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PALAEOECOLOGICAL INTERPRETATION OF SOME VICTORIAN FOSSIL DIATOM FLORAS

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In an accompanying paper, Mr. B. Tindale sets out the determinations he kindly made of diatoms extracted by him from samples of diatomites in the National Museum collection. The following notes are an effort to interpret the results in the light of the writer's studies of the areas concerned.

A. Yarra Delta Floras

The upper part of the Yarra Delta consists of two formations, viz., a lower fossiliferous yellow marine clay into which streams in time gone by cut a terrestrial physiography which reaches far below present sea-level. The clay was thus penetrated by air and oxidized. This buried river system has been infilled and the yellow clay completely covered, by the second higher and younger formation of highly fossiliferous black marine silt, which occurs to about ten feet above low-water Hobson's Bay. One of the commonest shells in this deposit is the stenothermal *Anadara trapezia,* which is almost extinct in Port Phillip Bay but occurs in countless numbers in the delta. The fossil ones are also about twice the size of the extant ones. The species still flourishes further north where the waters are warmer. *Anadara trapezia* is common, too, in the underlying yellow clay. A number of pieces of fossil wood has been found in the black silt, and these have been kindly determined by Mr. H. D. Ingle, B.For.Sc., of the C.S.I.R.O. Forest Products Division, as red gum, *Eucalyptus rostrata.* It is hoped to obtain radiocarbon analyses of both the wood and the shells, thus obtaining an absolute dating for the silt. The yellow clay is regarded as late Pleistocene, and the deep erosion as a function of the last glacial. The black silt is thought to belong to the mid-Holocene Thermal Maximum, because of the presence of such forms as *Anadara trapezia,* and because their elevation above sea-level is consistent with the widely-recognized mid-Holocene ten-foot level. The diatomites in localities 1 to 5 belong to the black silt formation, and so their age is probably mid-Holocene, or a little younger for the deeper layers.

Details of the Yarra Delta localities are given below, and their ecology as shown in the diagrams in text-figure 2 are discussed. This form of representation was designed so that the floras could be viewed as a whole, and their comparisons and contrasts readily seen. Each radial bar represents a species, so the number of bars signifies the richness or poverty in species of the flora. Each

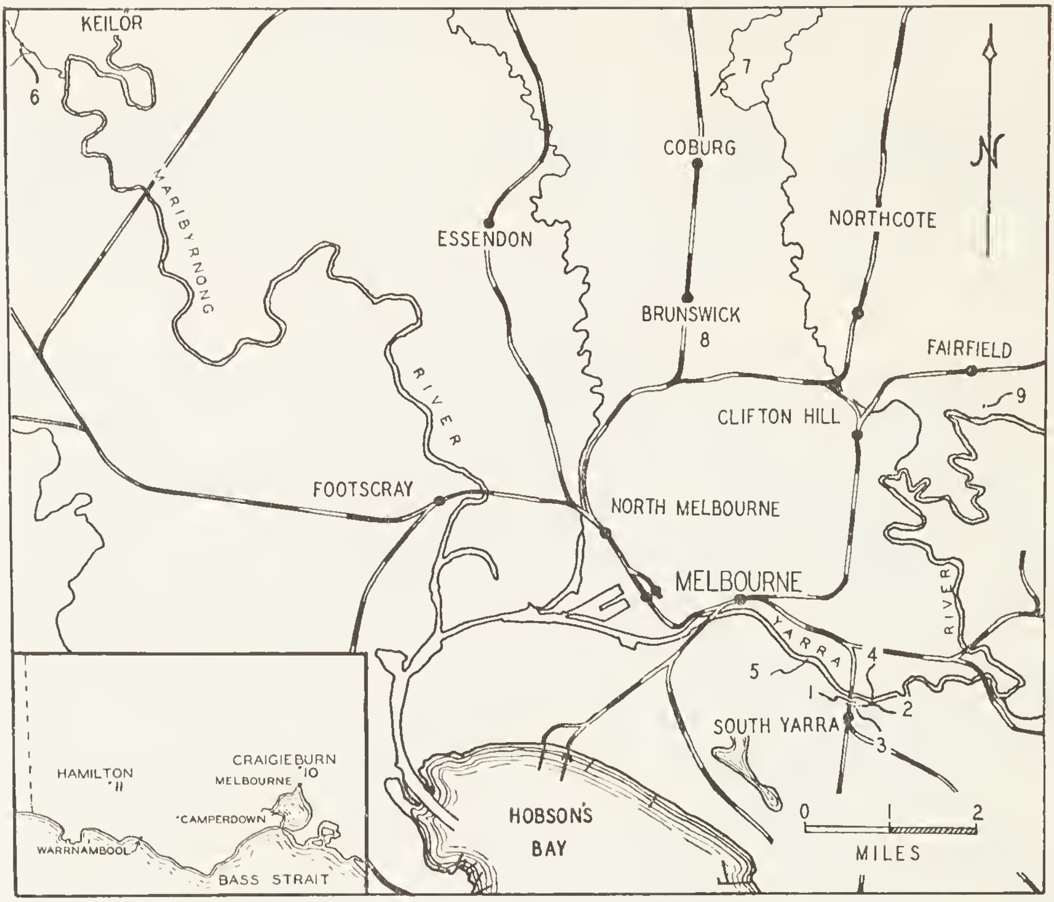


Fig. 1

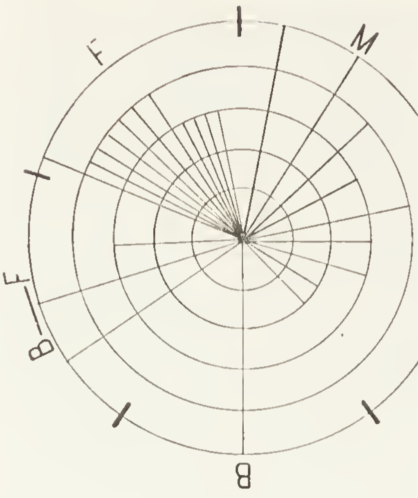
Localities for fossil diatoms.

concentric circle represents a degree of abundance (from the centre outwards these are very rare, rare, few, common, abundant), so a glance at the diagram can give an idea of relative frequencies, the lengths of the bars signifying the richness or poverty in numbers of the various species. The division of the circle into sectors covering the various habitats means that the direction of a bar provides information on the ecology of that species. The habitats for the various species are those shown on Mr. Tindale's list, but *Epithemia gibberula* is omitted because its different varieties occur in marine, brackish, and freshwater environments respectively. Thus much important ecological information concerning a flora can be represented in one diagram. In text-figure 2, the diagrams carry the same locality numbers as appear in Mr. Tindale's paper and this one.

The first claim to find fossil diatoms in Victoria was made by Blandowski (1858), but Mahony (1912) suggests that he confused copi with diatomaceous earth. The first indubitable record is that of Coates (1861), who discovered a deposit at South Yarra, in the Yarra Delta. Card and Dun (1897) comment on this and other Victorian localities, while Dobson (1884, p. 37) recorded diatoms from the silt of the Yarra River and "in a drain dug for the West Melbourne Swamp". Lucas (1887) listed diatoms "proper to brackish or salt water" from "the deposits of the West Melbourne Swamp". Cornwall (1889) refers to living diatoms in the same swamp, while Pritchard (1910) mentions fossil diatoms from there (cf. also Anonymous 1912). Mr. Tindale found sponge spicules but no diatoms in a sample of silt I collected from the Appleton Dock excavations (Slide P 15371 Nat. Mus. Vic.).

Locality 1

The sample of diatomite examined was collected by Mr. F. P. Spry from "Near junction Yarra River and South Yarra Railway Station. Overlaid by silt." Spry, an inspector for the Melbourne and Metropolitan Board of Works, was a keen naturalist who collected much valuable material from early sewerage excavations in Melbourne; he later joined the staff of the National Museum. Mr. M. Teese of the M.M.B.W. has kindly provided me with information which throws light on our localities 1 to 3. A sewerage tunnel was excavated from Richmond, under the Yarra River, and along Yarra Street, which is on the east side of the South Yarra railway station. Spry's material referred to above almost certainly came from this excavation. The floor of the tunnel is 25 feet below low-water, M.M.B.W. datum (i.e. 0·19 feet *below* Admiralty datum, which is used also for military maps and by the Melbourne Harbour Trust, and 0·36 feet *above* the Crown Lands datum). Shepard (1897) reported Spry's specimens as coming from "30 feet below the level of the River Yarra". The Richmond main enters the South Yarra one at a point to be found by producing Domain Road eastwards to Yarra Street. Samples 1 to 3 are all from depth and so differ from the material collected in this vicinity by Coates (1861), which was from the surface.



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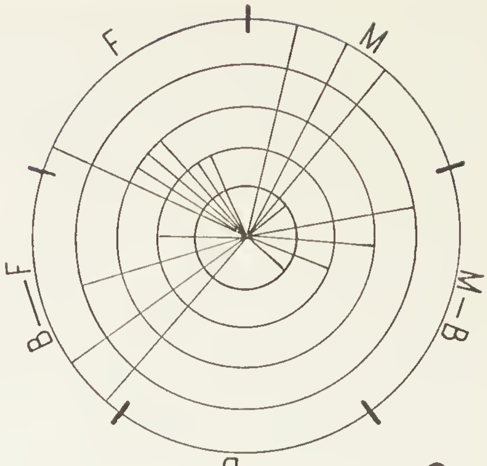

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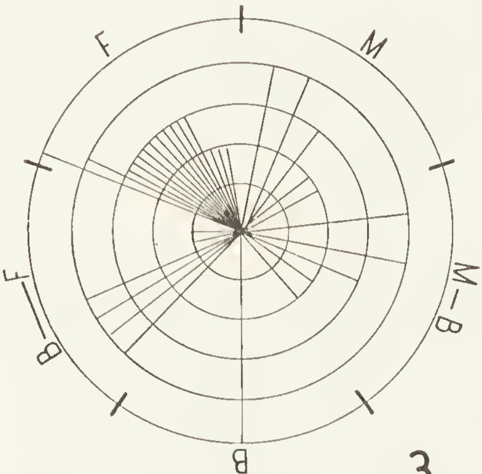

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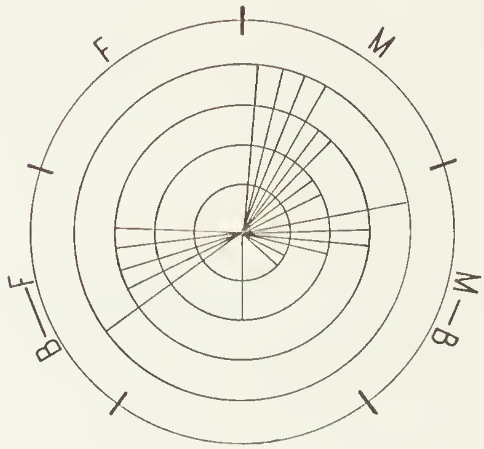

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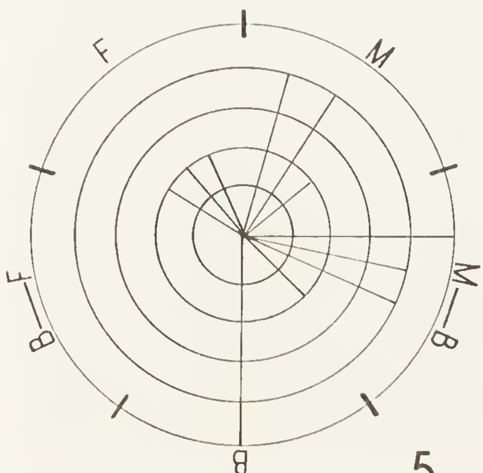

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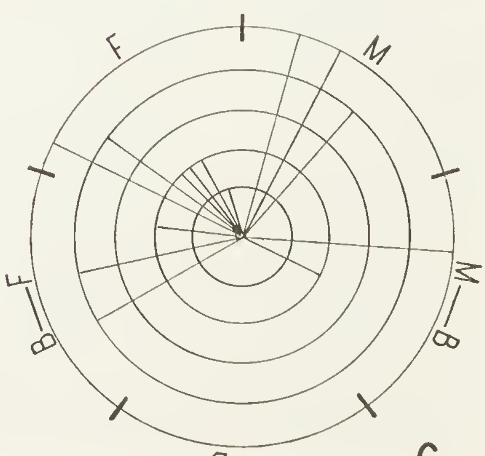

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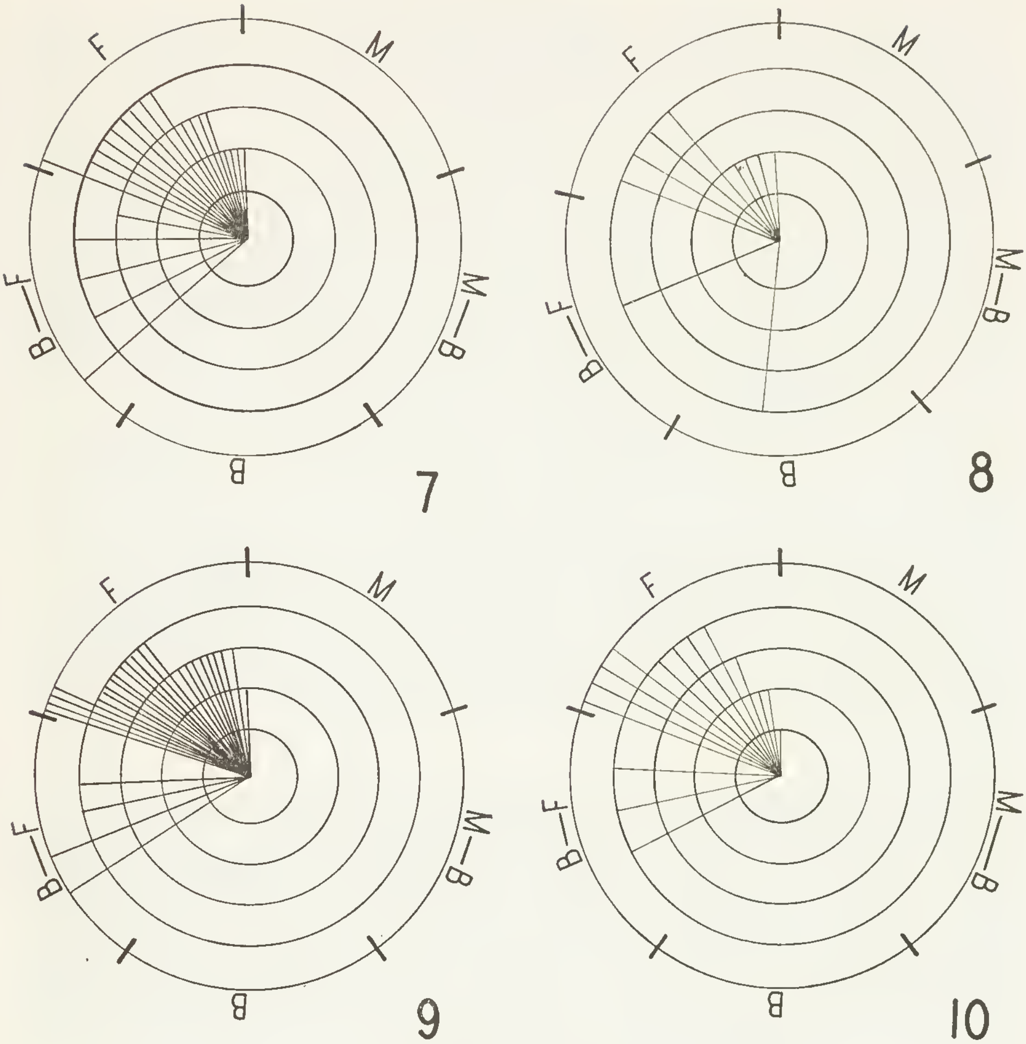

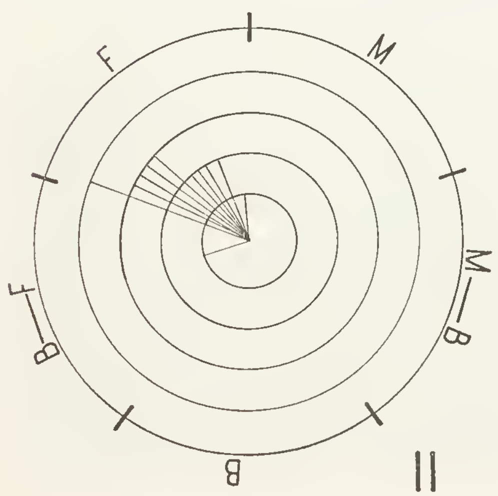

FIG. 2

Diagrams showing number of species, relative number of individuals of each species, and their habitats for the diatom floras discussed in this paper.

Each radius represents a species, and its length the relative frequency of that species, viz. the circles from the innermost to the outermost represent the frequencies very rare, rare, few, common, abundant. The habitats are represented by segments of the circle, viz. M = marine, M-B = marine and brackish, B = brackish, B-F = brackish and freshwater, F = freshwater.

The numbers of the diagrams correspond with the numbers of localities given in the paper.

Coates says the silts here are 60 feet deep, which is to be expected as a result of Pleistocene low level erosion (Gill 1949, p. 39). His identifications are of species from a number of habitats, like the floras of localities 1 to 3, so must be marine because freshwater diatoms can easily be washed into the sea, but not *vice versa*. Thus it may be surmised that the dark silts are marine right to the surface, which finding corresponds with Coates' record of "marine shells, more or less perfect, pieces of cuttle-fish bone, and the débris of echini . . . and numerous foraminiferous shells" (pp. 158-159). He also mentions "spicula of sponge, and the object known as *Dictyocha*" (p. 162).

From text-figure 2 it can be readily seen that the flora of locality 1 is rich in both species and numbers of individuals, and that all five habitats are represented, four by abundant forms, and the fifth by a common form. The sediments are marine, but for most of the species, a thanatocoenose. The presence of so strong an assemblage of freshwater species indicates that a freshwater stream debouched into the estuary at this point; reference to text-figure 1 shows this to be the case. This, and all the other diatomites from the Yarra Delta, are impure.

Locality 2

F. P. Spry collected the specimen of diatomite concerned on 27th April, 1898, from "Sewerage tunnel, near railway station, South Yarra". Lithologically, this is the same as the diatomite from locality 1, but the diatom content is a little different. Text-figure 2 shows the flora to be less in both species and numbers of individuals. The fall in frequency of species is limited almost entirely to the freshwater forms, suggesting that this locality was out of the course of the inflowing creek.

Locality 3

"Junction of South Yarra and Richmond main sewers." From the information given above, it is possible to pinpoint this locality, and to say that the diatomite came from 25 feet or a little less below low-water. If the geological interpretation given earlier in this paper be correct, then the diatomites from localities 1 to 3 were laid down as the sea rose from the glacial low to the mid-Holocene ten-foot level, something like 8,000 years ago.

The flora from locality 3 is remarkable for having 32 species, and that although a marine bed, half this number are restricted freshwater forms. The interpretation of these facts seems to be that this part of the lagoon was right on the line of creek entry.

In the National Museum of Victoria, there are marine fossils in black silt collected on 30th July, 1860, when excavations were in progress for the nearby Cremorne railway bridge. The fossils came from a shaft at a depth of 25 feet. Also in the Museum are marine barnacles obtained by F. P. Spry "31 feet from the surface between Yarra Street and Chapel Street, South Yarra", i.e. between the South Yarra railway station and the Melbourne Boys' High School. These fossils would no doubt be from the sewerage tunnel which passes deep under the school dropping slowly to 25 feet below low-water at Yarra Street. The site is now covered by the playing field of the Melbourne Boys' High School, which 5,000 or 6,000 years ago was occupied by the salt water of a branch of the enlarged Yarra estuary.

Locality 4

"Church Street bridge, Richmond. 13 feet below high-water mark. Presented by A. Lynch, Esq., 20/5/22." So reads the label. The mean tidal range at Williamstown is 2·8 feet, and at Church Street bridge would be about 2 feet. "13 feet below high-water" therefore means about 11 feet below low-water, which figure allows direct comparison with the depth of the specimens from localities 1 to 3.

The flora from locality 4 has diatoms from the full range of habitats, as was the case with those from localities 1 to 3, but the marine element has strengthened relative to the rest. Localities 3 and 4 have 32 and 29 species respectively, with the marine element constituting 17% in the first and 28% in the second. As the site is on the main river course, it would be a tideway and so feel the effect of the marine water more. The non-marine diatoms, and the plant remains also found in the rock, would be washed in by the flow of the river following the receding tide.

It is of interest to note that at whatever depth the samples are taken the lithology is the same—a dark silt with distincly litoral flora and fauna. The picture this gives is of the deep valleys cut by erosion during the glacial low sea-level being slowly filled, but the waters at no time being either deep or fast-flowing. The molluscs indicate shallow waters, and neither the diatomite nor the fine silts could have accumulated if there had been currents of any appreciable strength.

Locality 5

The dark grey silty diatomite or diatomaceous silt from this locality is labelled, "Yarra Improvement Work. From bottom of old river bed near Botanical Bridge. Collected by F. P. Spry

20/4/49." Kitson (1900, 1902) has given an account of these works, which were undertaken to straighten the course of the River Yarra to aid flood control. In his 1902 paper, he refers to the diatom content of certain beds in this and other parts of the Yarra Delta. In reviews of diatomite deposits, Mahony (1912) and Crespin (1947) have referred to the South Yarra occurrences.

The embayments in the vicinity of the South Yarra railway station and the Botanical Gardens have resulted from the basalt flow forcing the River Yarra against the Silurian rocks of the south bank (see text-figure 1). In the Museum I have found the collections of marine shells listed by Kitson. At that time, Dr. G. B. Pritchard also made a collection from the Friendly Societies' Gardens (now Olympic Park) frontage of the Improvement Works, and this also is in the Museum. The fauna includes a number of small shells of *Anadara trapezia,* the warmer water form so characteristic of the black silt formation. Brander's Ferry was at the downstream end of the Improvement Works, and marine fossils collected from there by F. P. Spry on 5th February 1897 are in the Museum. The writer collected black silt with marine fossils from the excavations for the Swan Street bridge, but the material may not have been *in situ.*

The diatom flora of locality 5 (see text-figure 2) presents an interesting contrast with those of localities 1 to 4. It is definitely marine and has diatoms from a number of habitats, but the freshwater element is reduced to three rare species. This is due to the fact that no stream enters the river at this locality.

Locality 6

Green Gully, Keilor. Mr. A. A. Baker, of the Field Naturalists Club, kindly drew my attention to this occurrence, which Miss Irene Crespin noted in 1926 (p. 103). The deposit is in a miniature island about five feet high in the floor of the small creek which runs down this valley. The site is about three-quarters of a mile in a direct line up the creek from its junction with the Maribyrnong River, south of Keilor. The 100 ft. contour of the military map is practically on the spot. The diatoms occur in a dark carbonaceous sandy clay with plant remains, which in turn is overlain by a light-brownish gravel from which the writer collected a marsupial bone.

The composition of the flora is shown in text-figure 2, and shows the deposit to be a marine one into which a limited amount of freshwater forms were washed. There are no specifically brackish forms. The explanation lies in the youthful physiography of the area. The creek has a deep and steep valley. As the stream is a small one, no great quantity of freshwater diatoms would grow there, and being steep, no brackish water is likely to accumulate. The occurrence of the brackish-water gasteropod *Coxiella* in a small deposit of limestone a little further downstream may be connected with the retreat of marine waters. However, too little is known at present of the area to provide a fully satisfactory explanation.

B. Freshwater Floras

Omitting Blandowski's doubtful reference, Ulrich's (1875) brief description of the Talbot "infusorial earth" is the earliest account of a Victorian fossil freshwater diatom flora I can find. Krause (1886, 1887), Card and Dun (1897), Herman (1902), Gregory (1903), Kitson (1906), Hunter 1909), Mahony (1912), Chapman (1914, 1919), Dun (1917), Howitt (1936), Thomas (1937), and Crespin (1946) list and/or describe freshwater diatomites in Victoria not mentioned in this paper.

Locality 7

Coburg, Victoria. An account of this deposit is given by Hanks (1930). The locations he describes are in the vicinity of the Batman railway station, and on the west side of Merri Creek. The diatomite is pure, and Mr. Hanks advises me that it is younger than the Newer Basalt. About a mile from this site, Mr. Hanks discovered a clay overlying the basalt and containing *Diprotodon*, a giant kangaroo of the *Macropus titan* group, and other marsupials (Hanks 1931, 1934*a*, 1934*b*). He also found bones of extinct marsupials in deposits under the basalt. On such evidence, and on physiographic grounds, the basalt is considered to be late Pleistocene in age.

The diagram in text-figure 2 presents a sharp contrast with those for the deposits from the Yarra Delta. There is no longer a wide spread of habitats, the radii being limited to two sectors of the diagram. Of 22 species, all are freshwater except for five which are tolerant also of brackish conditions. The diatomite is a typical freshwater deposit, and was probably laid down in a small lake.

Locality 8

Brunswick, Victoria. Mahony (1912) noted the presence of this specimen in the Museum, and Crespin (1947) listed it, but no other information seems to be available concerning the precise origin of the rock or its stratigraphical relationships. Text-figure 2 shows the flora to possess eight freshwater species and two brackish species. This diatomite varies from most of this series by the presence of definitely brackish water forms.

Locality 9

Yarraford Avenue, Fairfield. Mahony (1912) gives details of this occurrence. Yarraford Avenue runs south from Heidelberg Road to the River Yarra, south-east of Fairfield Park railway station. Stratigraphically, this rather pure diatomite overlies the Newer Basalt, and so is Pleistocene or Holocene in age. The diagram in text-figure 2 indicates a rich flora of 26 species all of which are freshwater except three that are tolerant also of brackish-water conditions.

Locality 10

Craigieburn, Victoria. This locality is 25 miles N.N.W. of Melbourne, and is also known as Mickleham. Its pure diatomite has been worked commercially (Mahony 1912) and is a typical freshwater deposit (see text-figure 2).

Locality 11

Grange Burn, Western Victoria. This is a new locality from which a sample was collected by the writer when investigating other fossil plants at the site. Mr. G. Coates of the nearby town of Hamilton found the outcrop, and with Mr. P. McNaughton kindly guided me to the place. Grange Burn is a creek which runs west from Hamilton, flowing ultimately into the Wannon River. About one and a half miles west of Hamilton, the road to "Clifton" and "The Caves" branches off from the Digby Road, and on the north side of Grange Burn north-west of this corner (immediately east of the east boundary of Mr. P. McNaughton's property) is locality 11 (military map, Hamilton sheet, grid reference 496,346). Text-figure 3 shows a field notebook sketch of the relationships of the rocks. The shaft noted was put down by Mr. Coates on an area stripped of basalt for road metal. The final part of the excavation was made by auger, and finished on hard bedrock believed to be quartz porphyry. The section proved was as follows:

1 ft. 6 in.	yellowish diatomite
1 ft. 6 in.	grey clay
8 ft. 0 in.	black sapropelic clay with pollen and some leaves
	? quartz porphyry
11 ft. 0 in.	Total depth

The talus in text-figure 3 marks the location of a minor fault, a number of which was noted in the area. The creek section shows the diatomite to occur immediately under the basalt. The black clay contains *Araucariacites australis* (see Cookson and Duigan 1951). A nearby bore in the property of Mr. P. D. McNaughton penetrated about thirty feet of basalt, under which was limestone

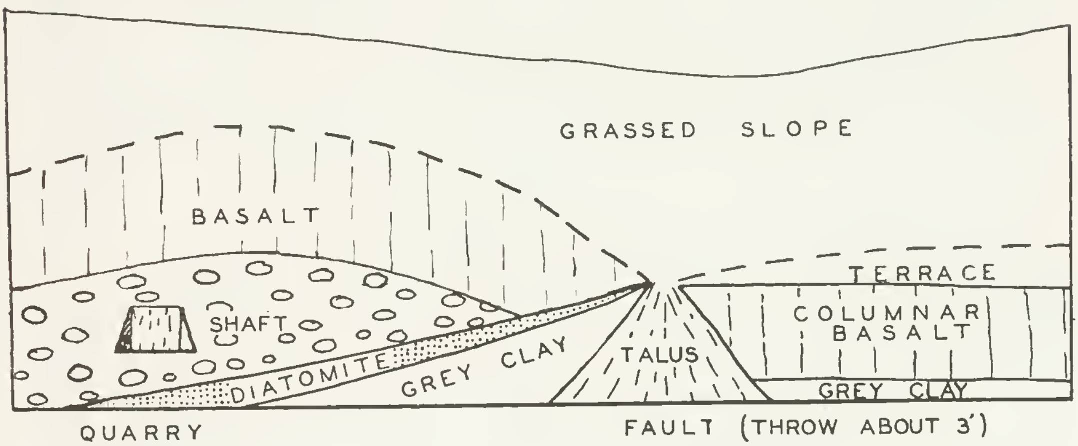

FIG. 3

Diagrammatic sketch showing field relationships of the Grange Burn diatomite. The black clay containing *Araucariacites* pollen came from the shaft shown above.

and shells. Further downstream where the creek has cut through the basalt, the limestone can be seen under the lava. Fossils show the limestone to be marine and of Lower Pliocene age. On it has been developed a podsol soil, and small softwood trees have been preserved by the basalt in place of growth in the soil, though charred by the heat of the basalt. Thus, after the retreat of the Lower Pliocene sea, a terrestrial facies was developed as evidenced by the podsol fossil soil, a marsupial tooth found therein, the trees, leaves, pollen, and diatomite, all of which were covered by the basalt. The pollen and the wood prove the existence of the old Tertiary softwood forest which grew in sub-tropical conditions, and which disappeared with the onset of the comparatively frigid conditions of the Ice Age. The foregoing evidence shows the age therefore to be Upper Pliocene. It is intended to provide later a full account of the late Tertiary ecology as shown by these sections, and its implications for Quaternary studies.

Text-figure 2 shows that the Grange Burn diatomite possesses a typical freshwater flora.

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