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GEOLOGICAL EVIDENCE IN WESTERN VICTORIA RELATIVE TO THE ANTIQUITY OF THE AUSTRALIAN ABORIGINES

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Plates I - IV

Summary

Three periods of aboriginal occupation of the Lake Colongulac area are known, viz.: (1) Time of the extinct giant marsupials, before the local ash vulcanism, as shown by fossil dingo and a carved bone. The age is thought to be late Pleistocene. (2) The mid-Holocene arid period, as shown by a fossil aborigine in a loess dune. (3) The very recent period.

At Pejark Marsh a millstone proves the presence of aborigines as a contemporary of the extinct marsupials and before the local ash vulcanism. The age is believed to be late Pleistocene or early Holocene.

At Bushfield, an axe, bones, and other circumstantial evidence shows the aborigines were present when the Tower Hill volcano first became active, which is thought to be not very much more than 1,000 years ago.

Two series of aboriginal kitchen middens of different ages are described.

Introduction

Three sites in the Western District of Victoria have been reported as significant in a study of the antiquity of man, viz:

1. Lake Colongulac, near Camperdown.
2. Pejark Marsh, near Terang.
3. Bushfield, near Warrnambool.

Geological work in this part of Victoria has thrown some light on the age of the sites, and so each of the above will be discussed in order below. Middens for which radiocarbon age determinations have been made are reported.

1. Lake Colongulac

The general geology of the area has been studied as far as needed to fix geological age, and a detailed examination made of the site at Lake Colongulac. For previous work on the area see Grayson and Mahony (1910).

Bullenmerri Calcareous Clay

The bedrock of the area is a marine calcareous clay, highly fossiliferous. It is yellow where it outcrops round the crater lakes, but blue or bluish-grey when met at depth in bores. The yellow colour seems to be due to oxidation of the fossil land surface it represents. The best exposure of this rock is round Lake Bullenmerri, and so the formational name *Bullenmerri Calcareous Clay* is proposed. Kennon (1885), Tate and Dennant (1893, p. 215), Searle (1912), and Chapman and Crespin (1935, p. 123) refer to the fossil content of this rock. In the National Museum of Victoria (Cudmore Collection) there are fossils labelled "Wirigils, N.E. Camperdown. Rock samples of limestone and clay, probably from a boring or sinking". The specimens show that the Bullenmerri Calcareous Clay was met under the volcanics of Mt. Wiridgil. Mr. J. C. Jehu, boring contractor, of Camperdown, informs me that only once has he been successful in piercing the blue clay, and that was with a bore sunk on the property "Pumyart", 7 miles N.W. of Camperdown, in the homestead paddock near the tennis court about 100 yards north of the house. The log of bore 1* shows:

Black clay and buckshot	4 ft.
Grey clay	8 ft.
Yellow drift sand	3 ft.
Pure white pipeclay	20 ft.
Yellow clay and salt water	43 ft.
Blue marine clay and shells	100 ft.
Black coarse sand, and shell fragments ..	4 ft.
Total depth bored	182 ft.

Mr. Jehu obliged me with a sample of the sand from the bottom of the bore, and it was found to contain a few polyzoa and numerous foraminifera. The latter were sent to Mr. A. C. Collins, who reported on them (slide N.M.V.† P15546) as follows:

I have found no evidence in the form of restricted species to place it definitely, but on the general assemblage it appears to me to be Balcombian, having some likeness to the Orphanage Hill and Western Beach beds. Species suggesting this relationship are—

Liebusella rudis (Costa) recorded from Orphanage Hill, Western Beach, Balcombe Bay, and Altona Bay coal shaft.

Gaudryina collinsi (Cushman) recorded from Western Beach.

Triloculina sp. A large heavy triloculine with a ring-shaped tooth in the aperture, probably undescribed. Common at Western Beach and Orphanage Hill.

Dorothia sp. A large smooth form, which seems to be undescribed (not *parri*). Occurs at Orphanage Hill.

*For ease of reference, bores and excavations mentioned in this paper are numbered serially, and shown on the maps by these numbers.

†N.M.V. = National Museum of Victoria registered number.
P. = Palaeontological collection.

Gnotuk Basalt

Over the eroded surface of the Bullenmerri Calcareous Clay was poured a number of basalt flows which Grayson and Mahony (1910) have termed the earlier basalts, to distinguish them from the later flows associated with the ash and scoria. The two basalt suites are readily distinguished both physiographically and lithologically. The former are widespread, weathered, eroded, generally compact, and tend to be coarse-grained, while the latter are restricted flows, very fresh, commonly vesicular, fine-grained, but often full of blebs or bigger masses of olivine. As far as is known, no ash was associated with the earlier vulcanism, whereas fragmental ejectamenta characterize the latter, the lava flows being subsidiary. There is thus a big difference in the gas/lava ratios of the two vulcanisms, the former being effusive and the second essentially explosive. These flows are part of the great basalt plain of Western Victoria, which covers some 9,000 square miles, and reputed to be the third largest in the world. Mahony and Grayson (1910) gave an account of the petrology of these rocks. Recently, Dr. A. B. Edwards determined the rock on the S.W. side of Lake Bullenmerri for Mr. A. N. Carter as crinanite (analcite-olivine-dolerite).

Evidence for there being a number of flows is provided by bores on the "Chocolyn" estate, on the east side of Lake Colongulac, the logs of which were kindly made available by Mr. P. Law Smith. They are bore 2 on the south side of the homestead, and bores 3 and 4 on the west and east sides respectively of a dam on a small creek $\frac{3}{4}$ mile E.N.E. of the homestead. The creek has no name, but is called Windmill Creek in this paper.

Rock	Bore 2	Bore 3	Bore 4
Surface soil	3 ft.	9 ft.	2 ft.
Black clay	8 ft.	12 ft.	15 ft.
Very stiff yellow clay (loess)	11 ft.	4 ft.	15 ft.
Black basalt	37 ft.	15 ft.	10 ft.
Red gravel	3 ft.	2 ft.	4 ft.
Blue clay	3 ft.		
Blue basalt	5 ft.		
Red gravel	2 ft.		
Black basalt	1 ft.		
Total depth bored	73 ft.	42 ft.	46 ft.

The top of bore 2 is 36 ft. above the extra high 1951 winter level of the lake (hereinafter referred to as H.W.M.), while bores 3 and 4 are 22 ft. above the same level. Analyses of the water by Avery and Anderson are as shown below.

Substance	Bore 2	Bores 3 & 4
Ca	11·1	5·3
Mg	8·0	8·0
Na	27·3	24·9 (Na + K)
K	2·9	
HCO_3	63·4	63·4
Cl	48·7	31·3
SO_3	1·9	2·0
NO_3	0·75	Trace

Grayson and Mahony (1910, p. 14) record a well (excavation 22 in text-figure 1) between Lake Gnotuk and Lake Colongulac having three basalt flows separated by decomposed rock and covered by 15 ft. tuff, making a total depth of 70 ft. The inter-basaltic deposits indicate not inconsiderable erosion intervals between the flows. These three basalts could be the same three flows as met with in the "Chocolyn" bores. However, it is not easy to define the extent of the earlier basalt flows nor to describe the nature of their terrain, for this is now covered by a blanket of tuff and other deposits.

What is apparently a point of eruption was noticed south of the Mt. Leura caldera (see text-figure 1). In a quarry (excavation 1) on the north side of the road there were counted some thirty pieces of country rock in the basalt. They were pinkish-yellow, fine-grained, non-calcareous sandstones baked by the lava. Two specimens were selected, viz. (a) a piece showing signs of stratification, and containing somewhat greenish angular inclusions of a similar rock. The structures were reminiscent of those seen in some Jurassic strata in Victoria; and (b) a finer grained homogeneous specimen with some basalt attached. These samples were kindly examined by Dr. A. W. Beasley, the Mineralogist of the National Museum of Victoria, who reported that they have a similar mineral composition, consisting chiefly of felspar, quartz, and mica, with the felspar/quartz ratio about three to one. The rocks are therefore felspathic sandstones or arkoses, and undoubtedly come from the underlying Jurassic strata. That they should be so numerous, and only altered in colour, suggests that the Jurassic rocks are not at a very great depth. Skeats and James (1937, p. 247) report that "Among the ejectamenta included in the scoria beds of Glen Alvie, near Red Rock, are fragments of plant-bearing, freshwater, Jurassic felspathic sandstones, and of marine Cainozoic sediments". Alongside Excavation 1 is the highest point at which the basalt occurs in this area. As the ground slopes

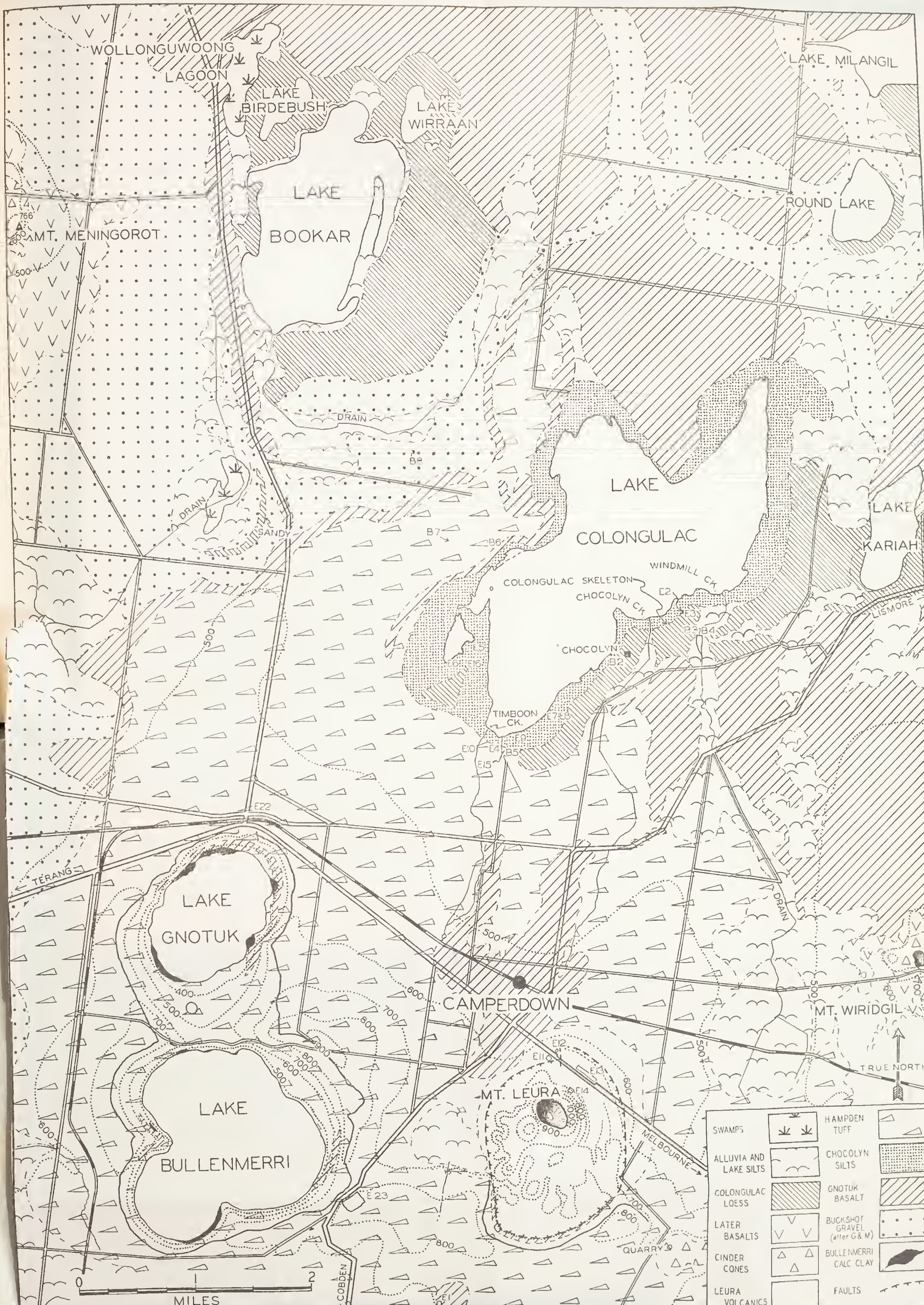

Fig. 1

Geological Map of the Camperdown District based on Grayson and Mahony (1910), but modified where field observations provided new information. Aerial photographs were also used for Lake Colongulac and the area south of it. The lake levels shown are low summer levels. The numbers prefixed by B are bore sites, and those prefixed by E are excavation sites as detailed in the text.

in the direction of Lake Colongulac, it is quite possible that the basalt there came from this eruption centre.

The earlier basalt outcrops round the south rim of the Mt. Leura caldera, where it is covered by something like 40 ft. of tuff; it also outcrops strongly round the rims of the crater lakes Bullenmerri and Gnotuk. For this formation the name *Gnotuk Basalt* is proposed. The basalt forms cliffs about 12 ft. high on the west and north shores of Lake Colongulac; it outcrops also on the east shores from under the loess, forming headlands. Only one small outcrop was noted on the south shore, where older rocks are mantled with tuff. However, it outcrops strongly ¾ mile further south towards Camperdown, and this seems to have been the shore of the pre-tuff lake.

A bore put down at the sanitary depot (bore 5) at the south end of the lake went through a few feet of black soil, some tuff, and then to 62 ft. in yellow clay, finishing in drift sand. The top of this bore is about 20 ft. above the winter level of the lake. A windmill bore (no. 6) on the west side of Lake Colongulac proved:

Black soil	6 ft.
Tuff	55 ft.
Red buckshot	4 ft.

Bore 7 for a windmill in the same area proved:

Soil	5 ft. - 6 ft.
Basalt	60 ft.

Bore 8 nearby proved soil and tuff to a depth of 21 ft. The bores thus indicate that the basalt does not now at any rate form a continuous cover, and its surface was diversified before being covered by the ash spread.

Two Types of Lakes

In the area under discussion there are two types of lakes (*cf.* Grayson and Mahony, 1910) viz.:

1. Deep, roundish, crater lakes.
2. Shallow, irregularly-shaped, consequent lakes.

The levels of the former are a function of the water-table, while the levels of the latter are a function of surface accumulation. Lake Colongulac and the associated Lake Kariah belong to the second type, while the nearby lakes Bullenmerri, Gnotuk, Keilambete, and Purrumbete belong to the first type. Lake Colongulac has an area of 3,500 acres, Kariah 350, Bullenmerri 1,330, Gnotuk 600, Keilambete 770, and Purrumbete 1,450 (Hall, 1912).

There has been considerable confusion over the name of Lake Colongulac. Dr. Hobson, in a letter dated 1846, said the aborigines called the lake "Colungoolac". In pioneers' letters dated 1853 (see Bride 1898), only the name Lake Timboon is given. In 1855 Adeney (see Owen 1877, pp. 184-185) gave the name as Timboon or Colungulac, stating that the aboriginal name was Golongulac. In the same year Bonwick referred to it as Timboon or Corungulac. The same author in 1858 called it Colongulac or Timboon. Etheridge (1878, p. 194) and Johnston (1888, p. 312) refer to Lake Columgoolac. Dawson (1881) gave the native name as Kuurnkolak, and its meaning as "small sand". Wall (1888) spelt it Colangulac. In 1903 Gregory gave the name variously as Kolongulac (pp. 124, 126) and Colongulac (p. 125 map). Hall (1912) in the official Year-Book spelt the name Colongulac and gave the alternative name Timboon. In all publications of later date noted, the name is invariably Colongulac, and there is seldom reference to the older name of Timboon. When the area was first settled, there was a village called Timboon on Timboon Creek near the lake, which was also called Timboon. In 1851, Surveyor R. D. Scott laid out the present town of Camperdown, and wisely put it on higher ground. The village of Timboon gradually disappeared, but confusion has been caused by the fact that a much more recent township about 20 miles to the south has been given the old name of Timboon. Lake Colongulac thus has had two names, and for the present name at least nine spellings have appeared in print. Lake Timboon and Lake Colongulac have been quoted as separate localities for the giant extinct marsupials, but they are one and the same place. (See Plate 1, figures 1 and 2.)

Chocolyn Silts

Overlying the Gnotuk Basalt at Lake Colongulac is a series of clayey silts of lacustrine origin. The Lake Colongulac area was originally a sheep station called "Chocolyn", and the original homestead with a smaller holding still occupies the S.E. side of the lake. This is taken as the formational name of the silts. The type locality selected is the shallow quarry on the present "Chocolyn" estate south of Windmill Creek and just south of a basalt headland (see text-figure 1). From this quarry a collection of the bones of extinct giant marsupials was made by Mr. Law Smith senr., and presented to the National Museum in 1923-24. A spade excavation continued by an auger hole (excavation 2) proved the following succession:

Top	8 in.	grey silt and superficial deposits
	11 in.	reddish gravel rock with *Coxiella confusa* Smith*

*Miss H. Macpherson, Conchologist, of the National Museum of Victoria, says, "The nomenclature of the genus *Coxiella* appears to be in a very confused state, but the above shell is that described by A. E. Smith as *C. confusa*.

2 in. grey silt
6 in. reddish gravel rock with *Coxiella;* at the base is a *Coxiella* band
28 in. grey silt at top, then yellow underneath.
Bottom Basalt at 4 ft. 7 in.

Coxiella is indicative of brackish water conditions, but it has a wide range of tolerance, being found both in comparatively fresh lakes like Lake Bullenmerri and in very salty waters. The silt beds are clayey but contain a considerable amount of fine quartz and other minerals. The grey and yellow silts are compact, and the reddish gravel rock tough, Mr. Law Smith using explosive to quarry it.

The relationship of the Chocolyn Silts to the loess is shown by an auger hole (Excavation 3) on the edge of the loess cliff immediately behind the quarry, the top of the hole being 16 ft. above H.W.M.

9 in. black soil hillwash
4 ft. 1 in. yellow loess
3 ft. 7 in. red gravel in brownish clay
1 ft. 9 in. solid red gravel rock
Basalt chipped at 10 ft. 2 in.

The red gravel in clay may be an old soil horizon. The loess was powdery although bored in mid-winter. The boring contractor who put down the "Chocolyn" bores referred to the loess as "very sticky yellow clay" probably because he puddled water into it with percussion tools. The above auger hole shows that the basalt underneath rises away from the lake, while the grey and yellow silts thin out. The red gravel rock is not very extensive, being only a couple of chains in extent laterally. There is another deposit of similar size, also on the south side of a basalt headland, near the "Chocolyn" homestead. Grayson and Mahony (1910) mark this as "bone bed", but Mr. Law Smith found no fossils there when he quarried it. Both the above localities for red gravel are in protecting arcs of basalt. The presence of little red pebbles of this material in conglomerate at the S.E. corner of the lake suggests that this rock once had a wider extent.

The red gravel rock is a most unusual type of sediment. It consists of roundish pebbles from about 1-16th inch to 1½ inches in diameter, but usually ⅛ inch to ¼ inch. Roughly half of them are of the same rather light grey of the silt stratum underneath, while the rest are brick-red in colour, giving the rock its general reddish appearance. In the fresh rock there do not appear to be any intermediate stages—either the pebbles are grey or they are red. The pebbles are of silt, and they have been secondarily cemented so as to constitute quite a hard, or rather tough, rock. Dr. A. W. Beasley and the author examined some of the pebbles and found they contained a small percentage of heavy minerals, mostly rounded, from both granitic and basaltic sources; the light fraction includes a good deal of quartz and somewhat decomposed felspar and biotite.

The best section of grey silt observed was in a spade excavation (no. 4) and auger hole put down in a creeklet about 100 yards west of the Rifle Range at the south end of the lake, and two chains from the lake cliff. The following succession was proved:

3 ft. 6 in. black soil (alluvium)
3 ft. horizontally stratified tuff (base of tuff 9 ft. 2 in. above H.W.M.)
5 ft. 2 in. light-grey compact silt (not penetrated)

At the northerly tip of the flats (former lake bed) round the headland on the south shore of the lake a spade excavation (no. 5) showed:

12 in. grey silt
3 in. red ironstone sand and gravel
9 in. yellow clayey silt (not penetrated)

On the west side of the same flats a similar succession was found (Excavation 6):

8 in. grey silt
2 in. dark-yellow iron concretions and red ironstone sand
6 in. yellow silt (not penetrated)

Numerous spade excavations showed that the grey silt is always over the yellow silt. In Excavations 5 and 6 ferruginous deposits intervene, and this is due to a large bed of massed buckshot gravel* mostly lithified to an ironstone which occupies the lake bed on the east side of the headland. Tools available could not pierce the ironstone, but its geological relationships suggest that it lies on the yellow silt.

The Pre-Tuff Lake

The Chocolyn Silts have been traced by a series of spade and auger holes round the lakeside from Excavation 2 to where they pass under the tuff at the south end of the lake. At the S.E. corner of the lake, about 200 yards north of the windmill at the sanitary depot, two spade excavations proved the silts under the tuff which in turn was under the loess.

*The term used in Victoria for what elsewhere is called ironstone gravel or pedalferric nodules.

Excavation 7 (on former lake floor not far from cliff):

6 in. soil
8 in. horizontally bedded tuff *in situ*
8 in. grey silt (not penetrated)

Excavation 8 (at base of cliff):

1 ft. 4 in. soil and loess
3 in. tuff
8 in. grey silt with some brownish patches (not penetrated).

On the south shore near the foot of the cliff in the sanitary depot Excavation 9 showed:

1 ft. 6 in. tuff
6 in. pebbles
6 in. grey silt (not penetrated).

Excavation 4 and a section in Timboon Creek (Excavation 10) both showed the grey silt under the tuff. Over this distance, which is about half a mile, the grey silt is horizontol, being overlain by horizontally-bedded tuff except along the lake cliff where a former high level has undercut the tuff, causing the collapse of large blocks.

The volcanic ash fell into a lake more extensive than the present one, for the tuff (i.e. lithified ash) in the creek sections lies directly on horizontal lacustrine silt with no soil layer intervening. At Excavation 4, a fine carbonaceous layer was noted between the silt and the tuff; in it were poorly preserved plant remains that suggested water weeds. In the bottom layers of the tuff were found small fragments of shells, some of which were clearly from lamellibranchs. A fragment showing a piece of hingeline was shown to Miss Hope Macpherson, Conchologist of the National Museum of Victoria, who stated that it is almost certainly *Corbicula*. In the salt and brackish water lakes of the Western District, *Coxiella* is the only shell found so far (*cf.* Shepard 1918), no lamellibranchs being present apparently. *Corbicula* is common, but always in fresh water, especially moving water as in rivers and creeks.

The pebbles found in Excavation 9 were of calcareous concretions mostly, but some were of tuff. They were mixed with rounded grains of milky quartz, clear quartz, rose quartz, fresh olivine, limonite, iron ore, and fragments of ?*Corbicula*. The lake was brackish at the time the Chocolyn Silts were laid down, as shown by the presence of *Coxiella,* and it is suggested that this deeper water at the S.E. end of the lake led to where a creek entered. That the water was deeper is shown by the fact that for a short distance at the sanitary depot, the tuff occurs about 10 ft. lower than its usual level. To interpret all the above facts as a creek entry would account for the *Corbicula,* their invariably fragmented condition, the pebbles (including tuff ones), and the coarse sand (including fresh olivine). The creek probably drained the slopes of the basalt flows from the vent referred to on page 28, for the town of Camperdown lies in an open valley of basalt partly filled with tuff.

The pre-tuff lake was more than 10 ft. deeper than the present lake at its highest level in living memory (H.W.M.), local residents claiming the 1951 level to be the highest for over 30 years. The pre-tuff lake reached further south, but in the west had much the same boundary, being confined by the basalt. On the east it spread to the basalt shown in bores 2-4, but ran a considerable distance up the creek beds. To the north the pre-tuff lake extended for a considerable distance, coalescing with the present Lake Kariah and small lakes still further north. Also the lake floor has had an ash spread thrown over it in addition to erosion products, so that the pre-tuff lake basin would be deeper than the present one, even though some sediment was blown away during the arid period. The whole geologic process is towards the elimination of lakes by filling their basins with sediments. The climate at the time of the ash vulcanism must therefore have been much more pluvial than the present one in order to fill a deeper and much more extensive basin, and at the same time to deposit silts to a level some ten feet higher than the highest experienced level of water. Consequent lakes like Lake Colongulac have a vast surface area relative to their volume, and so a rise of over ten feet in level represents a big change in conditions. Constant renewal is necessary if the level is to be maintained because of the extensive evaporation surface.

In times of drought Lake Colongulac dries up completely in midsummer, and the floor glistens with a layer of salt. From records kept by Mr. Law Smith senr., it was ascertained that during the past 30 years, the lake went dry in twelve summers, viz., 1923, 1927-1931, 1933, 1935, 1938, 1940-41, 1945. Other factors besides evaporation can affect the drying of the lake. For example, it dries very rapidly when the wind keeps reversing. The water then blows up and down the lake floor, being spread over extensive areas of dry surface, which quickly absorb a considerable quantity. The lake has not dried up during the years 1946-1951.

Extinct Giant Marsupials

Lake Colongulac is the classic locality in Victoria for the extinct marsupial fauna. From thence came the first fossils of that fauna from Victoria; they were described by Professor Sir Richard Owen of the Royal College of Surgeons, London, and among them was the holotype of *Thylacoleo carnifex* (Owen 1859). The fauna recorded is as follows:

Animal	Literature Reference
Diprotodon optatum Owen	McCoy 1876, Keble 1945
Thylacoleo carnifex Owen	Owen 1859
Procoptodon goliah Owen	McCoy 1879, De Vis and Hall 1899
?Palorchestes ("The Colongulac Bone")	Spencer and Walcott 1911 Keble 1947
Macropus titan Owen	McCoy 1879
M. magister De Vis	De Vis and Hall 1899
M. pan De Vis	*Ibid.*
Thylacinus rostralis De Vis	De Vis and Hall 1899
Canis familiaris dingo Blumenbach	McCoy 1882
Doubtful	
Vombatus pliocenus (McCoy)	McCoy 1879
Macropus canguru (Müller)	De Vis and Hall 1899

The *Diprotodon* is that usually called *D. australis,* but as Simpson (1930) has pointed out, Owen overlooked his own earlier name for this species. It should be noted that De Vis says the jaw of the thylacine is larger than the type. The presence of *Vombatus pliocenus* is questioned because no specimen has been found in any of the collections from the Chocolyn Silts. McCoy (1879, p. 10) records, "Specimens (of *Procoptodon goliah*) figured are from the Pliocene Tertiary clays of Lake Timboon, on the shores of which they are cast up after storms, with various species of *Macropus,* the *Phascolomys pliocenus* McCoy, and the *Thylacoleo carnifex* Owen." *Vombatus* does occur with the extinct marsupial fauna, but that it occurs with this fauna in the Chocolyn Silts has yet to be proved. The specimens of *V. pliocenus* figured by McCoy in his *Prodromus* from the Camperdown District are from Lake Bullenmerri and Holocene in age (uppermost Pleistocene at earliest). One of the specimens is red and mineralized (N.M.V. P7441) while the other (P7442) is whitish and unmineralized. However, mineralization is not necessarily an indication of antiquity. The writer found on the shores of Lake Bullenmerri a red and mineralized leg bone of a cow which was almost exactly twice the weight of a similar unmineralized one. As the district has been occupied by white people for only a little over a century, the mineralization has taken place in that time. As the first settlers were sheep farmers, the bone is probably well under 100 years old.

Macropus canguru is also placed on the doubtful list. Morrison-Scott and Sawyer (1950) have shown that "Captain Cook's Kangaroo" is the Great Grey Kangaroo, which is therefore not to be called *M. giganteus* Shaw or *M. major* Shaw, but *M. canguru* (Müller) 1776. De Vis says that the specimen of *M. canguru* he examined from Lake Colongulac was not mineralized, so may not belong to the old fauna, but was a surface bone picked up with the others at the time. In Law Smith's collection, there are two comparatively whitish and less mineralized jaws of *M. canguru* (one with soil attached) that either belong to a later period, or have been leached at or near the surface.*

Many collections have been made from Lake Colongulac in the past hundred years, but they have all been picked up loose on the beach, the bed from which they came being unknown. In order to establish the antiquity of man at this site, it is necessary to know

(a) from which bed or beds the fossils came, and
(b) the age of the bed or beds.

The writer has been able to determine the former, and estimate the latter. The first white people to live in the Camperdown district were the brothers Manifold, who settled on the banks of Lake Purrumbete in 1839. In 1843 the area about Lake Colongulac was taken over by a settler named William Adeney. In January 1846, Dr. Henry Hobson of Melbourne wrote to Professor Owen, stating, "I send . . . . a box which contains some interesting fossil bones, from a lake 80 miles S.W. of Melbourne. They were discovered and kindly forwarded to me by Mr. W. Adeney, who has a sheep station on the banks of the lake. I have since visited the lake, which is called by the aborigines *Colungoolac*. . . . The fragment of skull and incisor I hope may be new to you." In August 1855, Adeney himself wrote to Owen, describing the occurrence of the bones. He said, "On the beach in 1843 when I first arrived *disjecta membra* overspread many yards of the surface. . . . I have given away hundreds of these specimens." The fossils were thus numerous but *non in situ*. Hall likewise records (1899, p. 108), "The bones, accompanied by concretionary nodules of calcareous matter, lie loose on the lake beach almost due north of the township, and appear to have come from a clay bed which occurs about water level. As the banks of the lake are

*Since this paper was written, the determination of fluorine/phosphate ratios suggests that *Macropus canguru* did belong to the ancient fauna.

low, it is not easy to say from the evidence there displayed whether the bone bed or the tuff is the older, though my impression has long been that the clay was the underlying deposit. I have recently been informed that in well-sinking not far from the lake margin, bones were obtained in a clay bed which was reached after sinking through the sandstone." "Sandstone" is the local name for the tuff. Pieces of conglomerate with the light-grey calcareous nodules have been found by the writer with pieces of bone in them. The conglomerate also has fragments of shell and red silt pebbles as found in Excavation 2. The conglomerate occurs only at the S.E. corner of the lake where a pre-tuff creek used to enter. The clay bed Hall referred to is the Chocolyn Silt which has been traced by excavations and auger holes, and it definitely underlies the tuff. Grayson and Mahony (1910) were inclined to the opinion that the bones came from the tuff itself, while Keble (1945) listed the bone-bed above the tuff. Chapman (1930) thought the bones might be old cave deposits. In the National Museum of Victoria there are two collections of extinct marsupial bones presented in 1923 and 1924 by Mr. and Mrs. Law Smith senr., who at that time and until recently occupied "Chocolyn". Mr. Law Smith kindly showed me where these bones came from, and I collected some fragments myself. They were blasted from the red gravel bed of the Chocolyn Silts at Excavation 2. The unusual matrix of the quarry is to be seen on many specimens in the Museum. On examining the other collections in the Museum from Lake Colongulac (those of Dr. T. S. Hall, Mr. G. Sweet, Mr. A. D. Hardy, Dr. G. B. Pritchard, and others) it was found that many of the fossils had matrix attached that proved they came from either the red gravel, the conglomerate of the S.E. corner, or the grey clayey silt, *i.e.* they all came from the Chocolyn Silts formation. None possessed a matrix of either tuff or loess—the only other rock types in the area from which they could possibly have come.

Bonwick (1855, p. 26) says the type of *Thylacoleo carnifex* came from the eastern side of the lake.

Preservation of the Fossils

The bones from the Chocolyn Silts are heavy because highly mineralized, are red in colour, and when fresh the surfaces are shiny. A few have been bleached either in part or wholly through exposure on the shore of the lake. As basalt underlies the Chocolyn Silts, the only other formations from which the bones could come are the Hampden Tuff and the Colongulac Loess, but as stated, the bones did not come from them. No bones have been found in the tuff, but some have come from the loess, and contrast with those found in the silts. They are generally slightly leached in that porous matrix, unmineralized, and light instead of heavy. They are yellow and not red, and their surfaces dull and not shiny.

Another important feature about the bones from Law Smith's quarry, and from the conglomerate at the S.E. corner of the lake, is that they are remanié. Inside the bones is a fine light-grey silt, such as forms the lowest member of the Chocolyn Silts, but which contrasts with the gravel or conglomerate on the outside. Dr. A. W. Beasley kindly made a petrological examination of the matrix infilling the bones presented by Mr. Law Smith. The light minerals present are quartz, decomposed felspar, and a little mica. The heavy minerals (slide E535) in order of abundance are black iron ore, pyroxene (mainly augite, but also enstatite and hypersthene), zircon, garnet, olivine, rutile, and tourmaline. The iron ore (probably ilmenite) and pyroxene grains are generally large, little rounded, and poorly sorted. Their detrital history has not been long, and they with the olivine have come from the underlying basalt. The zircon, rutile, and tourmaline grains are smaller and much more abraded. They come from granitic rocks known to underlie some of the area, and their detrital history has been much longer. The grey silt matrix on a bone in the Hall collection of Lake Colongulac fossils was examined and found to have a closely similar mineralogical composition (slide E536). A sample of grey Chocolyn Silt from the auger hole at Excavation 4, at a depth of five feet below the tuff, proved also to be indistinguishable mineralogically (slide E537) from the matrix infilling the bones from Law Smith's quarry. On the other hand, the mineral composition of the overlying loess contrasts with that of the silt in that the percentage of basaltic minerals is greatly increased. This is to be expected in view of the fact that an ash spread took place between the deposition of the Chocolyn Silts and the building of the loess dunes.

The grey silt is in a condition of chemical reduction, turning light brown on ignition. The red mineralized bones, being in a condition of chemical oxidation, could not have reached their present condition in this silt, and so must have been in a different environment before coming where they were found. The larger bones are little affected by transport and cannot have come far, but the small pieces of bone are well worn, apparently due to being washed up and down the beach. It appears that the bones were mineralized (perhaps in an old terrace), then washed into the grey silt, and then into the gravel or conglomerate. This involves two levels of the lake much higher than any experienced since

European occupation of the area, and two cycles of erosion and deposition.

Extinct and Extant Faunas

The extinct fauna found in the Chocolyn Silts is found at a number of sites in the lake district of Western Victoria. McCoy in his *Prodromus* records many giant forms from Lake Colac. Grayson and Mahony (1910) found similar fossils at Blind Creek, while Keble (1947) found *Diprotodon* under the tuff at Pejark Marsh where Spencer and Walcott (1911) had found *Palorchestes* cf. *azael* and *Macropus* cf. *titan*. Keble (1945) records *Nototherium* from Watch Hill on the N.E. shore of Lake Corangamite between Beeac and Cressy, but had some doubt concerning the locality because of confusion over the name of the place. That Keble's explanation of the site is probably correct is shown by the following letter found recently in the Museum:

Berry Bank,
Cressy.
September 1872.

Professor McCoy,

Enclosed I send you some bones that were found in lime stones when sinking a well, about twenty-two feet deep, on Messrs. Bell and Armstrong's property at Watch Hill.

As we cannot make out what sort of animal they belong to, if possible will you be kind enough to let me know what they are, and you will much oblige,

Yours truly,
(Signed) Joseph Mack.

The mineralized bones with the letter are *Vombatus*. The same gentleman sent from the same place in 1906 a mineralized calcaneum of a large kangaroo. Thus the Watch Hill people found fossil bones, were in touch with the National Museum, and may well have sent the bones referred to by Keble. A giant kangaroo jaw was found at Ondit, east of Lake Corangamite.

Giant marsupial jaws in a silty matrix are in the National Museum "from Hon. Neil Black's station". Mr. Neil Black was one of the original settlers of the area round Mt. Noorat. In July 1951, Mr. John Manifold of "Purrumbete", near Camperdown, presented to the Museum a large collection of fossils including many extinct marsupials such as *Diprotodon, Thylacoleo,* giant *Macropus,* and a jaw of *Sarcophilus* larger than the extant species. Mr. Manifold had no record of the locality from which these bones came, but a study of the matrix showed that it is not probable that they came from Lake Colongulac. For instance, pieces of volcanic cinders are attached to some of the specimens, and ejectamenta as coarse as that have not been seen by me at Lake Colongulac. In the National Museum there are some giant marsupial bones presented by Mr. W. T. Manifold (father of Mr. John Manifold) which appear to be a selection from the same collection. In 1916 Mr. W. T. Manifold presented a fossil jaw of the *Macropus titan* type, which was labelled "Purrumbete, Victoria". One could assume that this is the locality from which they came, but it could be only the donor's address. Thus the locality for the collection is unknown, but it could be Lake Purrumbete. Along with the extinct marsupial bones were also lightly mineralized bones of different preservation belonging to extant forms, bones of aborigines, and aboriginal implements; some of these bones and implements are known definitely to have been found on the property, and this increases the possibility of the whole collection coming from there. The extinct fauna is a pre-tuff one, because the matrix is a fine silt similar to the Chocolyn Silt, but in some cases with little pebbles of cinders attached after the bones were washed out of the original bed.

In 1933, during sewerage excavations in the city of Warrnambool, a cave was opened in Pleistocene aeolianite on the south side of Skene Street, between Banyan and Kelp Streets, ten feet from the surface. A number of bones, unmineralized to mineralized, were obtained from Mr. J. Jukes, and were determined at the time by Mr. C. W. Brazenor, Mammalogist, National Museum of Victoria, as

Procoptodon sp.
Macropus cf. *anak* Owen
Vombatus mitchelli (Owen)
Thylacoleo carnifex Owen
Aepyprymnus rufescens (Gray)

in addition to other kangaroo, wallaby, bird, sheep and rabbit remains. Extinct marsupial bones are also known from Hawkesdale, north of Warrnambool.

The extinct giant marsupial fauna is thus quite widespread round the area under discussion, and not limited to Lake Colongulac. Where the age of the giant forms can be determined, as at Lake Colongulac and Pejark Marsh, they are Pleistocene, and earlier than the local ash vulcanism.

In striking contrast with the extinct fauna is the post-tuff fauna which consists entirely of living species. At Lake Colongulac, all the forms definitely from the Chocolyn Silts are extinct except for the dingo. On the other hand, quite numerous vertebrate fossils have been collected from the terraces of the crater lakes nearby, but none of them belong to extinct species. Typical is the fauna from Lake Keilambete, which includes

Macropus canguru (Müller)	Great grey kangaroo
Wallabia	Wallaby
Vombatus cf. *mitchelli* (Owen)	Wombat
Potorous tridactylus (Kerr)	Dark rat-kangaroo
Cygnus atratus (Latham)	Black Swan

Similar faunas have been collected from Lakes Gnotuk and Bullenmerri. McCoy (1882) recorded *Sarcophilus ursinus* from a cave in the tuff at Lake Purrumbete, and *Dasyurus viverrinus* has been found in the tuff at Terang.

Although there is this marked break between pre-tuff and post-tuff faunas, there is no evidence to suggest that the volcanic eruptions were responsible for the extinction of the former in this area. The bones found under the tuff at Lake Colongulac are remanié, and so do not belong to the time immediately before the eruption. Nevertheless the blanketing of vast areas with a layer of volcanic ash must have had considerable biological repercussions, and although no connection between the disappearance of the giant marsupials and the eruptions can be demonstrated, it is certain that when the area was re-populated, only living species were present to effect this. Even though the vulcanism itself may have occupied a comparatively short period of time, probably quite a considerable break is represented between the extinct and extant faunas as found fossil in the Lake Colongulac area. As far as present evidence goes, the extinct fauna is Pleistocene, and the extant fauna Holocene. The passing of the pluvial period prior to the mid-Holocene "Thermal Maximum" (when the loess dunes were built) is taken as the end of the Pleistocene.

Hampden Tuff

This formational name was given by Grayson and Mahony (1910) to finely-bedded tuffs that cover much of the Camperdown and contiguous districts. This very wide use of a formational name is scarcely in keeping with the definition since established (Glaessner *et al.* 1948). Each distinguishable ash spread is a separate lithological unit, and to merge them can be confusing. The Terang Tuff, Keilambete Tuff, and Purrumbete Tuff are such separate units, and hereby proposed as formations; the respective lake bank sections provide the obvious type localities. At Mt. Leura there is a yellow tuff readily distinguishable from the earlier slate-grey tuff of the initial cone, and it is herein separated from the Hampden Tuff and included in the Leura

Volcanics. Referring to the Hampden Tuff, Grayson and Mahony (1910, p. 6) say, "The best sections are seen in the cuttings along the road which crosses the neck of land between Lakes Bullenmerri and Gnotuk . . ." This first-named site may be taken as the type locality of the Hampden Tuff.

An average rainfall of 29·11 inches falls on the Hampden Tuff each year (Hounam 1949); the State average is 24·27 inches (Aird 1945). This small rainfall is fairly well distributed over the year (the lowest monthly fall is February 1·45 inches, and the highest is August 3·41 inches), and the tuff is highly absorbent. The result is that no permanent streams flow over it. Further west is the Mt. Emu Creek which in spite of being 165 miles long (15 miles longer than the River Yarra) never becomes a large stream. A strongly incised physiography is therefore not to be expected in the tuffs, but there are other evidences of considerable weathering. The soils are deep and there is a well-developed layer of buckshot gravel. For example, on the flat ground near Excavation 4, a spade and auger hole proved (Excavation 15):

2 ft. 6 in.	heavy, black, alluvial soil
2 in.	large buckshot nodules in soil
11 in.	decomposed tuff (ground increasingly tuffaceous)
	solid tuff at 3 ft. 7 in.

Excavations in connection with the reservoir at the top of the hill on the Camperdown-Cobden road, two miles S.W. of Camperdown, show the plentiful development of buckshot in the soil on the tuff (cf. Grayson and Mahony 1910, p. 9). However, the nodules are not as numerous as in the pre-basaltic soil profiles, which are laterized.

Another notable weathering feature is the presence of soil pipes. Plate 4, figure 8, shows these in the south wall of Excavation 13 near Mt. Leura. The dark chocolate soil, which is 2 ft. 6 in. deep, extends down into pipes which are a further 4 ft. 6in., the bottom of the longest pipe being thus 7 ft. from ground level. The pipe narrows from 23 in. diameter at 4 ft. from the bottom to 9 in. diameter three inches from the bottom. The pipes figured are in reddish-brown to blackish volcanic cinders, but are seen also in the yellow tuff exposed in the same quarry and in the quarry on the opposite side of the road (Excavation 14). They are not so deep as in the cinders, which may be due to the rock being much less porous. Dr. Tomlinson (1941) has described in England a brown loam with ironstone nodules which extends into underlying gravels as pipes. The stratification of the gravels is apparently quite unaffected by the process of pipe-formation (Plate XXI, fig. 2). Such pipes appear to be the product of percolating waters in a time of plentiful rainfall.

Support for this explanation is provided by the fact that soil pipes are not found on the very steep slopes. For instance, in the quarry at the foot of the steep cinder cone of Mt. Leura (Excavation 14), pipes are absent from the steep side of the quarry, but numerous where the slope eases off into flatter ground. Also the pipes tend to be associated with hollows in the terrain. They appear to be homologues of the solution pipes found in the Pleistocene aeolianite. These are vertical tubes of travertine which are no longer in use as natural drains. and usually filled with fossil soil (cf. solution pipes in English chalk—Burnaby 1950). The soil pipes are thus surely solution channels, but it should be noted that where they occur on the cinders and agglomeratic yellow tuff at Mt. Leura (Excavations 13 and 14), and on cinders at Mt. Noorat (large quarry on west side), they are associated with unleached and immature, though deep, soils. These soils are dark brown to chocolate loams 2 ft. 6 in. to 3 in. thick, but without a profile developed in them. The soils on the Leura Volcanics are quite immature, while those on the surrounding grey tuffs are well-developed podsols. Professor G. W. Leeper, of the University of Melbourne, kindly examined a series of fossil and extant soils for the writer, and described the soil seen on tuff in the excavation for the reservoir 1½ miles S.W. of Camperdown (Excavation 23) at a mature podsol with a grey silt-loam A horizon, and a red-yellow-grey mottled clay with buckshot gravel as a B horizon. At present it is not understood whether the immaturity of the soils on the Leura Volcanics is due to younger age, or difference in pedogenic process from that on the Hampden Tuff.

The Hampden Tuff contrasts with the Tower Hill Tuff which has a shallow soil, and no buckshot gravel layer. There are no soil pipes in the latter, although there are soil pipes associated with the soil on which it lies. The Hampden Tuff was ejected a considerable time before the mid-Holocene arid period as represented by the loess dunes resting on its eroded surface. On the other hand, the Tower Hill Tuff was subsequent to mid-Holocene clay and limestone on an emerged late Pleistocene marine shell-bed to be seen on the Moyne River near Tower Hill (pp. 74-76). At Camperdown the extant marsupial fauna is always found on top of the tuff, while in the Warrnambool district it is found under the tuff as well as over it. The Hampden Tuff is thus older than the Tower Hill Tuff.

The Volcanoes

In attempting to determine the age of the Chocolyn Silts and their contained fossils, it is important to know when the volcanoes were active and for how long. It is possible that small quantities of volcanic ash reached Lake Colongulac from afar, but the five or six feet of finely-bedded horizontal tuff seen at the south end of the lake must have been derived from one or more of the three volcanoes nearby, viz., Leura, Bullenmerri, and Gnotuk. Brough Smyth (1858), Bonwick (1858, 1866), Gregory (1903), Grayson and Mahony (1910), Barnard (1911), Searle and Shepard (1915), Singleton (1935), Sussmilch (1937) and Hills (1939*a*, 1940*b*) have commented on these volcanoes.

Mt. Leura (Plate I, figures 1-2). Although previously not recorded as such, Mt. Leura is a caldera, oval in shape and orientated north-south, being about two miles long and one and a half miles wide. It is thus comparable in both size and shape with two other Western District calderas, viz. Tower Hill and Mt. Warrnambool (Gill 1950). Mt. Leura has had two phases—the ash phase, and the cinder phase, in that order. Volcanic activity began by the punching of a vent through the underlying Bullenmerri Clay and the Gnotuk Basalt. A great mass of grey ash and lapilli was ejected, most falling on the southern side of the vent. Indeed, it is now difficult to find bedded grey tuff on the west, north, and east sides of the caldera. There are quarries (Excavations 11 and 12) in basalt on the south and north sides respectively of the Prince's Highway on the N.W. rim of the caldera, and just east of these quarries is the ring fault of the caldera, while just west of them in the road cutting can be seen bedded grey tuff with very fine cinders therein. A considerable area of basalt separates this tuff from the Bullenmerri-Gnotuk spread. Caldera formation has left a high scarp at the southern end of the collapsed area (Plate 2, figs. 3-4), consisting of roughly 50 feet of earlier (pre-caldera) basalt and 40 feet of tuff (measurements by eye only). Between the basalt and the tuff is a well-developed soil. No evidence of any break in the layers of tuff was discovered, and it was concluded that, like most of the ash volcanoes of the Western District, this was a somewhat maar-like kind of activity, being continuous and occupying but a short period of time from a geological point of view. Measurements have not been made, but the volume of ash appears to approximate the volume of the caldera.

Another quarry (Excavation 13) about a quarter of a mile east of Excavation 12, and also on the north side of Prince's

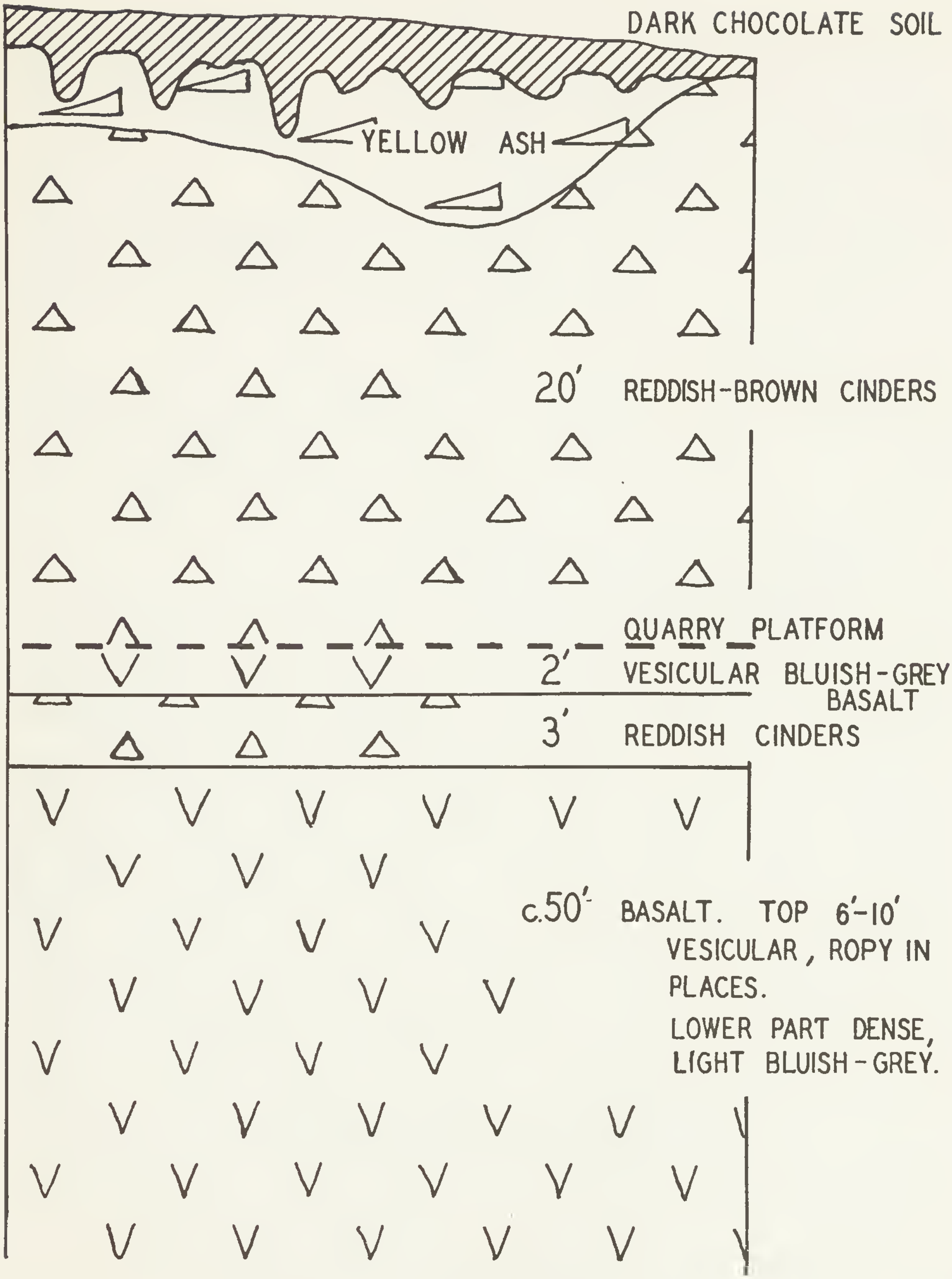

Fig. 2

Diagram of part of the south wall of the large quarry on the north side of Princes Highway, near Mt. Leura (E 13).

Highway, provides an epitome of some of the caldera's post-collapse history. The north end of the wall shows blackish cinders (quarried for roads) dipping at 15° towards the centre of the caldera, and against the truncated ends of these beds is very fresh "later basalt" which is somewhat columnar in places. The junction is a fault line which strikes E.20°S. After the main caldera formation there has been subsidence, causing the cinders to dip inwards to the vent instead of outwards, and faulting the subsequent small flow of basalt against the cinders. On the south wall of the quarry is the succession shown in text figure 2, while text figure 3 shows that on the north wall.

Over both basalt and cinders is a massive yellow tuff with lapilli and angular fragments, contrasting with the earlier grey tuff in both structure and colour. Cinders and yellow tuff can be seen in the road cuttings on the highway east of Excavation 13. A quarry immediately west of the Camperdown Showground reveals some thin flows of later basalt.

Almost opposite Excavation 13 is a quarry (Excavation 14) which is cut into the base of the Mt. Leura cone. As Plate II, figure 3, shows, there is actually a complex of cones, the highest of which is 1,027 feet above sea-level. On the S.W. of the latter is a crater, inset on the edge of which is another high cone. Dawson (1881) records how the aborigines distinguished between these two peaks, called the higher one *Lehuura* (=*nose,* hence the present name *Leura*), and the other *Tuunuunbee heear* (=*moving moving female*). There are over 25 cones in the central complex of Mt. Leura, which is thus a nested caldera. Excavation 14 shows that the cone is made of cinders with numerous volcanic bombs of all sizes from an inch to three feet in diameter. Some of the bombs are of solid basalt, while many have cores of olivine, or iddingsitized olivine (cf. Edwards 1938); a few have cores of anorthoclase and rarely one of country rock is found (cf. Atkinson 1897). On the slopes of the cones are numerous pieces of scoria and ropy lava, and at first sight one is inclined to think that the cones are built of such materials, but it seems that these are rather pieces of spatter thrown out in the dying phases of the volcano's activity.

So the succession of events can be shown to be thus:

1. *Ash phase.* Ejection of grey finely-bedded ash and lapilli (earliest event).
2. *Caldera formation* by collapse (no coarse material can be found in the rim ejectamenta).

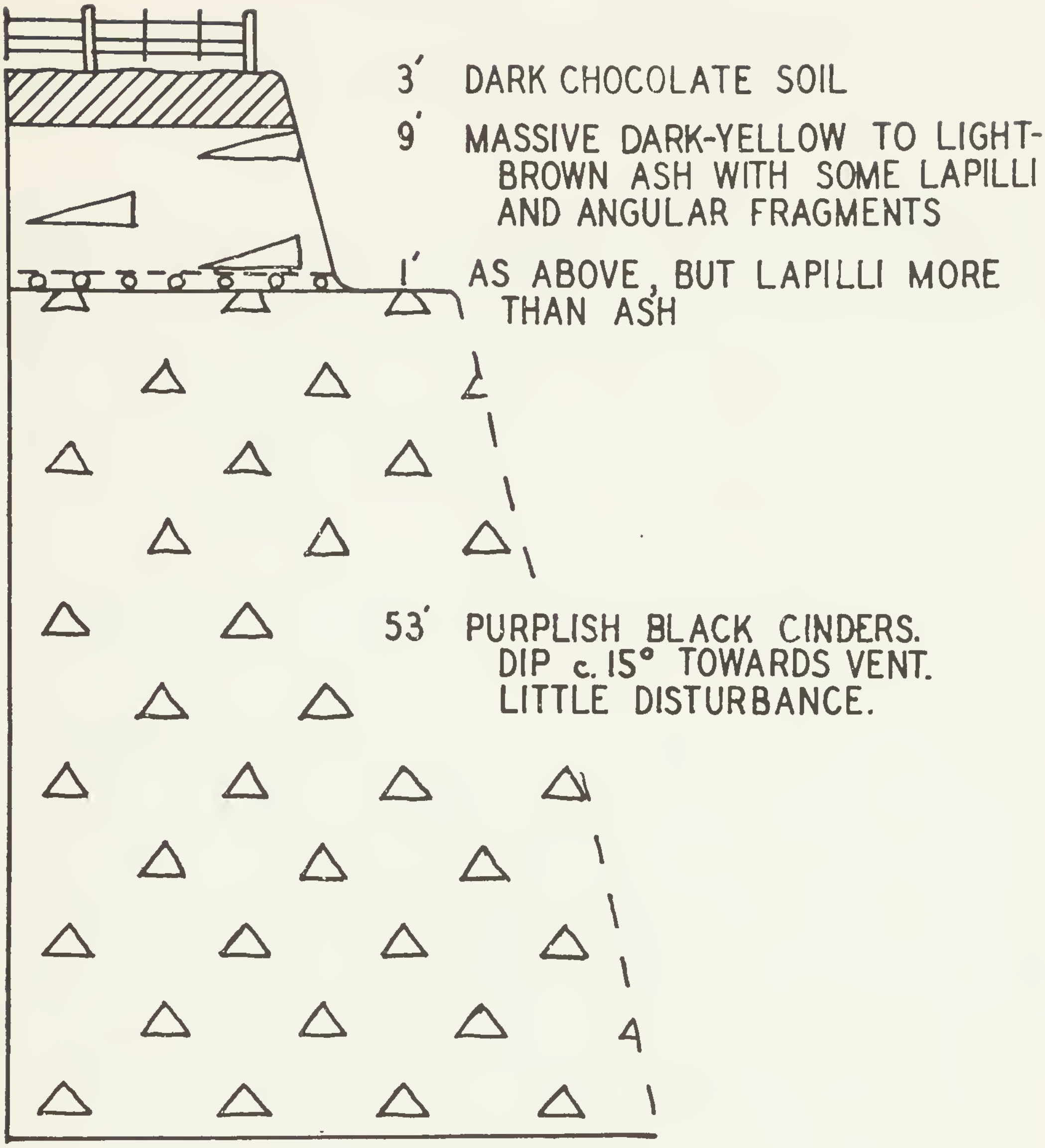

FIG. 3

Diagram of part of the north wall of the large quarry on the north side of Princes Highway, near Mt. Leura (E 13).

3. *Cinder phase.* Illustrated by Excavation 13, which shows—
   (a) Ejection of cinders
   (b) Subsidence(s) giving cinders vent-wards dip, and causing faults as in Excavation 13, and ridges shown in map (text fig. 1)
   (c) First lava flow
   (d) Brief ejection of cinders

(e) Second lava flow (see text figure 2)
(f) Further ejection of cinders
(g) Ejection of massive yellow tuff and lapilli (agglomeratic in places)

4. *Formation of soil,* and solution pipes.

For the volcanic rocks formed subsequent to the caldera subsidence (i.e. by event 3 above), the formational name *Leura Volcanics* is proposed. It appears from analogy that the whole series of events 1 to 4 took place in a short space of time, from the geological point of view, but the soils on the Leura Volcanics are surprisingly immature. For this reason there may be a break in time between events 2 and 3, but this would not affect the age of the tuff, which is the main consideration at present.

Volcanoes Bullenmerri and Gnotuk

High steep banks of finely bedded grey tuff on earlier basalt surround these two lakes, which are collapse craters. Lake Gnotuk is about $1\frac{1}{4}$ miles long and one mile wide, while Lake Bullenmerri is roughly $1\frac{1}{2}$ miles in diameter. The latter is of a curious shape for such a crater, and Hills (1940*b*) has probably rightly suggested that it was formed by the coalescence of three vents.

Most of the tuff from these volcanoes is within half a mile of the crater rim, and fairly evenly distributed around it (like Lake Keilambete), but the original terrain was irregular. The high accumulation of tuff close round these vents, the absence of any signs in the tuff sequence of any intermission in the activity, and also the subsequent collapse, suggest a violent and short-lived vulcanism of the maar type. Between lakes Bullenmerri and Gnotuk there is a low ridge with a channel cut in it, over which the water used to flow in flood time from the higher Lake Bullenmerri to the lower Lake Gnotuk. The aborigines had a name for this (explaining it as due to a Bunyip dragging itself across the ridge, and also for the barely perceptible channel from the north end of Lake Gnotuk to Mt. Emu Creek, whence flood waters ran (Dawson 1881). It is a long time now since enough water accumulated to cause an overflow either from one lake to the other, or from Lake Gnotuk to Mt. Emu Creek, the lower part of which is called Taylor's River in some of the early literature (map opp. p. 39 in Bride 1898).

Order of Eruption

Similar podsol soils have been developed on the grey tuffs at the three volcanoes, which fact suggests that their age is the same or similar.

A section that may be significant is to be seen on the road which rises westwards to the rim from the ridge separating Lakes Bullenmerri and Gnotuk (see text figure 4). The section shows:

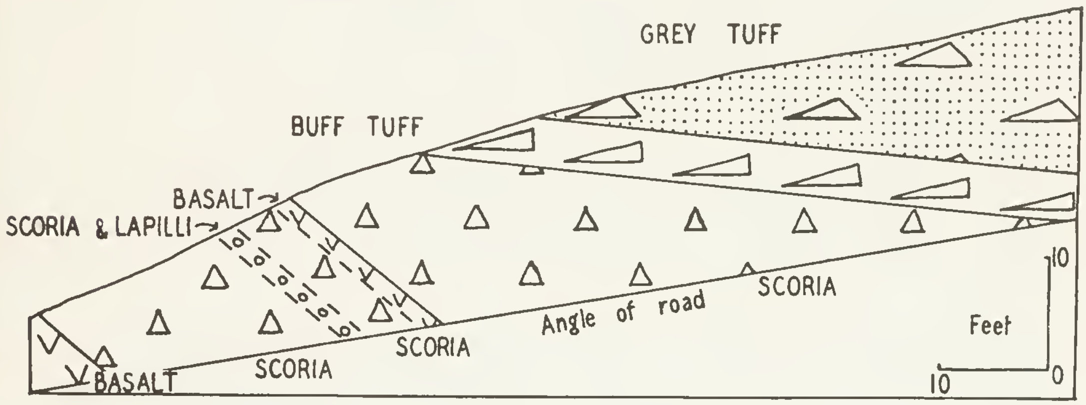

Fig. 4

Section on south side of the road ascending the caldera rim west of the land bridge between Lakes Bullenmerri and Gnotuk.

9. Surface soil (top).
8. About 15 ft. of grey, very finely bedded tuff and lapilli. Strike N. 25° E. and dip 8° W. Similar dip and strike to 7 but not quite the same.
7. 4ft. 6in. yellow to buff tuff. The lower 1 ft. 6 in. is softer and unstratified, while the 3 ft. above is harder and finely stratified. This is finer than the grey tuff above; also it contrasts in having suffered minute displacements. Dip 7° W. Grayson and Mahony (1910, Pl. 4, fig. 2) thought this bed might be a fossil soil.
6. 3 ft. to 15 ft. of reddish scoria occupies an area of change of dip and strike.
5. 1ft. 6in. of solid dark-grey basalt. Dip 25° N.W. and strike about N. 55° E.
4. 4ft. 6in. of reddish scoria merging at the top into scoriaceous basalt, and so to the solid basalt above.
3. 1 ft. 6 in. of reddish scoria and lapilli.
2. About 15 ft. of reddish scoria.
1. Vesicular basalt, six feet only of which is seen in the section. A little further down the hill, the Bullenmerri Calcareous Clay outcrops.

If the yellow tuff is from Mt. Leura (cf. yellow tuff in Excavations 13 and 14), then Leura erupted before Bullenmerri and Gnotuk, whose grey tuff covers the yellow. However, as soil-forming processes had no time to operate on the yellow tuff before it was covered by the later ejectments, any difference in age is negligible.

The information given about the volcanoes shows that probably ash from Gnotuk largely built the tuff bed now to be seen at the south end of Lake Colongulac. Leura ejected very little grey ash to the north, while that from Bullenmerri and Gnotuk was mostly deposited near the vents especially to the east. As Gnotuk is nearest Lake Colongulac, it probably contributed most ash to that area. The tuff is an important stratigraphical marker in the district.

The Colongulac Loess

Along the S.E. shores of Lake Colongulac are the remnants of dunes over 50 feet high, which Grayson and Mahony called "dunes of re-deposited tuff" on Quarter Sheet 8 N.E. Physiographically, these structures are clearly aeolian, although now considerably modified. Bores 2-4 show that in part at least the dunes were piled against and over low basaltic cliffs, perhaps comparable with those still to be seen on the west shores of the lake. Since they were formed, lake waters have cut cliffs in them twenty to thirty feet high, and streams have cut valleys in them. On their surface a black, silty loam has developed. Lithologically, they consist of a non-stratified, yellow, highly calcareous porous, very fine-grained material with a tendency to vertical cleavage. The rock is light yellow when dry and darker when wet. The rock *in situ* is comparatively dry even in wet winters like that of 1951, but if it becomes puddled with water it becomes sticky, due to the clay minerals present. The black soil on top becomes very sticky in winter. Calcareous concretions are common, and are of any size up to about 2½ inches in diameter. The rock is probably best called loess. Twenhofel (1950) says, "Loess has been variously interpreted, and several different types of materials have at times been included under the term. The present general practice is to limit the term to an aeolian deposit composed of particles of clay and silt dimension." Flint (1947, p. 175) writes, "Loess is a buff-coloured non-indurated sedimentary deposit consisting predominantly of particles of silt size. Commonly it is non-stratified, homogeneous, calcareous and porous, and it may possess a weak vertical structure resembling jointing." The Lake Colongulac rock fits these definitions well, and it is proposed that the formation be known as the *Colongulac Loess* (Plate 3, fig. 5).

The mineralogy of the loess was examined by Dr. A. W. Beasley, who reported that the clay fraction is prominent, and the heavy mineral percentage small (computed by eye as of the order of 0·05%). The rock is very fine-grained, and most of the grains are rounded. There is a large percentage of quartz. The heavy fraction is chiefly of basaltic origin, and consists largely of black iron ore; it is fairly well sorted and rounded, which shows that the period of time since it was ejected as tuff was not short. Minerals of granitic origin are also present, including zircon. The mineral grains of the loess contrast with those of the tuff in the roundness of the grains and the presence of non-tuff minerals. The loess contrasts with the underlying Chocolyn Silts in that it possesses a greatly increased percentage of basaltic minerals. This is to be expected in view of the intervening basaltic ash vulcanism. The grain size is also slightly larger.*

The Colongulac Loess was once a much more extensive formation than it is now. The present lake has cut cliffs (Plate 3, fig. 5) into the loess which are 20 ft. to 30 ft. high, and have a slope of 32° to 33°. The cliffs are on the windward side of the dunes, and as this is the side of the low angle of dunes, they must originally have stretched far out into what is now the lake. In the middle of the southern shore of the lake there is a headland which Grayson and Mahony mapped as tuff, but excavations proved to consist of loess. The surface slopes southwards towards the shore, and lake waters once surrounded it. There is a small outcrop of basalt at the south end of the west shore of the headland, so this rock may be connected with the formation of the dune at that place. Loess was proved at a number of points in the cliffs of the headland itself, and then an auger hole (Excavation 16) was put down near the foot of the cliff at its northern extremity; it penetrated 6 ft. 3 in. of loess but was still in that formation although below the level of the base of the cliff. On the northern shore of Lake Colongulac there is also a headland; this consists of about ten feet of basalt surmounted by ten feet of loess (represented in the cliff wash by the yellow loess concretions) and black soil. The foregoing facts indicate that there were two lines of dunes when the loess was built up; the first connected what are now the two headlands, and the second is represented by the eroded dunes of the eastern side of the lake. For these to build up, the lake must have disappeared altogether for a considerable period of time,

*Since this paper was written, Prof. F. E. Zeuner has kindly examined a sample of this rock in his London laboratory, and pointed out its variation from the periglacial type of loess found in Europe. He reports: "Its calcium carbonate is as high as 71%. . . . It contains as much as 38% of clay finer than 0.001 mm. . . . It is essentially a clay (44%) with some silt (38%) and about 18% fine sand. There is a concentration on the sand/silt boundary; as much as 15% of the material being between 0.05 and 0.07 mm." The high percentage of $CaCO_3$ is probably due to broken down *Coxiella* shells.

and the old lake floor desiccated to provide the materials. To become so rounded, fine-grained, and well-sorted, the grains must have blown about for a considerable time.

The disposition of the loess shows that it was blown into dunes by N.W. winds, but the prevailing winds at present are S.W. Through the kind help of Mr. J. C. Foley, B.Sc., and Mr. B. W. Newman, B.Sc., of the Commonwealth Meteorological Bureau, I was able to obtain wind analyses for Camperdown covering the years 1946-1950 inclusive, and from these the wind rose shown in text figure 5 was constructed. The analyses are made from

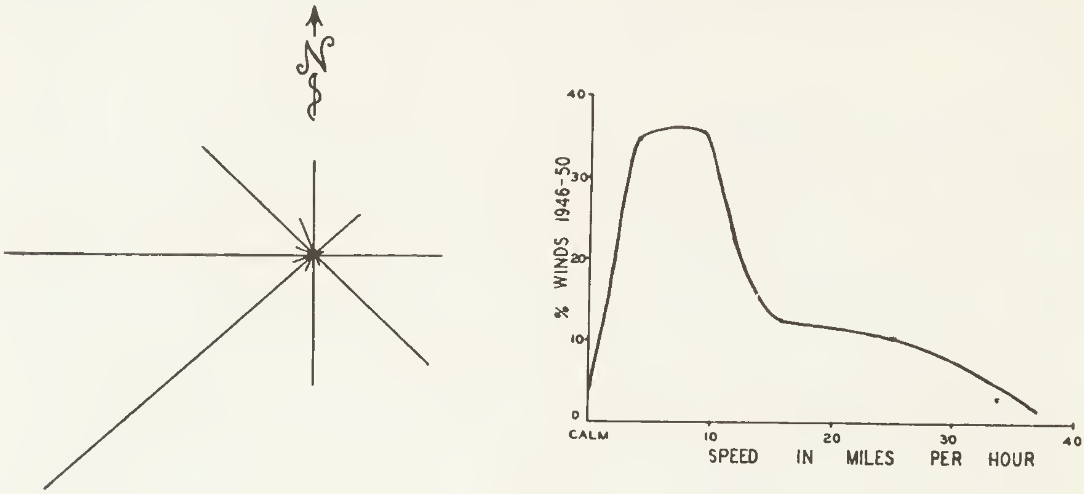

Fig. 5

Wind rose showing directions and relative frequencies of winds at Camperdown during 1946-1950. Graph shows for same period the frequencies of winds of various speeds.

readings taken daily at 9 a.m. from 1946 to 1950; the commonest frequencies were 22·33% S.W., 19·08% W., 9·92% S.E., and 9·75% N.W. From this it is clear that the prevailing winds are S.W., with westerlies next in frequency. The prevailing S.W. winds are well spread over the year. In the driest quarter of the year (January to March), the S.W. winds are twice as frequent as the west winds, and the southerlies are second in frequency. A study of the strengths of the winds shows that 75% were of 12 m.p.h. or less, and that their spread introduces no big variant factor. The west and S.W. winds are a little stronger on the whole than the N.W. winds.

It is therefore clear that the dunes were built when conditions were very different from the present, in that—

1. Lake Colongulac was completely dry for all or practically all the year. In time of drought now when the lake dries up, a little dust accumulates but is washed away by the rain

except in some instances when the farmers take measures to retain it). When the Colongulac Loess was being accumulated, high dunes covered the lake floor.

2. The direction of prevailing winds was dominantly N.W. then, whereas now the prevailing winds are S.W. Of interest is an aboriginal tradition on the origin of the wind which says it came from the N.W. (Bride 1898, pp. 89-90).

Many writers (e.g. Crocker 1941, Browne 1945, Crocker 1946, Crocker and Cotton 1946, Crocker and Wood 1947, Keble 1947) have postulated a mid-Holocene arid period in south-eastern Australia, and this seems to be synchronous with the "Post-glacial Optimum" of other parts of the world (see Zeuner 1945, Brooks 1949, Zeuner 1950, and references). Hough (1950) records evidence from Antarctic bores for the same climatic change. The writer's opinion is that the Colongulac Loess belongs to this period. Beds which are the result of a recent comparatively arid period rest on the eroded 25 ft. emerged marine shell bed on the Moyne River (pp. 74-76), thus linking terrestrial occurrences with a eustatic level and providing a means of extrapolation.

Wishing to make sure that the loess dunes at Lake Colongulac were a function of a general climatic change and not just a local phenomenon, the other occurrences mapped by Grayson and Mahony were examined, as well as the shores of a large number of other lakes including Lake Corangamite, the largest lake in Victoria. Both north and south of Pelican Point over many miles of the eastern shore of Lake Corangamite, similar dunes were observed. For instance, a road cutting on the Dreeite North road, about a mile south of the Cundare turn-off (Colac 4 mls. = 1 in. military map grid reference 637, 295), yellowish loess can be seen resting on stony rises (basalt). Farther north, in a road cutting (Beeac 1 ml. = 1 in. military map grid reference 628,956), similar material is to be seen but full of broken *Coxiella* shells.

The study of the loess dunes involves the question of their relationship, if any, to the lunettes so named by Hills (1940*a*), who considered these ridges to be formed by precipitation of atmospheric dust by spray from the lakes. This implies a period more pluvial than the present, a time when the basins (on the east sides of which these crescentic ridges stand) were filled with water. When discussing these structures, Hills (1939*b*, p. 31 2) referred to the dunes at Lake Colongulac and Lake Kariah. Stephens and Crocker (1946) described lunettes from Tasmania, Victoria, New South Wales, South Australia, and Western Australia, but considered them to be purely aeolian structures built in a period more arid than the present. This interpretation had previously been put forward with some hesitation by Harris (1938). In U.S.A. similar loam ridges have long been known as "clay dunes", and recently Huffman and Price (1949) have described in more detail the process by which they are being built now in Texas. Granules of clayey material are stripped from the edges of mud-crack polygons and piled into transverse ridges; subsequent wetting causes the clay to consolidate and so establish the dune. These dunes are thus a result of comparatively arid conditions. The Texas clay dunes have both sides with about equal degree of slope (20:1 windward and 25:1 leeward in the example given), which may well be due to flowage when the clay granules are wet by rain and so distributed on the dune surface. In the lunettes described by Hills and by Stephens and Crocker, the windward side is often comparatively steep and the leeward side comparatively flat—the opposite of what is normal in purely aeolian dunes, and different from what is to be seen in the American "clay dunes". It is possible that there is some analogy here with the Lake Colongulac dunes. The lunettes may have been built up in an arid period, then the windward sides steepened by lacustrine erosion when the basins filled with water in a succeeding pluvial period. It appears to the writer that the N.W. Victorian lunettes and the Lake Colongulac loess dunes are genetically related, and were built during the same arid period, but differ on account of the differing materials and environment in the two areas. The Lake Colongulac dunes are not lunettes in that they lack the characteristic crescentic shape, but lunettes do occur in the area, e.g. on S.E. sides of small shallow lakes (called salt pans on the 1 in. = 1 ml. military map) about 3 miles E.S.E. of Mortlake (see N.W. corner, Quarter Sheet 8 N.E.). When away from tuff beds as these lakes are, the dunes are more clayey.

Upper Holocene Pluvial Period

On the east side of Lake Colongulac are two creeks, one just north of the "Chocolyn" homestead and called Chocolyn Creek on the map (text figure 1), and another half a mile farther N.E. called Windmill Creek on the map. In these creeks there is a high level alluvium up to about ten feet above H.W.M., which for convenience is hereafter referred to as the ten-foot terrace. Much of the terrace at the mouth of Windmill Creek is only seven feet about H.W.M., but has suffered more erosion than Chocolyn Creek which is restricted at its mouth. An attempt was made to benefit from this by building a dam there, but the next flood washed it away. The ten-foot terrace has been incised since the lake level fell (Pl. 3, fig. 6). In addition to the high-level alluvium in the creeks, a platform found variously in silt, tuff and basalt is to be seen in a number of places round the lake shore. For example, near Excavation 4 on the south side of the lake there is a well-defined terrace at 9·1 ft. (average of three readings) above H.W.M. On the east side of Lake Kariah there is a similar terrace at 9 ft. above H.W.M. Detailed work has not been done on these terraces, but there is ample evidence to show that since the loess dunes were built, there has been a maintained level of the lake approximately 10 ft. higher than the highest level in living memory. Since the earliest historical record in 1843 there has always been a "beach" consisting of part of the former lake floor (see Adeney in Owen 1877, pp. 184-185). A rise of 10 ft. in the level of a shallow consequent lake is a lot, especially as it would cause the lake to spread over a greater area.

One can only conclude that since the arid period there has been a time of greater rainfall than the present. High level terraces cut in loess are found round other Western District lakes, and are well marked on the east side of Lake Corangamite, the largest lake of all. Alluvium representing former (often anastomosing) lakes and swamps are shown on the map (text figure 1). The thick bed of black clay overlying a limestone band in the Moyne River section (pp. 74-76) is no doubt largely an expression of the same phase. In many places in the Western District there are peat deposits (no longer forming to any appreciable degree) resting on clays (e.g. Errey 1896, Gill 1947*b*). The present climatic trend appears to be toward the arid rather than the pluvial side.

If the Colongulac Loess is mid-Holocene as argued above, then the soil developed thereupon, and the alluvia developed since that time are Upper Holocene. The Hampden Tuff belongs to a period before the lake water began to dry up, and indeed to a time when the lake was maintained at about 10 ft. above H.W.M. As the lake was deeper and more extensive then, the period must have been even more pluvious than during the Upper Holocene 10 ft. level. Although the vulcanism itself may have been short-lived, a considerable period of time is involved in the lithification of the volcanic ash, and then the erosion of the resultant tuff so as to present cliffs along the southern shore of the lake. Since the loess dunes were built, the tuff has been eroded back something like a chain. It is not unreasonable to suggest that it would take as long or longer for the tuff to be eroded to where it was when the loess dunes were built. If this be correct, then the vulcanism occurred about the dawn of the Holocene or the close of the Pleistocene, when the effects of the last glacial period were disappearing. The rounded nature of the grains of tuff materials in the

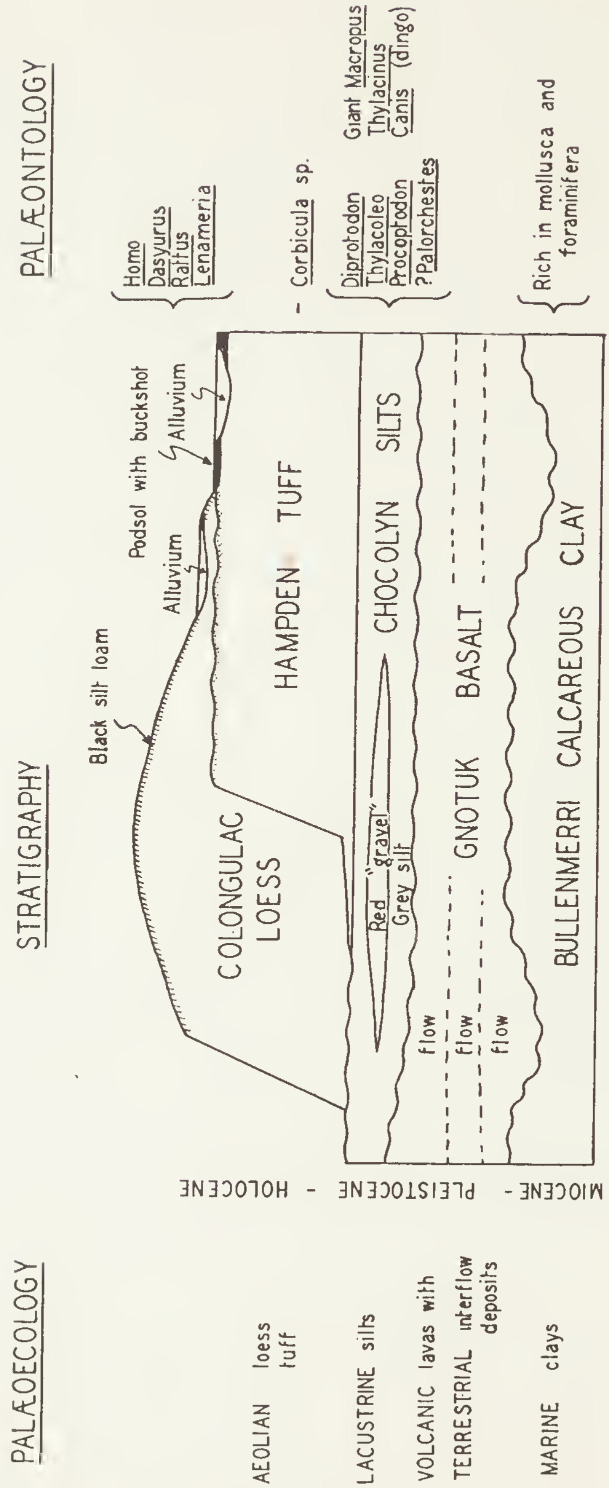

FIG. 6

Diagram of the geology of the Lake Colongulac area.

Colongulac Loess also indicate the lapse of a considerable span of time between the vulcanism and the building of the dunes. The Chocolyn Silts were deposited prior to that, and the bones in them suffered a couple of cycles of erosion and deposition. It is therefore considered that the animals of which they are the remains lived during late Pleistocene time. The geology of Lake Colongulac is diagrammatically presented in text figure 6.

Evidence of Pleistocene Aboriginal Occupation

Associated with the late Pleistocene extinct marsupial fauna at Lake Colongulac, there has been found evidence of human occupation in the form of (a) a dingo jaw, and (b) a cut bone. Both have the characteristic preservation of bones from that horizon, and (as shown earlier in the paper) there is no other bed from which they could have come.

(*a*) *Dingo jaw.* This fossil was described originally by McCoy (1882). Wood Jones (1921) and others (cf. Brazenor 1950, p. 83) have made it clear that the only way the dingo could have reached Australia was by being ferried here by the aborigines. The Tasmanian aborigines had no dingo, but readily took to the dogs introduced by white people. Also the dingo has not been found fossil in Tasmania. We therefore can say the mainland aborigines brought the dingo. If the Tasmanian aborigines passed over the Australian mainland, then the dingo was brought to this continent later than the passage through it of the Tasmanians. Dawson (1881, p. 89) has told how the aborigines of Western Victoria prized their dingoes and used them in hunting. Boldrewood (1896, pp. 40, 122) and Dawson have referred to the many wild dingoes that existed in the area when white people first came.

As the presence of dingo in a geological horizon in Australia means the presence of the aborigine at that time, it can be used as a means of determining the antiquity of the aborigines. It is therefore of interest to note where the dingo has been found fossil. It was found in the Wellington Caves, N.S.W. (Mahony 1943, p. 24) when shafts were sunk in the bone-breccia whence came *Diprotodon, Nototherium* and *Thylacoleo.* Mahony (1943, pp. 25-26) has reviewed the discussion concerning an alleged human tooth from there, and since then Finlayson (1949) has amassed evidence for the rejection of its supposed human origin. Owen and many writers since have expressed regret that no human remains have been found with the extinct marsupials at Wellington Caves, but if the presence of dingo means the presence of aborigines in the land at the same time, then the desired evidence is there after all. Association of man with the extinct giant marsupial fauna is recorded from Pejark Marsh, Victoria (Keble 1947), Forbes, N.S.W. (Andrews 1910, Mahony 1943), and Lake Menindie, N.S.W. (Movius 1940), as well as at the Wellington Caves and Lake Colongulac as described above. Fossil dingoes have also been found in the Murray River valley (Hale and Tindale 1930), and in the Tantanoola Caves, S.A. (Tindale 1934). In the National Museum of Victoria are dingo bones from the following Victorian localities—Gisborne, Bairnsdale, Meredith, Colac, and Bushfield (p. 72). *Canis familiaris dingo* has stratigraphical value as a fossil, being indicative of Upper Pleistocene or Holocene age.

(b) *A cut bone,* known as the *Colongulac Bone,* has been described by Spencer and Walcott (1911), Keble (1947), and the writer (Gill 1951*b*). It consists of the fourth metatarsal of a giant kangaroo (*?Palorchestes*), whose matrix and preservation show that it came from the Chocolyn Silts, whence came the dingo jaw and the bones of the extinct marsupials. Spencer and Walcott first thought the Colongulac Bone was human workmanship, but finally (although with some misgiving) included it among bones which they claimed had been chewed by *Thylacoleo,* the so-called marsupial lion. The cuts comprise two wedge-shaped incisions which meet on the side of the bone, and appear to be an attempt to remove the head. The bone is not crushed, but pieces removed; it has therefore not been chopped but cut. Removal of bone without crushing, and the forming of two precisely confluent cuts (the bottoms of which make an angle of 72°) is impossible for an animal. In any case, it is widely held now that *Thylacoleo* was not a carnivore, and no reason suggests itself why an animal should attempt to remove the head of a metatarsal. On the other hand, an aboriginal might attempt to do so as a stage in the manufacure of an implement or ornament. Mr. H. V. V. Noone examined the bone and drew attention to some fine ridges on the sides of the cuts, and to undercutting on the side of one incision. He pointed out that neither of these features is consistent with chewing by *Thylacoleo,* but both are consistent with work by an aboriginal tool. They suggest a sawing motion and not a squeezing one as when an animal bites. The Colongulac Bone was collected by William Adeney, the first white settler at the lake where it was found, and the cuts were made before the bone was mineralized. If not made by an animal (which hypothesis is rejected), the cuts must have been made by an aborigine (see also Gill 1952).

(c) *Ecology.* There are certain aspects of the occurrence of the bones at Lake Colongulac that call for explanation. Firstly, the bones are much broken. Jaws are plentiful, but no complete skulls. A mutilated skull of *Thylacoleo* (the type) is the only skull known from the lake. Most of the fragments are pieces of limb bones, no whole ones have been seen. If we exclude *Thylacoleo* (for which there is good reason), there is no predator or scavenger of the times, no carnivore, which could chew these bones and so fragment them. As the adjacent countryside is so very flat, and the bones have not been transported far, the fragmentation cannot be attributed to fracture in transport. Another possibility is that other animals trampled on them and so broke them. This is likely to happen if the bones are at a watering hole on a creek or similar site, but they do not occur in such a situation. The animals would not drink from the lake, as it was salty then, as shown by the presence of fossil *Coxiella*. Any breaks made in the bones in extracting them from their matrix, or since, are readily recognizable, and cannot be confused with breaks that occurred before mineralization. With this and related problems in mind, hundreds of bones and fragments of bones were collected from sub-recent middens at Tower Hill beach, between Warrnambool and Port Fairy (Gill 1951*a*). It was noted that no complete skulls and rarely any whole limb bones were found, although pieces of such were common. Dawson (1881, p. 18), in his account of the aborigines of Western Victoria, says, "Skulls and bones are split up, and the brains and marrow roasted".

Secondly, the bones are very localized in occurrence. Those from Excavation 2 came from an area not exceeding a chain in diameter. In a letter to Owen, Adeney described how the bones were numerous and scattered thickly over the beach near where he lived. In both cases, the sites are near creeks of that time, but not on them. The original sites of the bones were probably on the basalt cliffs or rises beside the lake, and the red gravel in which some of the bones occur suggests silts impregnated with iron oxide from the weathering of the basalt. Such sites are what one would expect aboriginals to choose for camps, being near water and yet affording a good lookout.

In the author's opinion, there is insufficient evidence to prove what the original ecology of these bones was, but they could have been part of a midden site. Such an interpretation fits the presence of dingo and cut bone. If the site is a midden, it means that the aborigines used *Diprotodon, Procoptodon, Thylacoleo,* etc., for food. In the Pleistocene there were both large and small marsupials, as fossiliferous beds show, but it is noteworthy that at Lake Colongulac only the giant forms are present in the Chocolyn Silts. This indicates some kind of selection. If the bones are the remains of a midden, it shows that the aborigines hunted the big heavy marsupials in preference to the smaller forms. The giant species would be easier to catch because less agile and each success in the hunt would yield a much bigger volume of food. With the passing of the giant marsupials, the aborigines would have to adapt themselves to changes in food-fauna as well as to climatic changes.

Evidence of Mid-Holocene Aboriginal Occupation

The greater part of the skeleton of an aborigine was found in the Mid-Holocene ancient dune formation called the Colongulac Loess. The site has been mapped (Gill 1951*b*); it is on the east side of Lake Colongulac between Excavation 2 and Chocolyn Creek. It is suggested that the skeleton be known as the *Colongulac Skeleton*. Professor S. Sunderland and Dr. L. J. Ray, of the Department of Anatomy, University of Melbourne, have kindly examined the bones, and report as follows:

Sex. Female.

Age. No epiphysial remains can be seen in any of the long bones. The skull is not present, but three teeth are included and these show a high degree of attrition, so it must be concluded that the skeleton is that of an adult of at least middle age.

General. The general condition of those bones present is good, although most of them show various degrees of damage.

A full list of the bones is provided in Appendix I to this paper, and it will be noted that they comprise the limb bones except for a humerus, the pelvic girdle but no pectoral girdle, only six vertebrae, some rib fragments, and three teeth but no skull. The bones are yellowish in colour, like the containing loess, and appear to be slightly leached.

The Colongulac Skeleton was found in the side of the cliff (32° slope) cut by a former high lake level. The cliff is about 25 ft. high, and the skeleton was dug out half-way up the cliff. When the Colongulac Loess was being searched for fossils, the only success was at the place where the skeleton was ultimately found. The jaw of a native cat, *Dasyurus viverrinus,* an incisor tooth and bone of a rat, and two phalanges were discovered. The Mammalogist at the National Museum of Victoria, Mr. C. W. Brazenor, identified the phalanges as human. By the time of the next visit to the locality, erosion had brought to view the ends of a couple of bones, and careful excavation was made, the bones enumerated in the appendix being discovered. They were photographed *in situ* before removal, as shown in Plate 4, fig. 7. The position of the bones is reminiscent of a flexed burial, but on the other hand most of the light bones had been scattered or had disappeared altogether, and the skull, pectoral girdle, and one humerus are missing. The skeleton could not be a recent burial from the top of the one-time dune, because it is too deep, and it is not easy material to excavate, like sand is. Nor was a burial effected into the side of the cliff, because if this were done, the black clayey soil washed from the top over the surface of the cliff could not but be mixed with the underlying yellow loess, whereas the bones were in a homogeneous matrix, as can be seen in the photograph. Probably the skeleton was buried originally when the dune was about half built, but the blowing of the dune material by the wind has uncovered the skeleton, scattering the lighter bones, and perhaps the missing skull, pectoral girdle, and humerus were decomposed by exposure at that time, only a few teeth remaining. Whether that was the fate of those bones or not is necessarily conjecture, but the attitude of the preserved bones suggests a flexed burial uncovered and then re-buried in a disturbed condition, such as we see taking place with bones on coastal dunes in our own time. The antiquity of the Colongulac Skeleton is the age of the loess formation in which it occurs. In other words, it is mid-Holocene, something like 5,000 years old.

Other Evidences of Aboriginal Occupation

In an earlier paper (Gill 1951*b*), some artefacts from Lake Colongulac were recorded, and since then another semi-circular quartzite artefact was found on the east side of the loess headland on the south shore of the lake. It was accompanied by numerous sharp-edged milky quartz flakes, obviously imported and not occurring naturally. Similar flakes, and a rough basalt axe which had also been used as a grindstone, were found by the writer on the ridge on which the "Carinya" homestead stands on the Mortlake Road north of Lake Gnotuk. Mr. Woodmason, who has a property on the south side of the lake on the Hampden Tuff, reports ploughing up an aboriginal skull near the lake. Mr. P. Law Smith kindly donated to the Museum a basalt boulder with two mill-holes in it, and one grinder, found on the "Chocolyn" estate. In the surrounding district numerous ground-edge axes have been found in the soil, and Casey (1936) has recorded an unusual type of implement dug up at Tallindert near Camperdown. Aborigines were living in the area when white people came (Dawson 1881, Kenyon 1930).

Thus there is evidence at Lake Colongulac of aboriginal occupation in the pluvial period prior to the ejection of the Hampden Tuff (Late Pleistocene), and in the succeeding Arid Period (Mid-Holocene), and since then up to the time of arrival of Europeans.

There is no reason to doubt that the aborigines lived more or less continuously in the district throughout the time represented.

2. Pejark Marsh

The general geology of this area has been mapped by Grayson and Mahony (1910), while Spencer and Walcott (1911, and as recorded in Keble 1947) provide an account of the finding of an aboriginal millstone under the tuff. Mahony *et al.* (1936) expressed some doubt on the matter (see also Mahony 1943), but Keble (1947) made an excavation which put the succession beyond all doubt. The millstone came from below bones of *Diprotodon optatum,* proving that the aborigines were there in the time of the giant marsupials. The site is in section XVI (1), Parish of Terang, and the geological section is as shown in text figure 7. The various formations, in order from the surface, will now be commented upon.

Alluvium and Tuff

About a quarter of a mile N.E. of the site, a spade hole was dug for three feet into the superficial alluvium, and it was found to be rich in the shells of the freshwater snail *Lenameria tenuistriata* (Sowerby). The Terang Tuff which underlies this alluvium can be traced continuously from Lake Terang, which is a crater lake, to Pejark Marsh, and it undoubtedly came from that volcano. Bonwick (1858, p. 35) gives the following well-log from the Terang township:

Black soil	3 feet
Ash-stone (= tuff)	5 feet
Clay	2 feet
Sandy clay	5 feet
	15 feet

Walcott (1919) discussed whether the tuff has been re-deposited or not. The purity of the tuff, its fine regular stratification, and the manner in which it flattened swamp reeds indicates that the tuff is largely where it fell. If it were re-deposited at any considerable interval of time after the eruption, it would be mixed with other sediments.

High in the tuff at the S.E. corner of Pejark Marsh (Excavation 17), a few specimens of *Coxiella* were found, and this suggests that the water into which the tuff fell was brackish, contrasting with the freshness of the present marsh. The fairly long history

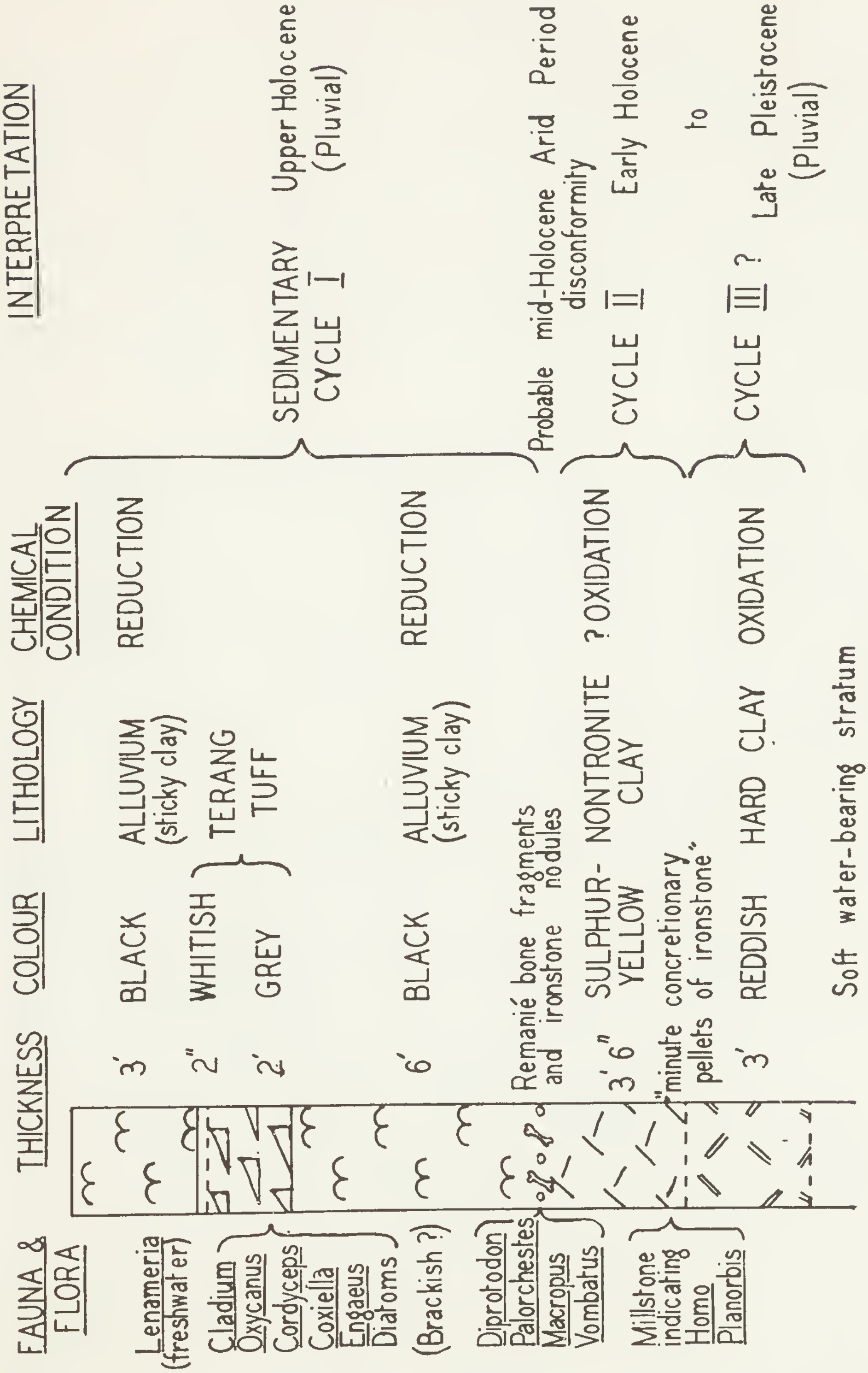

Fig. 7

Summary of the geology of the Pejark Marsh site, and its interpretation.

of the swamp makes it quite possible that the waters were brackish, and Mr. J. H. Willis of the National Herbarium tells me that this is not inconsistent, on present knowledge, with the occurrence of *Cladium tetragonum* which is recorded from the base of the tuff, although little is really known of the ecology of this plant. Chapman (in Spencer and Walcott 1911, p. 4) recorded 'freshwater diatoms' from this tuff, but most diatoms have a broad range of tolerance. Moreover, the range of salinity of which *Coxiella* is tolerant is not known, but the form is recorded from Boneo Swamp (Chapman 1919), and the writer has collected it from Lake Bullenmerri which is only mildly saline (relative salinity, sea 100, Bullenmerri 18·4—Anderson 1941, p. 149). Skeats and James (1937) reported *Coxiella* in tuff at Lake Corangamite.

Lake Keilambete, 2½ miles N.W. from the site, is a maar-like caldera, the ejected material being comparable in volume with the size of the crater. The nearby Lake Terang is a similar feature but more complex. The high ground on the S.W. side of the lake consists of poorly-bedded yellow tuff with abundant lapilli, judging by the cemetery excavations and spoil heaps of rabbit burrows.

Walcott (1919) says a well near the cemetery passed through eighty feet of tuff. Further east on the south side of the lake, the ground quickly loses elevation but the slopes become steeper; this is due to the rocks there being volcanic agglomerate consisting of coarse lapilli, scoria, and basalt. The so-called Mt. Terang, a low hill on the N.W. side of the lake, is the only other comparatively high pile of volcanic material. On the west side of it is a crater, and on the N.E. side a quarry reveals finely bedded grey tuff and lapilli dipping up to 9° N.E., overlain by a few thin flows of basalt. The direction of the dip shows that the tuff came from the nearby crater, and not the Lake Terang caldera. Grey tuff can also be seen in the north bank of the lake, next the Scout Hall, and it is this rock which is found at the Pejark Marsh site a little under a mile away (see text figure 8). The detailed history of the eruption has not been worked out because not important for the present purpose. However, enough was done to show that the eruption was a short and rather violent one, ejecting a comparatively small quantity of volcanic material, and culminating in the subsidence of an area half a mile by over three-quarters of a mile. The Terang Tuff occurs over the southern end of Pejark Marsh, as the following spade and auger holes (see text figure 8 for locations) show, but how far north it extends has not been ascertained.

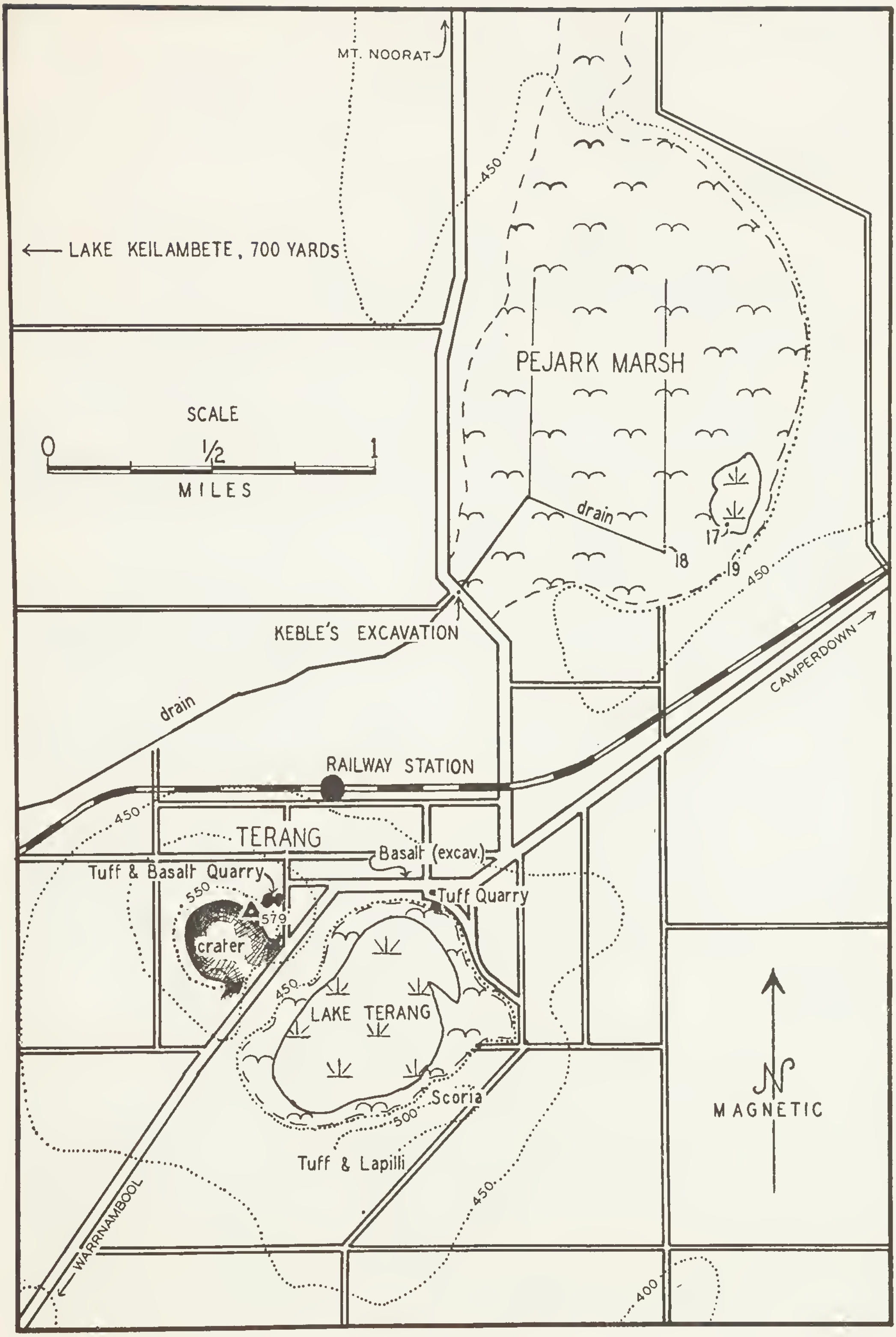

Fig. 8

Map showing the location and relationships of the Pejark Marsh site. The figures 17, 18 and 19 refer to excavation sites mentioned in the text.

Excavation 17. Lowest part of S.E. corner of Pejark Marsh.

6 in. black peaty loam
6 in. dark grey to black silty clay with *Lenameria*
Brownish tuff with *Coxiella* (not penetrated)

Excavation 18. South end of Pejark Marsh near corner of main drain.

1 ft. 0 in. black loam
$\frac{1}{2}$ in. calcareous concretionary layer
1 ft. 3 in. grey tuffaceous alluvium
3 ft. 0 in. fairly pure, brownish-grey tuff with occasional cross-bedding; fossil reeds
3 ft. 0 in. bluish-black alluvium (not penetrated)

The calcareous layer is a secondary deposition and hard enough to be used by the owner of the property as paving stones for garden paths. Fossil reeds were found in the basal layers of the tuff, like those reported by Spencer and Walcott (1911) and Keble (1947) in their excavations further west.

Age of Terang Tuff

Search was made for evidence of the age of the vulcanism that yielded the tuff at Pejark Marsh, and the following observations were made:

1. A skull of *Dasyurus viverrinus,* the extant native cat, preserved in tuff, was found in the National Museum, having been discovered in a cutting made for the bowling green in the Public Park beside Lake Terang.

2. The soil on Mt. Terang is thin and rocky, an immature dark-brown loam contrasting with the mature soil on the tuff at Camperdown. It has no buckshot gravel like the Camperdown podsol. Soils on basalt and on tuff in the township have been observed and they are likewise immature, with a negligible amount of ironstone nodules. No soil pipes have been seen in any of the profiles.

3. Both Lake Terang and Pejark Marsh are fresh, and contrast with the very salt Lake Colongulac. It has long been recognized that the accumulation of salt in a lake is a function of time. Formerly, the explanation has generally been that salts were derived by solution from the country rock, then concentrated in lakes by evaporation. Anderson (1941, 1945) has now shown, however, that the earlier explanation is inadequate, the waters deriving most of their saltness from "cyclic salt", i.e. salt in water swept up by winds racing over the whipped-up surface of stormy seas, then deposited in rain. Woodcock (1950) has measured the amount of salt in the air at a shoreline location.

The lakes of the Western District vary from fresh to saltier than the sea. Lake Terang, although a crater lake, has never been deep. Bonwick (1858, p. 34) claimed that "it has an average depth of forty feet, without an outlet. The variation of level does not exceed three feet." Walcott (1919) records, "It is said that when the early settlers came to Terang there were thirty feet or more of water in Lake Terang, and that it even flowed out through the gap in the S.W. side." "The greatest depth of water (in 1909) was said to be three feet." Grayson and Mahony (1910) said the lake was then already partly swamp. The Australian Handbook for 1897 (p. 294) says, "Lake Terang teems with fish". It is now dry in summer and a swamp in winter. A few years ago, during a drought, the peat on its floor caught fire and burned for about a year. Lake Terang has always been fresh, and this is interpreted as evidence of the lake being so recent that it has collected no appreciable amount of cyclic salt. The same applies to Pejark Marsh.

4. In discussing the Colongulac Loess, mention was made of the fact that the majority of shallow lakes and the swamps have windblown silts or clays on their S.E. borders—a result, it is believed, of the mid-Holocene arid period. Lake Terang and Pejark Marsh are exceptional in that they have no such aeolian structures. This fact is taken to mean that the volcano and the post-tuff form of the Marsh came into existence after the arid period. Set within the steep banks of the S.E. corner of the Marsh is higher ground which could be windblown material covered by tuff. An auger hole on this elevated ground passed through three feet of dark-brown soil and one foot of partly decomposed tuff before being stopped by solid tuff (Excavation 19).

It is to be concluded from the foregoing evidence that the Lake Terang volcano erupted comparatively recently, and in age is to be compared with Tower Hill rather than with the crater lakes Bullenmerri and Gnotuk near Camperdown. Such an age determination fits in well with the rest of the evidence.

Alluvium under Tuff

The nature of the alluvium under the tuff in Excavation 18 indicates that the conditions of deposition were the same or similar to those yielding the alluvium above the tuff. The volcanic eruption interrupted the slow deposition of the swamp alluvium which at present (and even more so in the near past) is the expression of comparatively pluvial conditions. In that the thickness of the alluvium over the tuff is half that under the tuff, it may be inferred in the circumstances that the period of deposition is roughly of the order of half that of the lower bed. The alluvium under the tuff shows that the swamp is older than the vulcanism, and not caused by it blocking the local drainage. The alluvium under the tuff and that over it belong to the one sedimentary cycle.

From the bottom of this black clay bed under the tuff Keble obtained bones including teeth of *Diprotodon optatum*. Similarly, Spencer and Walcott record that "Just at the junction of the two clays the majority of bones occurred" (1911, p. 93). No better assurance could be desired that the bones were *in situ* than that they were discovered under the finely-stratified tuff. This rock is so hard as to be difficult to disturb, and when it has been disturbed, the fact is obvious. The fauna so far determined is:

Diprotodon optatum Owen
Palorchestes cf. *azael* Owen
Macropus cf. *titan* Owen
Vombatus sp.

Most of the bones are fragments which Spencer and Walcott at first thought had been fragmented by aborigines, but later decided were the work of *Thylacoleo carnifex*. However, *Thylacoleo* was almost certainly not a carnivore. The bones were broken before mineralization. The country is so flat that even in flood time there could hardly be forces sufficient to fragment the bones to this extent. The possibilities remaining are fracture by the feet of other wild animals and/or by the aborigines.

Probable Disconformity

Although there is no marked break between the black clay and the underlying yellow clay, the cumulative effect of the following evidence strongly suggests that there is a disconformity at that level.

(a) *Condition of the bones.* The black clay is "highly carbonaceous", and as one would expect in a swamp, in a state of chemical reduction. On the other hand the bones are red and highly mineralized. Bones in swamp deposits as at Bushfield are black due to chemical reduction, so the bones at Pejark Marsh could not have reached their present condition in that setting. Both the bones collected by Spencer and Walcott and those collected by Keble are red, highly mineralized, and very polished. As the bones occur at the junction of the two clays, it may be inferred that the bones were mineralized in oxidizing conditions (the red being taken to be iron oxide) at a time when the swamp was dry, i.e. it was not a swamp at all. As shown by the geological history of some other fossil bones, and by that of buckshot gravel, such iron oxide is remarkably stable.

(b) *Aggregation of bones.* Keble found bones only at the base of the black clay, and Spencer and Walcott said nearly all theirs came from the junction of the two clays. If the silt (or whatever the material was) in which the bones were mineralized were blown away, then when swamp conditions came, bringing about the deposition of the black clay, the bones would be aggregated at the base of the new bed.

(c) *Presence of ironstone nodules.* Keble shows a layer of ironstone nodules at the junction of the black and yellow clays, and this is probably a residuum (buckshot) from a soil dispersed before the black clay was deposited. The mid-Holocene arid period could have dried up the lake or swamp, and dispersed the soil, concentrating both bones and ironstone gravel.

(d) *Presence of fossil roots.* "In the upper part of the yellow clay are also seen fine black fibrous impressions left by rootlets sent down by plants" (Spencer and Walcott 1911).

(e) *Lithological Change.* With the fossils from Pejark Marsh at the National Museum there was found a piece of the yellow clay which underlies the sub-tuff black alluvium. It was noted that the clay was not the common limonite-yellow but a decided sulphur-yellow. The clay did not effervesce in HCl; it turned brownish-red on ignition (but without smell of sulphur), and gave a negative silver-coin test. A sample was submitted to Mr. A. J. Gaskin, M.Sc., of the University of Melbourne, who determined the yellow material as the bentonite mineral *nontronite* which is greenish in colour but oxidizes yellow very readily. Nontronite develops under stagnant water reducing conditions, and is derived probably from the contiguous earlier plains basalt. All who observed the clay *in situ* (including experienced field geologists) referred to it as a yellow and not greenish clay; this suggests that the clay had already been oxidized. It would be in keeping with the rest of the evidence to think of the nontronite clay as having been deposited in a swamp under reducing conditions, then oxidized when the swamp dried up in the arid period. Part of a *Planorbis* was found in this clay, indicating a freshwater environment (slide P15656).

Underneath the yellow clay is a hard red clay which may belong to a third and yet older cycle of sedimentation. Spencer and Walcott mention "minute concretionary pellets of limonite", which suggests buckshot formation.

Age of Aboriginal Occupation

The evidence for occupation is a millstone found in the yellow nontronite clay. If the interpretation given above be correct, then the fragmental remanié bones of extinct giant marsupials were aggregated from an earlier bed on the top of the yellow clay during the mid-Holocene arid period. That earlier bed may well have been an eroded part of the yellow clay, because Merry records (in Keble 1947, p. 47) numerous bones therefrom. In any case the aborigines were in the Terang area at the time of the existence there of the giant extinct marsupial fauna. The yellow clay would be laid down in a lake or swamp under reducing conditions, and this ecology indicates the early Holocene or late Pleistocene when the country was emerging from the last glacial period. It seems that most of our present swamps were built up during the recent pluvial period, while the earlier swamps were built up during the pre-arid pluvial period, represented by the Chocolyn Silts at Lake Colongulac.

Many surface evidences of recent aboriginal occupation have been reported in the area. Local residents have dug up aboriginal stone axes on the higher ground just north of the Pejark Marsh site. Further north at Glenormiston a skeleton has been found (Gill and Manning 1950). Bonwick (1858) and Dawson (1891) have given accounts of the aborigines present when Europeans arrived.

3. Bushfield

Keble (1947, pp. 56-58) recorded a basaltic axe found in tuffaceous limestone under tuff in a terrace of the Merri River, near Bushfield, north of Warrnambool, Western Victoria (see text figure 9). With the aboriginal axe were found bones of *Macropus* and *Vombatus* which are mineralized, dense black, and with shiny surface, which are no doubt due to preservation in conditions of chemical reduction.

The tuff is from the Tower Hill volcano. In this area, about eight miles from the vent, the falls of ash were comparatively small, and so little tuff is found on the high ground, most of what fell there being washed into the steeply incised river course. The ash appears to have blocked the river somewhat, resulting in strong cross-bedding of the tuff. It would appear that interference with the flow of the river caused local swampy or lake conditions to prevail, so that a good deal of calcareous matter (including the snail shells *Lenameria acutispira* and *Lymnaea brazieri*) accumulated with the tuff. However, the volcanic ash soon fell so frequently that beds of pure ash covered the more calcareous lower layers. The site was investigated by the writer, and a section (text figure 10) surveyed across the river and through the place where the excavation was made. The river

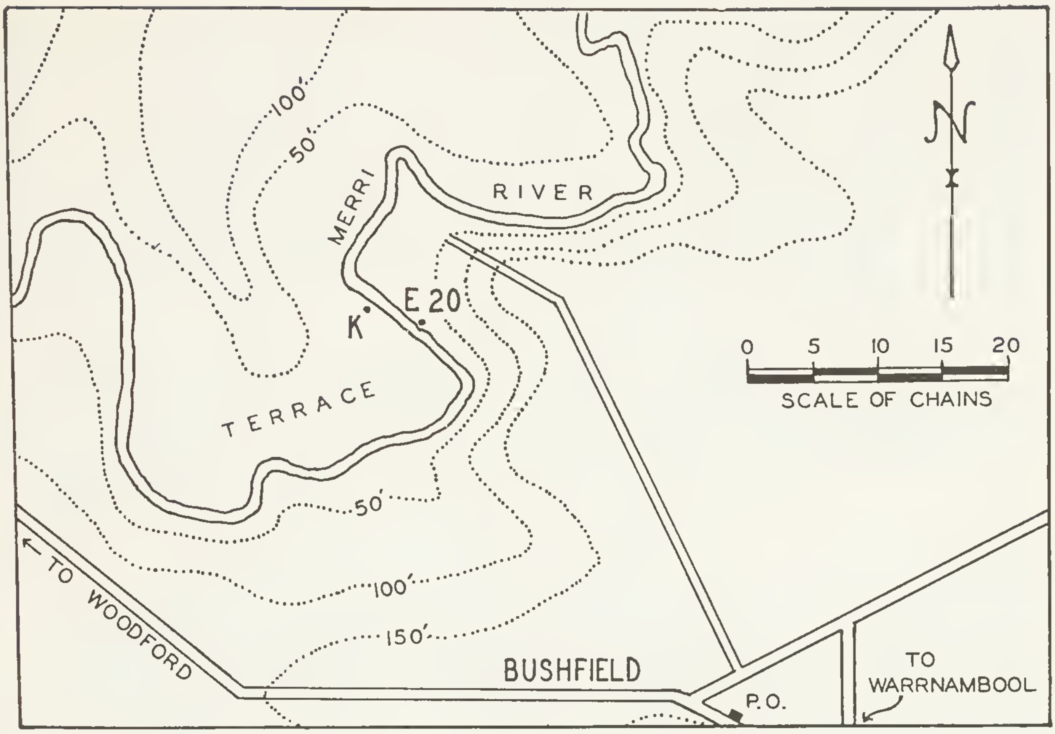

FIG. 9

Map showing the location of the Bushfield site. E 20 is the excavation shown also in Fig. 11.

sections of tuff were searched for the calcareous layer with the fossil snails, but without success; it was covered, or the horizon is a lenticle cutting out so as not to appear in the river section. Nor could any bones be found in the tuff. However, four and a half chains downstream from the excavation there is a platform on the left bank were the sub-tuff light-grey clay outcrops, held together by the roots of old trees, as shown in text-figure 11. A spade hole (Excavation 20) proved the clay for four feet beneath

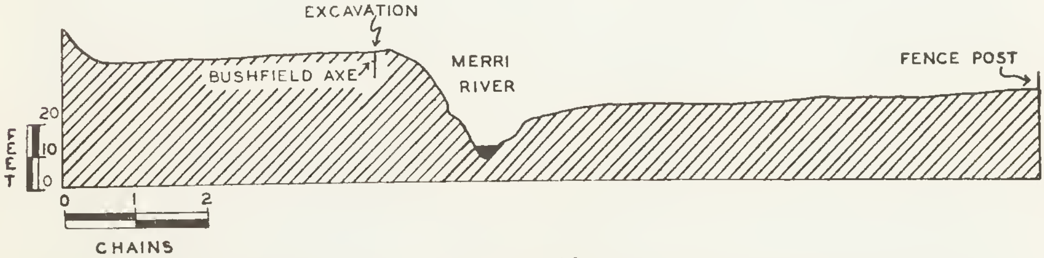

FIG. 10

River terraces, Bushfield site. Surveyed section from the end of the nearby road (see Fig. 9) through the excavation from which came the Bushfield axe.

the tuff. Scour hollows in this platform have been filled by the river with quartz gravel and re-deposited clay, and the sediments were found to contain numerous bones in exactly the same condition as those accompanying the axe, i.e. mineralized, black, and shiny. The walls of the valley consist of Miocene marine limestone capped with basalt, so the bones can only come from the tuff or under it. The fauna comprises living animals only, and the National Museum Mammalogist, Mr. C. W. Brazenor, kindly

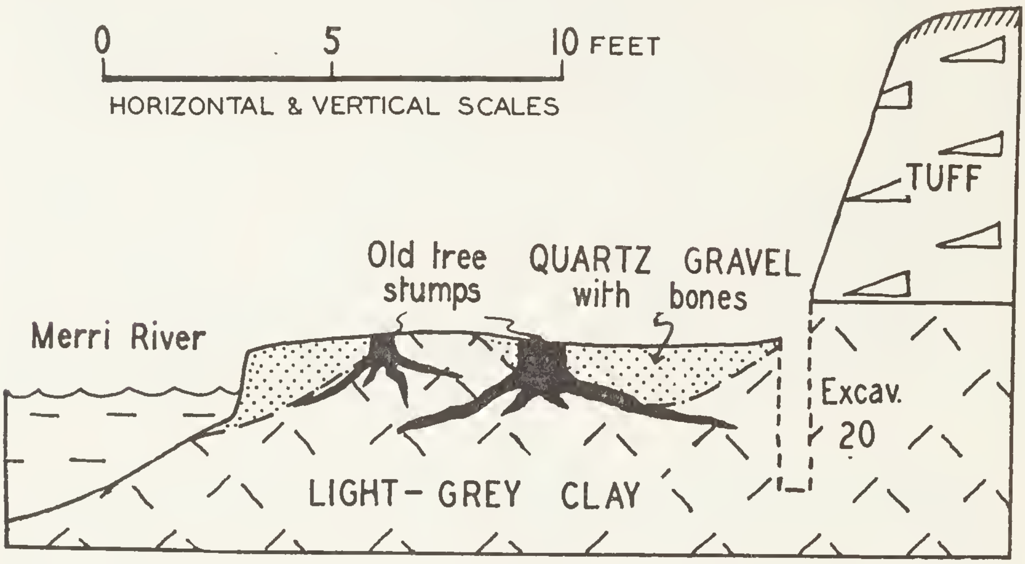

FIG. 11

Section of east bank of Merri River at Bushfield, showing the bone-bed and Excavation 20 (see Fig. 9).

identified them as follows:

Canis familiaris dingo Blumenbach ..	Dingo
Sarcophilus harrisii (Boitard)	Tasmanian Devil
Dasyurus viverrinus (Shaw)	Native Cat
Sminthopsis sp.	Pouched Mouse
Isoodon obesulus (Shaw)	Short-nosed Bandicoot
Trichosurus vulpeculus (Kerr)	Silver-grey Possum
Pseudocheirus laniginosus (Gould) ..	Ringtail Possum
Vombatus hirsutus (Perry)	Wombat
Potorous tridactylus (Kerr)	Dark Rat-Kangaroo
Wallabia bicolor (Desmarest)	Black-tailed Wallaby
Wallabia rufogrisea (Desmarest)	Red-necked Wallaby or Brush Kangaroo
Macropus canguru (Müller)	Captain Cook's Kangaroo (= Great grey or forester)
Mastacomys fuscus Thomas	Broad-toothed Rat
Rattus assimilis (Gould)	Allied Rat

This fossil locality has been visited regularly for some years, and as far as one can tell, the supply of bones is not being renewed by river action. The river was searched for a mile downstream but no fossils found. Upstream a few have been found opposite the excavation site, and a few chains further upstream again a few small bones, chiefly *Rattus,* have been discovered. It seems that in cutting through the tuff, the river has eroded the bed containing bones such as discovered in association with the Bushfield Axe, and many of these fossils were caught in the natural trap of the old platform a few chains downstream. It is clear from the condition of the bones that they have not travelled very far. Along with the fossil bones, the writer found a number of aboriginal flint and bone implements, and these were passed to the National Museum Ethnologist, Mr. D. J. Tugby, for study.

Age of Aboriginal Occupation

The presence of dingo bones proves the presence of aborigines in the country in addition to the evidence of the Bushfield Axe. Coming from under lithified tuff, there is no doubt about the axe and bones recorded by Keble being *in situ.* The marsupial bones, found by Keble, belong to living species, as do all the bones found by the writer. This indicates that the occupation is a later one than those at Lake Colongulac and Pejark Marsh, where there are the bones of the extinct giant marsupials.

Archibald (1894) discussed the antiquity of the aborigines of the Warrnambool district, and claimed this to be considerable

(a) because of alleged human imprints in the aeolianite on which the city is built. The interpretation of the prints as human has been much doubted (*vide* Officer 1891, Dennant 1891, 1892, McDowell 1899, Pritchard 1895, Stirling *et. al.* 1903-1904, Gregory 1904, Brancho 1905, Noetling 1907, Klaatsch 1906, 1908, Mulder 1909, Daley 1910, Chapman 1914, Gill 1943, Mahony 1943). Through the kindness of Mr. Charles Foyle at Warrnambool, I have been able to obtain a copy of a very sharp photograph taken at the time. That impressions were made by something is indubitable, but that they were made by humans is doubtful, and quite inadequate when it is the sole evidence.

(b) because of the finding of stone axes with hafting grooves. When white people arrived in the area, the aborigines were using non-grooved diorite axes. The grooved ones are much rarer, are generally of some rock other than diorite, and are often found in circumstances suggesting antiquity. There is a good deal of evidence to support Archibald's opinion, and it is of interest to note that the Bushfield axe is of basalt and possesses a hafting-groove. The Ballarat implement (see Mahony 1943, p. 41) is a patinated pointed implement with hafting-groove found at a depth of 22 inches at Ballarat in undisturbed gravelly clay. Recently, a large felspar porphyry axe $4\frac{1}{2}$ inches wide, $6\frac{1}{2}$ inches long (incomplete), and $1\frac{1}{2}$ inches thick, from Gerangamete in the Otway Ranges was presented to the Museum by Mr. E. R. Rotherham (reg. no. 47906). It has been weathered to a depth of about half a centimetre since manufacture, and was found at a depth of three feet in whitish pipeclay when a well was being sunk by Messrs. C. and J. Grant on their property two miles west of Yaugher railway station and half a mile east of the West Barwon River. Like the Bushfield Axe and the Ballarat Implement, the Gerangamete Axe possesses a hafting groove.

As the Bushfield Axe, flint implements, and fossil bones came from the Tower Hill Tuff, their age must be that of the tuff, which will now therefore be discussed.

Age of the Tower Hill Tuff

A general account of the geology of the Warrnambool area has been previously given (Gill 1943) and the age of the Tower Hill Tuff discussed (Gill 1950*a*), wherein it was pointed out that the sea must have receded from a higher level to about where it is now by the time the Tower Hill volcano erupted. Since then a greater area has been mapped, and a more detailed study made, resulting in the following information.

1. *Evidence from Eustatic Sea Levels*

Following lines laid down earlier (Fairbridge and Gill 1947), a study was made of the emerged shell beds from Peterborough to Portland with special attention to the Warrnambool-Port Fairy area. This is not the place to enter into a detailed account of these, but in brief the findings are—

(a) There are extensive, horizontally-bedded emerged shell-beds laid down by a sea about 25 feet higher than the present one. It was a warmer sea, as indicated by the presence of four genera of subtropical foraminifera (Collins 1953), and by the mollusca, which include *Anadara trapezia* and *Ninella torquata*. These beds are now widely travertinized and penetrated by solution pipes no longer active. The 25-ft. sea is believed to represent a late Pleistocene eustatic level widely reported throughout the world. It was followed by a sea-level much lower than the present one when deep gorges were cut by coastal rivers. When the sea returned from this low level, the valleys were infilled with silt. In addition to the depositional evidence of the 25-ft. sea, there is erosional evidence represented by platforms cut in Pleistocene aeolianite and other rocks. The low sea-level is no doubt that of the last glacial. The Tower Hill Tuff is found resting on the 25-ft. sea shell-beds. An instructive section is to be seen on the Moyne River (see also Collins 1953) where the 25-ft. shell bed has been eroded as far as a basalt bar would allow, and then as the sea came up again, blocking of the drainage caused deposition of very fine sediment, viz. clay, and of limestone, which means comparative absence of

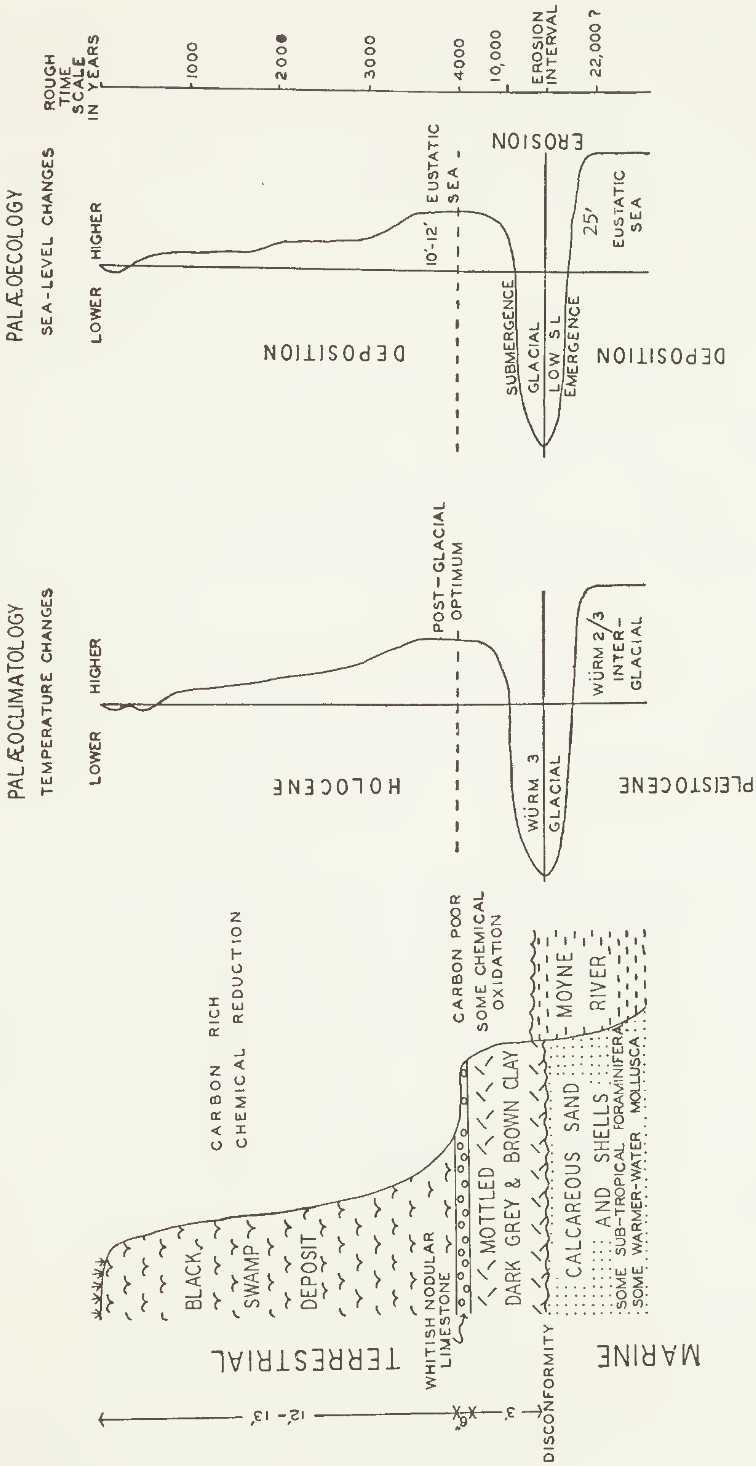

Fig. 12

Section on the right bank of the Moyne River, Rosebrook, and its interpretation.

terrigenous material. The presence of Hystrichosphaeridae (Cookson 1953) in the brown clay is evidence of the proximity of the sea, as also is the frequent occurrence of chenopodiaceean pollen—probably *Salicornia,* the salt bush. The brown clay thus presents a brackish water facies in contrast with the freshwater facies of the overlying black alluvium, with which the Tower Hill Tuff is associated. The black clay is poor in plant microfossils, only fern spores being recognized.

The limestone band occurs at the junction of the two clays and consists of very irregular off-white nodules of re-crystallized calcite. A slide (P15253) showed a cryptocrystalline structure, but neither in the slide nor by other methods could Mr. B. Tindale find any diatoms. Professor G. W. Leeper examined the section and did not think the limestone a pedological feature because limited so precisely to the junction between the two clays, which although different in colour are very similar in texture. It is suggested that the lower clay was deposited in the times of the ten-foot sea when this area was probably a saline swamp. When the sea began to retreat, the swamp would drain and the clay be oxidized by the air, because the climate then was arid compared with the present. If a small lake (perhaps seasonal) existed in this low-lying area, its fauna could provide the limestone, which since then has completely recrystallized. With the onset of more pluvial conditions, the black alluvium began to be deposited, and this process still continues. The Tower Hill Tuff is associated with this alluvium (see page 81). It is therefore later than the ten-foot sea (which conclusion is supported by observations elsewhere), and associated with the present cycle of deposition.

(b) The ten-foot* eustatic level of the sea cut shore-platforms as can be seen along the coast (Gill 1947*b*), and in embayments, e.g. behind the beach at Warrnambool, east of Pertobe Road, where there is the remnants of a platform in aeolianite 10·6 feet above low-water Warrnambool Harbour. Depositional as well as erosional evidence of this sea is to be found in the form of shell beds which are not travertinized or pierced by solution pipes. (In some earlier papers the 25-foot and 10-foot levels have been run in together and referred to as a 15-foot level.) Teichert (1946, 1950) and Fairbridge (1947*a*, 1948, 1950) have described evidence of 25-foot and 10-foot eustatic sea-levels in Western Australia, but have been able also to establish 5-foot and 2-foot stages in the retreat of the 10-foot sea. Conditions in the area studied provide

*The ten-foot, five-foot and two-foot eustatic levels are so named following Fairbridge 1950.

special opportunities for recording such small differences, and although these conditions do not apply in the Warrnambool-Port Fairy area, there are features which would fit well such an interpretation. The writer thinks that the sea went a short distance below the present level before rising very recently to where it is now (Gill 1950*b*), and there is evidence that it is still rising (Gutenberg 1941, Fairbridge 1947*b*, Teichert 1947; cf. Hanson 1934, Dyson 1948, etc.).

(c) Cannon Hill and Lighthouse Sections, Warrnambool. More detailed work has been done on these since the earlier description (Gill 1950*a*). At Cannon Hill three auger holes were put down as shown in text-figure 13. The first auger hole (Excavation 24) was put down approximately 6 chains 45 feet west of the west fenceline of Pertobe Road, and 20 feet north of the north fenceline of the railway. The surface of this point is 13·3 feet and the bottom of the auger hole 4·5 feet above low-water Warrnambool harbour.

4 ft. 4 in.	tuff and black loamy soil
1 ft. 0 in.	dark-greyish to blackish sand with swamp fossils
1 ft. 3 in.	greyish-brown sand
2 ft. 3 in.	reddish for a few inches then bright red clayey sand
0½ in.	yellow aeolianite
8 ft. 10½ in.	Total depth

At the top of the reddish clayey sand *Melliteryx helmsi* (Hedley) and *Austropyrgus buccinoides* (Quoy and Gaimard) were obtained. The second auger hole (Excavation 25) was put down approximately 6 chains 29 feet west of the west fenceline of Pertobe Road, and 18 ft. 6 in. south of the north fenceline of the railway. The surface at this point is 8·2 ft. and the bottom of the auger hole 4·2 ft. above low-water.

9 in.	black clayey sand with swamp fossils
3 in.	brownish sand and marine shells running into above
2 ft. 6 in.	greyish, very compact sand
6 in.	red sandy soil
0½ in.	yellow aeolianite
4 ft. 0½ in.	Total depth

A third auger hole (Excavation 26) was put down in line with Excavations 24 and 25, and approximately half-way between the railway line and the south fenceline of the railway. The surface at this point is 4·6 ft. and the bottom of the auger hole 0·4 ft. above low-water.

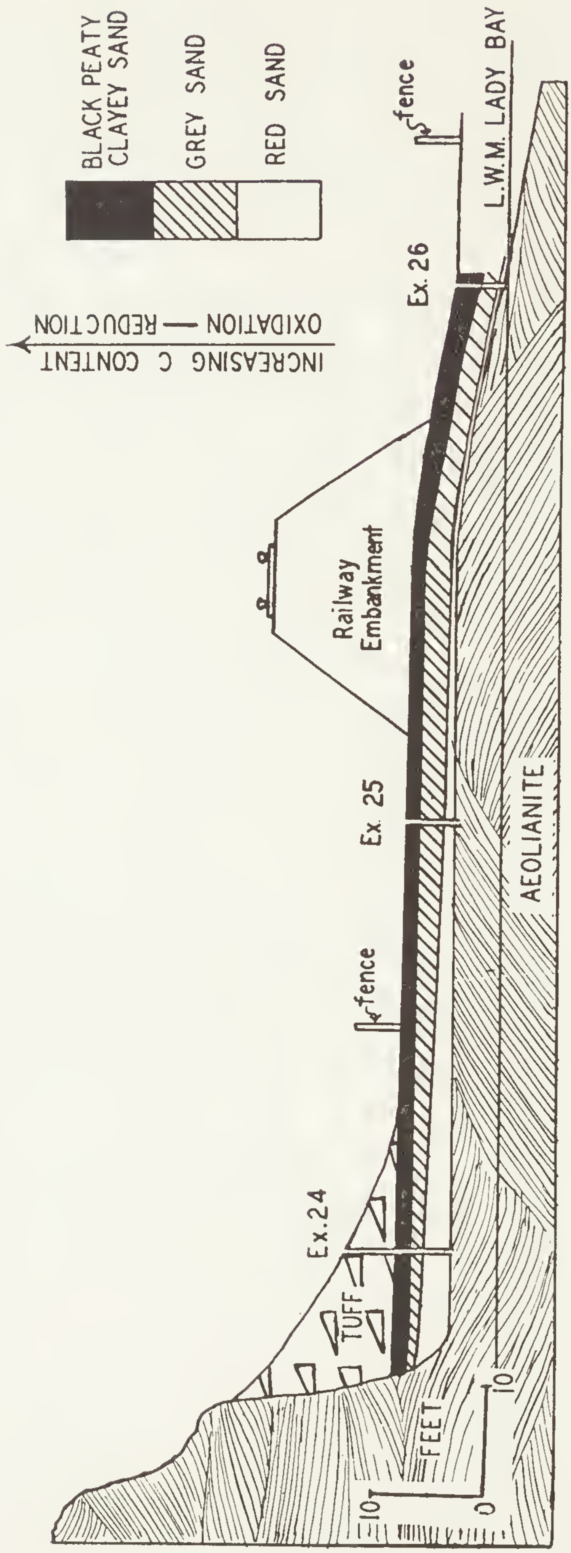

Fig. 13

Cross-section at Cannon Hill, Warrnambool, at site shown in Fig. 12.

Swamp facies	4 in.	black alluvium with some brownish patches
	11 in.	black alluvium with numerous swamp fossils
Mixed facies	6 in.	grey clayey sand with swamp fossils, and occasional marine shells
	2 in.	same matrix with numerous marine fossils, swamp shells, and plant remains intermixed
	1 in.	hard, light-grey concretionary band
	1 ft. 11 in.	brownish-grey sand with fragments of marine shells
Terrestrial facies	3 in.	red sandy soil
Marine platform	0½in.	yellow aeolianite
	4 ft. 2½in.	Total depth

The fauna of the band at 21 in. to 23 in. includes *Bythinella* which is a marsh and estuarine mud flat shell, *Notospisula trigonella* which is found on salty sandy mud beside beaches, and marine shells such as *Austrocochlea obtusa porcata* (a mud flat species kindly determined by Mrs. A. N. Carter), *Batillaria australis, Bembicium auratum* (sandy-mud dwellers), *Macoma deltoidalis* (sand dweller), *Mysella donaciformis, Mytilus* (rock-dweller), *Ostraea,* and *Zeacumantus cerithium.* In addition there is *Melliteryx helmsi* (Hedley) found in the top two inches of silt in Lake Pertobe at present. This mixture of facies shows that some shells have been washed in.

The datum used in these surveys is low-water Warrnambool harbour, fixed about 1925 when the local sewerage scheme was being introduced. The tidal range on the open coast is something like six feet (not measured), while the calculated mean tidal range in the harbour is 2·34 feet. Warrnambool or Lady Bay appears open to the sea, but it has a submerged bay bar of aeolianite (see Admiralty Chart). Slightly higher eustatic levels would be affected by the bay bar (probably higher then if the sea has been lower in the meantime), so low-water Warrnambool harbour is a better datum to use than low-water on the open coast.

The section below the lighthouse was explored by an auger hole (Excavation 27) which was put down 1 chain 55 feet west of the east fenceline of the railway (approximately on the line of section B in Gill 1950*a*). The surface at this point is 12·6 feet and the bottom 3·2 feet above low-water. This suggests the presence of the same buried aeolianite platform proved in the Cannon Hill section. When Lake Pertobe dried up in May 1950, a sample of the top two inches of sediment was collected and found to contain *Melliteryx helmsi* (Hedley), *Austropyrgus buccinoides* (Quoy and

Gaimard), and *Laevilitorina mariae* (Tennison Woods). The first two were found in Excavation 24 just above the fossil red soil, and the first in Excavation 26 at a depth of 22 inches. *Austropyrgus buccinoides* is found in freshwater habitats, such as on the Merri River near the Bushfield Axe site, and in brackish water habitats, but not in marine habitats. The occurrence of true marine shells mixed with swamp shells and plants in the Cannon Hill

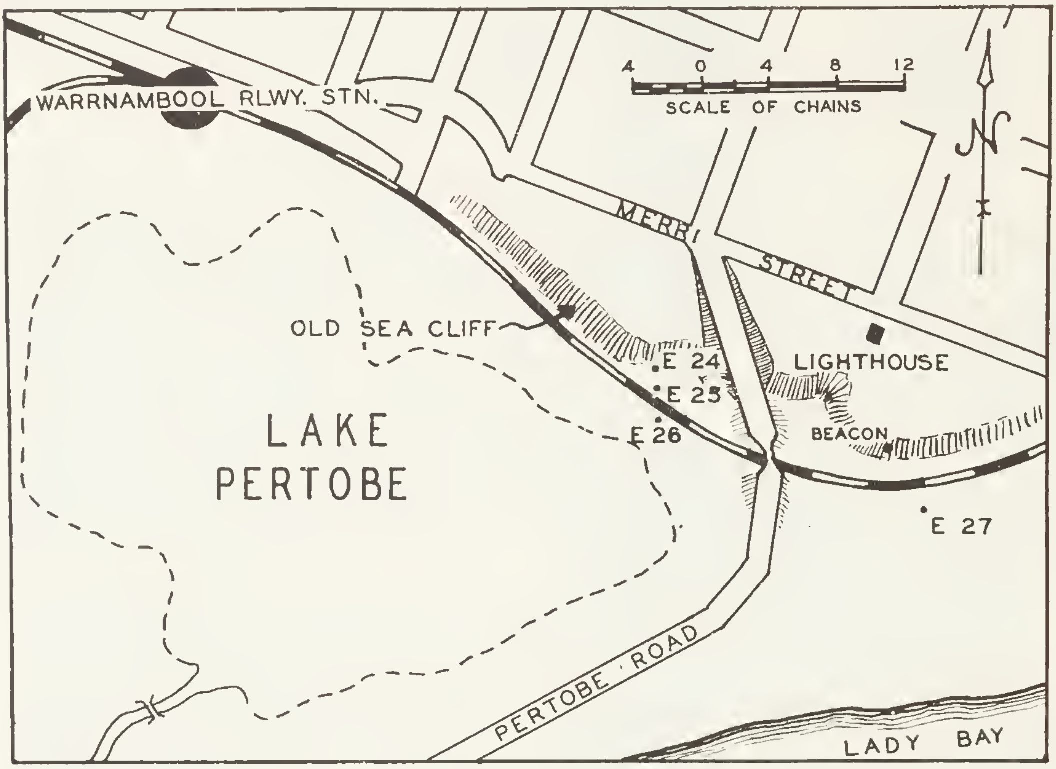

FIG. 14

Map of Lake Pertobe area, Warrnambool, showing sites of excavations 24 to 27.

auger holes is to be attributed to storm waves washing in the former. Mr. Henri Worland, former Town Clerk of Warrnambool and a local historian, kindly allowed me to view old photographs showing the sea washing over the beach at Lady Bay, across Pertobe Road, and into Lake Pertobe. The beach improvements and the introduction of marram grass at the beginning of this century have now caused an effective barrier to be raised against the sea.

In interpreting the Cannon Hill and Lighthouse sections, the following suggestions are put forward:

I. When the sea was a few feet higher than at present (later than both the 25-foot and 10-foot levels), a platform was cut in the calcareous aeolianite below Cannon Hill, the sea then being where Lake Pertobe is now.

II. When the sea withdrew, red (oxidized) sandy soil formed on the former shore platform. It is very immature, shallow, and thins out rapidly seawards, so could not have had a long time to form. Under present conditions it would be impossible for such a soil to form in this situation, as marine and/or swamp waters would cover it. It appears to the writer that the sea went lower than it is at present, allowing the soil to develop from loose sand blown against the old sea-cliff, then as the sea came up, swampy conditions were generated. The succession in time of red, grey, then black deposits, and their respective faunas and floras, indicate increasing carbon content, and increasing conditions of chemical reduction as against oxidation.

III. The deposition of the tuff is associated with the present cycle of deposition in Lake Pertobe, in the same way as the tuff is associated with the present cycle of deposition of black clay in the Tower Hill Marsh. Although freshly-deposited volcanic ash is the most easily eroded of deposits, it has not been washed away from the old sea cliff at Cannon Hill and below the Lighthouse, proving that at the time of eruption of Tower Hill the sea was approximately where it is now. The deposition of the ash by the wind against the old sea cliff is therefore a very recent event indeed. Dr. A. W. Beasley, the National Museum Mineralogist, has confirmed the field determination of the material as volcanic ash (slide E538).

(d) *Koroit Beach Section.* (Text-figure 15; also Gill 1951*a*, plate O.) The area concerned is underlain by the tuff and lapilli, with occasional larger ejectamenta, from the nearby Tower Hill caldera. The ejectamenta constitute the shore platform. In fine weather the platform is mostly covered with sand, but in storm weather it is swept clean. The surveyed section shown in text-figure 15 is based on the level of the tuff platform near its outer edge (approximately low-water), no other datum being available for miles. The section line runs north-south at right angles to the shore, parallel to Gorman's Lane (which provides access to the beach) and about three-quarters of a chain east of its east fence-line.

Excavation 28. A spade hole four feet deep was dug in the yellow calcareous sand to make sure that the beach ridges of blocks of tuff and lapilli were two separate ridges. Since then wind scour has provided conclusive evidence that the beach ridge being formed at present is well separated from the fossil one further inland (see text-figure 15).

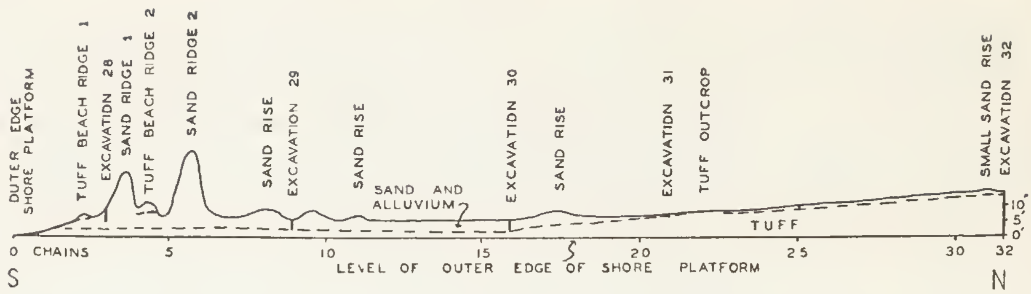

FIG. 15

Surveyed section on a north-south line at Koroit Beach, near the Tower Hill volcano, between Warrnambool and Port Fairy.

Excavation 29. Beside a sand-rise three feet high, an auger hole was sunk in a hollow through 4 ft. 2 in. of swamp deposits, finishing on tuff.

Excavation 30. Spade hole in a swampy depression about two feet below the surrounding terrain penetrated one foot of swamp deposits, finishing on tuff.

Excavation 31. Spade hole in a swampy depression about two feet below the surrounding terrain penetrated only superficial swamp deposits. Tuff outcrops in side of depression.

Excavation 32. Spade hole showed six inches of soil on tuff. In places over this section line are small sand rises varying from one to four feet high. The tuff platform shown by this section at about two feet above the present one, in addition to the repeated sand ridges and beach ridges of tuff blocks probably signify an emergence of a couple of feet. No reason was found for interpreting this emergence tectonically as a result of the local vulcanism, although it is difficult to trace such small movements. The dips and faults round the caldera have been mapped, and all appear to be limited to the caldera rim. It has been shown that the tuff from Tower Hill is later than the 25-foot and 10-foot platforms, and later than a platform five feet above low-water at Cannon Hill. If the two-foot platform at Koroit Beach is of the same age as the two-foot platform in Western Australia, then it is of the order of 1,000 years old, according to the calculations of Teichert (1947) and Fairbridge (1947*d*).

2. *Evidence from Radiocarbon Analysis*

Charcoal from the aboriginal kitchen midden on the Koroit Beach was sent to Professor W. F. Libby through the kind cooperation of Professor Hallam L. Movius Jnr. The sample was from the site shown in the photograph constituting plate O in Gill 1951*a*. The carbon-14 count gave an age of 538±200 years.

The midden is associated with a soil layer underlain only by sand and then the tuff. Later middens occur on the sand ridges themselves, e.g. immediately opposite the end of Gorman's Lane, and aborigines were still visiting the beach when white people arrived in the Country.

3. *Evidence from Stratigraphy*

The Cannon Hill and Koroit Beach sections show that the deposits on top of the tuff are comparatively thin and very recent. In numerous drain sections in the Tower Hill Marsh, one to six feet of black alluvium (like that seen in the Moyne River section) can be observed overlying the tuff. The tuff is associated with the formation at present in process of deposition.

4. *Evidence from Pedology*

Professor G. W. Leeper kindly examined a number of the fossil and extant soils in the Warrnambool area for me. On the top of the Miocene marine limestone and immediately under the tuff on the south side of the Tower Hill caldera is a fossil *terra rossa*. On the top of the tuff is a very immature loamy soil. Although the soil on the volcanic cinders (as seen in the quarry on the north side of the central cone complex) is rocky and immature, there is a band of re-deposited lime under the soil. With a view to ascertaining if this were due to the presence of comminuted limestone bedrock in the ejectamenta, samples of cinders from Mt. Leura, Mt. Noorat, and Tower Hill were treated with acid, and were found to lose 3%, 4% and 16% dry weight respectively. The soils on the Tower Hill tuff have a negligible quantity (if any) of buckshot gravel, thus contrasting with older tuffs such as those at Camperdown on which there is a well-developed podsol with buckshot. The richness of the Tower Hill soil is due to its youth. The pedological evidence thus indicates a very recent age for the Tower Hill tuff.

5. *Evidence from Physiography*

The Tower Hill Tuff follows the present contour of the country, but so also does the Hampden Tuff which is older. That the Merri River has not yet cut through the tuff all along its course, and that the ash spread is orientated to the present prevailing wind direction (Gill 1950*a*) are indications of a recent age. The fault scarp of the Tower Hill caldera is very sharp, and the amount of talus gathered at the bottom contrasts with the older calderas of Mt. Leura (Plate 3, figs. 3-4), Lake Bullenmerri, and Lake Gnotuk, where there is quite a lot of differential weathering, and in places of talus accumulation.

In review of the age of the Tower Hill Tuff, and so of the age of the Bushfield Axe and fossil bones, it can be concluded that it is very recent indeed. If the radiocarbon and eustatic sea-level datings are sound, the age is something like a thousand years.

4. Two Series of Middens

While studying the emerged shell beds of the Warrnambool and Port Fairy districts, a series of middens associated with the 25-foot shoreline was discovered. No middens were found between the very recent middens of the present coastline and those of the fossil shoreline, except along waterways, viz. the Hopkins River, the River Merri, the River Moyne and Goose Lagoon, 4½ miles west of Port Fairy—an ancient estuary. There are thus two separate series of middens, except where they are joined along waterways.

(a) *Coastal Middens.* These occur along sand dunes and aeolianite cliffs right on the present coast. Many have been destroyed of recent years by coastal erosion. The best known of this series of middens is that at Koroit Beach, Armstrong's Bay, north-west of Warrnambool (Kenyon 1912, Gill 1951*a*). Charcoal from this midden was sent to Professor W. F. Libby for radiocarbon analysis through the kind co-operation of Professor Hallam L. Movius Jnr. of Harvard University. The age given was 538±200 years, which is of the order anticipated (Libby 1951, Johnson 1951).

(b) *Inland Middens.* Examples of this series of sites are:

1. On the hill on the east side of Merri River, Dennington, above Moulden's sand quarry. This is near where the river enters extensive swamps behind large sand dunes. The site is well over a mile in a direct line from the present coast. Military Map, Port Fairy Sheet 1942, grid reference 377,694.

2. On top of aeolianite cliff, just north of Princes Highway, and one and a quarter miles east of Rosebrook, on west side of drain which cuts through aeolianite and underlying basalt. This site is over a mile in a direct line from the present coast. Same military sheet, grid reference 224,714.

3. A number of sites was found at Goose Lagoon, and from one of these charcoal was sent to Professor Libby for radiocarbon analysis. The site is on the northern slope of an aeolianite ridge, north of the Princes Highway, and on the east side of Goose Lagoon, near where a drain cuts through basalt and an emerged marine shell bed; it is three-quarters of a mile in a direct line from the present coast. Same military sheet, grid reference 127,674. The C14 dating was 1,177±175 years, which is much

younger than anticipated. The inland middens, like the coastal ones, consist of charcoal, marine shells of edible kinds and sizes, and flakes of flint. No proper implements were found in the inland middens, and none in the coastal middens except at Koroit Beach, where the writer has found a stone axe and numerous bone implements. The inland middens are in sites relative to the 25-foot shoreline comparable with the sites of recent middens relative to the extant shoreline, so much so that most of the localities were found by working on the analogy of the modern middens. It is generally believed that the aborigines did not carry the marine shellfish they collected any distance inland, but ate them near where they were found. For example, Dawson (1881, p. 19) says, "These immense mounds of shells being met with only near the sea, and nowhere in the interior, leads to the conclusion that the aborigines who fed on the mollusca and fish, never left the shore during the fishing season, and that, if they came from the interior, they never carried away any shellfish with them". MacPherson (1885, p. 55) noted "in some mounds about half a mile from the bay at Geelong there are fragments of shells which no doubt were brought from the neighbouring seashore". A few marine shells at a site is no criterion of an inland midden, because sea-shells were traded inland for use as implements and ornaments (see Dawson 1881, pp. 25, 78; Smyth 1878). If the middens are so young as the radiocarbon age given, then the shells must have been carried inland, but how did the aborigines come to select the 25-foot shoreline on which to have their feasts? As swamps often occupy the former bays, it might be thought that the aborigines chose the old shoreline because they found water in the adjacent swamps, but this could not apply to the middens along a waterway like the Hopkins River, and in some cases (as at Goose Lagoon) there was water nearer the coast. Further radiocarbon analyses are being arranged.

In Victoria, ancient middens now far from the sea have been reported by Dawson (1881, p. 19), Le Souef (1916), Kenyon (1927), and Keble (1928). In other States of Australia, Anderson (1890), Young (1926), Jardine (1928), and Voisey (1934) have reported comparable occurrences.

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Appendix I

Details of the *Colongulac Skeleton,* a fossil aborigine found in the loess dune at Lake Colongulac, Victoria.

Determinations by Professor S. Sunderland and Dr. L. J. Ray, Department of Anatomy, University of Melbourne.

P 15437 Femur Left
P 15438 Femur Right
P 15439 Sacrum
P 15440 Os Coxae Left
P 15441 Os Coxae Right
P 15442 Tibia Right
P 15443 Tibia Left
P 15444 Humerus Right
P 15445 Fibula Left
P 15446 Fibula (part missing) Right
P 15447 Ulna Left (incomplete)
P 15448 Radius Right
P 15449 Radius Left
P 15450 Ulna Right
P 15451 Trochlea Phalangis
P 15452 Os Pisiforme
P 15453 Patella Left
P 15454-62 Costae fragments
P 15463 Calcaneus Left
P 15464 Calcaneus Right
P 15465 Talus Left
P 15466 Talus Right
P 15467 Os Naviculare Left
P 15468 Os Cuneiforme Primus Right
P 15469 Os Metacarpale I Right
P 15470 Os Metatarsale IV Right
P 15471 Os Metatarsale I Left
P 15472 Os Metacarpale (base missing)
P 15473 Os Metacarpale I Left
P 15474 Phalanx Secunda
P 15475 Phalanx Prima
P 15476 Phalanx Prima
P 15477 Os Metacarpale III Right
P 15478 Phalanx Prima
P 15479 Phalanx Prima
P 15480 Phalanx Prima
P 15481 Os Metacarpale III Left
P 15482 Os Metacarpale II Left
P 15483 Phalanx Prima
P 15484 Os Metacarpale II Right
P 15485 Phalanx Prima
P 15486 Os Metatarsale II Right
P 15487 Phalanx Prima
P 15488 Os Metacarpale V Right
P 15489 Os Metacarpale V Left
P 15490 Os Metacarpale IV Right
P 15491 Os Metacarpale I Right
P 15492 Phalanx Tertia
P 15493 ,, ,,
P 15494 ,, ,,
P 15495 ,, ,,
P 15496 Phalanx Secunda
P 15497 Phalanx Prima
P 15498 Phalanx Secunda
P 15499 Phalanx Tertia
P 15500 Phalanx Secunda
P 15501 Phalanx Prima
P 15502 Phalanx Secunda
P 15503 Os Multangulum Minus (Trapezoid) Right
P 15504 Os Lunatum (Lunate) Right
P 15505 Os Naviculare Left
P 15506 Os Hamatum Left
P 15507 Os Metatarsal III Left
P 15508 Os Metatarsale V Left
P 15509 Fragmentum indet
P 15510 Vertebra Lumbalis I
P 15511 Vertebra Lumbalis III
P 15512 Vertebra Lumbalis IV (laminae of)
P 15513 Vertebra Cervicalis
P 15514 Vertebra Cervicalis VII
P 15515 Vertebra Cervicalis
P 15516
P 15517 Fragmentum indet.
P 15518 Os Cuboideum
P 15519 Os Cuneiforme Primum Right
P 15520 Os Capitatum Left
P 15521 Os Cuneiforme Tertium Left
P 15522 Os Cuneiforme Secondum Left
P 15523 Fragmentum indet.
P 15524 Fragmentum indet.
P 15525 Os Capitatum Right
P 15526 Dentis Incisivus
P 15527 Dentis
P 15528 Dentis

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DESCRIPTION OF PLATES

Plate I

Figure 1. Lake Colongulac seen from Mt. Leura, with other volcanoes in the distance.

Figure 2. Lake Colongulac, looking towards Mt. Leura from the point at the north end of the lake. In the middle distance, in front of Mt. Leura, is "Chocolyn".

Plate II

Figure 3. The central cone complex of the Mt. Leura nested caldera. View looking north from the S.W. corner of the caldera. Figure standing on grey bedded tuff.

Figure 4. Same vicinity, looking south to show the somewhat eroded rim of grey bedded tuff and lapilli.

Plate III

Figure 5. Lake Colongulac, east shore, looking N.E. from the mouth of Chocolyn Creek. Photograph taken at time of very low summer level. Note the cliffs cut in the Colongulac Loess. The Colongulac Skeleton came from the cliff at the extreme right of the photograph.

Figure 6. Mouth of Chocolyn Creek, looking upstream, showing the high level alluvium, and the incised meanders.

Plate IV

Figure 7. The Colongulac Skeleton *in situ* after excavation but before removal from the Colongulac Loess.

Figure 8. Soil pipes in the south wall of the large quarry on the north side of the Princes Highway, near Mt. Leura (E 13 on text-figure 1).


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