 30 represents portion of an unusual, thin, broad type which carries eight shallow, elliptical bubble craters on its posterior surface; five form a cluster (in the bottom part of the photograph) and two others have coalesced. A remnant of the core attached to the fragment is distended by the escape of a large gas bubble, originally at least 10 mm. across. Such a form would be very prone to fragmentation. The bases of the bubble craters on the flange fragment are marked by occasional flow lines and minute bubble pits. Between the bubble pits, the glass of the flange is also flow-lined.

The outer and inner rims of flanges in Plate XIII are generally smooth, but their continuity is sometimes interrupted by small bubble craters (fig. 21). Wrinkled flow ridges at the equators of anterior surfaces occasionally cause the outer to be less symmetrical than the inner edges (figs. 28, 29). The truncated portion at the bottom of fig. 26 is caused by a fracture.

Localities: From between half and $5\frac{1}{2}$ miles east of Port Campbell, except No. 22, which came from near Marble Arch, 3 miles west of Port Campbell.

Plate XIV

Figs. 31A and 31B. A flange fragment embedded in sandstone of Recent age, overlying post Miocene clays; the cementing medium in this rock is argillaceous. The specimen came from a steep slope near the cliff edge in a small bay north of Gravel Point, $2\frac{1}{4}$ miles east of Port Campbell. The sandstone forms a hard band a few feet thick below 4 feet of clay and surface soil.

Australites usually occur on wind-blown or rain-swept surfaces, or have been washed out of loose, incoherent deposits. The only other record of an australite in consolidated rock is a specimen from Gawler, South Australia (Tate, 1879); it was enclosed in a travertine nodule forming part of the Recent crust limestone in that area.

Table I

Measurements of Certain Australites

Fig. No.	Type	Weight (gm.)	Sp. Gr.	Diameter (mm.)	Length (mm.)	Breadth (mm.)	Depth (mm.)	Width of Flange (mm.)
1	Small tray	0.0645	2.350	—	9	6	1	—
2	Flat oval plate	0.276	2.380	—	13	10	1	8–10
3	Elongate bowl	0.135	2.410	—	7.5	5	3	—
4	Curious button	0.439	2.425	—	11	7	5	2
5	Irregular oval	0.865	2.436	—	12	10.5	4.5	—
6	Aberrant	4.247	2.430	—	30	11.16	4–7	1–2
7	Aberrant	1.592	2.408	—	20	16	0.5–7	1–2
8	Elongated tray with bubble craters	0.277	2.401	—	18.5	8.5	2	—
9	Pear-shaped form	16.315	2.426	—	43	1–24	2–17	1.5–8.0
10	Ladle-like form	0.520	2.418	—	13.5	3–6.5	1–5	0.5
11	"Aerial Bomb"	18.860	2.425	—	36	21	20	—
12	Aberrant	1.554	2.413	—	18	1–12	1–10	—
13	Club-like form	5.422	2.451	—	35	—	—	—
14	Club-like form	2.440	2.440	—	26	—	—	—
15	Flange fragment	0.429	2.400	—	—	—	4	4
16	Complete flange	0.750	2.381	15 (7.5)	—	—	3.5	3.75
17	Complete flange	0.749	2.385	—	18.5	17	3	3
18	Complete flange	0.961	2.394	18 (10)	—	—	4	4
19	Complete flange	0.915	2.395	18 (11)	—	—	4	3.5
20	Complete flange	0.730	2.409	15 (7)	—	—	3	3.5
21	Complete flange	0.591	2.400	14 (8)	—	—	3	3
22	Complete flange	0.649	2.380	14 (8)	—	—	3–4	3
23	Complete flange	0.731	2.405	16 (9)	—	—	3	3.5
24	Flange fragment	0.272	2.410	17 (11.5)	—	—	1.5–2	2.5–3.0
25	Flange fragment	1.005	2.421	20.5 (12.5)	—	—	3	3.5–4.0
26	Complete flange	0.750	2.381	15 (7.5)	—	—	3.5	3.75
27	Complete flange	0.731	2.404	15 (8)	—	—	3.5	4
28	Flange fragment	0.874	2.369	—	24 (16)	20 (12)	4	4.0–4.5
29	Flange fragment	0.992	2.378	23 (15)	—	—	3–4	4
30	Flange fragment	0.446	2.335	—	—	—	1–3.5	4–5
31	Flange fragment embedded in sandstone	—	—	—	—	—	3.5	—

Acknowledgments

The author is indebted to the late Director of the National Museum of Victoria, D. J. Mahony, for criticism of the manuscript, and to Miss M. L. Johnston of the Geological Department, Melbourne University, for the preparation of the photographs used in the plates.

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THE CONTEMPORANEITY OF THE RIVER TERRACES OF THE MARIBYRNONG RIVER, VICTORIA, WITH THOSE OF THE UPPER PLEISTOCENE IN EUROPE.

By R. A. Keble, F.G.S., Palaeontologist, and J. Hope Macpherson, Conchologist, National Museum of Victoria.

Plate XV.

(Received for publication 18th January, 1945)

The examination of the terraces of the Maribyrnong River valley was undertaken to prove the antiquity of what has come to be known as the Keilor skull. There is now reason for believing that the skeleton may have been a burial, and the age of the terrace in which it was found is not necessarily its age. Nevertheless, although the skull is suspect, the investigation was in the much neglected field of Victorian Pleistocene geology, and is an attempt to correlate the Maribyrnong River terraces with those of the Ice Age of Europe. Doubtless, the correlation will facilitate an understanding of the ecology of the Recent and Pleistocene fauna and flora concerning which little is known in Australia.

Early in October, 1940, the Keilor skull was found with fragments of limb bones in Hughes's sand pit near the junction of Dry Creek and the Maribyrnong River, a mile north of the Keilor township. In the following December the approximate site was inspected by Messrs. Mahony, Brazenor, and Keble, of the National Museum, the circumstances of the discovery being later partly detailed by Mahony (1943), together with papers on the anatomy of the skull by Wunderly (1943), and on the palate and upper dental arch by Adam (1943). Hughes's sand pit is excavated in a river terrace (Pl. XV, Fig. 1) referred to by us as the Keilor Terrace. The skull and bones were stated to have come from one level 18 feet below its surface, and within a few feet horizontally. At the site where it was discovered, the surface of the Keilor Terrace adjoining the pit had been lowered 9 feet by excavation of sand for industrial purposes; the wall of the pit is 9 feet high.

We have endeavoured in this contribution

(i) to determine the sequence of flood plains and terraces formed in the Maribyrnong River valley since the extrusion of the Keilor Plains basaltic lava on which the valley was formed. The Keilor Flood Plain is the final manifestation of the Keilor cycle of erosion—the first cycle on the Keilor Plains lava field. It was followed by two cycles of erosion—the Braybrook and Maribyrnong Cycles, and

(ii) to tie up these flood plains and terraces with the last post glacial 15 to 20 feet eustatic fall of sea level. Evidence of this rise is seen (Fig. 1) in the Yarra Delta, and on the shores of

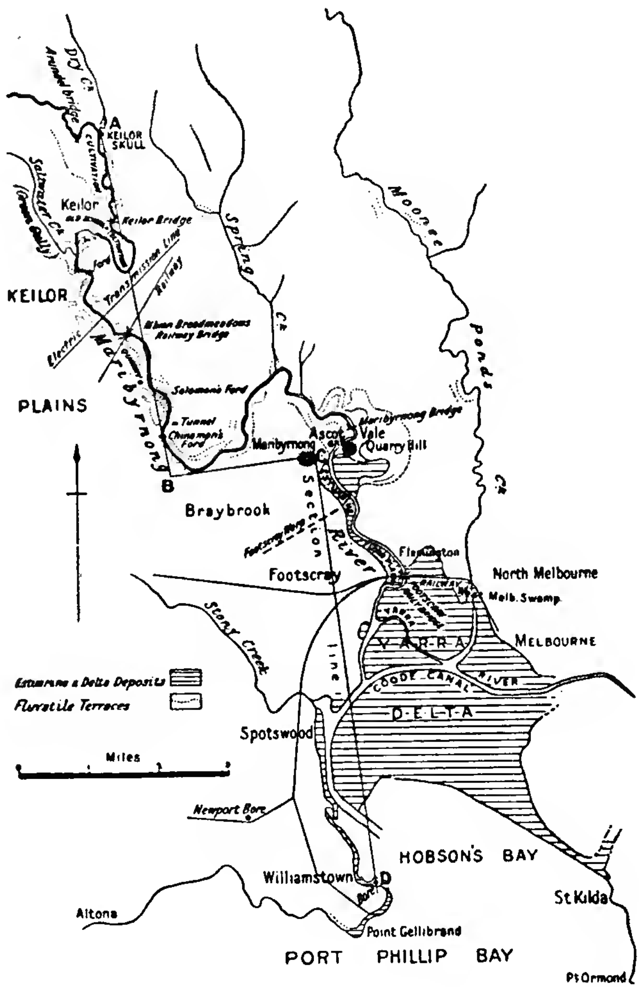

FIG. 1.

Map showing the Maribyrnong valley between Dry Creek and Port Phillip Bay.

Port Phillip Bay both east and west of the outlet into the Bay of the confluent Maribyrnong and Yarra Rivers.

The Maribyrnong valley and its fluviatile deposits downstream from Dry Creek have been examined, and the levels of the terraces and river bed determined. The datum to which heights are referred is low water mark at Williamstown (the datum commonly used in Victoria) and referred to hereafter as L.W.M.

The mean diurnal range of tide at Williamstown is 2 feet. Bench marks have been fixed by the Victorian Railways Department and the Country Roads Board at points between Dry Creek and the Bay. Between these official bench marks, at intervals of about 500 yards, subsidiary bench marks were fixed with a dumpy level, and the heights of the terraces ascertained from these by us with an Abney level. Where our levels of the terraces were checked by more exact methods, our error was found to be less than a foot.

Hughes's Sand Pit and the Adjoining Area

The human remains were associated (Pl. XV, Fig. 2) with a sinuous band of greyish-red sand, about two inches thick, in which are thin layers of calcined bones, ashes, and fragments of red ochre, indicating an occupational level. Thin layers of ash, a few feet long, were observed on the south side of the pit, about 4 feet above its floor but not elsewhere. Protruding from the two-inch band a quartzite flake was found by Professor E. S. Hills of Melbourne University, while he was inspecting it with us; the flake is illustrated by Mahony (1943). Many small flakes found on the floor of the pit may have come from the terrace sands, or have fallen from the surface when sand was being removed.

The sand forming the bulk of the terrace consists of small, well rounded quartz grains, together with some larger, less rounded grains; in addition there is sufficient clay to bind the whole into a compacted mass. Below the floor of the pit, the sand becomes coarser, and the base of the terrace, where visible on the bank of the river, is composed of coarse sand, grit, pebbles, and boulders.

The three terraces—the Keilor, Braybrook, and Maribyrnong Terraces—in Dry Creek, have been mapped (Fig. 2) by us. Their surfaces are respectively 45 feet, 38 feet, and 27 feet above the bed of the River. The surface of the Keilor Flood Plain is 103 feet above L.W.M.

In Dry Creek, the Keilor Terrace was originally over 150 yards wide and 32 feet thick, but it has been reduced in width and thickness by erosion; it is best preserved on the west side of the Creek.

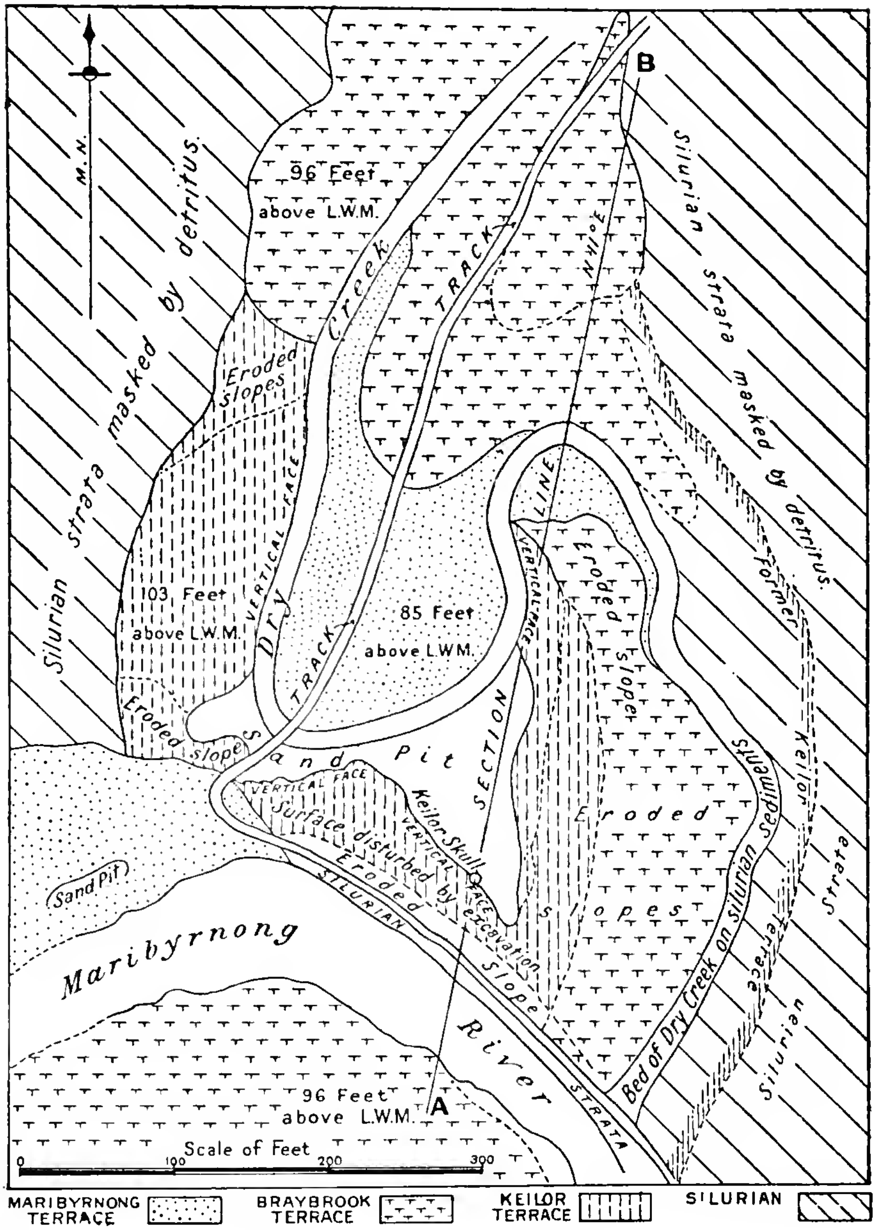

FIG. 2.

Geological Map of the Area at the Confluence of Dry Creek and the Maribyrnong River, showing Hughes's Sand Pit.

The widest portion of the Braybrook Terrace still preserved in Dry Creek is above the Sand Pit; it is a paired terrace over 80 yards wide and 15 feet thick. At the Sand Pit itself erosion has removed all but a small portion on the right bank of the creek.

On the right bank of the Maribyrnong River opposite the confluence of the creek this terrace is fairly extensive. The remnant of the Maribyrnong Terrace in Dry Creek valley is small, but it is developed extensively in the river valley a short distance downstream.

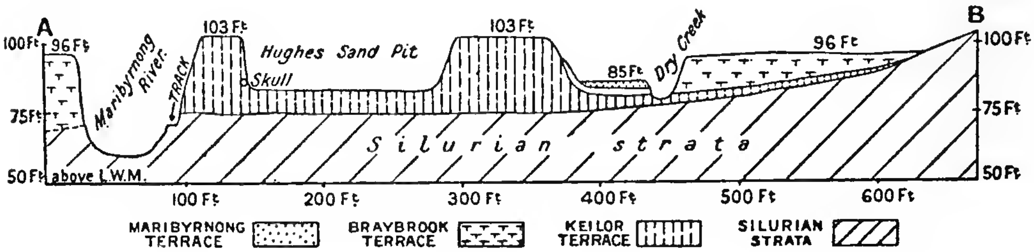

FIG. 3.

Section along a Line (AB, Fig. 2) passing through the Terraces and Sand Pit, at the Site of the Discovery of the Keilor Skull.

The Maribyrnong River and Dry Creek

The Maribyrnong or Saltwater River is the longest tributary of the Yarra River, which it joins near Spotswood (Fig. 1). It rises in the Cobaw Ranges north of Macedon, flows eastwards towards Lancefield, and then turns in a southerly direction to its junction with the Yarra. For many miles its valley is cut through Newer Volcanic lava (New Basalt) into the underlying rocks.

River gaugings taken at Keilor by the State Rivers and Water Supply Commission, Victoria, show that its mean discharge is 90 cubic feet (560 gallons) per second, and that its flow stops, or almost ceases, for two or three of the dryer months each year. The highest recorded flood level was 35 feet above the river bed. The Commission estimates its drainage area above Keilor at 550 square miles.

At Keilor, the valley is about a mile wide, 100 feet deep, and flat-bottomed. In it are extensive alluvial deposits. Downstream it narrows from half to quarter of a mile wide and becomes shallower. Below Ascot Vale Gap it opens out on to the wide alluvium of the Estuarine Flood Plain (Fig. 6) which is about 10 feet above sea level. The Estuarine Flood Plain merges into the Yarra Delta. Below Chinaman's Ford the river is tidal.

Dry Creek is a small gully, 4 miles long, which descends from the basalt plateau to the river, a fall of about 130 feet. It carries water only after rain, and is graded near its confluence. By Recent vertical erosion, it has cut through the terrace material into the underlying Silurian strata to a depth of about 8 feet.

Age of the Keilor Plains Basalt

The Keilor Plains basaltic lava averages about 45 feet in thickness, and is one of the series of flows known in Victoria as the Newer Basalt.

We have recognized two phases in the Newer Basalt. During the earlier one, the great lava fields such as those of the Keilor Plains and the Western District were formed. The later or scoria cone phase extended well into the Recent, and during it, scoria cone flows issued from points of eruption on the great lava fields and the highlands to the north. The Keilor Cycle of erosion commenced on the Keilor Plains lava field immediately after the lava covered the area. There is, however, a difference of opinion as to the age of this lava field. Hills (1939), on physiographical evidence, came to the conclusion that it was certainly post-Kalimnan (Lower Pliocene) but that there is nothing to indicate whether it is Pliocene or Pleistocene. In consequence of this uncertainty, we have fixed the age of the Maribyrnong River valley cycles by working backwards from the last eustatic 15 to 20 feet fall of sea level (indicated by platforms and ridges on the Yarra Delta and the shores of Port Phillip Bay), not by working forwards from the Keilor Plains lava field. Nevertheless, the evidence as to the age of the lava field, which restricts the downward extension of the physiographic cycles, seems to support our correlation of the cycles, and we have discussed it at some length.

Immediately beneath the Keilor Plains basalt is a widespread bed (referred to here as the "Sub-Basalt Sands") that is predominately sand, but sometimes consists of clays, sandstone, grit, pebbles, etc. It has a thickness of about 40 feet in the neighbourhood of Keilor, but about 80 feet south of the Ascot Vale Gap. It was evidently deposited on a peneplain, and after it was deposited, presented a peneplain surface to the enveloping lava. The only fossils recorded from it (Crespin, 1926) are unrestricted freshwater mollusca, ?*Cyclas* or *Unio,* and sponge spicules, *Spongilla*.

The nearest place to the Maribyrnong River valley where evidence of the age of the Newer Basalt can be ascertained with some certainty is at the Moorabool Viaduct, about 30 miles to the south-west. Here the Newer Basalt overlies ferruginous sandstone, which rests on marine fossiliferous Werrikooian or Upper Pliocene beds. Singleton (1941) discusses the viewpoints held by Dennant; Tate and Dennant; Tate, Hall and Pritchard; Dennant and Kitson; Chapman; and Singleton, on the age of these fossiliferous beds; these differ mainly as to whether it should be assigned to the Upper Pliocene or Lower Pleistocene. He summarises the evidence by remarking that "a critical study has shown that five per cent. of the mollusca are extinct species, so that the Werrikooian may be placed in the uppermost Pliocene, immediately preceding the Pleistocene, with a molluscan fauna of living species only." As the Newer Basalt at the viaduct rests in a shallow valley in the ferruginous sandstone (Pliocene-Pleistocene)—a valley that represents a short time interval between the depositing of the sandstone and the extrusion of the basalt, Singleton's summary leads to the conclusion that the basalt is Pleistocene. Nevertheless, although the Keilor Plains and the Moorabool Viaduct basalts have been assigned to the Newer Basalt, they are so far apart that we cannot be certain that the flows are wholly contemporaneous.

It would be possible to fix the age of the Keilor Plains basalt if there were means of estimating the time taken for the vertical erosion of the Keilor Cycle. However, assuming on the inconclusive evidence that the basalt is Pleistocene, and the sequence of the Maribyrnong River valley flood plains and terraces is Upper Pleistocene, the lava field is Middle Pleistocene.

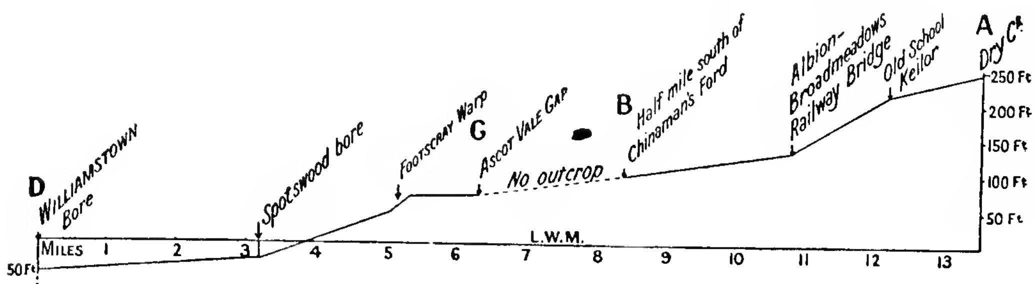

FIG. 4.
Levels between Dry Creek and Williamstown of Contact of Lower Surface of Keilor Plains Basalt with Sub-Basalt Sands.

Warping and Tilting

Although the Keilor Plains lava field is warped and tilted, eustatic adjustment, not tectonic movement, is regarded as responsible for the deposit and subsequent terracing of the Keilor and Braybrook Flood Plains. It is also responsible for the deposit of the Maribyrnong Flood Plain, and, for the most part, its terracing; warping has contributed to this, but to an insignificant extent.

The Keilor Plains lava field, and the Sub-Basalt Sands, are tilted in a south-south-easterly direction. The tilting occurred along zones of warping approximately parallel to the north-west shore of Port Phillip Bay. One zone crosses the Maribyrnong River between Albion-Broadmeadows railway bridge and the old Keilor school (Fig. 4); another—the Footscray Warp—is evident in the section (Fig. 4) on the west side of the River at Footscray, about a quarter of a mile north of the Ballarat Road. The tilting on the Footscray Warp brought about the complete submergence of the Port Phillip Sunklands—Port Phillip Bay then assumed its present form. No fracture lines are known in any part of the Maribyrnong River valley or the Keilor Plains lava field.

Fluviatile Deposits of the Maribyrnong Valley

The earliest reference to terraces in the Maribyrnong River valley appears to be that of Officer (1893) at Keilor, while Hills (1939) noted paired terraces at West Essendon and at Maribyrnong (Ascot Vale Gap).

All the flood plains subsequent to the Keilor Flood Plain were formed of the resorted material of that flood plain, and are lithologically similar. The only way of distinguishing between them is by noting their relative positions in the field, and by accurate levelling. There are no traces in them of volcanic ejectamenta from adjacent scoria cones such as the tuffs of the Camperdown area (Grayson and Mahony, 1910), and this indicates that none of these scoria cones were in eruption while the flood plains were being formed.

The six major episodes evident in the development of the Maribyrnong River from Dry Creek to Ascot Vale Gap are:

First, a cycle of erosion—the Keilor Cycle—which started on the Keilor Plains lava field. During this cycle, the valley was vertically eroded, the erosion reaching the beds underlying the basalt; this was followed by lateral erosion, when the Keilor Flood Plain was deposited to a depth of 45 feet.

Second, a cycle of erosion—the Braybrook Cycle—during which the Keilor Flood Plain was entrenched, the Keilor Terrace formed, and the Braybrook Flood Plain deposited.

Third, a cycle of erosion—the Maribyrnong Cycle—during which the Braybrook Flood Plain was entrenched, the Braybrook Terrace formed and the Maribyrnong Flood Plain deposited.

Fourth, the beginning of a cycle of vertical erosion, due partly to eustatic adjustment and partly to the Footscray Warp, during which the Maribyrnong Flood Plain was entrenched, and the Maribyrnong Terrace formed.

Fifth, Post-glacial 15 to 20 feet eustatic rise of sea level shown by wave platforms, and ridges that were submarine banks on the Yarra Delta and the shores of Port Phillip Bay.

Sixth, eustatic fall of sea level, and resumption of the vertical erosion started in the fourth episode.

The Keilor and the Braybrook Terraces occur at short intervals between Dry Creek and Ascot Vale Gap, and the Maribyrnong Terrace as far downstream as the Footscray Warp. The Maribyrnong River has been entrenched upstream from the Yarra Delta; it formerly flowed east of Quarry Hill, but the entrenchment was responsible for the breaching of the rock barrier west of Quarry Hill, to form the Ascot Vale Gap. The material removed has been progressively deposited in the entrenchment, and has formed the Estuarine Flood Plain and the Yarra Delta. The Estuarine Flood Plain is a northerly prolongation of the Yarra Delta, and is mapped by Aplin (1858) at the direction of A. R. C. Selwyn (then Director of Geological

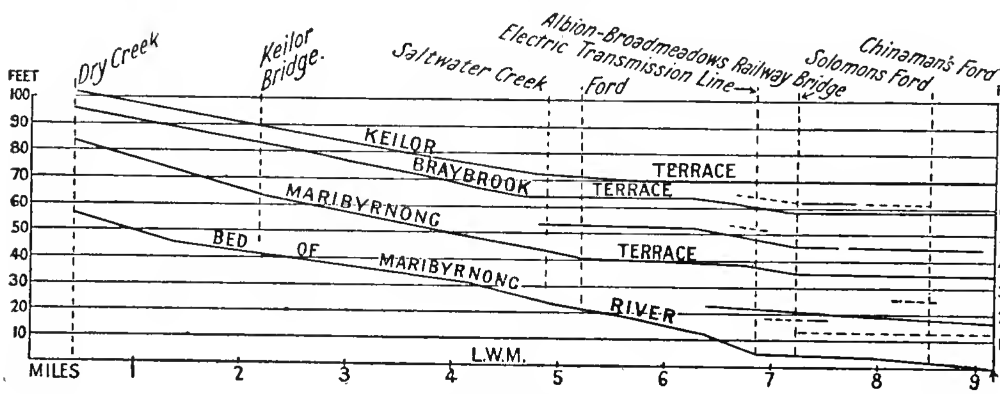

FIG. 5.

Profile of Surfaces of Terraces and Bed of Maribyrnong River between Dry Creek and Chinaman's Ford.

Survey) on Quarter Sheet 1 N.W. as "Post Pliocene-raised beaches, estuary beds, etc." The surface bed consists of 3 feet of grey soil resting on 5 feet of yellow clay. Both beds are unfossiliferous, but crossing the Estuarine Flood Plain, a short distance below the Ascot Vale Gap, is a drain in the bottom of which, and also in the excavated material beside it, are a number of Recent estuarine shells that may have come from a bed hidden beneath the silt in the drain. It is scarcely necessary to add that such a careful observer as Selwyn would not record the estuarine nature of the Flood Plain without definite evidence of such.

The Keilor, Braybrook, and Maribyrnong Terraces have not been preserved between the Footscray Warp and Port Phillip Bay, but on the floor of the Bay there is evidence of cycles of erosion in the form of marine platforms and delta deposits that may possibly be correlated with the Maribyrnong River cycles.

The heights of the terraces above L.W.M. decrease as they are followed downstream from Dry Creek, but their heights above

Fig. 1. The Keilor Terrace, Keilor
(in middle distance)

river level increase. In some places their surfaces have been modified by cultivation and operations for irrigation purposes. Where this has happened, exact levels of the original surface cannot be accurately determined. Paired terraces have been formed at several places (Fig. 1) such as Dry Creek, near Saltwater Creek, the Electric Transmission Line, below the Albion-Broadmeadows railway bridge, at Chinaman's Ford, and, as noted by Hills, at Maribyrnong (Ascot Vale Gap) and West Essendon. There are also a number of subsidiary terraces due to minor adjustments and alterations of the streams such as shifting meanders. One or more of the terraces have in some places been almost obliterated by erosion.

On the right bank of the river between Dry Creek and Keilor township, the Keilor Terrace is about a quarter of a mile wide, but its surface level has been disturbed by cultivation. The most extensive portion retaining its natural surface is near the Electric Transmission Line; it is here about 150 yards wide. The surface of the Keilor Terrace marks the level of the first, the highest, and the most extensive flood plain in the Maribyrnong Valley.

The level of the Braybrook Terrace at Dry Creek is 7 feet below the Keilor Terrace, but at Chinaman's Ford (Fig. 5) the difference in levels is 13 feet. The largest remnant, measuring about a mile north and south, and a third of a mile east and west, is situated at Braybrook; its surface level there is 58 feet above L.W.M.

The Maribyrnong Terrace continues below Ascot Vale Gap (Fig. 6) along the former course of the river east of Quarry Hill; in this locality it was a paired terrace about a third of a mile wide. Its surface upstream from the Footscray Warp is 32 feet above L.W.M., and adjoining it is another terrace 27 feet above L.W.M., a meander of the higher one. At Dry Creek, its surface is 18 feet below that of the Keilor Terrace, and at Chinaman's Ford 35 feet.

Evidence of Post Glacial Eustatic Adjustments on the Shores of Port Phillip Bay and the Yarra Delta

The evidence of the post glacial 15-20 feet eustatic fall of sea level found at so many places on the Australian coast is preserved at a number of points on the shores of Port Phillip Bay. It will suffice to mention two that have been examined in some detail: one at Hampton, east of the Yarra Delta, by Hart (1893), and the other at Altona, west of the delta, by Hills (1940).

At Hampton the wave platform (Fig. 7) which appears to have been formed on a raised beach is 23 feet above L.W.M., but there is evidence of a small amount of tectonic uplift since it was

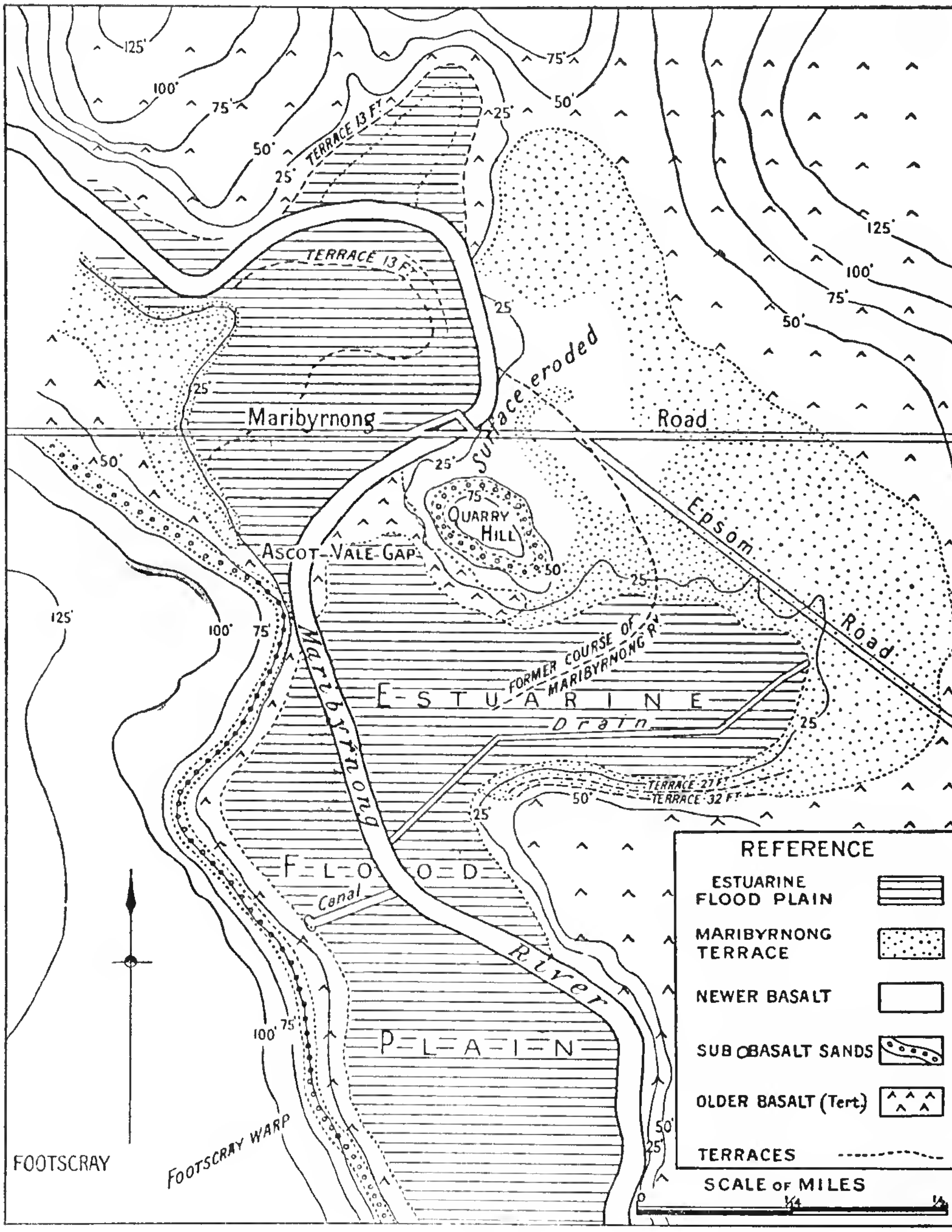

FIG. 6.

Map of the Area surrounding Ascot Vale Gap and the Estuarine Flood Plain showing the Maribyrnong Terrace, the 13 feet Platform, Footscray Warp and other Features.

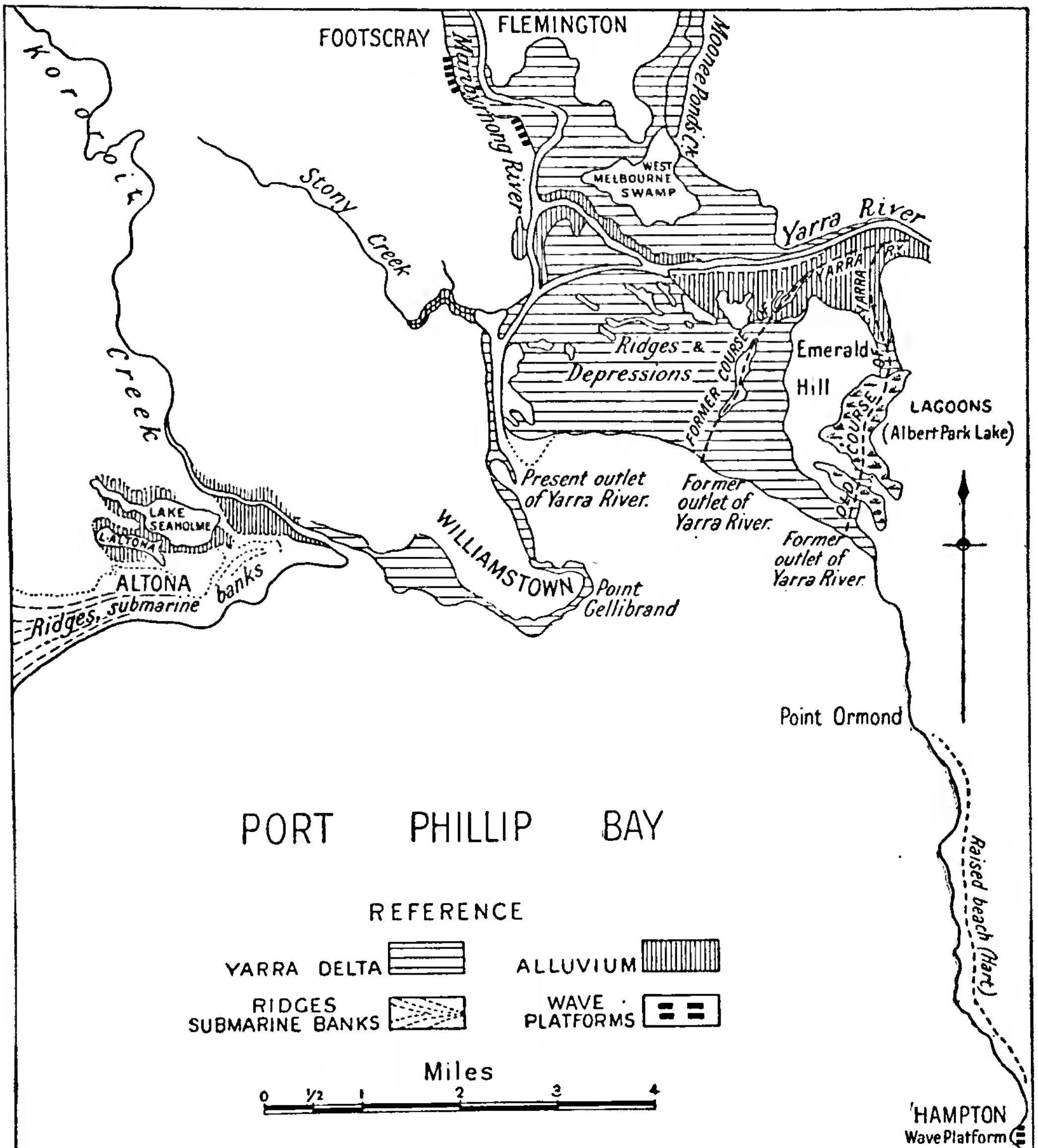

FIG. 7.
Map showing Yarra Delta, Wave Platform at Hampton, and Banks formerly submerged at Altona.

formed. It is covered with comminuted shells, mainly mussels, which may belong to the period of eustatic rise of sea level, or, as some maintain, to human agency, the platform showing evidence of having been the site of an aboriginal kitchen midden. Thirty or more species of mollusca, some marine worms, and a coral—all littoral species—are definitely associated with the formation of the raised beach.

The raised beach is plastered on the eroded scarp left by the subsidence of the Port Phillip Sunkland which assumed its present configuration at the close of the Pleistocene: the age of the raised beach and the wave platform is Recent.

The Altona shell beds (Fig. 7) rest on Newer Basalt—the southerly extension of the Keilor Plains lava field. Hills (1940) points out that they are well bedded, and there is no evidence of current bedding: the bivalves are thin-shelled and well preserved, the majority lying with their convex surfaces uppermost, indicating that they were deposited below high water mark out of the reach of the turbulent swash of the waves breaking on the beach. The ridges are 8 feet high, are relatively low and broad, and there is a succession of them. He states:

> "that the underlying form of some at least of the ridges is that of submarine banks formed when the level of the sea was sufficiently high to cause it to flood over the basalt plains in the areas where the above-described ridges occur. It appears probable that, either at this time or as the sea retreated, these banks were added to in places by the growth of beach ridges, but the shell beds near the Williamstown Racecourse, and the lobate ridges near Altona, are regarded simply as upraised submarine banks."

There is general agreement that the shells are Recent. Of the nature of the emergence he remarks:

> "Evidence of Recent emergence is so common along the Victorian coast, . . . that a eustatic fall of sea level may be suspected of having contributed to it. Such Recent emergence has been described by others, or has been observed by the author at Marlo, the Ninety-Mile Beach, Waratah Bay, Cape Patterson, Port Phillip, Apollo Bay, Warrnambool and Portland."

If some of the ridges of the Altona area are submarine banks formed when the level of the sea was higher, there is no doubt that the Yarra Delta was similarly inundated. As most of the Delta has been modified by human agency, we are compelled to rely on old records and maps. The maps show many features like those of the Altona area—an orderly succession of spaced depressions and, inferentially, ridges, trending west-north-west behind the north shore of Port Phillip Bay. In the West Melbourne Swamp littoral and estuarine shells have been found similar to those in the shallow ephemeral lakes of Altona.

The West Melbourne Swamp (Fig. 7) was an open sheet of water between the Maribyrnong River and Moonee Ponds Creek; in latter years it has been drained and reclaimed. It was formed by the lower reaches of the Moonee Ponds Creek being dammed back by sands deposited before the 15 to 20 feet eustatic fall of sea level, and was therefore flooded when sea level rose. There are records of fossil mollusca in the Swamp—all littoral or estuarine forms at present living in Port Phillip Bay. There are also records of fishes, but without details as to what part of the Swamp they came from. One was a tooth of the White Shark, *Carcharodon carcharias* Lin.; another, the caudal spine of the Blue Spotted Ray, *Myliobatis australis* MacLeay. The skull of a dolphin is stated to have come from a depth of 10 feet, and was obviously deposited before the eustatic rise. The White Shark and the Ray imply some depth of water, and we are reliably informed that the White Shark does not frequent brackish or fresh water.

In the National Museum collection there is a gasteropod described thus: "*Marcia nitida* (Q. & G.) Pleistocene (Raised Beach) Saltwater River, Ascot Vale. Presented by Thomas Keys 17.4.06. No. 7616." We have been unable to locate the part of Ascot Vale from which the specimen came, but the inference is that it was one of several presented at the same time by Keys from sewerage excavations in Epsom Road (Fig. 6). If so, the site is south-east of Quarry Hill and the east side of the Estuarine Flood Plain.

Again, in regard to wave platforms round the Yarra Delta, we are dealing with an area that has undergone almost complete transformation since it was settled, but we are fortunate in having, at one locality at least, a reliable railway section made as far back as 1854. The section shows two platforms on the western fringe of the Delta, at the foot of the slope leading up from it to the Newer Basalt plain on which the city of Footscray is situated. The Delta here is approximately 1,500 yards wide and its surface about 5 feet above L.W.M. The shoulders of the platforms are masked by talus, but, allowing for this, their estimated levels are 9 feet and 13 feet above L.W.M. No platforms are evident on the opposite eastern fringe, but the grades of its slope alter at elevations corresponding approximately to the platforms on the western fringe. Less than a mile upstream, the 13 ft. platform is repeated in the same position as regards the fringe of the Delta. The fact that in both occurrences the platforms are at the same elevation negatives the possibility that they are the downstream extensions of the Maribyrnong Terrace, which would imply a fall for that flood plain of 19 feet to the mile. There is evidence of a 13 ft. terrace a short distance upstream from the head of the Estuarine Flood Plain (Fig. 6) and of a 10 ft. platform on the Flemington Racecourse.

We are unable to visualise the formation of terraces such as these by entrenching following tectonic uplifts of which there is no evidence in the Yarra Delta. Had there been uplift, the channel of the Maribyrnong River would have been lowered, and terraces formed in the delta deposits on the slopes of the entrenched portion. They appear to have been wave platforms formed during eustatic lowering of sea level.

Correlation of the Maribyrnong River Terraces

It is submitted that the Keilor Plains lava field on which the Keilor, Braybrook, and Maribyrnong Flood Plains were formed is of Pleistocene age, presumably Middle Pleistocene. The Keilor, Braybrook, and Maribyrnong Cycles occured in connected sequence during the time interval between the formation of the Keilor Plains lava field and postglacial 15-20 feet eustatic fall of sea level. By tieing them up with the 15-20 feet fall of sea level, and placing the physiographical events that preceded it in logical sequence, the three cycles seemingly fall into the Upper Pleistocene, and correspond to the period when the Upper Pleistocene glacial and interglacial stages occurred in Europe.

In attributing the deposition of the flood plains and their subsequent terracing to eustatic adjustment, we desire to emphasize the fact that there is no evidence of Pleistocene or Recent glaciation in Victoria. The absence of systematic investigations as to the migration and extinction of the marsupials and the difficulty of defining cultures and industries in connection with the Australian aborigines, make it impossible to apply European methods in subdividing the Australian Pleistocene. We have relied on the world-wide eustatic adjustments associated with the glacial and interglacial periods of the Northern Hemisphere, and correlated our terraces with them. The contemporaneity of the Tasmanian and European stages is probable, but has not been definitely established. It is submitted that, if the Maribyrnong valley terraces are not strictly correlative with the European stages, the fact that we have tied them up with the Recent 15-20 feet fall of sea level, and shown that they preceded it in orderly sequence, proves that their age cannot greatly differ from that of those stages.

In regard to regional tectonic movements, it has been pointed out that the Keilor Plains lava field has been tilted seawards, but the tilting has retarded rather than assisted entrenchment. Its effect has been to make the eustatic falls appear less than they actually were. The greatest amount of entrenchment appears to be less than 40 feet. The streams of each of the cycles debouched into an almost completely enclosed bay situated on what is now the Port Phillip Sunkland or Port Phillip Bay. On the floor of the latter there is evidence of deltas and other estuarine land forms, which may ultimately be correlated with the Maribyrnong River Valley cycles. The only localized warping that seems to have assisted erosion is the Footscray Warp, which occurred during the Maribyrnong Cycle, and therefore late in the physiographical sequence; its effect has been insignificant. No fracture lines are known to have occurred on the lava field.

Tabular View of Correlation

Age	Maribyrnong Valley Flood Plains and Terraces	Glacial & Interglacial Stages
Recent	Vertical erosion due to latest fall of sea level at present in progress above tide limit in Maribyrnong valley. Rise of sea level. Raised beaches, submarine banks, wave platforms.	Postglacial
Upper Pleistocene	Eustatic fall of sea level and Footscray Warp. Entrenchment of Maribyrnong Flood Plain and formation of Maribyrnong Terrace	Wurm 3
	Eustatic rise of sea level. Formation of Maribyrnong Flood Plain	W2/3 Interglacial
	Eustatic fall of sea level. Entrenchment of Braybrook Flood Plain and formation of Braybrook Terrace	Wurm 2
	Eustatic rise of sea level. Formation of Braybrook Flood Plain	W1/2 Interglacial
	Eustatic fall of sea level. Entrenchment of Keilor Flood Plain and formation of Keilor Terrace	Wurm 1
	Formation of Keilor Flood Plain.	
Middle Pleistocene	Vertical erosion of Keilor Cycle. Keilor Plains Basalt (Newer Basalt).	Riss-Wurm Interglacial

Acknowledgments

We desire to acknowledge our indebtedness to Mr. John Knight, B.Sc., of the State Coal Mine, Wonthaggi, and Mrs. S. Whincup, M.Sc.; they both entered wholeheartedly into the task of levelling and correlating the terraces in the Maribyrnong valley.

To Mr. I. W. Scott, of the Ways and Works Branch of the Victorian Railways, we also express our thanks for checking our Dry Creek datum by an accurate traverse from a Country Roads Board datum.

The plans were drawn by the Geological Survey of Victoria.

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Fig. 2. Hughes's Sand-pit. Matchbox in right-hand lower corner marks the place where the Keilor skull was found.

Mem. Nat. Mus. Vict., 14, Pt. 2, 1946.

THE SUNKLANDS OF PORT PHILLIP BAY AND BASS STRAIT

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Figs. 1-16.

(Received for publication 18th May, 1945)

The floors of Port Phillip Bay and Bass Strait were formerly portions of a continuous land surface joining Victoria with Tasmania. This land surface was drained by a river system of which the River Yarra was part, and was intersected by two orogenic ridges, the Bassian and King Island ridges, near its eastern and western margins respectively. With progressive subsidence and eustatic adjustment, these ridges became land bridges and the main route for the migration of the flora and fauna. At present, their former trend is indicated by the chains of islands in Bass Strait and the shallower portions of the Strait. The history of the development of the River Yarra is largely that of the former land surface and the King Island land bridge, and is the main theme for this discussion.

The Yarra River was developed, for the most part, during the Pleistocene or Ice Age. In Tasmania, there is direct evidence of the Ice Age in the form of U-shaped valleys, raised beaches, strandlines, and river terraces, but in Victoria the effects of glaciation are less apparent. A correlation of the Victorian with the Tasmanian deposits and land forms, and, incidentally, with the European and American, can only be obtained by ascertaining the conditions of sedimentation and accumulation of such deposits in Victoria, as can be seen at the surface, or as have been revealed by bores, particularly those on the Nepean Peninsula; by observing the succession of river terraces along the Maribyrnong River; and by reconstructing the floor of Port Phillip Bay, King Bay, and Bass Strait, and interpreting the submerged land forms revealed by the bathymetrical contours.

This contribution deals with the former courses of the Yarra River as a tributary stream to the trunk stream, the Tamar Major River, when the Yarra flowed over the land surfaces that are now the Port Phillip Bay, King Bay, and Bass Strait Sunklands, and at different horizons in the dune accumulations on the Nepean Peninsula. King Bay is the name of the triangular portion of Bass Strait immediately south of Port Phillip Bay and north of a line bearing westerly through Cape Schanck; it is so defined in a sketch of Lieut. James Grant's chart made by him in 1800, now in the historical collection of the Public Library of Victoria, Melbourne. This restricted application of the name was apparently realized by Boys (1935), who states that Grant named "the recess in the coast line to the south of Port Phillip Bay, Governor King's Bay." Grant's name has since been abbreviated to King Bay.

The valley of the Yarra and the Tamar Major Rivers during the Pleistocene or Ice Age has been reconstructed by connecting up the soundings on the Admiralty Charts into bathymetrical contour lines. Where the Admiralty has done this, as with the 10 fathom line in Port Phillip Bay, the sunken river system shows up distinctly. Evidence as to the former channels through the Nepean Bay Bar was afforded by bores, particularly the Wannaeue and Sorrento Bores. Briefly, before the middle of the Pleistocene, the Yarra flowed in a broad valley on a mature land surface as far, at least, as Cape Otway, and emptied into the Southern Ocean. Since then, due to the subsidence of the land surface and recurring rises of sea level, the broad valley and most of the higher ground that formed the watersheds have been flooded by the waters of the Southern Ocean, and the Yarra has emptied into the headwaters of King Bay or Port Phillip Bay.

This investigation is one in the field of Victorian and Tasmanian Pleistocene geology and climatology. It discusses the land connections between Victoria and Tasmania during the later part of the Pleistocene and the alternation of cool and warm climatic periods. On the assumption that the Tasmanian animals migrated, for the most part, from the Australian mainland, and some survivors of these migrations are still to be found on the Bass Strait islands, certain groups of the fauna and elements of the flora will be discussed from the standpoint of the evidence available as to the physical aspect of the former land connections.

Port Phillip Sunkland

I. Port Phillip Sunkland

Port Phillip Bay is a land-locked bay, with a length of about 31 miles from north to south and a breadth of 20 miles from east to west—it covers an area of about 735 square miles. Its eastern and western shores converge northwards, and north of Point

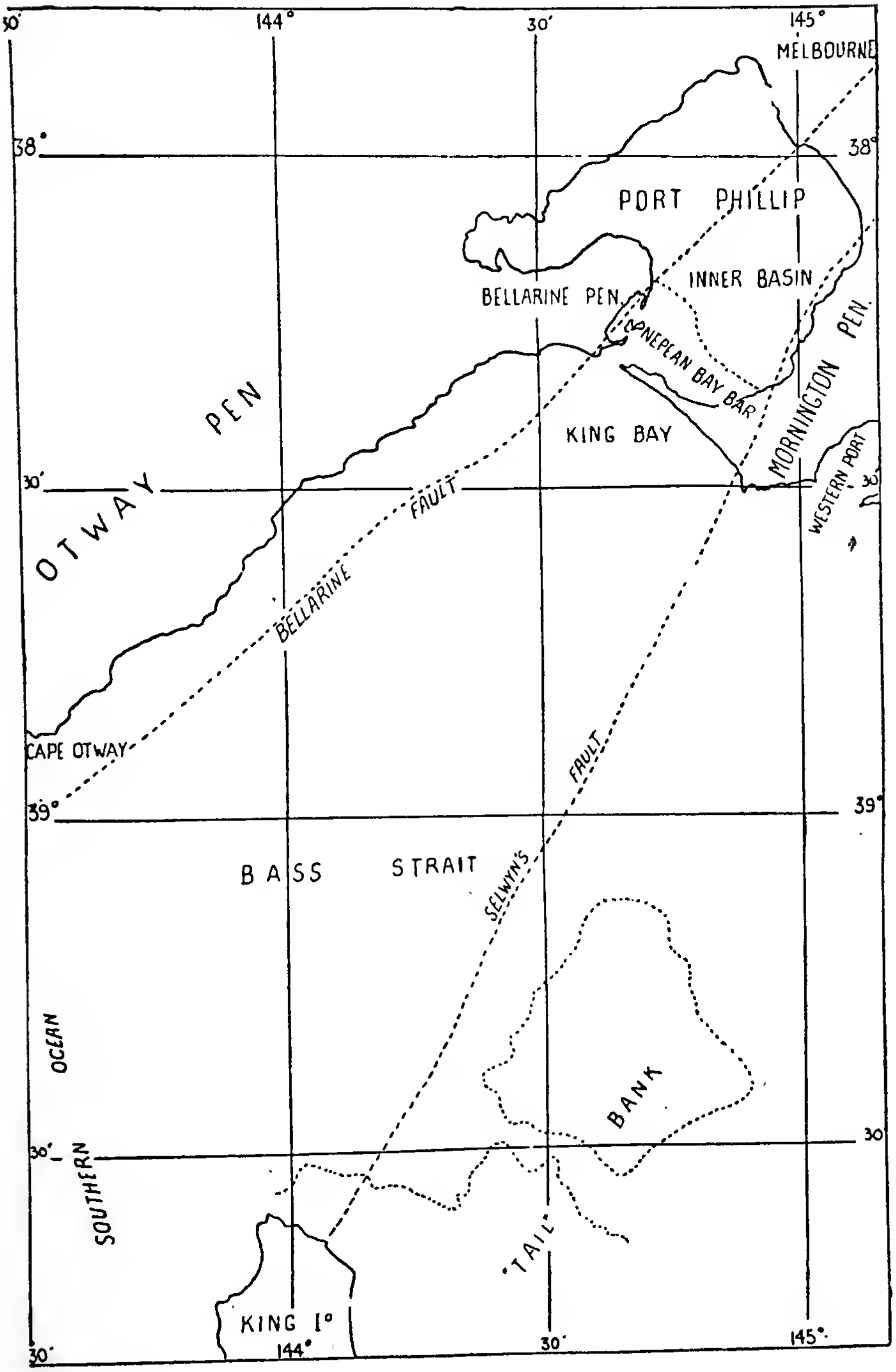

FIG. 1.
Locality Map showing the Port Phillip, King Bay, and Bass Strait Sunklands and the Nepean Peninsula (Nepean Bay Bar).

Gellibrand its headwaters are known as Hobson's Bay. The pear-shaped symmetry of Port Phillip is varied by the Bellarine Peninsula to the south-west: along the north shore of this Peninsula, an arm, forming the Geelong Inner and Outer Harbours, extends in a W.S.W. direction. There are several minor indentations in the shores of Port Phillip Bay such as Half Moon Bay, Davy Bay, Balcombe Bay, Dromana Bay, Swan Bay, and Altona Bay: a deep in the south-east portion is known as Capel Sound.

Long stretches of the eastern shores are low and shelving— they consist mainly of littoral, alluvial, or delta deposits, which have, at places, been piled up as dunes, or scoured out as submarine ridges uncovered, it is thought, by the eustatic fall of sea level. A considerable portion of these littoral and delta deposits has been submerged by the tectonic subsidence of the Port Phillip Sunkland. The bathymetrical contours of the submerged delta deposit at the head of Port Phillip show three outlets of the Yarra River—its present one near Williamstown, and two older ones at Port Melbourne and St. Kilda. Delta deposits also occur at the mouth of the Elsternwick Creek, between Mordialloc and Frankston, where they are fringed with dunes, at the mouth of Balcombe Creek, and between Mount Martha and Arthur's Seat. On the northern shore of Corio Bay, east of Limeburner's (Galena) Point, there are also delta deposits. On the eastern shore at Carrum, the shore of the delta deposits has advanced seawards which, according to Hills (1940) is due to uplift, not progradation. The coast is cliffed between these low stretches of coast.

The former shore line of the Inner Basin (Fig. 2) between the north end of Port Phillip Bay and Mordialloc is a down-warped coast; the undulating sedimentary beds exposed along that part of the shore were tilted seawards until they disappeared under the waters of the Bay. From this earlier shoreline, the present one has receded through erosion by the 2 knot current that sets from Hobson's Bay, until it has reached its present position.

From Frankston to Arthur's Seat, the coast is due to the monoclinal flexure known as Selwyn's Fault. Here, too, the original shore-line formed by the tilting on the flexure has receded by foreshore erosion. The north shore of the Bellarine Peninsula consists of ferruginous sandstone, Tertiary basalt, limestone, and Pleistocene basalt; it is a fault coast (Coulson 1939) that has receded before the erosion of the tidal stream.

The western shore of the Inner Basin affords a contrast to the eastern shore. For long stretches, it is flat and prograded; it is

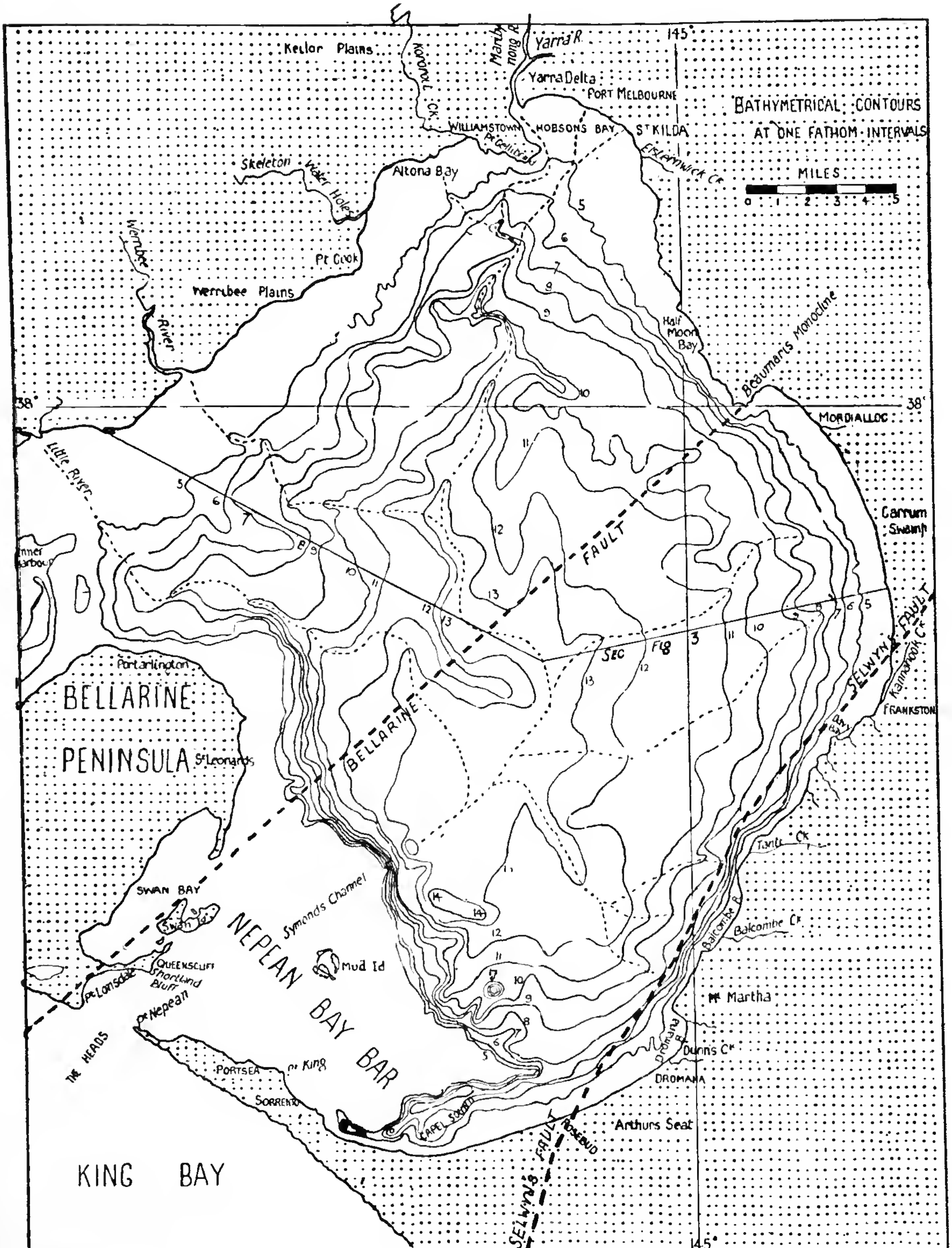

FIG. 2.
Bathymetrical Chart of Port Phillip Bay.

due to the gentle tilting on a warp inshore of the almost level surface of the Werribee Plains and Keilor Plains lava fields.

The Inner Basin north of the Nepean Bay Bar has a delta-form submerged level floor 78 feet below the surface of the Bay, and extending northwards for several miles; from this level floor, the Bay shallows northwards until the Yarra Delta on the north shore of Hobson's Bay is reached.

Port Phillip was surveyed by Commander Cox in 1861 and his chart, the groundwork of the present Admiralty Chart, and also of the bathymetrical chart (Fig. 2), was published in 1864. Cox's original chart is now in the possession of the Lands Department, Melbourne. Since 1861, various portions of the floor of Port Phillip have been the dumping grounds for silt from dredges, hoppers, and barges; but Cox's chart gives reliable information as to the nature of the original floor. By far the greater number of his soundings bottomed on mud. Those on the 78 feet level floor north of the Nepean Bay Bar bottomed, with a single exception, on mud or mud and shells, the exception being a bottom of sand. A short distance north of the Bay Bar, the bottom is mud or sand, sometimes with shells: the bottom of the 17-fathom scour hole is sand and shells. Out from the Carrum Swamp for about a mile the bottom is sand, but further out it is mud. Inshore along the precipitous granodiorite coast below Mount Martha, the bottom is sand but it quickly gives place to mud. At only one place in the central portion of the Bay is rock the bottom, namely, at 11 fathoms Long. 144° 50′ 12″, Lat. 38° 0′ 50″. Westwards of the 10 fathom line to the north-west shore of the Bay, and restricted to this portion, several soundings bottomed on stones.

The question of the Recent emergence of the shores of the Bay has been discussed by Jutson (1931) and Hills (1940). Hills thinks that the date of emergence may be Recent, and that a eustatic fall of sea level may be suspected of having contributed to it; at Portarlington, Duck Ponds Creek, and between Sorrento and Dromana, however, he points out that there are deposits, indicating that, at least in part, the emergence was due to tectonic movements of uplift.

II. *Subsidence of Port Phillip Sunkland.*

The Inner Basin of Port Phillip Bay is a tectonic subsidence caused by tilting. It has been pointed out that the shore of Port Phillip Bay between Frankston and Dromana is a coast that has receded by erosion from the monoclinal flexure known as Selwyn's Fault; this flexure has tilted the floor to the north-west. The tilting of the sediments between Hobson's Bay and Mordialloc has also been referred to. Likewise, due to tilting, the Werribee and Keilor Plains lava fields shelve under the waters of Port Phillip along its north-western shore; this movement is believed by Keble and Macpherson (1946) to have occurred near the close of the Pleistocene on the Footscray Warp, parallel to, and a few miles inland from the north-west shore. The north-west and south-east tilts are suggested by a slight inclination of the delta terraces (Fig. 4).

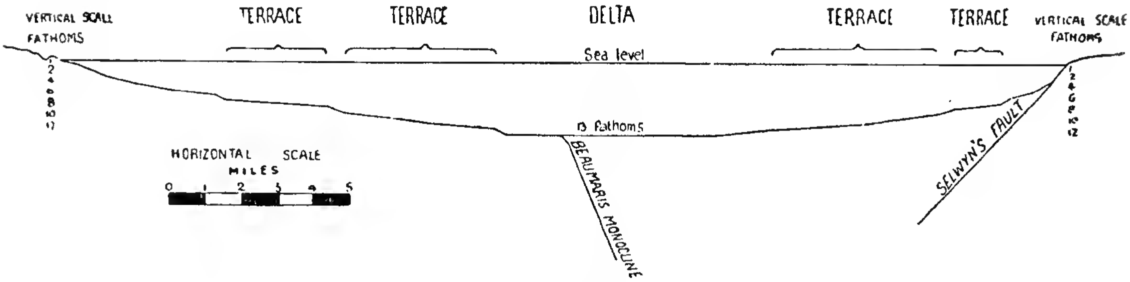

FIG. 3.
Section of Floor of Port Phillip. The Section line is shown on Fig. 2.

The line along which the tilting met is beneath the waters of the Bay, probably along the Bellarine Fault (vide p. 95).

The bathymetrical chart (Fig. 2) of the Inner Basin shows clearly that it is a sunkland—the submerged portion of the Yarra River System. The lower reaches of the tributaries that joined the lower Yarra are also clearly shown, and some of these join it on its delta. The tributaries from the west were the Werribee and Little Rivers, Kororoit Creek and the Skeleton Water Holes; from the east Mordialloc (*sic*), Kannanook, and other waterways—the outlets of Dandenong Creek, Balcombe Creek, Dunn's Creek and others. There are also valleys of streams that have ceased to function, their headwaters having been covered by basalt or dunes.

The trunk stream flowed on to an extensive delta, the submerged level floor at 78 feet, north of the Nepean Bay Bar. The mud on the delta, as elsewhere on the floor of the Bay, has, presumably, been brought down by the Yarra and its tributaries during the glacial stage, or equivalent pluvial stage, and resorted by the tidal streams during the interglacial or postglacial stages; the thickness of the sediment on the delta must be considerable.

The section (Fig. 3) across the floor of the Sunkland shows marine terraces 30 and 40 feet above the delta with a maximum width of 4¼ and 2 miles; respectively these surround the submerged delta except on the Nepean Bay Bar side, and extend northwards on both the east and west sides of the trunk stream, but some distance away from it. It is considered that these marine terraces were developed in the land-locked embayment behind the Bay Bar at the level of the eustatic rise of sea level when the delta and the lower portion of the valley were submerged. At that level, they were cut into the unresistant slopes rising from the submerged delta and the streams flowing into it, so that, apart from the slope given to them by the tilting, their elevation is everywhere the same, being fixed by a former sea level. On the sunkland, vertical erosion due to eustatic fall of sea level was restricted to the actual channel of the trunk stream and its tributaries, as in tectonic uplift; terraces so formed were typical fluviatile terraces, in contrast with the marine terraces formed some distance from the channels.

Concerning interglacial rises above present sea level, Daly (1934) suggests that the higher sea levels of the interglacial stages are represented by marine terraces at heights averaging 71 feet and 118 feet. He also gives Cooke's correlation (1932) of marine terraces and Pleistocene stages along the south-eastern shore of the United States. The Wisconsin (and Iowan ?) are the North American equivalents of the Wurm and these only are given here:

Terrace	Altitude (meters)	Observed extension as described	Corresponding stage of Glacial Epoch
. . .	. . .	. . . . . .	1st Wisconsin Glacial
Talbot	13 (51 ft.)	Delaware to Florida	1st Wisconsin Interglacial
. . .	. . .	. . . . . .	2nd Wisconsin Glacial
Pamlico	7·5 (29½ ft.)	Maryland to Florida	2nd Wisconsin Interglacial
. . .	. . .	. . . . . .	3rd Wisconsin Glacial
Prince Anne	4 (15½ ft.)		3rd Wisconsin Interglacial
. . .	. . .	. . . . . .	4th Wisconsin Glacial

Estimates of the interglacial rises from the marine terraces in Port Phillip Bay are, however, complicated by the down-tilting of the floor of the Bay.

A first stage in the formation of marine terraces in Port Phillip Bay was that of the marine ridges at Altona which Hills (1940a) suggests may have been formed by the retirement of the waters of the Bay. The marine terraces surrounding the submerged delta have been modified to the extent that any ridges that may have been formed on their surfaces, have been planed out by wave action. Having been formed by the same eustatic adjustments that formed the fluviatile terraces in the Maribyrnong River, they probably belong to the Braybrook and Maribyrnong Cycles of erosion.

Nepean Bay Bar

III. Evidence of Sorrento, Wannaeue and Other Bores on Nepean Bay Bar.

The Sorrento Bore (Fig. 5) was put down in 1910 by the Geological Survey of Victoria, on the Nepean Peninsula at the north-east corner of the Sorrento Recreation Reserve (Water Reserve, allot. 6A, Parish of Nepean), the bore site being 10 feet above sea level. The reduced levels of this and other bores are given here with the letters L.W.M.—low water mark Hobson's Bay—the datum usually adopted in Victoria. Incidentally, it may be mentioned that all deductions as to tectonic or other movements are based on L.W.M.

The drilling of the Sorrento Bore was done partly with a calyx bit to obtain a core, and with a core barrel when the sediments were uncompacted. Core samples were obtained at the depths indicated by Chapman (1928) in his report on the palaeontology of the bore. It was put down, as Chapman states, on the downthrow side of Selwyn's Fault and gives, according to him, a "succession of the Tertiary beds in the most complete form obtainable, since in no other spot would there be such a continuous and extremely thick deposit of practically the whole Tertiary Series." Hitherto, the information available as to the age of the Upper Dune Series, the surface deposit of the Nepean Peninsula, was meagre. A small portion of the Nepean Bay Bar—that eastwards for a few miles from Point Nepean—came into Quarter Sheet 29 N.E. surveyed by Daintree in 1861, who, following the advice of McCoy, mapped it as Newer Pliocene. The major part of the Quarter Sheet covers an area west of The Heads, and shows that the Upper Dune Series extends across that fairway. Daintree (1861-2) states in his report on the sheet that a skull of a wombat was found while the face of the cliff at Queenscliff was being removed. There is no doubt that the skull and lower jaws of an extinct Eared Seal described by McCoy (1877) as *Arctocephalus williamsi* came from the Upper Dune Series at Queenscliff. Dr. Williams, who sent it to McCoy, stated in his letter "it was found 5 feet below the surface in what was described as marl and sandstone, overlaid with limestone and sandy loam": dune limestone is the only calcareous bed that occurs at or near the surface in this part. With it was found the remains of an extinct wombat *Phascolomys pliocenus* (McCoy) and the Tasmanian Devil *Sarcophilus ursinus* (Harris), now extinct in Victoria but still living in Tasmania. McCoy (1877) states that *Arctocephalus williamsi* was found in the dune area at Cape Otway, but does not say in what association. Other mammals found at Queenscliff were the seal *Otaria forsteri* Lesson, and, in a cave, the dingo, *Canis dingo* Blumenbach.

Gregory (1901) recorded an extinct kangaroo from near Sorrento. The fossil was in the consolidated dune rock (Upper Dune Series) between tides and, according to him, probably *Palorchestes azael* (Owen).

Chapman (1919) identified a number of forms found in a shell marl in the Tootgarook (Boneo) Swamp, which rests on the Upper Dune Series, and listed both marine and freshwater species. These were, Pelecypoda: *Erycina helmsi* Hedley; Gasteropoda: *Coxiella striatula* (Menke) and *Bullinus acutispira* Tryon; Crustacea: *Cypris mytiloides* G. S. Brady, *C. sydneia* King, *C. tenuisculpta* Chap., *Candoncypris assimilis* Sars., *Cythere lubbockiana* G. S. Brady and *Limnocythere sicula* Chap. He considered the presence of marine shells indicated some antiquity—a Pleistocene age.

The core of the Sorrento Bore gave a record of the stratigraphical sequence of the Holocene and the Tertiary beds on the Nepean Bay Bar down to 1680 feet, and made it possible to correlate outcrops in other parts of the Port Phillip area. Nevertheless, as the samples were taken at intervals—some of them as far apart as 40 feet and others less than 10 feet, the average distance apart being about 20 feet—it constituted an imperfect record, not only of the Holocene and Tertiary succession, but of the events leading up to, and connected with, the formation of the Bay Bar. Since, too, in the Holocene part of the bore, many of the fossils are foraminifera, a doubt arises, where the containing beds are intercalated with dune deposits, which here predominate, as to whether these tiny forms were not blown in by wind. There are some beds with a recorded fauna of one or two foraminifera, and perhaps an equally small polyzoan.

Chapman's descriptions (Chapman 1928) of the Recent, Pleistocene, and transitional Pliocene (Werrikooian) core samples are as follows:

Depth in Feet	
67	Loose calcareous sand.
112	Dune-rock.
130	,, ,,
167	,, ,,
178	,, ,,
207	Shallow water limestone with (marine) bivalve and gasteropod shells, indet.
226	Consolidated dune-sand (dune-rock).

269 Limestone of shallow-water origin. Structure, porous, and with ferruginous staining. Some occasional mica flakes. Numerous casts of bivalves, indet.
275 Liver-coloured clay. Residuum after washing, a fine, ferruginous sand with a few quartz particles.
298 Calcareous dune-rock.
324 Calcareous quartzose sand and grit.
343 " " " " "
388 A fine-grained dune-rock.
397 A liver-coloured clay interbedded with micaceous and sandy mud.
408 Dune-rock with occasional shells.
416 Dune-rock.
430 " "
438 " "
445 Consolidated shelly beach-sand with bivalves. The intercalated clay particles or silty layers contain foraminifera.
460 Ochreous sandy clay.
476 Grey calcareous sandstone; actually a consolidated foraminiferal sand.
489 A dark, estuarine clay.
490 Ash-coloured clay. The residuum, after washing, is a fine white quartz sand. There are no microzoa.
503 Ochreous sandy clay. The residuum, after washing, consists of an angular and subangular quartz sand, with some ochreous particles. No organisms present.
520 Consolidated ferruginous and calcareous sandstone, largely composed of microzoa. None determined.

The dune-rock in the Sorrento Bore from the surface to 178 feet is referred to as the Upper Dune Series. This series having been deposited on a surface of fluviatile erosion varies in thickness; in the Wannaeue Bore No. 4 it is 153 feet thick and in the Queenscliff Bore 178 feet thick. The Dune Series in the Sorrento Bore from 408 feet to 438 feet, but probably of greater thickness, is referred to as the Lower Dune Series.

Chapman gives a classified list of the fossils in the Sorrento Bore with their depths. He determined many thousands of species comprising Foraminifera 185 species, Coelenterata 20 species, Vermes 3 species, Echinodermata 77 species, Mollusca 257 species and Arthropoda 69 species.

The following conditions of sedimentation and accumulation are suggested by Chapman's descriptions of the core samples:

1,680-585 feet. Highly fossiliferous marl, sand rock, and sandstone, with the sandy beds predominating in the upper limits. This is taken to indicate a gradually shallowing open sea.

585 feet. The summit of the Pliocene. The core was a shell sand with grit and pebbles which with microscopic shells were polished by wind action. Chapman says that they indicate shallow water and strand line conditions.

503-490 feet. An unfossiliferous clay, representing, presumably, the deepest fresh-water beds in the bore.

489 feet.	An estuarine clay resembling that now forming at the mouths of Victorian rivers.
476 feet.	A consolidated foraminiferal sand with many species of foraminifera and ostracoda indicating an open sea.
445 feet.	Shelly beach-sand with bivalves and foraminifera in intercalated clay particles and silty layers. In this sample *Ostrea* sp. was found.
438 feet.	Dune-rock. This is the lowest occurrence of undoubted terrigenous and dune conditions. Such, interrupted by occasional estuarine deposits, persist to the surface.

In regard to the surface beds, Chapman assumes that the loose calcareous sand down to a depth of 67 feet represents the Holocene—an assumption based on physical rather than palaeontological evidence, and consequently unsound. In restricting the downward limit of the Pleistocene to 489 feet, he relies on fossil species that are still living in adjoining waters and is on safer ground. The dune-rock, in its sporadic occurrences, is consolidated, he states, exactly like the old Sorrento limestone, and, it may be added, like that reached by the bores put down on the sand banks in the Bay (vide p. 87) and in the cliff at Queenscliff. It therefore extends across the whole width of the Nepean Bay Bar.

Below 489 feet there is, to quote Chapman, "no tangible palaeontological evidence on which to work in regard to the delimitation (of the Werrikooian), but in lieu of better evidence, we have taken the depth from 490 feet down to 520 feet as probably comprised in this series . . . In the present series allocated provisionally to the Werrikooian at the depth above indicated, the nature of the deposits . . . show a good deal of relationship to the Pleistocene." This delimitation of the Werrikooian is mentioned because surface beds near St. Leonards may be Werrikooian.

His correlation of the beds at 585 feet with the Pliocene (Kalimnan) is sound.

The Wannaeue Bores comprise eight bores (Fig. 2) put down along the E.b.S. boundary of the Nepean Bay Bar about 8 miles E.S.E. of the Sorrento Bore. Bore No. 1 Wannaeue is on the upthrow side of Selwyn's Fault, No. 2 to 7 Wannaeue and No. 2 Fingal on the downthrow side and consequently on the Nepean Bay Bar. No. 4 Wannaeue which was started about 20 feet above sea level has here been selected for a correlation with the Sorrento Bore. In it, as in all others put down at the time, samples were taken throughout the depth bored—there were no intervals as in the Sorrento Bore—and the core was examined by the author as it was brought to the surface.

The dune limestone was of different degrees of hardness but always a consolidated dune-rock. It consisted predominately of calcareous material with 71 to 81 per cent of $CaCO_3$; the remainder consisted mostly of rounded siliceous sand. The dune sand was unconsolidated, and had to be bored with a core barrel; no analyses

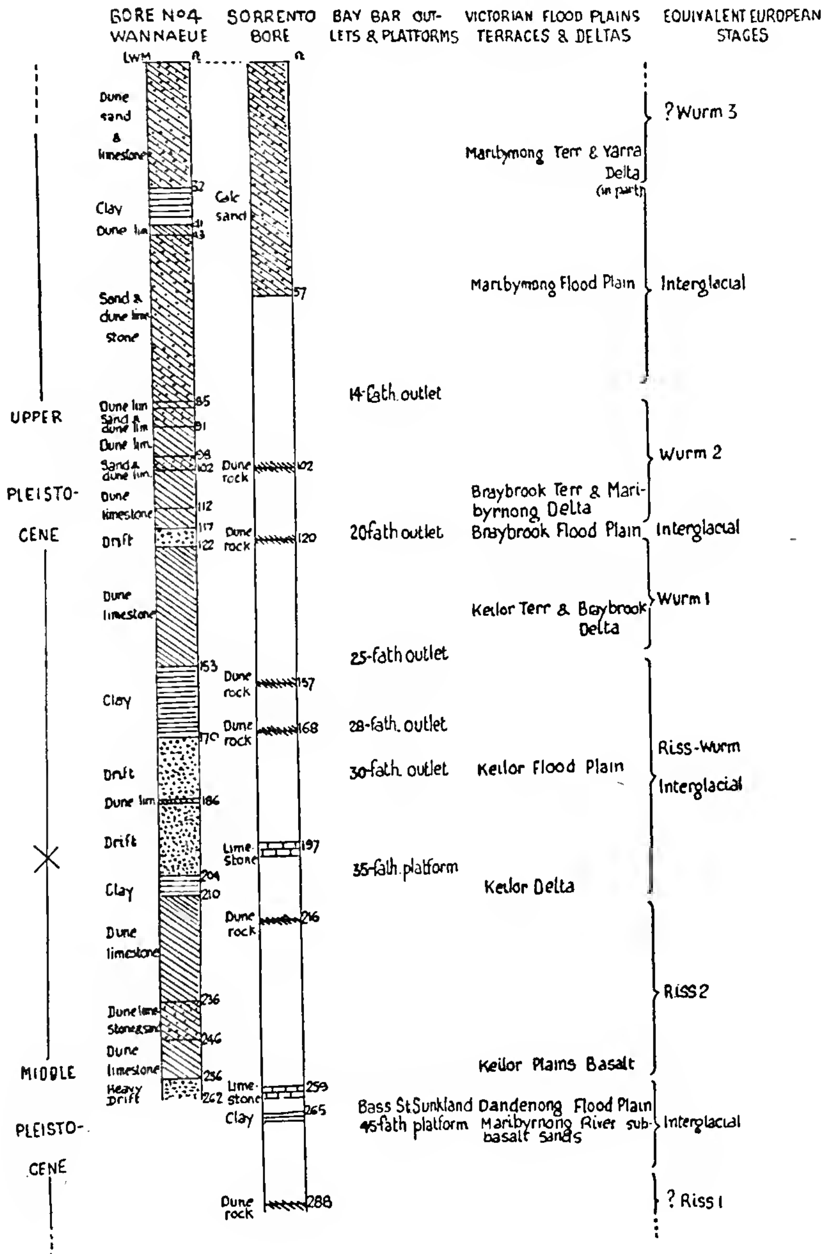

FIG. 4.

Tabular comparison of the Wannaeue and Sorrento Bores.

were made of this, but it apparently approximated to the dune limestone. In the bands of sand, and to some extent in those of the dune limestone, the shelly matter represented for the most part fragments of small bivalves. The shells were derived from a pre-existent bed-dune rock or some bed on the Bay Bar disintegrated by wind action, or resorted by wave action following eustatic rise of sea level similar to the sands above the dune-rock on the shoals of Port Phillip (Fig. 6).

In Bore No. 4 the first notable change in sedimentation comes in at 153 feet (L.W.M.), the base of the Upper Dune Series; from this depth to 210 feet (L.W.M.) there are marine and terrigenous clays intercalated with which, at 170 feet (L.W.M.) and 186 feet (L.W.M.), are bands, respectively 16 feet and 17 feet 6 inches thick, of what the drill foreman has termed "drift," actually material "drifted" in from outside the area of the Bay Bar. This marine and terrigenous series rests on a dune series extending from 210 feet (L.W.M.) to 256 feet (L.W.M.) which rests on heavy drift reaching to 262 feet (L.W.M.), the depth at which the bore stopped.

In Bore No. 1 Wannaeue no dune rock was met with indicating that the Upper Dune Series is restricted to the downthrow side of Selwyn's Fault.

Bore No. 1 Paywit (Fig. 5) was put down on the Bellarine Peninsula on the relative upthrow side of the Bellarine Fault. It started (Geol.-Surv. 1923-30) in a bed of clay 13 feet thick, and passed into a dune series consisting mainly of dune limestones and sands which continued for 118 feet. It then passed through clays, with ironstone bands, for 14 feet and sandy and ligneous clays for 255 feet to a depth of 400 feet.

The Queenscliff Bore (Fig. 5) was put down about 1860 on the Queenscliff Peninsula, about a mile north of Shortland Bluff. It reached a depth of 470 feet and according to Daintree (1861-2) passed through 178 feet of dune limestone which, with the 42 feet above it in the cliff, made a total of 220 feet.

IV. Tideways and Channels Through Nepean Bay Bar.

The essentials for the formation of the Nepean Bay Bar in its present form were:

(a) The former existence of an open bay—the headwaters of King Bay.

(b) Headlands at each end of the mouth of the bay approximately in a line with the direction of the current and the prevailing wind; this orientation lent itself to the formation of spits on the leeward side of the western headland—the seaward extension of the limestones and marls in the vicinity of Jan Juc. As the material comprising the Bay Bar is dune limestone, and the eastern headland—the relative upthrow side of Selwyn's Fault south-west of Cape Schanck—consisted of basalt extending some distance seawards, it is evident that most of the calcareous material came from Jan Juc.

(c) A plentiful source of material. The headlands at Jan Juc were attacked by current and wave action, and supplied the material for the extension of the spit; to this was added, from time to time, material contributed by the River Yarra from its valley to the north.

(d) A bay deep enough to ensure that the material came to rest at the end of the spit, and was undisturbed by the surface movement of the bay water. That this was so is evident from the subsequent formation of the Bay Bar.

(e) The building inward and upward of the spit, its emergence, and the subsequent formation of dunes on its surface.

This sequence is clearly shown by the record of Bore No. 4 Wannaeue (Fig. 4) upwards from 210 feet (L.W.M.). That the directions of the current and prevailing wind now found in Bass Strait persisted throughout the Pleistocene are shown by the fact that Jan Juc is to the south-west. The headland when the Bay Bar formed was about 4 miles east of the existing shoreline. A note on Admiralty Chart No. 1695B states:

> "A current averaging from ½ to 1½ knots will generally be found setting through Bass St.; after Westerly winds, it sets to the Eastd.; with and after Easterly winds, to the Westward. As Westerly and South-westerly Winds are the prevailing ones throughout the Strait, the current will generally be found setting to the East and North-east, its strength depending on the previous force of the wind."

Dannevig (1915) states that the flood tides enter Bass Strait from the west, north, and south past King Island, and the ebb tides pour out through the same channels. They assume a north-easterly direction on passing King Island: a northern branch pushes on past Cape Otway towards Port Phillip and Western Port, where small arms enter various inlets. The main body is swayed to the east and south-east towards the centre of the Strait. The current from the Southern Ocean presses against the southern coast of Victoria and King Island, and although its greater volume is diverted to the south-east and south long before reaching land, sufficient force remains to establish a general "drift" through the Strait from west to east. This current is, in the open ocean, accentuated by the dominating westerly winds and as this wind direction prevails in the Strait to the extent of about 16,000 miles per annum, its influence will make itself felt also upon the local waters. Another factor of some consequence is the powerful wave action associated with the prevailing winds, which materially assists in redistributing deposits.

From its present and former subaerial aspects, the Nepean Bay Bar may be considered from the standpoints of:

(I) Its geomorphology,
(II) its submerged land surfaces—the shoal of Port Phillip,
(III) the King Bay profile.

(I) The Geomorphology of the Nepean Bay Bar.

The Nepean Peninsula (Fig. 5) is a sickle-shaped land surface with its southern or King Bay shore slightly concave from the S.W. and its northern or Port Phillip shore concave from the N.N.E.; Point Nepean, the end of the sickle, points N.W.b.W. Its E.b.S. boundary is Selwyn's Fault which cuts across it from Dromana to Cape Schanck. It formerly extended to beyond Barwon Heads, but is now interrupted by the fairway through The Heads, which has been cut in dune limestone.

For some miles east of Point Nepean, the King Bay shore is a young coast; it is cliffy, with a steep inshore profile, and indented by small bays with pocket beaches, while along and near the shore are reefs, arches, caves, and blow holes. Nearer Cape Schanck, however, the coast becomes sub-mature, consisting of long beaches with a shelving profile, broken here and there by low headlands of dune-rock. The shore line from Point Lonsdale to Barwon Heads is a similar, submature coastline.

The Port Phillip shore of the Nepean Bay Bar consists, for the most part, of beaches, broken occasionally by cliffs of dune-rock; this contrasts with the shore of the Bellarine Peninsula which, at Point Lonsdale and Shortland Bluff, is cliffy, but further north is low lying, and composed largely of siliceous sand. At St. Leonards, further north, the low cliffs are composed of Pliocene (? Werrikooian) sandstones.

The area of the Nepean Peninsula is about 45 square miles. Locally, it is known as The Cups, an appropriate name, as most of it is a succession of calcareous dunes and dune ridges, separated by hollows with closed contours; the dune material has been consolidated into dune-rock by the solution and redeposition of the calcareous material. Few of the consolidated dunes east of Rye rise above 100 feet but near Sorrento, St. Pauls, a consolidated dune is 176 feet above L.W.M., and there is a record by Gregory (1901) of a dune nearer Point Nepean being 225 feet above L.W.M.

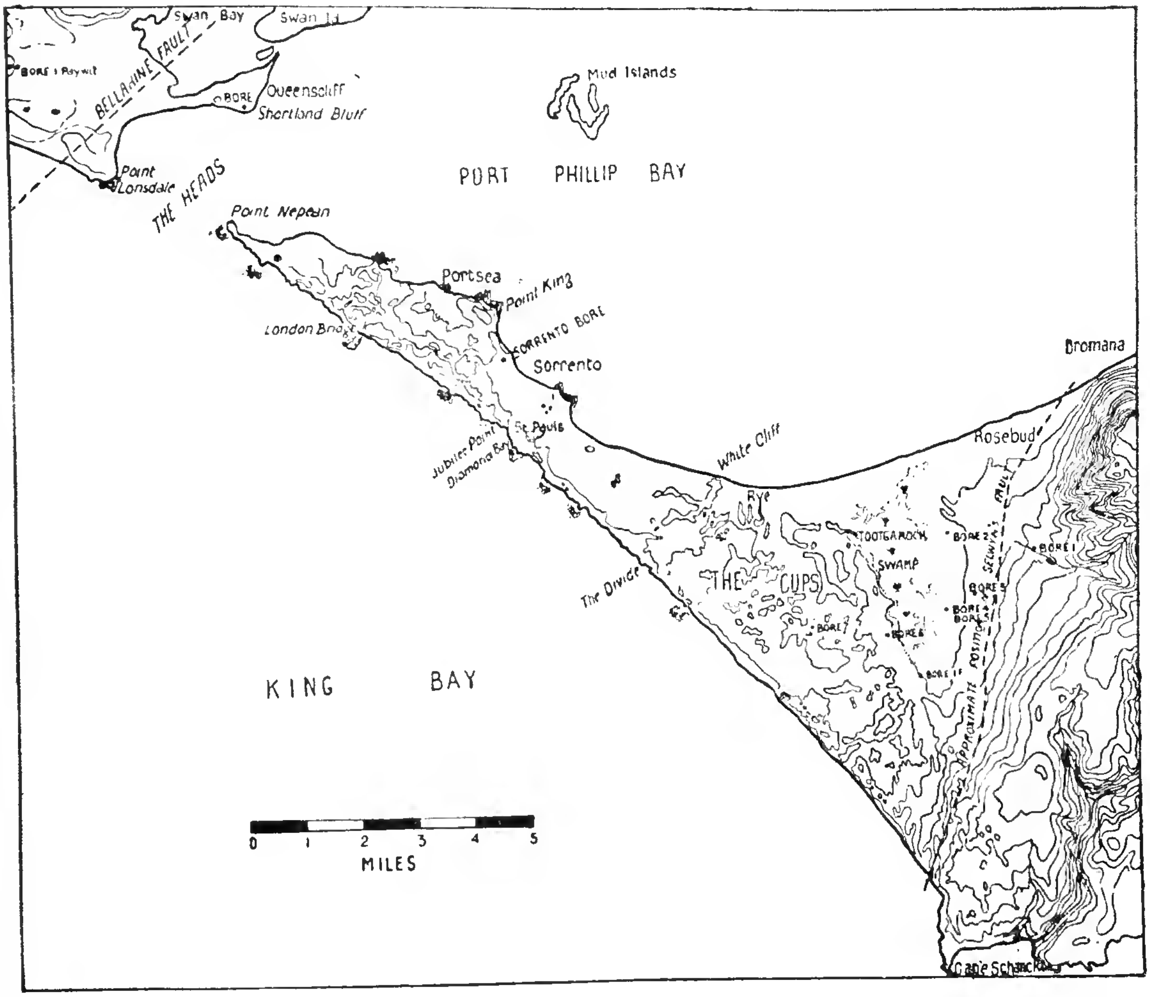

FIG. 5.
The Nepean Peninsula.

There are no water courses on the Nepean Peninsula. All the water that comes down in the stream channels on the denuded scarp of Selwyn's Fault percolates into the dune deposits at the foot of the scarp; the dune rock is too porous to hold up fluviatile waters. There is a shallow channel from the foot of that Fault to the Tootgarook Swamp cut by flood waters, but it is dry except during flood periods, and then water only flows in it for a few hours.

Between Rosebud and Rye, and extending inland towards the shore of King Bay, are the swamp deposits, peat and marl, of the Tootgarook Swamp; these were deposited in a former tideway—the Tootgarook Tideway. On the shores of Port Phillip and King Bays are raised beaches, and overlying these at places, unconsolidated dune sand, some of which has accumulated within the last 100 years. Since the Nepean Peninsula has been largely cleared of timber, the higher points of the consolidated dunes and dune ridges exposed to the prevailing wind are being disintegrated, and relapsing once more into moving dunes.

The Nepean Peninsula was geologically surveyed and contoured by the author in 1927, as far west as Rye; Fig. 5 is compiled from this survey and other sources.

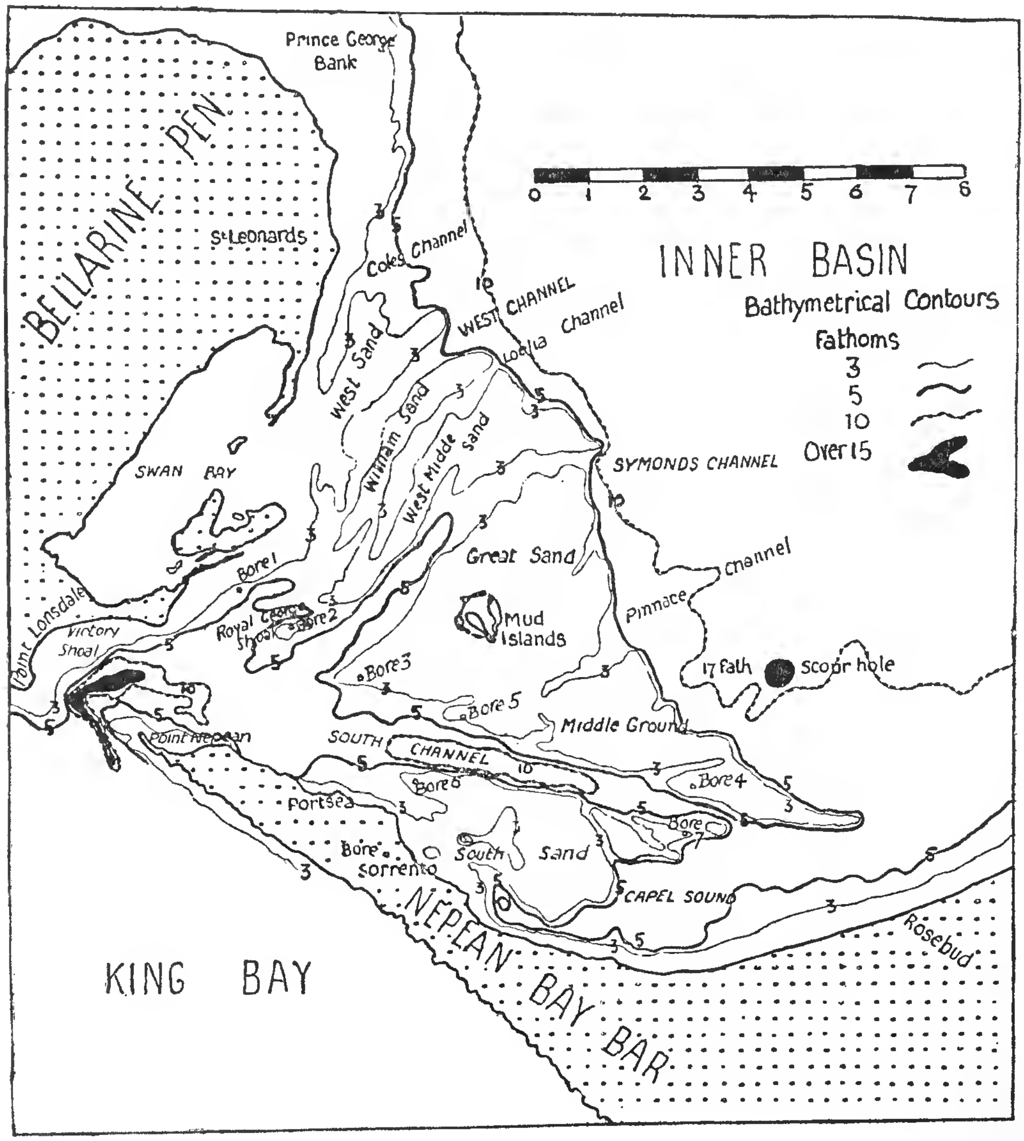

FIG. 6.
The Shoals of Port Phillip Bay.

(II) Shoals of Port Phillip Bay.

The shoals (Fig. 6) of Port Phillip Bay occupy the whole of the southern portion, south of a line from Rosebud, on the Nepean Peninsula, to St. Leonards, on the Bellarine Peninsula. This Rosebud-St. Leonards line marks the upper portion of the north-east face of the Upper Dune Series which slopes into the Inner Basin of Port Phillip.

The shoals at places awash are the South Sand, Middle Ground, Great Sand surrounding Mud Islands, West Middle Sand, William Sand, and West Sand; nearer the fairway through The Heads are the Royal George Shoal and the Victory Shoal. Bores (Parl. Pap. 1864-5) have been put down on some of them (Fig. 7). The following is a summary of the records of these bores, the datum being L.W.M.

Bores	1 ft.	1 in.	2 ft.	2 in.	3 ft.	3 in.	4 ft.	4 in.	5 ft.	5 in.	6 ft.	6 in.	7 ft.	7 in.
Depth of Water	13	0	7	0	8	0	5	6	4	6	12	0	15	0
Sand	23	8	9	0	9	0	8	6	21	6	15	3	17	0
Sandstone ..	3	4	8	3	7	0	16	6	3	6	4	9	5	0

An excerpt from the covering letter forwarding this information was as follows:

> The general result of the boring is, that, in every instance a bed of Sand varying from 8½ to 23½ feet thick was passed through terminating in Sandstone similar to that seen in the cliff at Queenscliff (dune-rock) and into which the borings were continued for depths varying from 3½ to 16½ feet.

Through the Sands are tideways—South Channel, Pinnace Channel, Symonds Channel, Loelia Channel, West Channel, Coles Channel and others of minor importance; some of these have been dredged and straightened, and it is impossible now to define their original courses. They were formed by the scour of the tidal streams, not by fluviatile erosion, hence the use of the term tideway for them. The Sands are persistently encroaching on them, but they are kept clear, partly by the tidal streams and partly by dredging.

The following extract is taken from remarks (Aust. Pilot Sup., 1926) on the tides and tidal streams of Port Phillip Bay, published by the Admiralty:

> Owing to the narrow entrance and the large area of Port Phillip the range of the tides within the Heads is small in comparison with that in the entrance, water level within the Port is consequently much affected by winds blowing for a long period in one direction and may remain above mean level continuously or for some time after southerly gales or below mean level continuously for some time after northerly gales.

It is high water, full and change at the undermentioned places in Port Phillip as follows:

		h.	m.				ft.	in.			ft.	in.
Entrance to Port Phillip	at	XI	37	approx.	spring	rise	7	0	neap	rise	5	6
Queenscliff	,,	2	0	,,	,,	,,	3	0	,,	,,	2	0
Dromana Bay	,,	2	19	,,	,,	,,	3	0	,,	,,	2	6
Snapper Point	,,	2	14	,,	,,	,,	2	8	,,	,,	2	0
Point Henry, Geelong	,,	2	39	,,	,,	,,	3	0	,,	,,	2	6
Williamstown Hobson Bay	,,	2	53	,,	,,	,,	2	3			—	
Queen's Wharf, Melbourne	,,	2	48	,,	,,	,,	2	8	,,	,,	2	2

The tidal streams in the entrance depend on the relative levels inside and outside the port; the greatest difference in levels occurs at about the time of high and low water in the entrance, and the stream therefore runs at its strongest, 5 to 8 knots, at these times; slack water occurs at about 3 hours before and after high water in the entrance when there is no difference in levels, and the stream runs in from about 3 hours before till 3 hours after high water, out at all other times; as the levels depend partly on winds, the times of slack water and the velocity of the stream are also affected by wind; the freshets may also affect the stream.

On an average it is high water at Port Phillip heads about 3¼ hours before that at Williamstown, but owing to weather causes, this interval may vary from 3 to 4 hours. As the tidal streams in the fairway run for about 3 hours after the time of high and low water by the shore at Point Lonsdale, it will, therefore, be approximately slack water flood at the Heads when it is high water at Williamstown.

The direction of the winds (Aust. Pilot, 1926) at the head of Port Phillip is as follows:

	No. of days a year
N.	59
N.E.	30
E.	48
S.E.	54
S.	64
S.W.	38
W.	17
N.W.	52
Calm	3

It is evident that the southerly wind is the prevalent wind but that northerlies are scarcely less prevalent.

The velocity of the tidal streams is practically the same from top to bottom. The rate of the out-going stream through the West and South Channels is from 2 to 3 knots, and in the Inner Basin 1½ knots. A velocity of half a knot is sufficient to drive sand along the bottom, 1 knot fine gravel, and 3½ knots stones 1½ inches in diameter (Marmer, 1926). Nevertheless, although the scouring effect of the streams in the tideways is seemingly sufficient, it does not prevent the depositing of mud along them.

Holes occur on the floor of the fairway at The Heads, and at places in the Inner Basin, near the south-east slope of the Nepean Bay Bar. The holes are due to the turbulence of the tidal streams, and are referred to here as "scour holes." They are assumed to be formed by the eddying of streams after they pass from a contracted tideway into a basin. Their formation is complicated by several factors, but it is beyond the scope of this contribution to consider such. It is apparent, however, that they may be formed by either the in-going or out-going streams, after they have passed from a tideway into a basin.

The scour hole (Fig. 6) at The Heads is roughly crescentric in shape, with the end in Port Phillip pointing E.b.S. towards the South Channel, and the end in King Bay pointing S.S.E. In Port Phillip, it occupies a position in the fairway between The Heads, midway between Point Nepean and Point Lonsdale; between the Nepean Peninsula and Shortland Bluff, it widens out into a deep basin with an average depth of 54 feet formed by the convergence of West, Symonds and the South Channels. Its deepest part is W.N.W. of Point Nepean, where it has a depth of 282 feet (47 fath.); it shallows quickly to the E.N.E., and where it turns to the S.S.E. At this S.S.E. extremity, there is a reef with, at places, less than 28 feet of water over it. This reef, which is responsible for the rip, slopes to the north into the scour hole; its slope to the south is part to the steadily deepening profile of King Bay.

The in-going tidal stream comes from the southward and eastward, increases in strength as it nears The Heads, sets right across the entrance, across through the reefs with great force, and spreads towards Shortland Bluff and Point King (Fig. 7); past that point, in the South Channel, it sets E.N.E. across the Middle Ground and through the Pinnace Channel (Fig. 7). The out-going stream from the Inner Basin passes obliquely through the various channels, the stream from Symonds Channel joining and turning that of the West Channel below the Royal George Shoal, setting towards the bight between Shortland Bluff and Point Lonsdale, and from thence through The Heads, the body of the stream setting athwart the entrance towards Point Nepean and away south-eastward along and into the shore between Point Nepean and Cape Schanck. Knowing the directions of the tidal streams both inside and outside The Heads, it is obvious how the scour hole became crescentic in shape. The fact that the King Bay coast E.b.S. of Point Nepean is young has already been mentioned; it is inferred from the position and direction of the scour hole that at its S.S.E. extremity it was formed in a tideway, and the coast formerly extended as far out, at least, as this.

The hole referred to here as the 17-fathom scour hole (Fig. 7) is in the Inner Basin near the toe of the inner scarp of the Bay Bar and about 1¼ miles N.N.E. of the inner outlet of an unnamed tideway that extends E.N.E. from the South Channel; it branches off from it about 4 miles west of that channel's outlet into the Inner Basin. For the greater part of its length, this unnamed channel is 20 feet deep, but narrow; near its outlet into the Inner Basin, it has been blocked by a sand bar over which there is only 4 feet of water. The 17-fathom scour hole, which is being rapidly silted up, was apparently formed in the Inner Basin by in-going tidal streams that flowed through a tideway of some width, and not the narrow unnamed tideway. To the south-west extremity of Capel Sound, there is evidence of an older scour hole that appears to have been connected with a former tideway that had an outlet (Fig. 7) into King Bay, and is disclosed by the bathymetrical contours at 20 fathoms on the profile (Fig. 7) of that Bay. Gregory (1903) suggests that this outlet may be a river outlet from Port Phillip Bay, but the alignment of the three suggests that they have been connected by a tideway, not a river channel.

There are large, but relatively shallow, scour holes at the inner entrance to Symonds Channel, but closer soundings are necessary to enable one to comment on them.

It has been stated that tideways are ephemeral. Due to the encroachment of dunes, they are constantly altering their courses, and move at different times throughout the length of a bay bar. Thus, the Tootgarook Tideway previously referred to was an earlier tideway than any of those now converging on The Heads; it was formed along Selwyn's Fault on its downthrow side, and entered King Bay on the submature portion of the coastline near where the Fault crosses it. Scoured out of the consolidated dune-rock, its former course can be clearly discerned from a view point such as Arthur's Seat.

(III) King Bay Profile

The slope of the profile (Fig. 7) shown by the bathymetrical contours of King Bay south of the Nepean Peninsula down to the 35 fathom (210 feet) platform is taken to be the outer or southern face of the Upper Dune Series. Eight outlets, some of tideways, others of river channels, are revealed by the bathymetrical contours (Fig. 7). They are referred to here by the fathom line at which they occur, and given in order of their priority in functioning as outlets. All are outlets of the Upper Pleistocene Yarra.

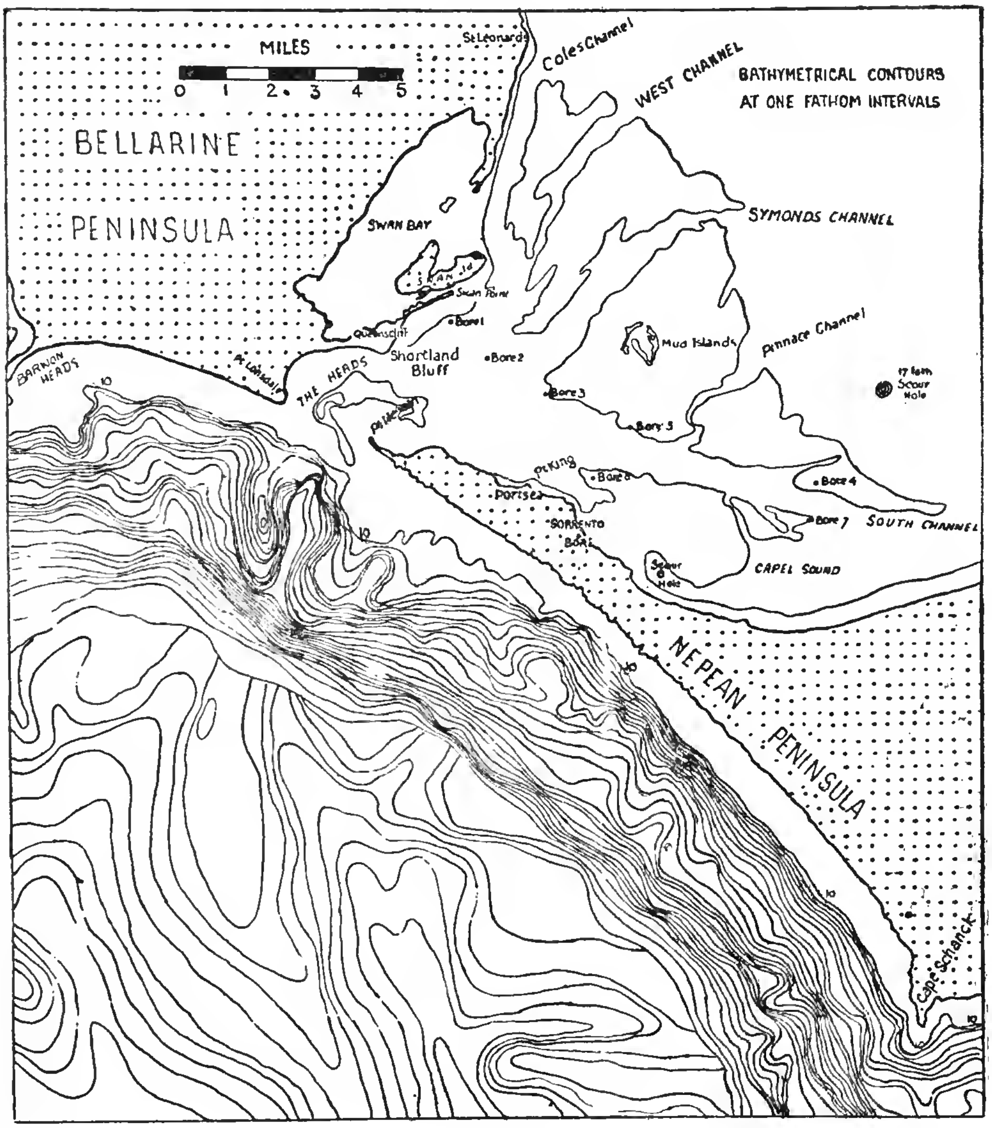

FIG. 7.

Bathymetrical Chart of King Bay showing the Outer Face of the Upper Dune Series resting on a Mature Surface of Fluviatile Erosion.

30-fathom outlets. There are two outlets, in close proximity, 3 miles west of Cape Schanck. The bent contours point northwards to the approximate position of the relatively recent Tootgarook Tideway, and open towards the 45-fathom depression; like the Tootgarook Tideway, they entered King Bay near to where Selwyn's Fault intersects the coast line. There is little doubt that the drift at 186 feet in Bore No. 4, Wannaeue, was deposited in a tideway that led to one of these outlets.

28-fathom outlet. About a mile E.b.N. of the 30-fathom outlet is the 28-fathom outlet, which also points N.N.W. towards the Tootgarook outlet. The drift at 170 feet in Bore No. 4, Wannaeue, was probably deposited in a tideway leading to it. It opens towards a tributary of the broad valley (Fig. 7) coming from the direction of The Heads that falls into the 45-fathom depression.

25-fathom outlets. Two of these outlets, respectively 7 and 8 miles W.N.W. of Cape Schanck, probably emptied into the same valley as the 28-fathom outlet.

24-fathom outlet. This, 3½ miles S.W. of The Heads and 4½ miles S.E. of Barwon Heads, served both as an outlet of the Barwon River, and an earlier cycle of the Yarra River.

20-fathom outlets. About 4 miles south of The Heads, and

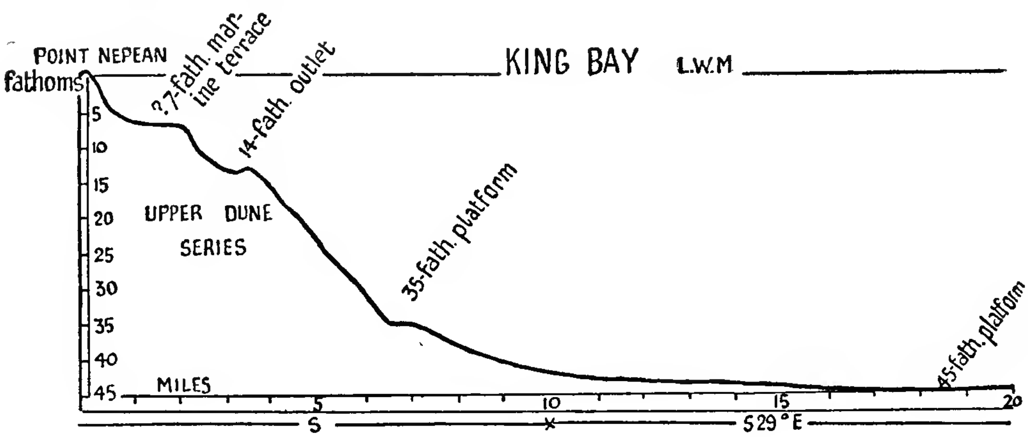

FIG. 8.
The Profile of the Upper Dune Series in King Bay.

pointing towards them, the main 20-fathom outlet is the most conspicuous and best formed of all the outlets. It is seemingly a cul-de-sac, narrow and relatively deep (54 feet), with steep sides sloping inwards towards its floor. About 6 miles E.b.S. of the previous outlet, is that of Capel Sound Tideway (p. 90).

14-fathom outlet. This is an outlet pointing N.E. b. N. towards Symonds Channel; it is 3½ miles south of Point Nepean.

V. Cycles of Sedimentation and Accumulation Evident in the bores.

Alternate cycles of sedimentation and accumulation can be recognised in the classes of sediment and their sequence in the Wannaeue and Sorrento Bores; these can be interpreted in the light of what is now happening on the Nepean Bay Bar. The cycle covering dune accumulation may be referred to as the "dune cycle." Before the dune cycle, the period from the time the sediment commenced to accumulate in the headwaters of King Bay up to that when it was followed by another dune cycle may be referred to as the "bay bar cycle." Tideways were formed connecting the land-locked waters behind the Bay Bar with the open Bay in front of it when the levels of each coincided. As has been stated, tideways, unlike river channels, have no gradients; such irregularities as do occur along their courses are caused by the encroachment of shifting shoals, or by constrictions in their channels. With the continued rise of sea level or slow subsidence, the tideways were submerged, fluvio-estuarine sediments were deposited along them, and in the Sorrento Bore shallow water limestone is found resting on the sediments. With the retreat of sea level, the tideways again functioned until the level of King Bay fell below the tideway bed. A new dune cycle then started, and dunes were piled up, and encroached on the former tideways.

There was no vertical erosion along the tideways when sea level was being lowered; the dune rock was too porous to hold up river or lacustrine waters. During the maximum rise of sea level there was a landlocked bay behind the Nepean Bay Bar, but this disappeared when the sea retreated—it never persisted as a lake or swamp. Only two swamps occur on the Nepean Peninsula—the Tootgarook Swamp and a salt lake near Sorrento; both are at sea level, and they probably owe their existence to the fact that sea level is the water table of the Peninsula. There are numerous "cups" with closed contours all above sea level, but none of them hold water or are their bottoms swampy.

VI. Evidence in the Bores as to Tectonic Movements

Excluding, for the time being, the effect of eustatic adjustment, the Pliocene, Pleistocene, and Recent deposits of the Sorrento and Wannaeue bores suggest the following tectonic movements:

(a) Regional uplift terminating near the close of the Pliocene.
(b) Pliocene-Pleistocene subsidence of the Bass Strait Sunkland accompanied by dune accumulation.
(c) Period of standstill. Fluviatile erosion of the Dandenong Creek Cycle (pre-Newer Basalt).
(d) Renewed subsidence of the Bass Strait Sunkland in the Middle Pleistocene to the extent of 170 feet accompanied by dune accumulation.
(e) Period of standstill. Fluviatile erosion during which Dandenong Creek Cycle continued on the east side of the Yarra drainage system and the Post-Newer Basalt draining (Keilor Cycle) began on the west side.
(f) Commencement of the subsidence and tilting of the Port Phillip Sunkland near the beginning of the Upper Pleistocene. This movement has proceeded to the extent of 100 feet and betrunked the lower portion of the Yarra River including the lower portion of Dandenong Creek and the streams that were developed on the Keilor and Werribee Plains lava fields.

That the uplift (a) was regional, is shown by the outcrops of Miocene and Pliocene beds of the same age as those in the Sorrento Bore in areas distant from Sorrento, as at Mornington, Grices Creek, Green Gully, Beaumaris, etc., and their existence in bores at Altona, South Oakleigh, and other places. The Pliocene samples in the Sorrento Bore below 575 feet (L.W.M.) indicate some depth of sea, and they had to be uplifted above sea level to make possible the succeeding Pleistocene phases. The Sorrento Bore sample marking the change over from uplift to subsidence is that at 575 feet (L.W.M.). The samples between that depth and 265 feet (L.W.M.), representing a thickness of 310 feet, consist for the most part of dune-rock—the Lower Dune Series—intercalated with which are some estuarine sands and shallow water limestones that accumulated near sea level.

Periods of standstill occurred at 265 feet (L.W.M.) in the Sorrento Bore equivalent to 262 feet (L.W.M.) in Bore No. 4, Wannaeue, and about 197 feet (L.W.M.) in the Sorrento Bore equivalent to 210 feet (L.W.M.) in the Wannaeue Bore. The fact that dune-rock and intercalated estuarine deposits are now a considerable depth below sea level is, apart from the consideration of eustatic adjustment, evidence of tectonic subsidence.

VII. Lines of Movement of Sunklands

The lines on which the Bass Strait and Port Phillip Sunklands have moved are referred to here as faults. Wherever they have been seen, in section, however, the lines of weakness are in the form of warps, and tilting caused by these warps has been largely responsible for the Sunklands. It is probable, nevertheless, that further afield these warps develop into faults. Beyond stating that the Bass Strait Sunkland sank on warps or faults coinciding with, on the whole, the shores of the Strait, its subsidence along three lines of movement are our immediate concern, viz., the Bellarine Fault, Selwyn's Fault, and a hypothetical fault between Rosebud on the Nepean Peninsula and St. Leonards on the Bellarine Peninsula.

The north-west boundary of both Sunklands (Fig. 9) is a fault line—the Bellarine Fault—which coincides in direction with a southern Victorian trend line exemplified by the Otway Coast. The south-east boundary is Selwyn's Fault, at least in part, which bears S.W.b.S. and coincides with a Palaeozoic tectonic line on the Mornington Peninsula: it is exemplified by the fault coast of Port Phillip Bay between Frankston and Dromana.

The section shown in Fig. 9 is generally across the trend of these lines, and ties up deep bores at Sorrento, near Cape Schanck, and at Flinders; it bears S.E.b.S. from Mount Bellarine to Sorrento, thence S.E. to Main Creek at a point N.E. of Cape Schanck, and, finally, easterly to Flinders. The Bellarine Fault is postulated about 7 miles off the shore from the Otway Coast (Fig. 12). Sections of the floor of Bass Strait suggest the downward extension of Torquay Fault (Hills, 1940), but when the exaggerated vertical scale of these sections is appreciated this seems improbable. Moreover, while the Torquay Fault curves in towards Geelong about 12 miles S.W. of Barwon Heads, the Bellarine Fault persists in its N.E. strike as the north-west boundary of the Sunklands as far as St. Leonards on the east shore of the Bellarine Peninsula; beyond this point it is covered by the waters of Port Phillip, but reappears on the east shore of the Bay as the Beaumaris

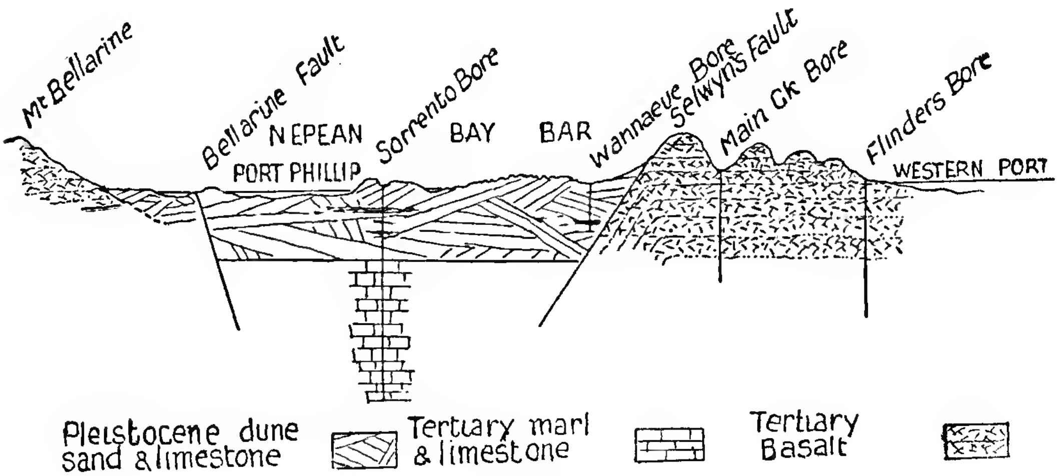

FIG. 9.
Section Line from Mt. Bellarine to Flinders.

Monocline, and extends some distance inland. The Beaumaris Monocline is the only appearance at the surface of this line of weakness; the evidence for it is, otherwise, largely inferential. It is known that the Carrum Swamp, probably the south-west extension of the Croydon Sunkland (Jutson, 1910) has been lowered by the monocline. The evidence for this is a bore about sea level near Mordialloc, which passed into Tertiary Older Basalt at 233 feet; north of Frankston, on the relative upthrow side of Selwyn's Fault, which is the S.E. boundary of the Sunkland, the Older Basalt outcrops at approximately 50 feet above sea level, suggesting a subsidence of about 280 feet. The profile of Dandenong Creek, from near Dandenong where it passes on to the Carrum Swamp, to the submerged delta on the floor of Port Phillip, is shown in Fig. 10. The Patterson River, a channel cut to drain the Swamp, marks, approximately, a former course of Dandenong Creek. A feature in this section is the steepness of the profile for about a mile in front of the Swamp.

Selwyn's Fault, a well authenticated line of movement, has, on the shore of Bass Strait, the appearance of a warp with incipient fractures: the warp tilts the beds on its north-west side downwards at a small angle. As a line of movement (Fig. 2) it can be traced from north-west of Frankston, along the east shore of Port Phillip, across the Nepean Peninsula, and under King Bay. The bathymetrical chart of Bass Strait (Fig. 12) suggests its extension

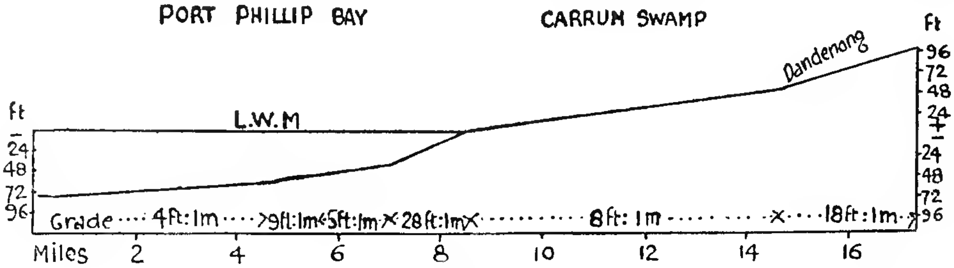

FIG. 10.
Profile of Dandenong Creek south of Dandenong.

as far as Cape Wickham, the northernmost point of King Island. Hills (1940) says "it is a *hinge fault,* the displacement dying out to the north but increasing towards the south, where a great thickness of marine Cainozoic rocks, which were penetrated in a bore at Sorrento, has been deposited on the downthrow block."

Parallel to Selwyn's Fault, there is, in the centre of the Mornington Peninsula, a well marked line of shatter belt called the Devilbend Fault, and still further east another line parallel to it, known as the Tyabb Fault. The existence of the Balcombe Fault between Selwyn's and the Devilbend Faults and parallel to them is inferred from the pattern of the stream system on that portion of the Peninsula.

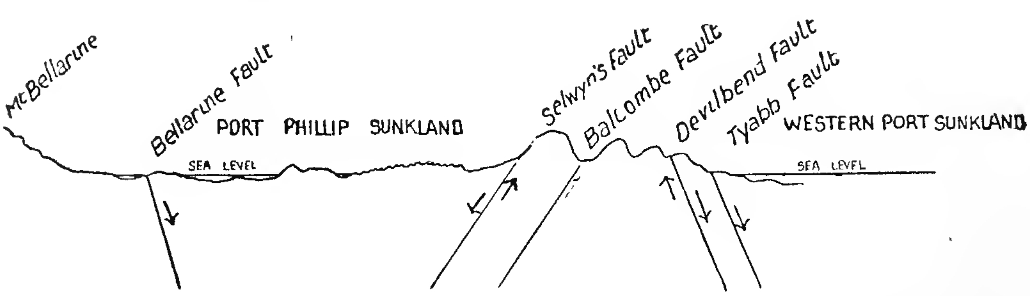

FIG. 11
Section of Mornington Peninsula showing Movements of Fault Blocks.

The movements along these lines are complicated by both upthrow, or uptilting, and downthrow, or downtilting, and, confining our remarks to the Mornington Peninsula, it is evident that, although there has been a cumulative downwarping of 585 feet on the north-west side of Selwyn's Fault, there has been an upward movement on the north-east side of between 400 and 500 feet; this is shown by the existence of a dune series, probably the Lower Dune Series, on the upthrow side near Cape Schanck, approximately 500 feet above L.W.M.

The problematical line between Rosebud and St. Leonards is near, and probably coincident with, the north-east face of the Upper Dune Series; south-west of it are the shoal waters of Port Phillip, and north-east the deeper waters of the Inner Basin. The inference that there has been movement along this line is based on the fact that south of it there is a big suite of beds in the Sorrento and other bores, typified by a class of sedimentation not found north of it, nor do the dune limestones occur to the north of it. There is possibly some connection between it and the Barrabool Hill-Curlewis Fault of Coulson (1939), which he says has a throw of 300 feet to the north of Ceres, near Geelong.

The late Pleistocene and Recent movement contributing to the final shaping of Port Phillip was downtilting on warps inland from the north-west shore of that Bay. This warping and tilting is parallel with the Bellarine Fault, and consequently the Otway Coast trend rather than that of the tectonic lines of the Mornington Peninsula.

King Bay and Bass Strait Sunklands

VIII. Evidence of the King Bay and Bass Strait Bathymetrical Contours.

The bathymetrical chart (fig. 12) of King Bay and Bass Strait is compiled from Admiralty Chart 1695B, corrected by the Admiralty up to 1943. From 1909 to 1914 the F.I.S. *Endeavour* explored the waters of Bass Strait and Dannevig prepared diagrams based on the exact soundings then taken; these, unfortunately, are not available—they were probably lost when the vessel foundered with him and all hands. In his notes, Dannevig (1915) points out that the compilation of the Admiralty Chart from soundings, for which various methods were employed, has been a gradual process since Bass Strait was discovered. He found that these soundings, particularly under 35 fathoms, show a greater depth, and the undulations suggested by the charts do not always occur. Irregularities are most pronounced in places where the waters are confined and the tidal streams and currents are strongest, such as to the north, north-west, and south of King Island; there the flood and ebb tides rush past at from 2 to 4 knots, and the disturbance is increased by rollers coming in from the Southern Ocean.

To the north from King Island, the main body of water enters Bass Strait in a north-easterly direction, and here we find a channel extending towards Port Phillip with a rough bottom,

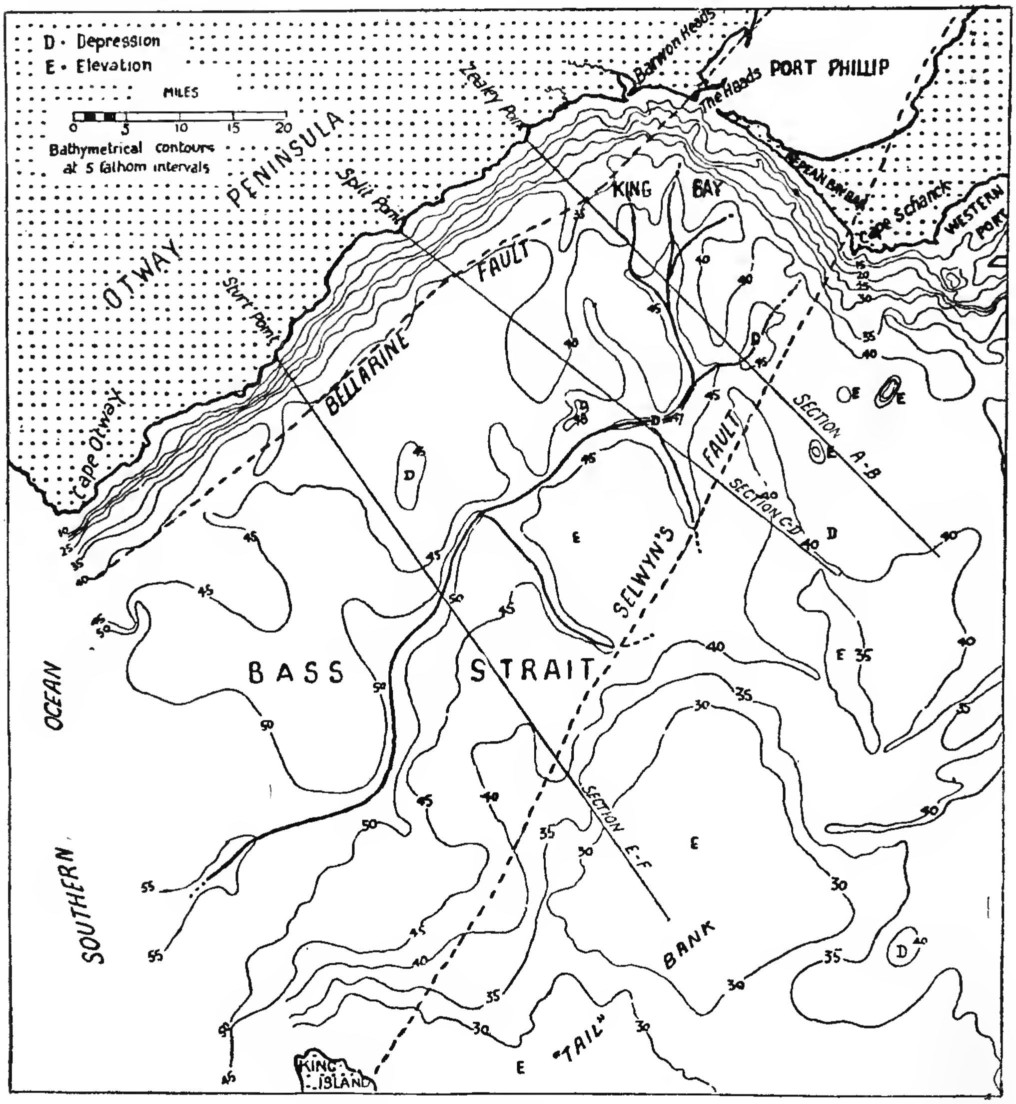

FIG 12
Bathymetrical Chart of King Bay and Bass Strait.

where coarse sand gradually replaces the outside rock conditions. At the north end of the Island, the flow of waters is accentuated, and has cut into the western edge of the relatively shallow "tail bank"—an extensive bank of heavy material extending north-east and east far into the Strait. The channel gradually decreases in depth from 60 to 48 fathoms. The survey of the "Endeavour" showed that the shallowest portion of the channel was 44 or 45 fathoms south of Western Port.

Dannevig concludes that there is no support for Noetling's suggestion that a barrier approximately 150 feet above the level of the central basin, which the "Endeavour" found ranged from 45 to 53 fathoms, extended between King Island and Western Port, and consequently there is no evidence of a lake. He states:

> On the contrary, we find that a number of rivers from north Tasmania would converge towards a centre (as indicated by Noetling), but instead of forming a gigantic lake they would join a magnificent river running to the north, north-west, and west along the present coast of Victoria, and ultimately enter the ocean somewhere to the east of Cape Otway. Into this river, which might suitably be named the Tamar Major, would also flow tributaries from the now extinct eastern and western slopes of the Bass Strait basin, so the approximate catchment area, extending from central Tasmania, in the south, and the Victorian Dividing Range (or further) in the north, would cover more than 50,000 square miles, producing 150,000 millions of cubic feet of water for rainfall of only one inch.

South-west of the Nepean Bay Bar, the floor of Bass Strait and King Bay (Fig. 12) between the south-westerly extensions of Selwyn's and the Bellarine Faults and below the 35-38 fathom contours, is the submerged mature surface formed by fluviatile erosion of the Port Phillip Sunkland: it is a fault block, for it has been let down 100 feet from the extensive Bass Strait Sunkland which had previously been lowered 170 feet. On the south-east side of the Port Phillip Sunkland, at an elevation of 100 feet, and on the relative upthrow side of Selwyn's Fault, is the easterly extension of the mature surface: on the north-west side of the Sunkland, beyond the Bellarine Fault, is the elevated, deeply dissected surface of the Otway Peninsula. The elevation to the south-east side, the so-called "tail bank" of Dannevig (1915), is for its greater part the mature surface of the 35-fathom platform —a fossil plain on the old rocks of King Island that apparently extended for some distance north-easterly. As indicated by Dannevig (1915) the currents and tidal streams cut into this barrier, and the material eroded from it has been deposited some distance away. Although not continuous, the barrier nevertheless did exist as claimed by Noetling (1910), although his inference as to the former presence of one large inland lake behind it is improbable.

On the mature surface of the Sunkland, the valley in which the Yarra River system flowed—Dannevig's channel extending towards Port Phillip—referred to here as the Middle Pleistocene Yarra, is well defined. This mature surface probably extended some distance beyond Cape Otway into the region now covered

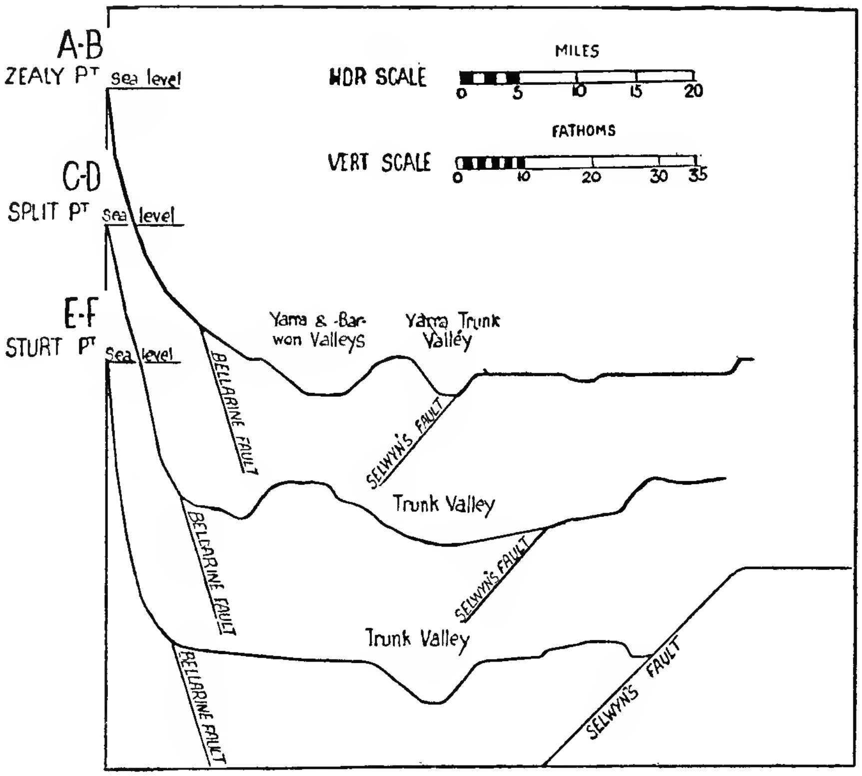

FIG. 13
Sections of the Floor of Bass Strait.

by the Southern Ocean: it was an extensive plain of fluviatile sediments, resting on the Lower Dune Series, and belonging to the same cycle of erosion as the fluviatile deposits under the Keilor Plains Basalt or the mature flood plain of the middle Dandenong Creek, of which it is the downstream extension. This cycle reached maturity in the Middle Pleistocene.

The trunk stream of this downstream extension of the Middle Pleistocene Yarra, flows in what appears to be a shallow valley that first shows up at the 45-fathom bathymetrical contour 8 miles W.S.W. of Cape Schanck as a shallow depression, and similar depressions appear along its valley at the 47-fathom and 48-fathom contours. About 30 miles upstream from a line joining Cape Otway and Cape Wickham, it flows into a tapering depression suggestive of an estuary.

The bathymetrical contours reveal also several confluent streams, some of which, joining it on the right bank, came from the north from the Nepean Bay Bar; others joining it on its left bank, came from the "tail bank" to the south-east. Certain valleys coming from the north head at the 35-fathom (210 feet) or the 38-fathom (228 feet) platforms both probably representing the same land surface which extends throughout the Bay Bar.

Briefly, the erosion on the Sunklands in King Bay and Bass Strait belongs to the Middle Pleistocene; it occurred before the Upper Dune Series had accumulated, and is in no way connected with the Upper Pleistocene or Recent cycles which had outlets through the Upper Dune Series. The Upper Pleistocene Yarra emptied into King Bay: the Middle Pleistocene Yarra into the Southern Ocean.

In the absence of Dannevig's (1915) corrected soundings we must, perforce, accept his Tamar Major River as flowing north, north-west, and west along the present coast of Victoria. The Tamar Major River was, then, part of the Middle Pleistocene stream system and what has been referred to as the Middle Pleistocene Yarra, is the south-western extension of it—its lower reaches. If the Western Port stream of Gregory (1903), his Tarago River, joined it, the confluence must have been by a boathook bend, for the bathymetrical contours (Fig. 14) show that the Mornington Peninsula extended some ten miles to the south, and the Tarago valley trended to the south-east.

The bathymetrical contours also show that there was a bay bar across Western Port Heads, and that the 21-fathom scour hole (Fig. 14), 3 miles W.S.W. of Point Grant, Phillip Island, was formed by a tideway, a relic of the Upper Pleistocene Western Port ebb and flow. The history of the development of Western Port is very similar to that of Port Phillip.

IX. *The Wannaeue and Sorrento Bores and the Stages of the Ice Age.*

The Pleistocene or Ice Age is represented by the core of the Sorrento Bore to a depth of 585 feet and its upper part by the Wannaeue Bore. It has been shown that the sediments and dune accumulations in these bores are the outcome of eustatic adjustments of sea level due to the glacial and interglacial stages during the Ice Age as well as to tectonic movements. The European equivalents of those parts of the bores discussed here are the Wurm, Riss-Wurm, and Riss Stages, covering part of the Middle Pleistocene and the whole of the Upper Pleistocene. The following inferences have been drawn:

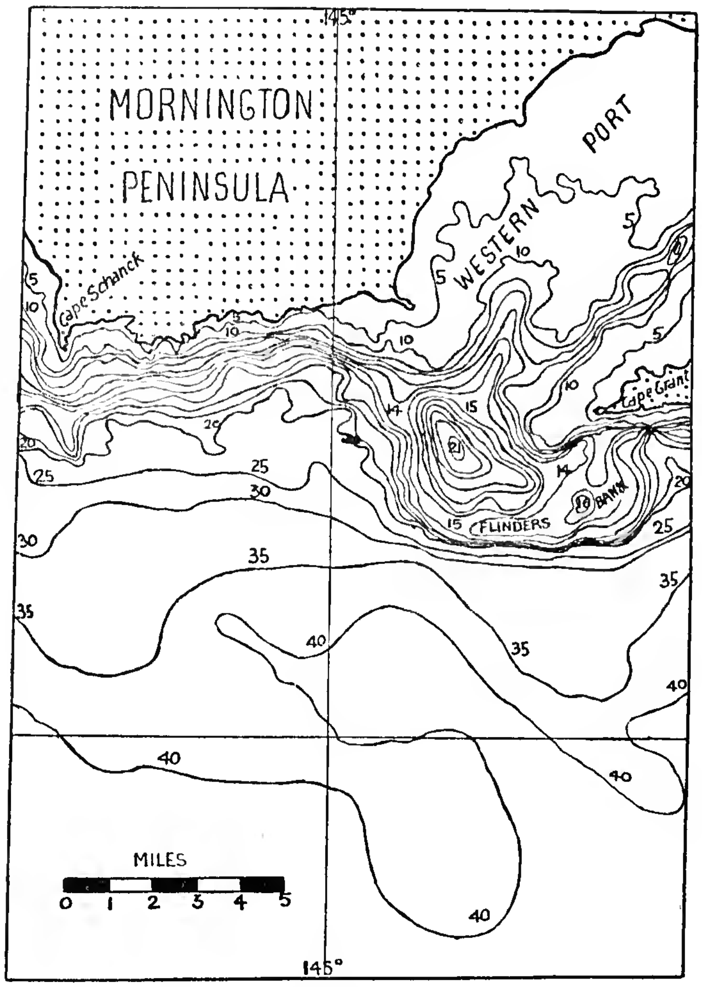

FIG. 14.
Bathymetrical Chart showing Bay Bar across Western Entrance, Western Port.

During eustatic rise of sea level in the interglacial stages or tectonic subsidence—

King Bay was formed.

Spits were deposited on the pre-existent dunes that had been levelled by wave action.

The Nepean Bay Bar was formed.

Tideways through the Nepean Bay Bar connected that part of King Bay behind it with the open sea in front of it.

Continued rise of sea level submerged the tideways, fluvio-estuarine sediments were deposited along or near them, and in some places shallow water limestones accumulated.

These deposits are found on the platforms, and represent periods of standstill in tectonic movement.

During eustatic fall of sea level in the glacial stages or tectonic uplift—

With the retreat of the sea the dune cycle commenced. In the early stages the tideways again functioned (the present stage of the shoal water in the southern part of Port Phillip) until the level of the open part of King Bay in front of the Bay Bar was lower than the beds of the tideways themselves. With continued retreat, the uncovered Bay Bar was piled up into dunes (cf. R. W. Sayles, 1931, and E. S. Hills, 1936).

Bore No. 4 Wannaeue, which is the most reliable for observation, shows that on the 35-fathom (210 feet) platform (Fig. 4) approximately 57 feet (153 feet to 210 feet) of sediments accumulated, some of which were shallow marine, others apparently terrigenous, but all of fluviatile origin, and composed for the most part of material derived from outside the area of the Bay Bar: they were obviously deposited during a eustatic rise of sea level. They rest on a dune series, and are succeeded by the Upper Dune Series, evidence of the fact that both before and after their being deposited, the sea had retreated from the area.

Likewise, in the Sorrento Bore (Fig. 4), the period of eustatic rise corresponding to 210 feet in the Wannaeue Bore is considered to be the shallow-water limestone of small, but unascertained thickness, with marine bivalve and gasteropod shells at 197 feet. This also occurs above dune-rock, is succeeded by the Upper Dune Series, implying, as in the Wannaeue Bore, retreat of the sea. The period occupied by the accumulation of the shallow marine and terrigenous sediments in both bores probably represents a period of standstill in the general tectonic subsidence.

The 45-fathom platform (Fig. 4) is shown in the Wannaeue Bore to be covered by heavy drift from 256 feet to 262 feet at which depth the bore ended. Overlying this is a dune series 46 feet thick. In the Sorrento Bore (Fig. 4), the equivalent sample is the shallow water limestone, with numerous casts of bivalves at 259 feet (L.W.M.). Under it at 265 feet (L.W.M.) is a liver-coloured clay with fine ferruginous sand and a few quartz particles; this is unfossiliferous. Below it is dune-rock at 288 feet (L.W.M.) and at 314 feet (L.W.M.), a calcareous quartzose sand and grit. These deposits also indicate marine transgression and retreat, implying eustatic rise and fall of sea level.

In the Maribyrnong River, which flows into the Yarra just before the latter empties into Hobson's Bay, the river terraces were formed, according to Keble and Macpherson (1946), by the vertical erosion caused by the eustatic fall of sea level; if tilting had any influence on this vertical erosion, it was subordinate to that caused by eustatic adjustment. They found that there were three main fluviatile terraces which appeared to them to have been formed during the fall of sea level at each of the three Wurm glaciation maxima. The fall of sea level during the first maximum (W1) entrenched the Keilor Flood Plain and formed the Keilor Terrace; during the rise of sea level in the succeeding interglacial stage (W1/2) the Braybrook Flood Plain was formed; it was entrenched by the fall of sea level in the second glaciation (W2), and during the succeeding interglacial stage (W2/3), the Maribyrnong Flood Plain was formed, and entrenched by the fall of sea level during the third glaciation (W3). This last entrenchment, together with the Footscray Warp (Keble and Macpherson 1946), partly supplied the material for the Yarra Delta, which was submerged by the 15 to 20 feet fall of sea level. The subsequent fall of sea level is indicated by entrenchment above tide limit in the Maribyrnong River.

Correlating these fluviatile cycles with the fluvio-estuarine cycles of the Nepean Bay Bar, the sediments on the 35-fathom platform from 153 feet to 210 feet in the Wannaeue Bore are taken to be the downstream extension of the Keilor Flood Plain, and the drift on the 45-fathom platform from 256 feet to 262 feet (the bottom of the bore) as the downstream extension of the sub-basalt sands under the Keilor Plains basalt. The Keilor Flood Plain and the fluviatile sub-basalt sands which were contemporaneous with the flood plain deposits of the middle Dandenong Creek are representative of the most sustained cycles in the physiography of the Yarra River System. The 35-fathom and 45-fathom platforms were surfaces exhibiting mature fluviatile erosion following the retreat of the sea from the Bay Bar. The maturity of the erosion, and the streams responsible for it, together with the place of the fluviatile deposits in the stratigraphic sequence justify the correlation: no other fluvio-estuarine deposits in the bore records could be correlated with this fluviatile erosion.

The following table (Fig. 15) is an attempt to correlate the records of the bores with the glacial and interglacial stages of Europe, America, and elsewhere in Australia, particularly in Tasmania; the correlation of David Tindale (1933), Lewis (1933, 1934), Edwards (1941) and David (1924), are included.

EUROPEAN ICE-AGE STAGES	VICTORIA Maribyrnong River Terraces Nepean Pen. Wannaeue: Keble and Macpherson	VICTORIA: Bore Keble	SOUTH AUSTRALIA Raised Beaches Tindale (1933)	UNITED STATES Raised Beaches Cooke (1930)	TASMANIA: Ice-Age Stages	TASMANIA: Lewis (1933, 1934)	TASMANIA: Edwards (1941)	AUSTRALIA David (1924)
Postglacial	Yarra Delta (in part)					Progressive rise in sea level	5–15 ft. raised beaches and terraces	10–15 ft. raised beach Tower Hill and Mt. Gambier scoria cones
Wurm 3	Maribyrnong Terrace. Yarra Delta (in parts)	Surface to 31 ft.						
W2/3 Interglacial	Maribyrnong Flood Plain	32–84 ft.	Woakwine	Mid-Wisconsin				
Wurm 2	Braybrook Terrace	85–116 ft.			Margaret	River Channel 20 ft. below floor of Derwent estuary		Lake basins, National Park, Tasmania. Mt. Kosciusko
W1/3 Interglacial	Braybrook Flood Plain	117–121 ft.						
Wurm 1	Keilor Terrace	122–152 ft.						
Riss-Wurm Interglacial	Keilor Flood Plain	153–209 ft.	Reedy Creek West Avenue	Peorian Sangamon	Yolande-Margaret	5–15 ft. raised beaches. Lowest river terraces	40–50 ft. raised beaches	V-shaped valleys superimposed on U-shaped valleys of Pieman and Snowy Rivers. Ringarooma flats excavated Mowbray Swamp peat deposits
Riss 2	Keilor Plains Basalt	210–256 ft.			Yolande	River erosion probably to 60 ft. below sea level	120–150 ft. submerged strand line	
R1/2	Sub-basalt Sands middle Dandenong Ck. Flood Plain	257 ft.						

FIG. 15.

The Bassian Fauna and Flora

The Bassian fauna and flora comprised the animal and plant life that formerly existed on the land surfaces between the mainland and Tasmania, and which migrated to what are now the Bass Strait Islands and Tasmania from the mainland. Spencer (1893) drew attention to the close alliance existing between the zoological groups of Tasmania and that part of Victoria south of the Dividing Range.

The present discussion of the fauna and flora is restricted to certain genera and species, both living and extinct, the ecology of which throws some light on the physical aspects of the land surfaces. The most informative are the land shells, freshwater shells, the earth-worms, and the mammalia, some of which are represented by fossil prototypes: important evidence is also forthcoming from other groups that are assumed to have existed on the land bridges.

Land shells are mainly vegetable feeders on plants, cryptogamic vegetation, decaying vegetation, etc. The vegetable nature of their food, and their preference for moist conditions, explains their prevalence in warm humid regions, particularly on islands; in hot and desert regions they appear only during the rainy seasons, or times of heavy dews. Some species of *Bothriembyron* bury themselves in the mud of swamps when they dry up. On the other hand *Helicarion* is found mostly in cold and temperate regions, or, if in the areas with warmer climate, in the cooler mountain tracts.

Of the land shells from Victoria listed and described by Gabriel (1930) and found in the Bass Strait Islands or Tasmania, the recorded habitats of only 6 per cent are on the northern drainage fall in Victoria and, excluding the widespread *Succinea australis,* (Ferr.) less than 3 per cent.; the rest were collected on the damper southern fall or the water-shed. Of the eleven species found on the Bass Strait Islands, seven—*Charopa albanensis* (Cox), *C. diemenensis* (Cox), *Helicarion cuvieri* (Ferr.), *Laoma minima* (Cox), *L. penolensis* (Cox), *Rhytida ruga* (Cox) and *Succinea australis* (Ferr.) are common to both Victoria and Tasmania; two—*Caryodes dufresni* (Leach) and *Bothriembyron gunnii* (Sow.) to the Islands and Tasmania; and one—*Chloritis victoriae* (Cox) to King Island and Victoria. May (1923) states that as far as the species *C. victoriae* is concerned, "its appearance seems to suggest the necessity of land communication with Victoria at some period, as this species occurs in that State but not in Tasmania." It is found in Victoria on the southern fall, and outside Victoria its mainland habitat is restricted to Mount Kosciusko.

Johnston (1880) records a fossil species *Helix simsoniana* (John.) from the Helicidae Sandstone, a member of the dune series in the Kent Group, and probably formerly extending to the Furneaux Group. Spencer (1893) records *Bothriembyron gunnii* (Sow.) as "a fossil found on Kent Island and in the yellow limestone of Hobart." *B. gunnii* is a living arborescent species found near the sea clustering on small trees and shrubs generally on sandy ground or hillocks a little above high water mark. *Charopa diemenensis* (Cox), *Laoma penolensis* (Cox), and *Succinea australis* (Ferr.) are also found in the Helicidae Sandstone. The first two are found in Victoria on the Southern fall; the third is "subaequatic living in damp places, near the margins of streams" (Tryon 1883).

The following living (L) and fossil (F) species are found in Victoria, the Bass Strait Islands, or Tasmania:

	Victoria	Bass St. Ids.	Tasmania
Allodiscus otwayensis (Pet.)	L		L
Bothriembyron gunnii (Sow.)		LF	L
Caryodes dufresni (Leach)		L	L
Charopa albanensis (Cox)	L	L	L
C. diemenensis (Cox)	L	F	L
C. sericatula (Pf.)	L		L
C. tamarensis (Pet.)	L		L
Chloritis victoriae (Cox)	L	L	
Cystopelta petterdi (Tate)	L		L
Helicarion cuvieri (Fer.)	L	L	L
Helix simsoniana (John)		F	
Laoma halli (Cox)	L		L
L. minima (Cox)	L	L	L
L. morti (Cox)	L		L
L. penolensis (Cox)	L	F	L
Paraphanta dyeri (Pet.)	L		L
Pupilla australis (Ad. & Ang.)	L		L
Rhytida lampra (Reeve)	L		L
R. lamproides (Cox)	L		L
R. ruga (Cox)	L	L	L
Succinea australis (Fer.)	L	F	L
S. australis var. queenboroughensis (Pet.)	L		L
Thalassohelix fordei var. McCoyi (Pet)	L		L

It is possible that forms recorded as fossil on the Islands may be still living there.

The freshwater mollusca of Victoria have been listed and described by Gabriel (1939). Excluding some recorded from King Island, the Bass Strait Island forms include *Ameria tenuistriata* var. *pyramidata* (Sow.), *Bythinella nitida* (John.) from the Helicidae Sandstone, *Coxiella badgerensis* (John.), *Ameria tenuistriata* (Sow.), *Acmea marginata* (Kuster.), *A. scalarina* (Cox) and *Sphaerium tasmanicum* (Ten. Woods.).

Johnston (1888) states that the older sand dunes of the Bass Strait Islands (Flinders, Barren, Badger, Kent, King and others) "frequently contain in abundance the fragmentary remains of marine shells, but more especially the well preserved remains of land shells now found living near the shore . . . In the consolidated beds of ancient lagoons, in old hollows of the Helicidae Sandstone occurs *Bythinella nitida* John. in rich abundance together with *Amphipeplea* = (*Limnaea*) *huonensis* (T. Woods), *Ameria tenuistriata* var. *pyramidata* (Sow) = (*Physa eburnea* Sow. = *P. tasmanica* T. Woods) and *Ameria* = *(Physa) mamillara* Sow.

The recorded living and fossil (Pleistocene and Recent) genera common to the mainland and Tasmania include *Bythinella*—(*B. nigra* Q. and G., *B. buccinoides* Q. and G.); *Ameria*—(*A. tenuistriata* var. *pyramidata* Sow.); *Ancylus*—(*A. tasmanicus* Ten. Woods); *Assiminea*; *Gundlachia*—(*G. petterdi* John.); *Hydriella*—(*H. australis* Lam.); *Limnaea*—(*L. gunni* Pet.); *Planorbis*—(*P. tasmanicus* Ten. Woods, *P. scottiana* John.) and *Segmentina*—(*S. victoriae* Smith). These genera are found in freshwater or brackish lagoons or pools. *Acmea marginata* (Kuster) and *A. scalarina* (Cox) are amphibious and live between tide marks; they can survive many weeks out of water. *A. scalarina* has been found on the raised beach at Altona in Port Phillip. *Coxiella badgerensis* (John.) is common in the salt lakes of western Victoria where its shells are found in layers, sometimes of considerable thickness, on the shores of the lakes. In other parts of Victoria, they are the predominant form in shelly beds on the surface of the Newer Volcanic lavas. Incidentally *Coxiella* (= *Blanfordiana*) *stirlingi* (Tat.) is found in the clay with *Diprotodon* at Lake Callabonna in South Australia, together with *Melania,* a brackish water shell which, too, is found in the *Diprotodon* breccias of Queensland. *Melania* occurs in the rivers of the warmer regions, and is well represented in Queensland; there is one Victorian species—*M. balonnensis* Conrad—but it is unrepresented in Tasmania.

The bivalves live for the most part on infusoria or microscopic plants—*Sphaerium* and *Hydriella* being attracted by decaying animal matter. *Sphaerium tasmanicum* (T. Woods) is found on

Flinders Island, in Victoria, and in Tasmania (the Great Lake and at Waratah); it also occurs as a fossil in the freshwater limestone underlying the Lower Pleistocene consolidated dunes at Burrabong Creek near Cape Schanck, Victoria. *Hydriella australis* (Lam.) is found in Tasmania only in the rivers flowing northwards into Bass Strait.

Although the earthworms are not found as fossils, Michaelson considers some of the *Oligochaeta* are most important for the purposes of palaeogeography. Stephenson (1930) maintains that they are of comparatively recent origin, and points out that, as their food consists of leaves and vegetable mould, they could have only originated after the spread of dicotyledonous plants which, too, took place in the Cretaceous. The recent origin of many present day genera, he observes, is indicated by the extraordinary variability of their species: the differentiation of the several families, and the evolution of the numerous genera, have occurred in the Tertiary and Quaternary. He cites the subfamily *Megascolecinae,* in a number of which the perichaetine arrangement of the setae is a fairly recent acquirement. This subfamily is typical of Australia and India, but is found to a lesser extent in the Malay Peninsula and Archipelago, the Philippines, China, Japan, Polynesia, and North America. The following is, as far as known, a tabular comparison of its Australia distribution:

Genera	Tasmania.	Victoria.	N.S.W.	Queensland.
Plutellus	—	—	—	
Megascolides ..	—	—	—	
Spenceriella ..		—		
Notoscolex ..	—	—	—	—
Megascolex ..	—	—	—	—
Diporochaeta ..	—	—		
Perionyx	—	—		
Digaster			—	—
Perissogaster ..			—	—
Didymogaster ..			—	
Pheretima ..				—
Diplotrema ..				—

Spencer (1900) states that *Megascolides* and *Diporochaeta* are distinctly characteristic of Victoria (and Tasmania), the first-named spreading to a slight extent up the east coast of Australia (Spencer, 1892). The two genera are striking evidence of a former land connection between Victoria and Tasmania.

Stephenson (1930) points out that earthworms must depend on their own activities to migrate to new regions, and the migration is consequently slow: the transference of cocoons by adventitious means is improbable. They cannot pass over mountain ranges that are bare of vegetation or covered by ice and snow, cannot live in desert tracts where there is an absence of moisture and organic matter, or migrate over arms of the sea. Some genera are restricted to warmer climates, while ice and snow, if they cover a region for a long period, cause their extermination. The earthworm population disappeared in those parts of Europe covered during the Ice Age, and those on the fringe are now spreading northwards: Spencer mentions his difficulty in obtaining earthworms near the glacial tarn of St. Clair in Tasmania, presumably due to the former ice cover during the Margaret glaciation. It is evident that a land bridge was essential for the migration of earthworms from Victoria to Tasmania, and it was once covered with a mesophytic flora, implying the existence of a moist or wet climate and a continuous belt of ordinary humus. *Perionyx* is found only in regions of heavier rainfall—in Australia, in the cooler wet portions of Victoria and Tasmania, or the tropical rain belt of the north. That the migration was southwards is suggested by the fact that the root genus of the *Megascolecinae* is *Diplotrema* found in Queensland and New Caledonia, and Queensland is thought to be the centre from which its distribution took place.

Spencer (1896) found in Central Australia a single species of earthworm, one of the *Acanthodrilinae-Acanthodrilus eremius,* Spencer in patches of damp black earth in the George Gill, McDonnell, and James Ranges. These patches were surrounded by a wide tract of desert country quite impassable to earthworms, and he considered *A. eremius* to be the only surviving species of the earthworm population of Central Australia before its climate changed and its desiccation ensued; the Acanthodrilids migrated to the tropical rain belt, or to the highlands of the south-east. They are found in north, north-east, and north-west Australia—for the most part in the tropical rain belt—also in the south-west, the cool rain belt; but on Mt. Kosciusko, the highest part of Australia, quite a different population is found belonging to the *Tubificidae* and *Phereodrilidae* which almost certainly existed when the Acanthodrilids prevailed in Australia.

The probable absence of ordinary humus on the eustatic land bridges was a barrier to migration; the *Megascolecinae* passed over to Tasmania on one of the more permanent land surfaces, presumably that during the Yolande or Riss glacial stage in the Middle Pleistocene.

Peripatus insignis is found in Victoria and Tasmania beneath the bark of old stumps, in rock crevices, and under stones.

Two of the freshwater fishes *Gadopsis marmoratus* Rich., the River Blackfish, and *Galaxias attenuatus* Jenys, the Jollytail, have a distribution that suggests a migration in streams from the mainland and Tasmania, that joined a trunk stream emptying into the Southern Ocean—the Tamar Major River. The first species is confined to the rivers from the mainland and from northern Tasmania emptying into Bass Strait; the second in the streams of King Island, southern Victoria and Tasmania. It is an interesting fact that the Jollytail is also found in New Zealand, Chatham Island, the Falkland Islands, and Chili.

The frogs *Lymnodynastes peronii* (D. and B.), *L. tasmanensis,* Gunth., *Hyla peronii* (Bibron), *H. aurea* (Less), and *H. ewingii* (D. and B.) are all common to Victoria and Tasmania, and *H. aurea* and *Lymnodynastes peronii* to King Island.

The following living (L) and fossil (F) marsupials are found in Tasmania, the Bass Strait Islands, or Victoria:

	Tasmania	Bass St. Ids.	Victoria
Diprotodon australis Owen ..		F	F
D. longiceps McCoy			F
Nototherium mitchelli Owen	F	F	F
N. inerme Owen			F
N. victoriae Owen		F	F
N. tasmanicum Scott	F		
Trichosurus fuliginosus (Ogilby)	L	L	
T. vulpecula (Kerr) ..	L		L
T. caninus (Ogilby) ..	L	L	L
Pseudochirus cooki (Desm.) ..	L	L	
Hypsiprymus spelaeus Owen			F
H. trisulcatus Owen	F		
Thylacoleo carnifex Owen ..			F
Thylacinus cynocephalus (Harris)	L		F
T. rostralis De Vis			F
Procoptodon goliah Owen ..			F
Macropus bennetti Water ..	L	L	L?
M. billardieri (Desm.) ..	L	L	L?
M. titan Owen			F
M. pan De Vis			F
M. magister De Vis			F
M. faunus De Vis			F

M. giganteus (Zim.)		F	L
Palorchestes azael Owen ..	F		F
Sthenurus atlas Owen ..			F
S. brehus Owen			F
Dasyurus affinis McCoy ..			F
Dasyurus viverrinus (Shaw)	L		L
D. maculatus (Kerr) ..	L	L	L
D. bowlingi Spen. & Ker. ..		F	
D. sp.			F
Sarcophilus ursinus (Harris)	L		?
Phascolomys pliocenus McCoy			F
P. ursinus (Shaw)		L	
P. mitchelli Owen			L
P. tasmaniensis Spen. & Ker	L		
Zaglossus harrissoni Scott ..		F	
Potorus tridactylus (Kerr) ..	L	L	L
Isoodon obesulus (Shaw.) ..	L		L
Parameles gunni Gray ..	L		L
Phascogale swainsoni Water ..	L		L
Sminthopsis leucopus (Gray)	L		L
Ornithorhynchus anatius (Shaw)	L	L	L
Dromicia nana (Desm.) ..	L		L
Tachyglossus setosus (Geoff)	L	L	

The fossil bones from Bass Strait Islands assigned to *Macropus giganteus* might well belong to *M. tasmaniensis* Le Souef, in which case the migration, if it occurred, was from Tasmania.

Of the above mentioned marsupials, the Great Kangaroo or Forester is found in open forest; Bennett's Wallaby and the Rufous-bellied Wallaby are also scrub forest dwellers, the former a hardy species thriving in a cold climate. The rat-kangaroo is found in all kinds of country except the heavy tropical scrubs of north-east Australia and swampy tracts. The opposums are arborescent, living in forest or scrubby country, and feeding on scrub foliage, particularly the eucalypts. The Marsupial Wolf, Tasmanian Devil, Tiger Cat and Native Cat likewise live in scrub forest country, the Native Cat also frequenting the coast line particularly the thick cover of the estuaries. The coarse-haired wombats of the ranges of south-eastern Australia and Tasmania are forest animals. The phascogales are largely insectivorous but feed, too, on small animals, birds, lizards, etc. The carnivorous Marsupial Wolf, Tasmanian Devil, and Native Cats prey on wallabies, rat-kangaroos, ground birds, etc. The wombats live on grass, the bark of certain trees and shrubs, particularly eucalypts, native cherry and sword grass, and fungi. The echidna or spiny ant-eater is found in rocky country in open forest or scrub. The living species of *Zaglossus* found fossil in Tasmania are now restricted to New Guinea.

The platypus is aquatic, and is found along most rivers in eastern Australia on both sides of the Dividing Range as well as in many rivers and lakes in Tasmania and the streams of King Island. It collects its food under water—small aquatic insects, worms, crustacea, etc—on the river or lake beds.

The remains of the food of *Diprotodon* found with its skeleton at Lake Callabonna, South Australia, consisted of small twigs and stems, but this may have been a starvation diet—the only food available in a region that had become arid (Stirling 1900).

Pleistocene Land Bridges

The Yolandean land surface that joined the mainland with Tasmania in the Yolande or Riss Pleistocene stage was, during the previous interglacial stages, beyond the reach of the eustatic rises of sea level: it was not until tectonic subsidence brought it within range in the subsequent interglacial stages that it was flooded. Along the eastern and western sides of this land surface, a short distance inland from the shores of the Tasman Sea and Southern Ocean, were two orogenic ridges trending S.S.W. The only remnants of the ridge on the east—the so-called Bassian Isthmus—are the islands between Wilson's Promontory in Victoria and Cape Portland in Tasmania, including the Furneaux and Kent Groups; that on the west extended from the Mornington Peninsula in Victoria to Cape Grim, the north-west extremity of Tasmania, and passed through King Island and the Hunter Group. Between these two ridges was the wide, mature valley of the middle reaches of the Tamar Major River, and between the King Island ridge and the Otway Peninsula were its lower reaches and estuary—the lowest part of the Bass Strait Sunkland.

The surface of the Tamar Major River basin was one of low relief. The physiognomy of its vegetation inferred from the ecology of the living and fossil faunas of both the islands of Bass Strait and Tasmania, on the assumption that they migrated from the mainland, was that of an open forest and a forest with strata of from taller to dwarf shrubs, herbs, and grass land. The food of the animals indicates the presence of insects, reptiles, birds, ants, land shells, fungi, etc., and of earthworms, implying the existence of ordinary humus. The distribution of the freshwater mussel, the River Blackfish, and the platypus indicates rivers flowing from the mainland and Tasmania, joining a trunk stream having an outlet into the ocean. The presence of freshwater pools, swamps, and billabongs is implied by the migration of the frogs, etc.

This is the ecology of a long-established flora and fauna. The open forest was probably on the interfluves of the Tamar Major River and its tributaries. The denser forest, it is assumed, was on the river flats and the estuary, and was comparable to that in the Otway Peninsula and Gippsland in Victoria, and to that of northern Tasmania behind the psammaphilous vegetation of the shore line. There is, however, evidence that the whole surface of the interfluves was not covered with soil: in the National Museum of Victoria collection at Melbourne is a piece of polyzoal limestone, weighing about 2 cwt., dredged by the *Endeavour* many miles south of the mainland.

During the post-Yolandean subsidence of the land surface the eastern and western ridges became, during the interglacial stages, the Bassian Isthmus and the King Island Isthmus, and, with continued subsidence, the Bass Strait islands; the King Island Isthmus was the first to be breached. These islands mark the higher points of the land bridges, and much of them has never been submerged; on them are found, too, survivals of the Bassian fauna, and probably the flora, both living and extinct. The lower reaches of the Tamar Major River were the first to be flooded from the Southern Ocean, and this flooding gradually inundated the middle reaches and its tributaries. Hedley (1913), discussing the marine mollusca of the waters of south-eastern Australia, noted the decided difference between the faunas east and west of the Bassian Isthmus, and proposed the terms Peronian and Adelaidean for them. Considerable interchange has, he states, taken place since the Bassian Isthmus was breached, accelerated by the westerly winds and currents. While these are partly responsible, the fact that the western end of the Bass Strait Sunkland was flooded first is the main reason. Hedley did not visualise the Port Phillip Sunkland or the King Island Isthmus.

Although the Bassian Isthmus seems to have been a land connection of considerable width and elevation—the highest peak in the Furneaux Group rises to a height of 2,550 feet and the last to be breached, it has, so far, yielded few fossil remains of mammals. Most of the evidence of the fossil fauna comes from the King Island Isthmus — from King Island itself, or from Mowbray Swamp in Tasmania, at the southern end of the

Isthmus. It would seem, therefore, that the King Island Isthmus was a main route for migration.

It is axiomatic that, if an herbivorous fauna passes over a land bridge, its passage must have been preceded by a migration of the flora. The Yolandean land surface was covered with an old and well established flora, but on the eustatic land bridges a new flora had to come into being. Conditions affecting the birth of this new flora were regulated by the nature of the land surface and the climate.

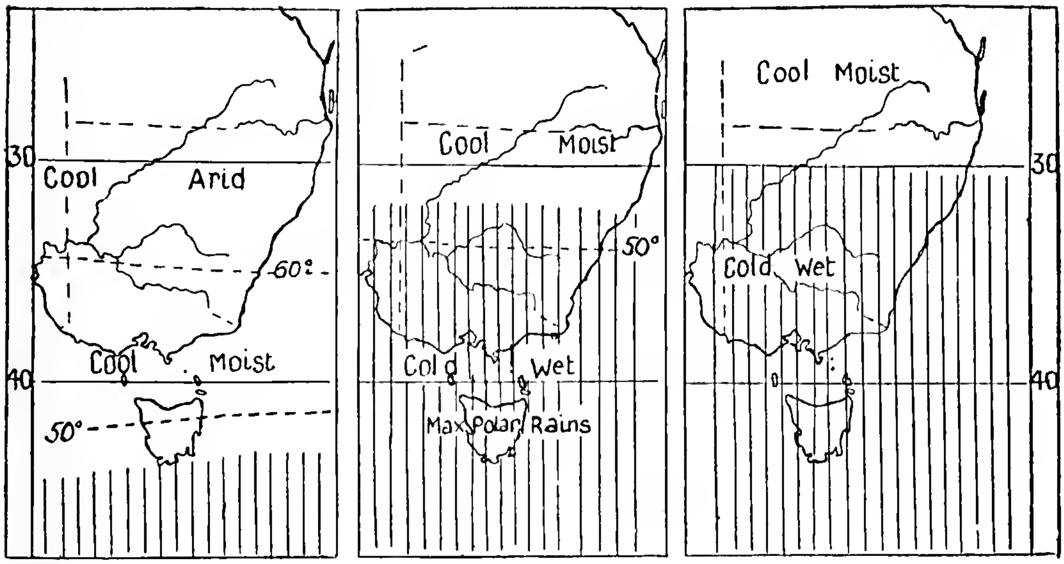

FIG. 16.
The Ranges of the Pleistocene Climates in South-East Australia. After Griffith Taylor (1919).

Regarding the latter, the period was one of changing climate: there were successive cool moist and cold wet periods, during which glacial conditions existed in the Tasmanian highlands.

"Ecologically, Tasmania is connected," states Patton (1930), "with the three heavy rainfall areas (of Victoria), South Gippsland, Otway and the Warburton-Healesville area," the first two bordering on Bass Strait; elsewhere he states that the vegetation of the two areas is similar, and passes down into Tasmania. They carry a close-canopied rain forest consisting of several strata. The rainfall of the glacial stages was certainly greater than it is now, and the Bassian flora grew on a well-watered land surface. He also points out that these heavy rainfall areas in Victoria are the meeting places of Antarctic and Malayan elements, the first by *Nothofagus* and *Lomatia Fraseri* occurring in Tasmania and exclusively southern climates, the second by tree ferns, sassafras, and other forms.

The floor of Bass Strait between the Bassian and King Island ridges suggests a peneplain. After it had been exposed to aerial conditions during the lowering of sea level in the glacial stages, much of it probably became a dune surface; it owes its slightly undulating surface to the flattening effect of wave action during the succeeding eustatic rise of sea level. Daly (1934) estimated that sea level was lowered 295 feet during the last glacial stage, and this uncovered most of the floor of Bass Strait. It exposed two types of sea-bottom—an inshore one, the dune surface of the Nepean Bay Bar extending 13 miles seawards from the southern shore of the Nepean Peninsula and of a total width of more than 15 miles, and an offshore sea-bottom to the south of this, the gently undulating surface of the Tamar Major River basin on which the Nepean Bay Bar was built up. During the glacial stages—the Yolande or Riss (in part), and the Margaret or Wurm 1, 2 and 3, there were presumably four land bridges—partly or completely uncovered sea-bottoms of these two types. The Nepean Peninsula up to the advent of the white settler had a representative marsupial fauna. Marsupial remains have also been found in the dune rock, some of extinct species, and it can be inferred that the psammiferous flora now on the Peninsula persisted during dune-building periods of the glacial stages. This flora is calciphilous, a characteristic to be expected from the limestone surface, but it owes its presence to the open texture, aeration, and low water-holding capacity of the surface. Mr. J. H. Willis, Botanist of the National Herbarium, has kindly supplied me with the following list and facts concerning species from near Sorrento, obtained by him in January; the list may be taken as representative of the limestone area.

Spinifex hirsutus Lab., also King Is. and Tasmania.
Distichlis distichophylla (Lab.) Fasset.
Poa poaeformis (Lab.) Druce, also King Island and Tasmania.
Agrostis avenacea Gmelin.
?*A. Billardieri* R.Br., also King Is. and Tasmania.
Stipa teretifolia Steud., also King Is. and Tasmania.
Scirpus nodosus Rott., also King Is. and Tasmania.
Casuarina stricta Ait., King Is. and Tasmania.
Muehlenbeckia adpressa Meisn, also King Is. and Tasmania.
Rhagodia baccata Moq., also King Is. and Tasmania.
Atriplex cinereum Poir., also King Is. and Tasmania.
Disphyma (*Mesembryanthemum*) *australe* (Sol.) Black, also King Is. and Tasmania.
Carpobrotus (*Mesembryanthemum*) *aequilaterus* (How.) King Is., also Tasmania.

Tetragonia implexicoma Hook., also King Is. and Tasmania.
Clematis microphylla D.C., also King Is. and Tasmania.
Cassytha pubescens R.Br., also King Is. and Tasmania.
Bursaria spinosa Cav., also King Is. and Tasmania.
Acaena sanguisorba Vahl., also King Is. and Tasmania.
Acacia rhetinodes Schlecht., neither in Bass St. Islands nor Tasmania.
A. sophorae R.Br., also King Is. and Tasmania.
Swainsona tessertifolia D.C., also King Is. and Tasmania.
Pelargonium australe Wild., also King Is. and Tasmania.
Zygophyllum Billardieri D.C., also in Bass St. Islands, but not Tasmania.
Correa alba Andr.
Beyeria Leschenaultii (D.C.) Baill., also King Is. and Tasmania.
Pomaderris racemosa Hk., and north coast of Tasmania.
Pimelea serpyllifolia R.Br., also Bass St. Islands, but uncommon in Tasmania.
Leptospermum laevigatum (Gaertn.) F.v.M., also King Is. and Tasmania.
Melaleuca pubescens Schau., not on Bass St. Islands or Tasmania.
Leucopogon parviflorus Lindl., also King Is. and Tasmania.
Samolus repens Pers., also King Is. and Tasmania.
Alyxia buxifolia R.Br., also King Is. and north coast of Tasmania.
Myoporum insulare R.Br., also King Is. and Tasmania.
Olearia axillaris F.v.M., also Bass St. Islands and north coast of Tasmania.
O. glutinosa (Benth.), also Bass St. Islands and north coast of Tasmania.
Brachycome parvula Hk.
Helichrysum cinereum F.v.M., also King Is. and Tasmania.
Calocephalus Brownii F.v.M., also Bass St. Islands and north coast of Tasmania.
Sonchus megalocarpus (Hk.) Black, also King Is. and Tasmania.
Stipa elatior (Benth.) Hughes, also Bass St. Islands.
Callitris tasmanica (Benth.) Baker *et* Smith, also Bass St. Islands and Tasmania.
Lepidosperma gladiatum Lab., also King Is. and Tasmania.

Melaleuca pubescens is the dominant shrub on the Nepean Peninsula. Although the migration is generally southwards, one species, *Cynthodes accerosa* R.Br., not occurring on the Nepean Peninsula, suggests a northward migration. It is a Tasmanian shrub found at only two points in Victoria, on the high granitic cliffs at Wilson's Promontory and Cape Woolamai.

It will be noted that, in the above list, *Eucalyptus* does not appear. The author, during his geological survey of a large portion of the limestone surface of the Nepean Peninsula, noted its absence and the prevalence of *Melaleuca* and *Leptospermum.* In regard to the absence of eucalypts, the Peninsula differs from the limestone surface at Buchan in eastern Victoria, which is lightly timbered with two species of it. Many of the forms of the Cheltenham Flora (Patton, 1932) on the shore of Port Phillip further north, are absent, due no doubt to their development on siliceous sandy beds containing very little lime.

The Nepean Peninsula vegetation is not that of a dune flora, although the dune topography has been preserved, hence the local name, "The Cups," for the area: the dunes have been consolidated with little alteration to their contours. Incidentally, it may be mentioned that the moving dunes on the King Bay shore have been formed since the occupation of the area by the white settlers, one of whom informed the author that they started to accumulate when the timber was thinned out in the sixties of last century; previous to this, the surface to high water mark was hard limestone. His statement was verified by the exposure, after the sand had been redeposited by a gale, of an old fence and Banksias bearing on their branches partly calcified leaves.

There is a similarity between the Nepean Peninsula flora and that of Deal Island, one of the Kent Group. Le Souef (1891) states that on the lower parts of it is thick, tussocky grass and on the higher ground a dense, short scrub, consisting principally of *Melaleuca*, ti-tree (*Leptospermum*), sheoak, a small species of *Eucalyptus*, a pine identified as *Callitris* (a rainfall-deficiency genus), *Banksia, Acacia,* and others. This flora grows on the Helicidae Limestone, a member of a dune series, and the presence of *Melaleuca* suggests its affinity to the Nepean Peninsula flora, of which it may be a surviving remnant.

The periods over which the various eustatic land bridges existed, more particularly those through King Island, were limited by the rate and amount of tectonic subsidence that was going on during the fall and rise of sea level. With the increase of subsidence towards the close of the Pleistocene, the life of the land bridges became successively shorter. Nature, states Ridley (1930), never allows an area, on which plants can grow, to remain bare for any appreciable length of time. Their appearance on a new soil is influenced mainly by the character of the soil or surface, its humidity or dryness, and the kinds of plants in the vicinity, and is not a criterion of the amount and class of seed which falls on the spot. Nevertheless, the xerophytic flora of Mud Islands in Port Phillip Bay, about 5 miles north of Sorrento, has been either wind-borne or sea-borne. It grows on sand or shelly beds, the surface of which was submerged by the rise of sea level during the postglacial, and uncovered again by the recession now in progress; it is about 3,000 years since the Mud Islands emerged.

Summary

Many attempts have been made to fix the times of the glacial stages of the Ice Age, and there is a diversity of estimates. There is, however, some agreement in fixing the time of the last glacial stage at about 18,000 years ago. This is so dated by Zeuner (1935), who bases his estimate on the solar radiation curve. The Yolande Glacial Stage of Tasmania is here taken to be the equivalent of

the Riss Stage of Europe, dated by Zeuner (1935) at about 183,000 years ago. Before, and in the first part of the Yolande Glacial Stage, the whole of what is now the floor of Bass Strait was a land surface—the south-eastern extension of the Australian mainland, including Tasmania; it was not until after that time that the waters of the Southern Ocean began to flood the area. It was a surface of low relief, similar to the gently undulating countryside on the east shore of Port Phillip north of the Carrum Swamp, and extending inland to the Gippsland railway. It was drained by the Tamar Major River, consisting, in parts, of the existing Tamar River, its former now submerged middle reaches extending north-west towards the Mornington Peninsula in Victoria, and its lower reaches extending formerly from near the Mornington Peninsula, south-westerly, and entering the Southern Ocean between Cape Otway and King Island. The Tamar Major River was a large stream flowing over wide river flats, and receiving tributary streams from both Tasmania and Victoria. Near the shore of the Tasman Sea was the Bassian Ridge trending north-easterly from what is now Cape Portland in Tasmania to Wilson's Promontory in Victoria, and towards its western side was the King Island Ridge separating the middle reaches of the Tamar Major from its lower reaches. On both sides of the river flats was a gently rolling countryside covered with open forest: on the river flats was a denser forest comparable to that of the Otway Peninsula or Gippsland, consisting of tall timber with strata of smaller trees and shrubs; but in places there were natural clearings with swamps and billabongs. In the open forest, the animal life was like that at present in a similar environment, and consisted of kangaroos (including the forester), wallabies, opossums, bandicoots, phalangers, native cats, echidnas, many kinds of reptiles, a diversified bird and insect population, and others. There were, too, animals now extinct, including the Giant Kangaroo, Procoptodon, Palorchestes, Sthenurus, and Zaglossus —the large ant eater. The Tasmanian Wolf and Tasmanian Devil, not now found on the mainland, frequented the forests, and the Giant Lizard, reputed to have attained a length of 20 feet, was probably present. On the river flats were to be found the wallaby, wombat, opossum and platypus, and, in the rivers themselves, the same species of fish now found in streams emptying into Bass Strait from both Victoria and Tasmania. In the swamps and billabongs were amphibians and crustaceans also of species now common to the two regions. In the initial stages of the subsidence of the Yolandean land surface, the lower reaches of the Tamar Major River were flooded.

As the subsidence proceeded, its middle reaches were flooded, and the configuration of the land was then that of a long peninsula —the unsubmerged part of the King Island Ridge—extending northerly from Cape Grim, at the north-west corner of Tasmania, almost to the Mornington Peninsula. The isthmus following the trend of the Bassian Ridge on the east remained intact; it was not until it was breached later that Bass Strait became a reality. Now, the only remnants of the land bridges are the islands at the east end of the Strait, the Kent Group, the Furneaux Group and others, and at its west end King Island and the Hunter Group.

The falls of sea level during the glacial stages following the Yolande Stage re-establishsed the Bassian Isthmus and the King Island Isthmus as land bridges. These were of a temporary nature, but lasted long enough for the flora and fauna to migrate to and from Tasmania and Victoria. Four of these bridges are presumed to have existed, the last less than 18,000 years ago. Although they were land routes, migration, for the most part, took place at the beginning of or before the Yolandean Stage.

It is a matter of common interest that Port Phillip Bay assumed its present form quite recently—about 9,000 years ago. It existed before in many forms, but was never as extensive as it is now. As sea level has been falling during the last 9,000 years, the Bay is gradually becoming shallower: its level has fallen about 3 inches since Collins landed at Sorrento in 1803.

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POST-TERTIARY FORAMINIFERA FROM A BORE NEAR ROSEBUD, VICTORIA

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(Received for publication 15th March, 1945)

The material examined and reported upon in this paper was collected by Mr. R. A. Keble, now Palaeontologist of the National Museum of Victoria, during his survey of the Mornington Peninsula, when an officer of the Geological Survey, and is from Mines Department Bore No. 5, parish of Wannaeue, 177-187 feet. The location of the bore is approximately 4 miles from Rosebud, on the road to Flinders. The greater part of the sample consisted of fine grey sand, which passed through a sieve of 60 meshes to the inch. The balance was almost wholly organic in origin, being made up of bryozoa, foraminifera, ostracoda, and molluscan remains, all being so broken up or small as with a few exceptions to pass through a sieve of 40 meshes to the inch.

The following species of foraminifera, which are considered to be indigenous to the deposit, were met with:

1.	*Textularia sagittula* Defrance	rare
2.	*Clavulina multicamerata* Chapman	rare
3.	*Planispirina bucculenta* (Brady)	rare
4.	*Nubecularia lucifuga* Defrance	rare
5.	*Quinqueloculina* sp. cf. *lamarckiana* d'Orbigny	very rare
6.	*Q. subpolygona* Parr	common
7.	*Q. costata* d'Orbigny	common
8.	*Q. seminulum* (Linne)	rare
9.	*Q. vulgaris* d'Orbigny	rare
10.	*Spiroloculina antillarum* d'Orbigny	very rare
11.	*S. milletti* Wiesner	frequent
12.	*Triloculina trigonula* (Lamarck)	rare
13.	*T. striato-trigonula* Parker and Jones	frequent
14.	*T. circularis* Bornemann	rare

15.	*T.* sp. aff. *sublineata* (Brady)	frequent
16.	*Pyrgo denticulata* (Brady)	rare
17.	*Peneroplis planatus* (Fichtel and Moll)	rare
18.	*Spirillina denticulata* Brady	frequent
19.	*S. limbata* Brady	very rare
20.	*S. inaequalis* Brady	common
21.	*Lenticulina* sp.	very rare
22.	*Planularia patens* (Brady)	very rare
23.	*Vaginulina vertebralis* Parr	rare
24.	*V. bassensis* Parr	rare
25.	*Dentalina mutsui* Hada	frequent
26.	*Lagena perlucida* (Montagu)	rare
27.	*L. sulcata* (Walker and Jacob)	common
28.	*L. acuticosta* Reuss, var. *ramulosa* Chapman	rare
29.	*L. distoma-margaritifera* Parker and Jones	frequent
30.	*L. distoma-margaritifera,* var. *victoriensis* Parr	frequent
31.	*Fissurina contusa* Parr	rare
32.	*F. orbignyana* Seguenza var.	rare
33.	*Entosolenia williamsoni* Alcock	very rare
34.	*E. squamosa* (Montagu)	frequent
35.	*E. variata* (Brady)	frequent
36.	*Guttulina regina* (Brady, Parker and Jones)	common
37.	*Globulina gibba* d'Orbigny, var. *globosa* (Münster)	frequent
38.	*Sigmoidella elegantissima* (Parker and Jones)	rare
39.	*Bolivinella folium* (Parker and Jones)	frequent
40.	*Buliminella elegantissima* (d'Orbigny)	rare
41.	*Buliminoides williamsonianus* (Brady)	very rare
42.	*Bulimina marginata* d'Orbigny (short form)	very rare
43.	*Bolivina pseudoplicata* Heron-Allen and Earland	rare
44.	*B. rugosa,* sp. nov.	common
45.	*B.* sp. nov.	very rare
46.	*Rectobolivina digitata* Parr	common

47.	*Reussella armata* (Parr)	very rare
48.	*Pavonina flabelliformis* d'Orbigny	very rare
49.	*Uvigerina* sp. aff. *pigmea* d'Orbigny	very common
50.	*Angulogerina carinata* Cushman, var. *bradyana* Cushman	rare
51.	*Patellinella inconspicua* (Brady)	rare
52.	*Discorbis dimidiatus* (Jones and Parker)	common
53.	*Discorbis australis* Parr	common
54.	*D. australensis* Heron-Allen and Earland	common
55.	*D. opercularis* (d'Orbigny)	common
56.	*D. williamsoni* Chapman and Parr	frequent
57.	*D. pulvinatus* (Brady)	very rare
58.	*Discorbinella biconcava* (Jones and Parker)	frequent
59.	*D. disparilis* (Heron-Allen and Earland)	rare
60.	*D. involuta* (Sidebottom)	very rare
61.	*Notorotalia clathrata* (Brady)	common
62.	*Streblus beccarii* (Linne)	frequent
63.	*Anomalina nonionoides* Parr	very rare
64.	*A. wüllerstorfi* Schwager	very rare
65.	*Cibicides lobatulus* (Walker and Jacob)	rare and small, some showing *Dyocibicides* plan of growth
66.	*Planorbulina mediterranensis* d'Orbigny	very rare
67.	*Acervulina inhaerens* Schultze	frequent
68.	*Gypsina vesicularis* (Parker and Jones)	rare, hemispherical specimens
69.	*Globigerina bulloides* d'Orbigny	common, small
70.	*G. inflata* d'Orbigny	common, small
71.	*Orbulina universa* d'Orbigny	frequent, small
72.	*Globorotalia pseudocrassa* Chapman and Parr	frequent, small
73.	*Elphidium argenteum* Parr	very rare
74.	*E. advenum* (Cushman)	rare
75.	*E. verriculatum* (Brady)	rare
76.	*E. macellum* (Fichtel and Moll)	frequent
77.	*E. crispum* (Linné)	common
78.	*E.* sp. aff. *minimum* (Seguenza)	common

This list of foraminifera may be compared with that given in a paper by the author (Parr, 1945). It will be seen that practically all of the species also occur in the shore sands of Barwon Heads. The remainder, with the exception of *Pavonina flabelliformis,* have been met with by the writer in other Victorian shore sands or in dredgings from Bass Strait. *P. flabelliformis* is typically a Recent Indo-Pacific species, although it occurs in the Pliocene of the Hamilton district, in western Victoria.

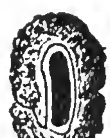
The following new species is described from the material:

Bolivina rugosa, sp. nov.

Text-figs. *a*, *b*.

Test comparatively small, from two and a half to three times as long as broad, only slightly compressed, rather regularly tapering throughout, with the margins lobulated, generally excavated along the median line, periphery broadly rounded, basal end blunt or pointed with a slight spine; chambers distinct in the latter stages, numbering from 12 to 14 in the adult, in the early portion broader than high, later with the height and width about equal, later chambers strongly inflated; sutures distinct, oblique, deeply depressed in the later chambers; wall coarsely perforate, the surface of all chambers except the terminal half of the last thickened and rough, often with a ridge around the base of the early chambers and developing longitudinal lines of coarse beads on the later chambers; aperture elongate, with a pronounced lip, generally with the base removed a little from the inner margin.

a.



b.

Length, 0·6 mm.; breadth, 0·22 mm.; thickness, 0·14 mm.

Examples of this species are common. It shows some resemblance to *B. parri* Cushman, from the Pliocene (Castlecliffian) of Castlecliff, Wanganui, New Zealand, but differs in its deeply depressed sutures and much greater amount of ornamentation.

The holotype of *Bolivina rugosa* and examples of the other species recorded are being deposited in the National Museum of Victoria.

Associated with the Post-tertiary foraminifera are some species which are undoubtedly derived from Tertiary deposits. They do not differ in preservation from the later forms but, in a long experience of Victorian fossil and living foraminifera, the writer has found them to occur only in the Tertiary. Fossil foraminifera, derived from nearby Tertiary deposits, were, it may be recalled, also associated with the Recent species in the shore sands at Barwon Heads.

The Tertiary foraminifera include a number of undescribed species, but the following may be mentioned with the known range of each:

Cornuspira crassisepta Brady	Balcombian-Janjukian
Fissurina sp. aff. *globosa* Bornemann	Balcombian (Batesford Sub-stage)
Ehrenbergina sp. aff. *mestayeri* Cushman	Balcombian-Janjukian
Discorbis margaritiferus (Heron-Allen and Earland)	Balcombian-Janjukian
D. sp. nov. (of *bertheloti* group)	Janjukian
Eponides sp. nov.	Janjukian
Heronallenia sp. nov.	Balcombian-Janjukian
Ceratobulimina hauerii (d'Orbigny), var. *australis* Cushman and Harris	Balcombian
Siphonina australis Cushman	Balcombian-Janjukian
Anomalina sp. aff. *rotula* d'Orbigny	Balcombian-Janjukian
Planorbulinella inaequilateralis (Heron-Allen and Earland)	Balcombian (Batesford Sub-stage)
P. plana (Heron-Allen and Earland).	Balcombian (Batesford Sub-stage)
Sherbornina sp. ? nov.	
Annulopatellina sp. nov.	

The genus *Sherbornina* is known only from one described species, *S. atkinsoni* Chapman, which occurs at Table Cape, Tasmania, and is also found in the Janjukian of Victoria. The present species appears to represent a new form. It is thicker than *S. atkinsoni,* and also has the centre of the upper surface more depressed. The species of *Annulopatellina* is also new, and is identical with a species which occurs in the clays intercalated between the limestones in the lower part of the section at Castle Cove, west of Cape Otway. This is low down in the Janjukian.

The source of these derived foraminifera remains to be considered. Tertiary deposits of Balcombian age now occur in the sea floor at Balcombe Bay, Mornington, and between Point Lonsdale and Barwon Heads. The nearest Janjukian deposits are on the coast in the vicinity of Torquay. It appears probable that the foraminifera were washed out of these deposits or some unknown nearer deposits and carried along a tidal channel to the position in which they were found.

References

1945. Parr, W. J. Recent Foraminifera from Barwon Heads, Victoria. Proc. Roy. Soc. Vict., 56 (n.s.), pt. 2, pp. 189-218.

Mem. Nat. Mus. Vict., 14, Pt. 2, 1946.

A NEW GEOGRAPHICAL RACE OF HETERONYMPHA PARADELPHA (LOWER)

(Lepidoptera, Satyridae)

By A. N. Burns, B.Sc., F.R.E.S., F.R.H.S., Entomologist, National Museum of Victoria.

Heteronympha paradelpha deervalensis nov.

Male:

Above.

Forewing black, median vein broadly rich golden brown, a spot at end of cell, a series of large discal and sub-apical spots rich golden brown, a subapical ocellus black with white pupil, a rich golden brown spot below it in area 4, a raised patch of sex scales in cell close to the median vein, dark brown-black.

Hindwing black, a spot at end of cell, a series of discal, and an interrupted series of subterminal spots rich golden brown; a subtornal ocellus black, white pupilled.

Beneath.

Forewing rich brown-black, base broadly dark golden brown, apex reddish brown, spots as above but paler though rich golden brown, ocellus as above.

Hindwing rich yellow-brown suffused reddish brown, a basal, a discal, a subterminal and a terminal broad interrupted waved line rich reddish brown, a small subapical and a subtornal ringed ocellus, black.

Female:

Above.

Forewing as in the male, median vein broadly rich golden brown, spots larger, brighter, and more clearly defined; sex scales absent.

Hindwing as in male, spots larger, brighter and more clearly defined.

Beneath.

Forewing as in the male.

Hindwing markings as in the male but the whole with a light opalescent purplish suffusion.

LOCALITY:

Deervale, Dorrigo, Ebor, at 4,000-5,000 feet during January and February.

This race is considerably darker and richer in colour than specimens of *H. paradelpha* from Victoria and the Blue Mountains; while all Victorian specimens I have seen are lighter in colour than examples from the Blue Mountains, which more closely approximate to the Deervale race.

In Victoria, I have seen specimens of *H. paradelpha* from Ferntree Gully, the Dandenong Mountains in general, Trafalgar, Lorne, Nowa Nowa, and Mallacoota, where it occurs in February and early March. It is a difficult species to capture on the wing, preferring to keep among the tops of trees. On odd occasions, when it comes to the ground, it is very wary and, on being disturbed, immediately returns to the tops of the trees. This does not appear to be the case with specimens of the newly described race taken at Deervale and Dorrigo, where invariably they are to be found flitting close to the ground among low bushes, and visiting flowers of the Dandelion and wild raspberry.

In addition, *H. paradelpha* appears to be very local in Victoria, occurring in small, localised areas only—this habit is much less marked in *deervalensis,* where specimens are encountered over a large area or wherever patches of gum forest occur.

While *H. paradelpha* is generally regarded as a mountain butterfly, occurring in the Blue Mountains in New South Wales, and the Dandenong Ranges in Victoria at over 400 feet, it however occurs freely in localised areas at Lorne, Nowa Nowa and Mallacoota, practically at sea level.

MEM. NAT. MUS. VICT., 14, PT. 2, 1946.

NOTES ON THE BUTTERFLY, *CATOPSILIA SCYLLA GORGOPHONE*, F. *HINDA* BUTLER (Lepidoptera, Pieridae)

By A. N. Burns, B.Sc., F.R.E.S., F.R.H.S., Entomologist, National Museum of Victoria.

This butterfly was originally described by Butler (1) in 1870 as a form of *Catopsilia pomona pomona* Fabr., and was catalogued as such by Waterhouse and Lyell (2) in 1914; but in 1932, Waterhouse (3) includes this form under *C. scylla gorgophone* Boisd.

The following notes made from actual field observations and breeding experiments by the writer at Westwood, 30 miles west of Rockhampton, on the central Queensland railway, will clearly show that f. *hinda* Butler is really a form of *C. scylla gorgophone.*

Both *C. pomona* and *C. scylla gorgophone* occur abundantly in this locality, the former species at times in great flights the general direction of which is from north to south. *C. scylla gorgophone* occurs freely during the months of October, January and March, though specimens are to be collected from September until May.

The larvae of each species feed on different species of Cassia; those of *C. pomona* on *Cassia fistula* (introduced) and on a native species, and *C. scylla gorgophone* on *Cassia glauca.* Many hundred *C. pomona* were bred from larvae and pupae taken from the food plants, and from these were obtained many interesting varieties, including the female form *catilla* and intergrades between this form and the normal female, but no *hinda.*

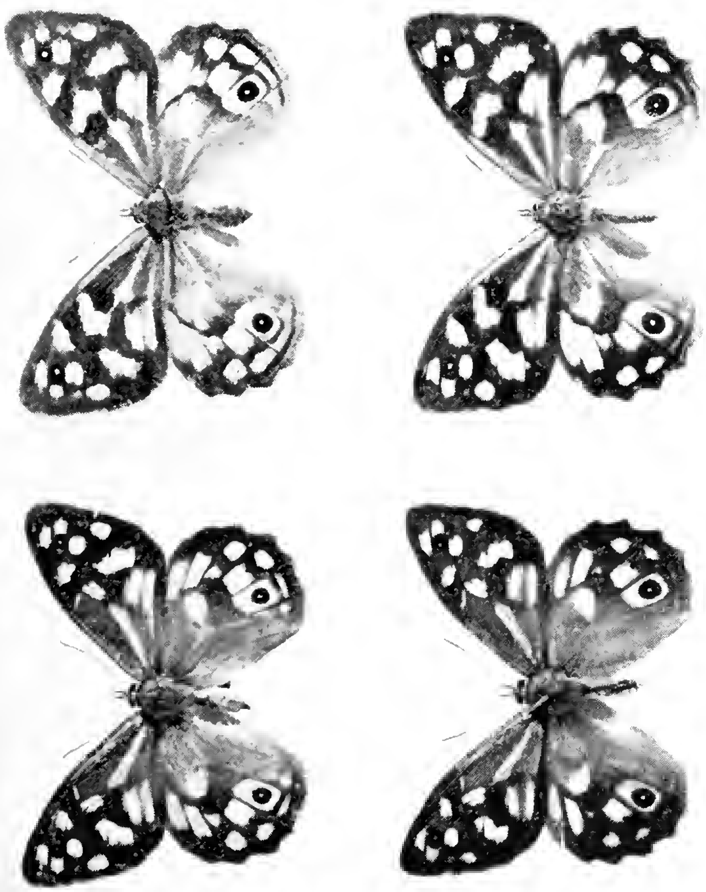
A number of different batches of larvae of *C. scylla gorgophone* was also bred through, and four *hinda* in all were obtained. During the same season, another *hinda* was captured flying with *gorgophone.* The writer has observed occasional specimens of *gorgophone* flying with *C. pomona* during a "flight." Such flights consist of all possible forms of pomona, and twice only has *C. gorgophone hinda* been identified in one of these flights. Their occurrence together cannot therefore be taken as supposing *hinda* to be a form of *C. pomona.*

During these mass occurrences of *C. pomona* it was possible to examine many hundreds of specimens as they were settled on the undersides of leaves and shrubs, but no specimen of hinda was ever seen. In the race *crocale* of *C. pomona* the antennae are black, those of *pomona pomona, C. scylla gorgophone* and *hinda,* are pinkish, and in the latter, the undersides of the wings have a definite pink suffusion which makes this form easily recognizable.

C. scylla gorgophone hinda has been recorded from Brisbane, Rockhampton (Jones), Bondoola (Jones) and Westwood, Queensland.

References

(1) 1870. Lepidoptera exotica, p. 31, pl. 12, fig. 9, 10.
(2) 1914. The Butterflies of Australia. Waterhouse and Lyell, G. Angus & Robertson, Sydney.
(3) 1932. Waterhouse, G. A. What Butterfly is that? Angus & Robertson, Sydney.



Top left. Heteronympha parodelpha paradelpha - mole.
Top right. Heteronympho parodelpha paradelpha - femole.
Lower left. Heteronympha parodelpha deervalensis - male.
Lower right. Heteronympha paradelpho deervalensis - female.

FURTHER TYPE SPECIMENS OF SHELLS IN THE COLLECTIONS OF THE NATIONAL MUSEUM OF VICTORIA

During 1945, the National Museum of Victoria received from Mr. C. J. Gabriel, of Melbourne, whose work on the Australian shells is so well known to all workers in this group, some twenty-six (26) type specimens of the following species:

AMPHINEURA

Ischnochiton falcatus Hull.
Ischnochiton gabrieli Hull.

GASTROPODA—Marine

Bullinella pygmaea A.Ad., var sculpta Gatl. and Gabr.
Cingulina rhyllensis Gatl. and Gabr.
Eulima victoriae Gatl and Gabr.
Jeffreysia wilfredi Gatl. and Gabr.
Larina turbinata Gatl. and Gabr.
Leiostraca joshuana Gatl. and Gabr.
Leiostraca kilcundae Gatl. and Gabr.
Leiostraca styliformis Gatl. and Gabr.
Marginella problematica Gatl. and Gabr.
Rissoa wilsonensis Gatl. and Gabr.
Rissoina rhyllensis Gatl and Gabr.

Terrestrial

Bifidaria bannertonensis Gabr.
Charopa bairnsdalensis Gabr.
Charopa erskinensis Gabr.
Charopa gatliffi Gabr.
Charopa scindocataracta Gabr.
Charopa tarravillensis Gabr.
Laoma sinistra Gabr.
Laoma turbinuloidea Gabr.

LAMELLIBRANCHIATA—Marine

Cuna planilirata Gatl. and Gabr.
Dosinia victoriae Gatl. and Gabr.
Lepton frenchiensis Gatl. and Gabr.
Modiolaria rhyllensis Gatl. and Gabr.
Saxicava subalata Gatl. and Gabr.

The attention of all workers in these groups is directed to the fact that these types are now lodged in the collections of the National Museum of Victoria.

OBITUARY

DANIEL JAMES MAHONY
Director, National Museum, 1931-1944

Daniel James Mahony was born on March 25, 1878; he was the son of Daniel Mahony, a Councillor and Mayor of the Municipality of Fitzroy, Victoria. He was educated at Xavier College, Melbourne, later at Downside School, Somerset, in England. On his return to Victoria, he entered the Melbourne University where, from 1902 to 1904, he was lecturer in geology, mineralogy and palaeontology; in 1905, he graduated in science with first-class final honours in those subjects. He took his Master's degree a few years later.

In 1906 he joined the staff of the Geological Survey of Victoria as petrologist and editor of the Survey publications, and in the succeeding twenty-five years contributed appendices on igneous rocks to several reports. He was largely responsible for the compilation of the lives of the founders of the Survey, including such well known geologists as A. R. C. Selwyn and others. His most important contribution to science while with the Geological Survey was with H. J. Grayson, concerning the geology of the Camperdown and Mt. Elephant districts—a report on two Quarter Sheets surveyed by the students of the Melbourne University under the direction of Professor J. W. Gregory, and published as a memoir by the Geological Survey. With T. Griffith Taylor he published, in 1913, a geological reconnaisance of the Federal Territory. From time to time he also contributed to the Royal Society of Victoria, the Field Naturalists' Club of Victoria, and the Australian Association for the Advancement of Science, numerous papers on igneous rocks, and a few on ethnology.

In 1916 he left for England to enlist in the Royal Artillery, and was on active service until 1919, rising to the rank of Captain. Later he acted as "locum tenens" for Sir Douglas Mawson at the Adelaide University during the latter's absence with his Polar Expedition.

The late Daniel James Mahony

On July 14, 1931, he was appointed Director of the National Museum as successor to J. A. Kershaw. He confined his attention to the administrative duties necessary, and thus could not specalise to any great extent in any particular subject. During his term of office he edited six memoirs comprising papers by the scientists of the Museum and others on a variety of subjects. In 1944, he compiled a useful bibliography on the antiquity of man in Australia, his last contribution to scientific literature. Seven modern dioramas representing the native fauna and aborigines of Australia were added to the Museum exhibition galleries during his directorship—excellent examples of staff team work, and commented upon favourably by overseas authorities and others.

He was President of the Royal Society of Victoria from 1939 to 1940, chairman of the Scientific Committee of the Zoological Board of Victoria, President of the McCoy Society of Victoria, and first President of the Museums Association of Australia and New Zealand.

He passed away suddenly on September 29, 1944, his death bringing forth expressions of regret from a wide circle of friends and admirers. He was unmarried.

—R.A.K.

December, 1945.