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Art. VII.—*The Age and Physiographic Relationships of the Cainozoic Volcanic Rocks of Victoria.*

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I. Introduction.

It has always been realized that the determination of the geological ages of the various Cainozoic lavas that occur in this State is a difficult task, and that, as Skeats has remarked, one's conclusions must frequently be based "only on conjecture or analogy." Nevertheless, by correlating stratigraphical, petrological and physiographical data collected over a long period, certain generalisations have been arrived at concerning these rocks, which have been widely, though not universally, accepted. Thus it has come to be believed that there were two main periods of eruptive activity during the Cainozoic Era, during which an Older Volcanic Series, of Oligocene to Lower Miocene age, and a Newer Volcanic Series, of Pliocene to Recent age, were developed (Smyth, 1858; Skeats, 1910; Singleton, 1935). Furthermore, maps published after 1902, on which the Older and Newer Volcanics are differentiated, show all the Cainozoic lavas east of the meridian of Melbourne as Older Volcanics, Newer Volcanics being restricted to the region west of the meridian of Melbourne. This view was tentatively accepted by Skeats (1910) in the absence of definite evidence that would indicate the presence of Newer Volcanics in eastern Victoria, and I also adopted it in discussing the physiography of the Eastern Highlands (1935). Recent work, however, indicates that this generalisation is unsound, and evidence for the presence of Newer Volcanic rocks in the Eastern Highlands will be presented in the first section of this paper.

The Newer Volcanic Series is currently regarded as dominantly Pleistocene with a few Pliocene and Recent members (Singleton, 1935, p. 134; Jutson and Coulson 1937), but Walcott (1920, p. 83) has suggested that the upper flows at Pitfield Plains, which are typical Newer Volcanics as far as their field occurrence is concerned, may be Miocene in age, and that there may have been no well marked break in volcanic activity between the extrusion of the Older and Newer Volcanic Series. Sussmilch (1937) has gone further, and grouped most of the Newer and Older Volcanics, so distinguished by Victorian geologists, together as Lower Pliocene, and David (1932, Table I.) regarded the main period of extrusion of the Newer Series as Upper Pliocene. In early official publications by members of the Geological Survey (summarised in Murray's *Victoria: Geology and Physiography*, 1895) the Newer Volcanic Series was also stated to be Pliocene, but in a recent pamphlet (Prospector's Guide, 3rd Edn., 1936) these rocks are classed as Pliocene to Recent.

In view of the conflict of opinion regarding the age relationships of the Older and Newer Volcanics, I propose to discuss in the second section of this paper the evidence adduced by previous authors concerning the age of these rocks, together with such new stratigraphical and physiographical evidence as I have been able to obtain. Edwards (1938) has recently discussed the petrology of the Older Volcanic lavas, and data from this aspect will be dealt with only incidentally in the following account.

II. The Cainozoic Lavas of Eastern Victoria.

In view of the wide acceptance of the generalisation concerning the non-existence of Newer Volcanics in this district, which is given official recognition in the latest geological map of the State published by the Mines Department (1936), and also in an earlier edition (1908), it is interesting to note that on the larger scale, 1902 map (1 inch=8 miles), several patches of Newer Volcanic rocks are marked in the Eastern Highlands. In the legend of this map, however, one such patch (Gelantipy) is classed as Older Volcanic, suggesting that this and the other patches may have been coloured as Newer Volcanic owing to an oversight. On the other hand, Dunn, who was Director of the Survey when the map was prepared, has referred in print (1914) to one such patch, a few miles south of Euroa, mentioning the occurrence of scoria cones, ash beds, and vesicular and dense lavas which he compared with the typical Newer Volcanics of Western Victoria. It may be, therefore, that the colouring was given to these occurrences intentionally, but, if so, no reason for the subsequent change in the 1908 map, on which they are shown as Older Volcanics, is known to me, and there are indications in the older literature that the view expressed on the 1902 map may have had some foundation in the beliefs of the geologists of the last century.

It is clear, for instance, that it was at first only McCoy's comparison (1878) of the sub-basaltic leaf remains on the Dargo and Bogong High Plains with the Miocene flora of Europe that caused the Survey to class these and other Cainozoic lavas in the Eastern and South Gippsland Highlands as Older Volcanics, for Howitt (1879) stated that he believed all the North Gippsland occurrences, including those of the High Plains, Morass Creek, Gelantipy, and South Buchan, to be Newer Volcanics. Owing to McCoy's work and the partial elucidation of the stratigraphy of South Gippsland, the High Plains occurrences and those of Aberfeldy, the South Gippsland Highlands, Berwick, &c., were subsequently classed as Older Volcanics, but since no published statement as to the existence of stratigraphical or physiographical evidence of the age of many of the smaller patches of lava in the Eastern Highlands had been made, I conclude that later reference to these as Older Volcanics (e.g. Dunn (1907) and Murray (1908) on Morass Creek, and the Geological Survey in the 1908 and 1936 maps) are based "only on conjecture or analogy."

Direct stratigraphical evidence that would serve to define precisely the ages of these patches is, indeed, lacking, and one is necessarily forced to rely on physiographical analogies with occurrences whose age can be determined from stratigraphical data. South Central Victoria and South Gippsland afford excellent standards by which to judge the age of the lavas of the Eastern Highlands, for their geology and physiography are known in considerable detail, and they afford examples of lavas of diverse age and physiographical setting. They will therefore be used as key areas in the following discussion.

Older Volcanics in South Central Victoria and South Gippsland.

Although Sussmilch has argued that the so-called Older Volcanic lavas of Berwick, Tanjil, Aberfeldy, Narracan, and Morwell are of Lower Pliocene age, all Victorian workers are agreed that they are either Oligocene or Lower Miocene. The latter belief is founded in part upon the direct stratigraphical evidence that the lavas are interbedded with the base of the main lignite series, which is regarded (Singleton, 1935, p. 128) as either of the same age or slightly older than Lower Miocene or Upper Oligocene marine beds penetrated in bores further to the east. This evidence appears to be reasonably sound if the lignites penetrated in the eastern bores may be correlated approximately with those of the Morwell district, and Sussmilch's claim that the Morwell lignites may pass upwards into the Lower Pliocene has little bearing on the age of the basalts, since these occur near the base of the series (Edwards, 1938).

By avoiding any attempt at correlation of the definitely Pre-Miocene Older Volcanics of the Mornington Peninsula and Melbourne District with those of Berwick and South Gippsland, Sussmilch minimizes the evidence that the former afford as to the age of the latter. This procedure is not justified, however, for the lavas of the Mornington Peninsula are separated from those of South Gippsland only by the Koo-wee-rup swamp, which is an area depressed by late Tertiary faulting, during which, as shown by boring, the basalts were thrown down to 436 feet below sea level at Lang Lang. There is no reason to doubt that before the faulting a more or less continuous lava field stretched from Drouin and Heath Hill to the Peninsula (Keble, 1918), with outlying residuals as at Berwick and Mt. Ararat, east of Berwick.

As in South Gippsland, leaf beds are associated with the lavas on the Mornington Peninsula and also in the Melbourne district. The continuity of physiographical conditions is obvious, and there can be little doubt as to the similarity of age. This is shown to be Lower or pre-Miocene by the evidence of bores at Tooradin and surface geology near Melbourne, so it may be concluded that, of the lavas specifically referred to as Lower Pliocene by Sussmilch, the Tanjil, Tanjil East, Narracan, Berwick, Morwell, and Aberfeldy occurrences are in reality Lower Miocene or Oligocene, and would therefore be referred to the Older Volcanic Series, as is generally recognized in Victoria.

Physiographically these lavas are characterized by their mature dissection, and the fact that they have been affected by block faulting of probable Middle or Upper Pliocene date (Hills, 1935). South of the Eastern Highland boundary the lavas have been elevated to 1,500 feet above sea level in the South Gippsland Highlands, and depressed 300 feet below sea level, beneath the Gippsland Plain at Yarragon. Where they have been exposed at the surface in these districts, all initial superficial features of the flows have been completely obliterated, and such centres of eruption as have been recognized have been completely degraded, no longer retaining the form of hills of accumulation (Edwards, 1934).

North of the Gippsland Plains, on the southern slopes of the Eastern Highlands, block faulting is no longer important, and residuals such as the Tanjil series and those on the interfluve between the Aberfeldy and Thomson Rivers slope gradually downwards towards the plains where they pass beneath Tertiary sediments. These residuals are maturely dissected, and again no initial superficial features are preserved. Their physiographic setting is shown in the block diagram (Fig. 1). In all essentials the authenticated Older Volcanics of the Melbourne district show physiographic features comparable with those above described for the Gippsland lavas.

The Cainozoic Lavas of the Eastern Highlands.

Morass Creek.—The lavas of the Morass Creek extend from Uplands, about 6 miles north of Benambra township, to the Gibbo River, a distance of about 10 miles. They have been mapped by Stirling (1888), who classed them simply as Tertiary, but on the 1902 geological map they are shown as Newer Volcanic, while on later maps they are shown as Older. Skeats (1910) followed the later maps, referring them to the Older Volcanic Series, and Murray (1908) did the same. In recent publications, however, Thomas (1937, pp. 572-575) and Kenny (1937, pp. 461-464) have briefly indicated the physiographic youth of the lavas, and Easton (1937,

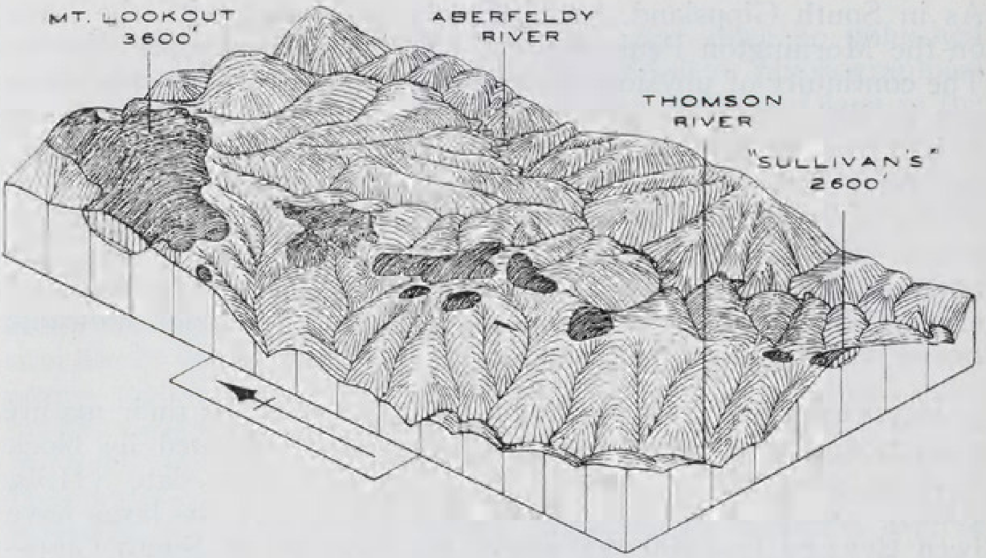

Fig. 1.—Block Diagram to illustrate the physiographic setting of the Older Volcanic lava residuals betwen the Thomson and Aberfeldy Rivers. Approximate scale North-South, 1 in. = 1½ miles.

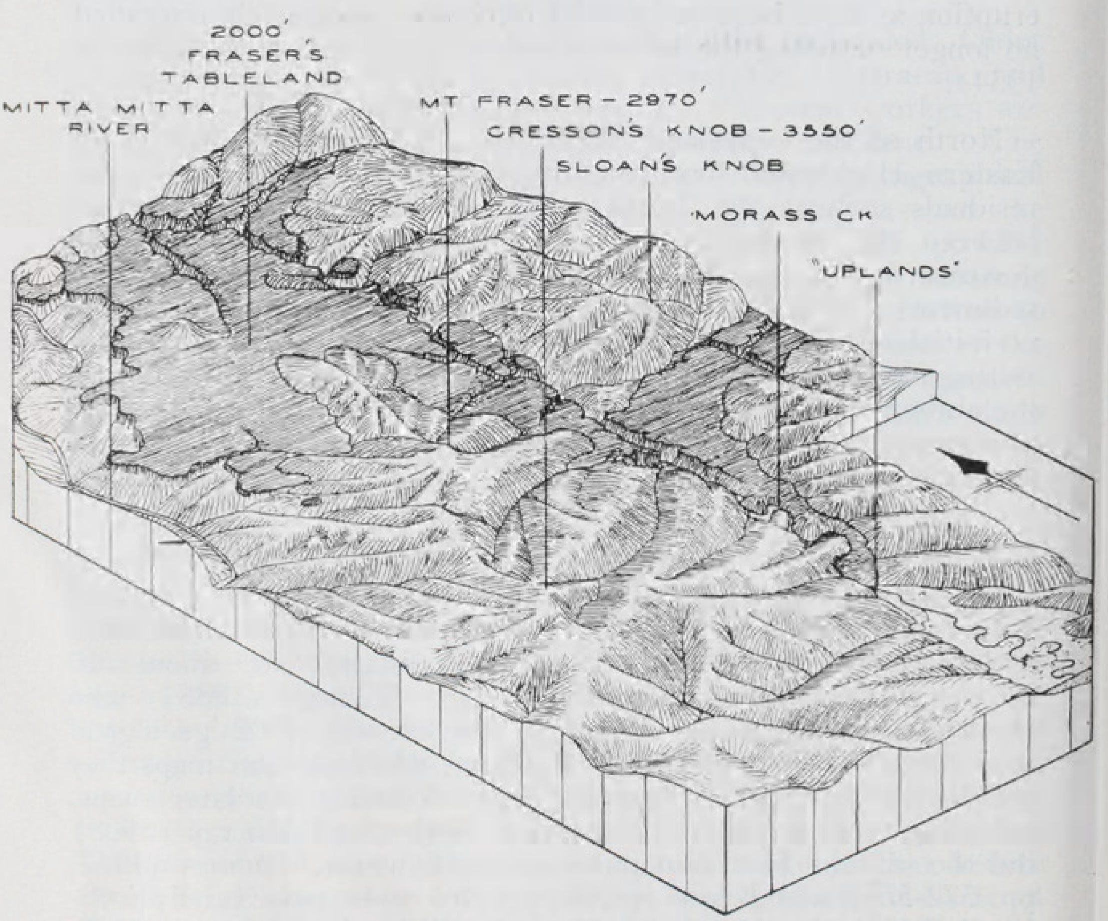

Fig. 2.—Block Diagram to illustrate the physiographic setting of the Morass Creek basalts. Approximate scale North-South, 1 in. = 1½ miles.

p. 507) actually refers to them as Newer Basalts. I visited the district in 1937, and the following account is based mainly on personal observation.

The valley of Morass Creek has been excavated in hard Palaeozoic rocks, mainly slates, conglomerates, gneisses, and porphyries. In the neighbourhood of Benambra the valley floor is broad and marshy with a shallow lake adjacent to the town, on the eastern side of the low ridge separating the basin of Lake Omeo from Morass Creek. The alluviated portion of the valley narrows to the north (downstream) and at Uplands the Morass Creek basalts are to be seen. From this point downstream to the Gibbo River, the main valley floor is occupied by lavas, several superposed flows being recognisable in cliff sections. All the specimens examined petrologically are basalts, and it will be convenient to refer to the suite as the Morass Creek basalts.

As is shown in the block diagram (Fig. 2), the walls of the pre-basaltic valley rise high above the lavas, which flowed both up and down the valley of the pre-existing stream, probably from a centre of eruption marked by the hill rising above Fraser's Tableland. They also flowed up the valleys of tributary streams, and, as Easton has shown, up the valley of the Gibbo River for a distance of about 5 miles, where they dammed the river and initiated a lake in which extensive deposits of alluvium were laid down (1937, p. 508). The flat-topped lava plateaus such as Fraser's Tableland, with their surfaces dotted with boulders of vesicular basalt, are reminiscent of many of the young lava plains of Western Victoria, and, as in this district, the stage of dissection of the flows is youthful. The Morass Creek has now cut a gorge, mainly along the eastern edge of the basalts, but over extensive areas the initial surfaces of the upper flows are but little modified by erosion.

A feature strongly indicative of youth is the preservation of the broad alluvial flats upstream from Uplands. Topographic data supplied by the maps of the State Electricity Commission show that the whole of the alluviated reach lies below the level of the top of the basalts and is indeed almost a horizontal plane surface. There can be no doubt that these flats were deposited in a lake formed by the damming of Morass Creek by the basalts. Although this lake has been drained owing to the lowering of the basalt barrier as the creek has become incised into it, large areas are still marshy, and near Benambra a small lake still remains. It is only in the actual vicinity of the barrier that the flats are now beginning to be removed by the stream.

It will be clear that the Morass Creek basalts are in no way comparable physiographically with the typical Older Volcanics of the key areas. The Aberfeldy residuals, which lie at approximately the same elevation above sea level as the Morass Creek flows, afford a standard for comparison (see Figs. 1 and 2), and the vastly greater denudation that these Older Volcanics have suffered under comparable physical conditions indicates the relative youthfulness of the Morass Creek flows. In the preservation of the lacustrine deposits, the slight degree of modification of the initial surface features of the flows by erosion, the existence of a hill of accumulation at the probable point of eruption, and the youthful nature of the Morass Creek where it traverses the lavas, they resemble the Newer Volcanic basalts that occupy the valley of the lower Yarra, which will later be shown to be probably Pleistocene in age.

In view of the fact that they are situated at an elevation of more than 2,000 feet above sea level, it may be assumed that the Morass Creek basalts are perhaps even younger than those of the Yarra valley. In any case, the conclusion is unavoidable that they are late Cainozoic, and thus referable to the Newer Volcanic Series. A short account of the petrology of the basalts will be found in the Appendix.

Gelantipy.—The Cainozoic lavas of this district lie on the tableland between the Murrendal River on the west and the Snowy River on the east, about 2,000 feet above the latter stream (Ferguson, 1899). They extend for about 20 miles as a north-south strip, commencing from a point about 10 miles north of Buchan. According to the reports of Ferguson, and Brough Smyth's account of Murray's explorations (1875, p. 5), the basalt ends in escarpments along the Snowy River, but hills of porphyry and Devonian limestone rise above the flows. Ferguson mentions the occurrence in shaly layers of the wash beneath the lavas, of leaf impressions "resembling Miocene forms" (1899, p. 21). Howitt (1879) at first regarded the lavas as Newer Volcanics, and they were marked as such on the 1902 map, but Dunn (1907) referred to them as Older Volcanics, and they have been marked as such on later maps. Petrologically all the specimens examined may be broadly described as basalts (see Appendix), and the suite will be referred to herein as the Gelantipy basalts.

The physiographic features shown by these lavas, where I examined them near Gelantipy, are certainly not as youthful as those of the Morass Creek basalts. In the Gelantipy district they do, however, still lie below the level of the walls of the pre-basaltic valleys, and it is clear from the above descriptions that they are also lower than remnants of the pre-basaltic interfluves in other places. The Snowy River is well known to be a particularly powerful stream, and Ferguson's account shows that it is physiographically youthful in the area under consideration. In places the walls of its gorge are only 30 feet apart. Thus, it is quite conceivable that its 2,000 feet deep valley should have been excavated along the edge of the basalt flows during a relatively short period. At Gelantipy the dissection of the flows is much less advanced than that of the Older Volcanic residuals at Aberfeldy and Tanjil, being comparable with that of many of the Newer Volcanic lavas on and near the divide in Central Victoria. I consider, therefore, that the Gelantipy basalts are younger than the Older Volcanics of South Gippsland. They are, however, older than the Morass Creek basalts, since the initial surface features of the flows have been much modified by erosion, and I would suggest that they are probably comparable in age with the Pliocene members of the Newer Volcanic Series, which will be described later.

South Buchan.—The small patch of basalt (see Appendix) occurring at this locality lies at an elevation of less than 1,000 feet above sea level. The surface features are largely obscured by soil, and it is possible that the existing occurrences are only remnants of larger flows.

On some of the hills both north and south of Buchan, high-level fluviatile gravels and sands occur that one would class, in the absence of definite evidence, as probably Pliocene, by analogy with the alluvial leads in Western Victoria. The Pliocene Torrent Gravels of the Gippsland Plain, too, extend up for some miles into the southern part of the Eastern Highlands as hill cappings up to 600 feet above sea level (Howitt, 1875), and it is not unreasonable to suppose that the Buchan gravels are of similar age to these. On a hill a few miles south of Buchan a thoroughly decomposed basic dyke, well exposed in a road cutting, cuts the gravels, and what appear to be lenticular basic flows, now also decomposed, are interbedded with them. In the absence of more definite evidence concerning the age of the gravels, it would be hazardous to assume a Pliocene age for the dyke and interbedded flows, or to relate them to the South Buchan basalts. The impression gained in the field is, however, that the latter may be even younger than the hill cappings of gravel, as they occur at lower levels than these, and also lie below the neighbouring hills of Devonian limestone. Although very indefinite, the indications are that the South Buchan basalts may perhaps be regarded as Upper Cainozoic or at least younger than the Oligocene and Miocene Older Volcanics of South Gippsland. Howitt (1879) mentioned them as Newer Volcanics, Murray (1875) as Older, and they were shown as Newer on the 1902 map, but Older on the 1908 and later ones.

Euroa.—In the valley of the Seven Creeks, from about three miles south of Euroa for a distance of seven miles upstream, there is an isolated patch of Cainozoic limburgites (see Appendix) which like those occurrences above discussed, was marked as Newer Volcanic on the 1902 map, and Older Volcanic on later maps. Dunn (1914) has given a very brief account of these lavas, referring to the presence of scoria and ash beds and small volcanic cones. From personal observation, I would confirm Dunn's remarks as to the recent appearance of the flows in this district, though in a rapid examination of the district I was unable to discover any scoriae or ashes. This small lava field occupies the floor of the main valley of the Seven Creeks, which is deeply incised into the surrounding granitic tableland of the Strathbogie Ranges. Both dense and vesicular varieties of the limburgites occur, and many of the small flows have the peculiar ridge-like form of the Western District stony rises. Two rocky prominences near the confluence of the Wombat and Seven Creeks are probably among those referred to as points of eruption by Dunn, but their real nature is not absolutely certain. They break suddenly up from the surrounding well grassed plains, and ridges suggesting flows emanate from them.

If they merely represent residual hills owing their rocky character to some initial difference in texture of the flows, it is difficult to explain the almost complete absence of limburgite boulders in the creeks, which are filled with sand from the neighbouring granites. In any case, the position of the lavas in the floor of the main valley, and the lack of co-ordination of the drainage in the lava-filled section of this valley, are clear evidence of the youth of the flows, and they are to be correlated with the younger members of the Newer Volcanic Series.

Although I have not investigated in detail any of the other patches of Cainozoic lavas in the Eastern Highlands, it may be pertinent to summarize such information as is available concerning them.

At Glenmaggie basalts whose relationships to the Tertiaries of the Gippsland plain are uncertain but which still lie below the level of the interfluves of the pre-volcanic streams, have been described by Murray (1877), who compared them with the Older Volcanics of Tanjil (p. 56). Mr. Baragwanath informs me, however, that he considers the Glenmaggie basalts to be younger than the typical Older Volcanics of South Gippsland, since they do not occur as residuals capping the hills, but lie in the pre-basaltic valleys, whose walls in places rise above them.

Owing to their association with the *Cinnamomum* flora, the Dargo and Bogong basalts must be regarded as not younger than the Lower Pliocene, and possibly as of greater antiquity than this, since this flora was already well developed in Oligocene times (see p. 124). Hunter (1898) considered that there is evidence of two flows in places, with an erosion interval between them. Mr. M. A. Condon has recently surveyed portions of these High Plains, and has kindly supplied me with a sketch section showing the mode of occurrence of a small patch of scoriae, agglomerate, and tuffs with associated lavas, at Roper's Lookout, near Mt. Cope. He considers the section to be portion of a denuded volcanic cone, and if this is substantiated by later work, it would constitute the first record of its kind in the High Plains. Occurring as it does as an isolated patch some distance from the main lava residuals, the occurrence has no direct bearing on the age of the latter. It does indicate, however, the possibility that late Cainozoic volcanic activity may have taken place in the district, for it is unlikely that a superficial and easily erodable deposit such as these pyroclastic rocks afford, would have been preserved under the conditions of strong denudation that obtain in the High Plains, since early or middle Cainozoic times.

Finally at Mahaikah, petrologically typical Older Volcanics overlie lignities of possibly Oligocene or Lower Miocene age (Edwards, 1938).

It will now be clear, firstly that definitely Newer Volcanic rocks occur in the Eastern Highlands, at Morass Creek and Euroa, and possibly also at Roper's Lookout, near Mt. Cope. Authentic Older Volcanic flows also occur at Mahiakah, in the Aberfeldy, Tanjil, Berwick, and other districts, and also in the South Gippsland Highlands, and in the Gippsland Plains. The Dargo and Bogong High Plains may have flows of several different ages, but the main suite is perhaps to be classed with the Older Volcanic Series. The Gelantipy and South Buchan basalts and also those of Glenmaggie are of doubtful age, but the available evidence indicates that they are intermediate between the Morass Creek basalts and the Older Volcanics of South Gippsland, and may provisionally be regarded as Newer Volcanics.

III. The Cainozoic Volcanic Rocks of Western Victoria.

In recent publications Singleton (1935), Sussmilch (1937), and Jutson and Coulson (1937) have discussed in general terms the question of the age of the so-called Newer Volcanic Series in the area west of the meridian of Melbourne. There is general agreement that some of these rocks are of Recent age, but while Singleton and also Jutson and Coulson place the main period of extrusive activity in the Pleistocene, Sussmilch regards is as Lower Pliocene. Coulson (1938) has defined with some precision the ages of several individual flows in the Geelong district, the ages assigned ranging from Upper Pliocene to Pleistocene.

The stratigraphic data used to determine the ages of the volcanic rocks by these authors differ to some extent. Sussmilch relies mainly upon the evidence of the deep lead floras such as those of Pitfield Plains and the Haddon lead, but makes use also of Keble's interpretation of the geology of the Drik Drik district, and physiographical evidence. Jutson and Coulson base their conclusions upon the relationship of the basalts to the old consolidated Pleistocene dunes, the Lara and Limeburner's Point limestones, the shell beds described by them at Portarlington, and on their interpretation of the history of the Port Phillip area during late Cainozoic times. Largely as a result of their interpretation of the Portarlington beds, they reach conclusions as to the coastal geology of the Port Phillip area which diverge widely from those formerly accepted, and would necessitate, if accepted, very considerable modification of our ideas as to the physiographic evolution of this area. References to most of the older literature are to be found in the above works, also in Walcott's paper (1920) on the age of the auriferous drifts, and in Hunter's account of the deep leads (1909).

The Evidence of the Fossil Floras.

As a result of his survey of the deep lead floras, Sussmilch draws the conclusion that the fruits and leaves occurring beneath or interbedded with the lavas of Dargo, Narracan, Berwick, Morwell, Bacchus Marsh, and Pitfield, in Victoria, Vegetable Creek and Dalton in New South Wales, and the Redbank Plains in south-eastern Queensland, belong essentially to a single floral association called by him the *Cinnamomum* Flora. Although he recognizes that some of the members of this flora existed in pre-Pliocene times, perhaps even in the Miocene, he concludes that the flora was "abundant and widespread in Pliocene times", and would regard most of the lavas associated with the flora as Lower Pliocene. This position seems to me to be untenable, for if the evidence from the bores in East Gippsland, above referred to, may be taken as demonstrating the Oligocene or Miocene age of the Yallournian lignites, then the *Cinnamomum* Flora must have been already well established in these periods. In view of Sussmilch's claim that the flora is more characteristic of the Pliocene than of older periods, the further evidence of its antiquity afforded by the Redbank Plains beds, in Queensland, is significant. There, *Cinnamomum* and other members of the flora are associated with fresh water fish remains, which I have referred, with some reservation, to the Oligocene (1934). Sussmilch, however, discounts the evidence of age afforded by the fishes, noting that *Epiceratodus denticulatus*, from the Redbank Plains beds, is close to the Pleistocene and Recent *E. forsteri*; that *Phareodus queenslandicus* is a new species and thus perhaps of little stratigraphical value; that *Notogoneus parvus* is of doubtful generic position, and that *Percalates antiquus* closely resembles the living *P. colonorum*. I have, however, gone further into the evidence of age afforded by these fishes, and have no reason to doubt their Lower Tertiary age.

It may be pointed out that all other known species of the genus *Phareodus*, as well as the related genus *Musperia* (Sanders, 1934), which occurs in Sumatra, are restricted to the Eocene. Furthermore, the distinction between *P. queenslandicus* and the Eocene *P. testis*, from North America, so far as I have been able to judge from published descriptions and from photographs kindly supplied by the Museum of Comparative Zoology, Harvard, and the American Museum of Natural History, New York, is based only on differences of a minor nature. They reside chiefly in the number of vertebrae, which may vary within the limits of a single species, and the dentition, which is largely developed in response to feeding habits: I have not been able to compare the squamation. In referring the Queensland species to the Oligocene I have made some concession to the evidence of a younger age for these beds, which is afforded by the presence in them of *Epiceratodus* and *Percalates* (see below).

Concerning the doubtful generic position of the Gonorhynchid, *Notogoneus,* upon which Mr. Sussmilch comments, I consider that the essential point for our present purposes is not the generic position of the fish, but the fact that we have to deal with a member of a well-defined group within the family. This group, which includes *Notogoneus* (with which the Queensland example is undoubtedly closely allied), *Colpopholis* and *Phalacropholis* of Europe and North America, is confined to fresh water deposits, whereas the living members of the family are marine. These fresh water Gonorhynchids range from Ypresian (Eocene) to Rupelian (Oligocene) (see Chabanaud, 1931), and there are therefore strong grounds for referring the Redbank Plains beds to one or other of these Lower Tertiary periods.

Although *Percalates antiquus* resembles the living *P. colonorum* very closely, I cannot agree that this indicates a younger age than I have suggested. The osteological characters of Percoid fishes are remarkably stable, even generic distinctions being based, when osteological characters are used as a criterion, on such minor features as the nature of the spines on the pre-operculum (see Woodward, 1901, p. 504). Thus, the Eocene *Cyclopoma* is distinguished from the living *Lates* solely on differences in these spines, and as the differences between *P. colonorum* and *P. antiquus* are of a higher order than this, though in my opinion not such as to warrant generic separation, I think it is reasonable to assume that the fossil species is not, of necessity, to be regarded as Upper Tertiary. Little can be said concerning the Dipnoan, *Epiceratodus denticulatus,* in view of the fragmentary nature of the remains, but it may be remarked that *Epiceratodus* ranges down into the Cretaceous (White, 1926), and as the Redbank Plains fish is distinct from *E. forsteri,* its occurrence in presumably Oligocene beds is not inconsistant with the known facts.

In view of these considerations, I think it is justifiable to rely mainly on the Osteoglossid and Gonorhynchid as index fossils, since these give definite evidence of age, in so far as our present knowledge goes. These forms indicate an Eocene or Oligocene age, and in suggesting the latter I have made some concession to the claims of the other species. In my opinion it is preferable to regard the evidence from the Redbank Plains as indicating the antiquity of the *Cinnamomum* flora, rather than the youth of the fish remains.

The *Cinnamomum* flora is essentially an Australian one (Deane, 1901), and includes not only genera (e.g. *Cinnamomum*) that are restricted to-day to the warmer and moister parts of the continent, but also genera such as *Casuarina* and *Eucalyptus* that still live in Victoria. It is clear, therefore, that climate or topographic changes have caused the dying out of the sub-tropical types in Victoria, while other genera have lived on in spite of such changes.

I have already shown (1935) that during the Pliocene, important earth movements took place in Victoria, and it may be that the existing floral association was initiated during and after these movements, which may have been accompanied by a climatic change. *Cinnamomum* itself is known to occur in beds at Beaumaris that may be either Lower Pliocene or Upper Miocene in age (Singleton, 1935), but there is no evidence of its occurrence in Victoria in beds shown by the evidence of marine fossils to be younger than the Lower Pliocene.

Due allowance being made for the incompleteness of the fossil record, it may be assumed, therefore, (1) that *Cinnamomum*, and other genera belonging to Deane's "brush" type of flora, not now living in Victoria but found in the warmer and moister parts of Australia, serve to indicate an Oligocene, Miocene, or possibly Lower Pliocene age; and (2) that an "open forest" flora from which the above types are absent, but which includes *Eucalyptus, Banksia, Casuarina*, and other genera now living in the State, indicates a post-Lower Pliocene age. The possibility must also be considered that communities of the older flora may have persisted locally under favourable conditions into post-Lower Pliocene times, especially along the southern portions of the Eastern Australian Cordillera, in New South Wales.

In view of these conclusions, the association of the *Cinnamomum* flora with volcanic rocks at Glenfine, south of Pitfield, assumes considerable importance. Sussmilch (1937, p. xvi) accepts this association at its face value as indicating that all the basalts at Pitfield, including the upper flows which are typical members of the Western District suite, are Lower Pliocene in age. Walcott (1920, p. 86) considers that the basalts may be even older than this, being Middle or Lower Tertiary, since they "must have had [their] origin in the same period" as the leaf beds and the gold drift.

Chapman and Singleton (1923, p. 14) have indicated, however, that the lower basalts at Glenfine are probably Older Volcanics, and this view has much to support it. The section at Glenfine is shown in Figure 3. There is only a patch of about 40 acres where the lower lavas occur (Hunter, 1901), and it will be noted that these occupy a valley eroded in the bedrock. The upper of the two basal flows has, in all probability, been planed down by fluviatile erosion to the level of the rock floor upon which the Pitfield wash rests, and the 40-acre patch of lower basalts must represent only a remnant of formerly more widespread flows. There is thus a considerable time gap between the upper flow and those that underlie it, so that the leaf beds do not prove the superficial lavas of the district to be Lower Pliocene or older.

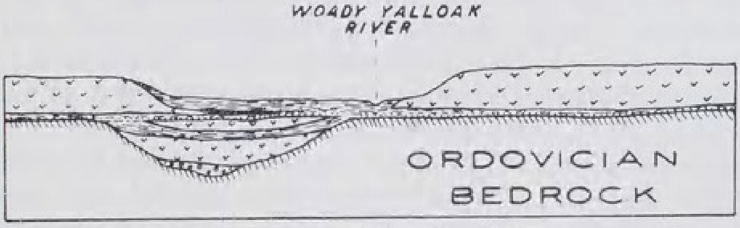

Fig. 3.—Section showing the relationship of the upper and lower lavas at Glenfine Consolidated Mine, Pitfield Plains. The leaf beds with *Cinnamomum* occur between the two lower flows. The auriferous Pitfield wash lies beneath the upper flow. Horizontal scale, 1,600 ft. = 1 in.; vertical scale, 800 ft. = 1 in., datum 140 ft. above S.L. (After Hunter, 1901.)

It remains now to consider the age of the fruit-bearing leads that in places underlie Cainozoic lavas in the Haddon, Nintingbool, Tanjil, Rokewood, and other districts, in relation to that of the *Cinnamomum* Flora, and of the leads with *Eucalyptus, Banksia,* and fossil wood, such as those of Creswick and Eldorado. I believe it to be unlikely that von Mueller's determinations of the affinities of the various fruits he described are to be relied upon, as Deane has shown that certain of his species are allied to living Australian genera, so that there is little point in discussing at length their stratigraphical significance. It is clear that some of the plants from which the fruits were derived existed in Oligocene or Miocene times, since they occur under the undoubted Older Volcanics of Tanjil, but neither their upper nor their lower limit has been precisely defined, and it may be that some of them ranged above the Lower Pliocene, which, as has been shown above, may be regarded as the upper limit of the *Cinnamomum* Flora in Victoria. The Haddon fruit-bearing leads are in all probability younger than the *Cinnamomum* beds of Pitfield (see p. 131).

The Evidence of the Pleistocene Dunes.

At several places around the Victorian coast, from Barwon Heads to Portland, Cainozoic volcanic rocks come into stratigraphic relationship with consolidated calcareous sand dunes that are generally accepted as Pleistocene in age, though Jutson and Coulson regard them as ranging from Upper Pleistocene to Recent (1937).

The Quaternary stratigraphy of Victoria is not known in sufficient detail to enable the age of the dune rocks to be determined by direct evidence, but if the theory propounded by Sayles (1931) to account for the formation of the remarkably similar ancient dunes of Bermuda be accepted, then it may be possible to arrive at the age of the Victorian dunes by analogy. Having found by detailed studies that there were five periods of active dune-building in Bermuda, separated by periods of soil formation, Sayles correlated the former with periods of maximum ice-cap development during the Pleistocene, and the latter with inter-glacial epochs. It is suggested that, as the waters of the oceans were lowered owing to the growth of ice caps, the broad tracts of sandy sea floor so exposed supplied the material for forming the dunes, and that during inter-glacial and post-glacial times the re-advance of the sea caused active dune building to cease. On this hypothesis, Pleistocene dune-building should have been a world-wide phenomenon, and if it should prove possible to correlate the periods of dune building with those of maximum ice cap development, then the old dunes would form a very convenient geological time scale in non-glaciated regions. Daly (1935) has interpreted the old dune series described by Durègne in Gascony along those lines, and it is interesting to note that Darwin (1876) has compared the consolidated dunes of King George Sound, in Western Australia, with those of the Cape of Good Hope, Madeira, and Bermuda, also noting (p. 99) that the dune limestones of St. Helena must have formed when that island was surrounded by a shelving coast quite unlike its present precipitous shores. Tate (1879) was also impressed with the necessity for postulating a lowering of sea level, which would produce a shelving sandy coastline, to explain the formation of the Pleistocene dunes at the head of the Bight.

The conditions postulated by Sayles and Daly would admirably explain the formation of the old dune series in Victoria. At times of maximum glaciation large tracts of Bass Strait would have been above the sea, and the masses of comminuted shells so exposed would have been blown by southerly and south-westerly winds over the present coastal fringe of Victoria, and the islands in Bass Strait.

On nearly all the islands in the Strait that were examined by Johnston (1888) old consolidated sand dunes occur up to a height of 100 feet above sea level. These old dunes are dominantly composed of fragments of marine shells, but owing to the presence in them of bands rich in various species of land snails such as *Helix*, *Succinea*, etc., Johnston named then the *Helicidae*

Sandstones. Myriads of individuals belonging to various species of these genera live to-day on the vegetation cover of the dunes, and their shells are washed into hollows, forming layers like those found in the dunes themselves. Johnston classed the dunes as Recent in the Table on p. 303 of his book, but listed certain of the fossils obtained from them as Pleistocene (p. 329). David (1932, Table I.) referred them to the base of the Recent period.

Around the south coast of Australia, in Victoria, South Australia, and Western Australia, the old consolidated dunes exhibit similar features to the *Helicidae* Sandstones. At Cape Schanck and Barwon Heads ancient soil layers formed during periods of cessation of dune building are rich in fossilised shells of *Helix* and other land gasteropods, Pritchard (1895) having recorded *Helix* and *Bulimus* from Barwon Heads and also from a point about a mile west of the Gellibrand River. Tate (1879) has referred to similar occurrences of *Helix* and *Bulimus* in the old dunes at the head of the Bight, and Darwin (1876, p. 163) recorded *Helix* from St. George's Sound, where the shells "abound in all the strata." These fossils have no stratigraphical significance since they have not been studied in detail, but they do indicate that the dunes were formed at these different localities under comparable physiographical conditions. All observers are agreed that the consolidated dunes are older than the coastal dunes now forming, and since it is necessary to postulate a different coastal topography from that which now exists, in order to adequately explain their development, it appears to me to be a reasonable assumption that they formed during the world-wide depressions of sea level that occurred during the Pleistocene glaciations.

A noteworthy feature of the old dunes is their division into roughly horizontal layers whose upper and lower surfaces truncate the planes of cross-bedding. This is well shown at Barwon Heads, Cape Schanck, and Cape Otway, and has been described by Wilkinson (1865), Griffiths (1887), and Coulson (1935) in Victoria, and by Tate (1879) in South Australia. These sub-horizontal layers represent periods of cessation of active dune building, during which friable sandy soils, white travertine bands, or black rubbly carbonaceous layers were developed.

At Barwon Heads there is evidence of the presence of five such periods of soil formation after the commencement of the formation of the dunes and before the present day. Without detailed study it would be unsafe to correlate them even tentatively with inter-glacial epochs, as Sayles does with the Bermuda dunes, but consideration of the record of the Sorrento bore (Chapman, 1928) does suggest that the Pleistocene period exhibits in Victoria a succession of periods of dune building with intervening periods of sand stability, and it may be tentatively assumed, therefore, that the old dunes of the Victorian coast range throughout the Pleistocene. Detailed studies will be necessary to confirm this, but in what follows, formations which are overlain by the consolidated dunes are referred either to pre-Pleistocene or Lower Pleistocene times. This view is opposed to that of Jutson and Coulson, who place the lower portions of the dune series in the Upper Pleistocene, and its upper portions in the Holocene (p. 323). On the view put forward here, the dunes would cease to form when the last ice maximum passed, so that it is only the unconsolidated, and usually very restricted dunes now in process of formation that would be classed as Holocene.

Where the Cainozoic volcanic rocks come into relationship to the Pleistocene dunes, as at Portland, Port Fairy, Warrnambool, and Barwon Heads, we find that the lavas underlie them, but between Port Fairy and Warrnambool, tuffs from Tower Hill overlie them. Clearly, therefore, the Tower Hill tuffs must be classed as late Pleistocene or Recent, and this view has always been the accepted one. The lavas, on the other hand, must be placed either within the Lower Pleistocene, if the dunes do not cover the whole of Pleistocene time, or in pre-Pleistocene times if the base of the dunes is Lower Pleistocene. Since the lavas are nowhere interbedded with the dunes, there are good grounds for assigning to them a pre-Pleistocene or basal Pleistocene age. This conclusion, of course, refers only to the flows at the particular points mentioned.

IV. Regional Summary of Occurrences.

West of the Hopkins River and Bushy Creek.

In the Portland district, basalts, in places deeply weathered and locally associated with tuffs (Kitson, 1906; Dennant, 1887), occupy valleys eroded through Barwonian limestones and through an oyster bed. The latter was referred to as Miocene by Dennant, but was doubtfully correlated with the Ostrea Limestone that conformably overlies the Werrikooian shell beds along the Glenelg River by Singleton (1935). If the Ostrea bed at Portland is Werrikooian, which is not certain, the basalts must be regarded as epi-Pliocene, for they are overlain by Pleistocene dunes at Cape Bridgewater. In places they have a thin capping of sand (Kitson), and have been extensively eroded by the sea along the coast.

Basalts which are probably older than the Portland flows, and form dissected plains and residual ridges, occur at Mt. Clay and the Kangaroo Range, Drik Drik. At the latter locality (see geologically coloured Parish Plan, Drik Drik; also Keble's remarks in Sussmilch, 1937) the basalts appear to be pre-Werrikooian and are certainly post-Barwonian. These occurrences are outlying patches of a dissected lava plain stretching from the coast northwards to Branxholme, Hamilton, and Dunkeld, and east to the Hopkins River. At Hamilton they overlie marine Kalimnan beds, and they form a physiographically well-defined unit (see Block Diagram, Fig. 4) characterised by deep dissection, especially in the north, and strong weathering. They may therefore be grouped together as post-Lower Pliocene (Kalimnan) and pre-Pleistocene, perhaps pre-Upper Pliocene if their relations to the Werrikooian are correcly interpreted. They may therefore be regarded as Middle Pliocene.

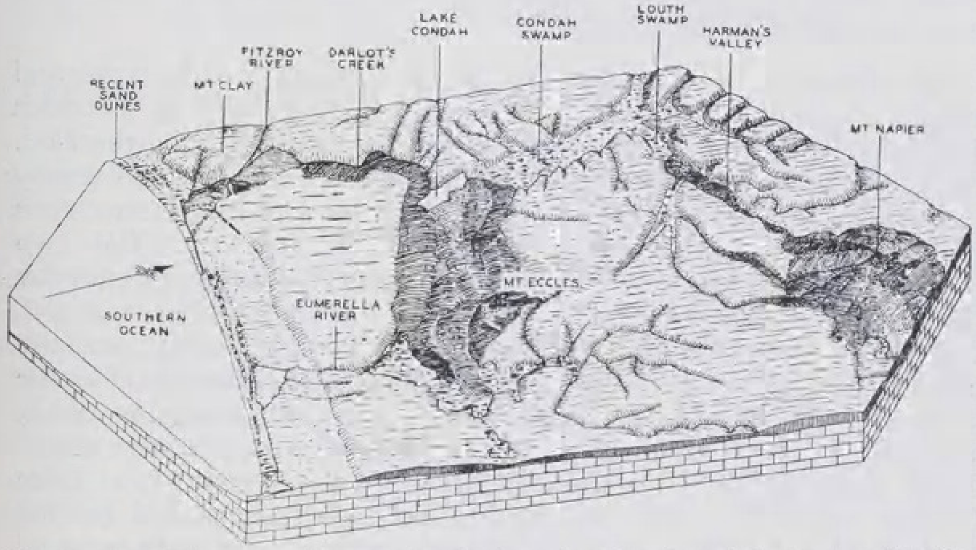

Fig. 4.—Block Diagram to illustrate the physiography of portion of the Western District lava plains. The bedrock, shown diagrammatically, consists of Miocene limestones. These are overlain by maturely dissected Middle Pliocene lavas, except near the coast where the limestones appear at the surface. The Stony Rise flows from Mt. Napier (1,440 ft.) and Mt. Eccles (580 ft.) are shown schematically. Approximate scale North-South, 1 in. = 13 miles.

The Stony Rises.—As shown by Mahony and Grayson (1910, Skeats and James (1937), and by Sussmilch (1937), there are at several localities in the Western District, flows of very recent appearance, which are known as Stony Rises.

In the district under consideration such flows occur around Mt. Napier, Mt. Eccles, and Mt. Rouse. That they are considerably younger than the older lavas referred to above is clear from the fact that, as at Byaduk and the Fitzroy River, they flowed down valleys cut into these lavas. The flow down Harman's Valley, at Byaduk North, appears to be the youngest in the district. At its lower termination, near Wallacedale, it spread out as a wide sheet over the upper reaches of the Condah Swamp, there known as the Louth Swamp, where a remarkable group of low domes, or "lava blisters," was formed by the expansion of water vapour imprisoned beneath the flow, as shown by Skeats and James. The Condah Swamp itself was caused by the damming back of Darlot's Creek by flows from Mt. Eccles, so that the Harman's Valley flow is younger than these latter. Details of the initial surface features of the flow are still perfectly preserved and there can be no doubt as to its Holocene age. As the other Stony Rises around Mt. Napier have exactly similar relationships to the pre-existing, dissected lava plain as does the Harman's Valley flow, they and the compound scoria cone at the summit of the mount, with its well developed breached crater on the western side, are also to be referred to this period. On the lower flanks of Mt. Napier, on the northern and eastern sides, there are perfectly preserved low scoria cones which are also undoubtedly Holocene.

Mt. Eccles is situated on the northern border of a large and roughly rectangular area of Stony Rises, extending between Darlot's Creek, on the west, and the Eumerella River on the east. A long lava tongue extends southwards from Lake Condah nearly to the coast, separating the Fitzroy River flowing along its western margin from Darlot's Creek along its eastern, until the two streams unite at the termination of the flow. Physiographically these Stony Rises are exactly comparable with those around Mt. Napier, as they occupy, or have over a large area actually obliterated, valleys eroded through the older, presumably Pliocene lavas and the Barwonian limestones that appear along the coast, and they preserve their initial surface features in perfect detail. They dammed back Darlot's Creek, forming the shallow Lake Condah and the Condah Swamp, and are also responsible for the formation of the swamps along the Eumerella River south-west of Macarthur. These features are all indicative of extreme youth, and the flows must be classed as Holocene.

Around Mt. Rouse, Stony Rises of recent appearance exist close to the scoria cone itself, but the flows extending southward for about 10 miles from Penshurst, although physiographically younger than the older flows of the Hamilton and Portland district, are not typical Stony Rises. They appear to be intermediate in age between the Recent flows and the more deeply dissected lavas near Port Fairy that pass beneath the dune limestones, for although they have been weathered much more deeply than the Stony Rises, their topography still reflects in large measure the configuration of individual flows. Nearer the coast stream dissection is important in determining the topography. The Moyne Swamp was not caused by interruption of pre-existing drainage lines by the lavas, as was the Condah Swamp, but occupies a sagged area, perhaps connected with the solution of underlying Tertiary limestones. Since the lavas near the coast pass beneath the Pleistocene dunes at Port Fairy (Ferguson, 1920), I would suggest that they are to be correlated with the Pliocene flows further west. The Stony Rises near Mt. Rouse are, by analogy with the occurrences at Mt. Napier and Mt. Eccles, to be regarded as Holocene, and the flows south of Penshurst are therefore possibly Pleistocene.

As already indicated, the tuffs from Tower Hill overlie the Pleistocene dunes, forming a layer of variable thickness that follows the topography of the underlying dunes at least as far east as Warrnambool, and west to Port Fairy. Tuffs cover the whole of the Tower Hill Swamp and the marsh north of the Barwonian limestone ridge that runs easterly from Tower Hill, and they also overlie Recent shell beds (Brough Smyth, 1858). The Recent age of the tuffs is thus confirmed.

The District between the Hopkins River and Inverleigh.

The youngest flows in this district are typical Stony Rises, which by analogy with those above described are to be regarded as Holocene. They are developed around Mt. Porndon, the Warrion Hills, and Red Rock (Skeats and James, 1937), and also around Mt. Elephant, Mt. Leura, and Mt. Terang (Mahony and Grayson, 1910). Large areas of the southern portion of this district are covered by tuffs which in places contain or overlie remains of extinct marsupials. At Mamre Station a fossil fern, *Pteris aquilina*, has been obtained from them (Mahony and Grayson, 1910). Although it is often assumed that the giant extinct marsupials are characteristically Pleistocene, Walcott (1920) has shown that they may range from Pliocene to Holocene, so that they cannot be used as index fossils. The tuffs at the Warrion Hills, Red Rock, and Mt. Porndon that overlie the Stony Rises must be Holocene, and those covering the floors of lakes and swamps south-east of Mt. Shadwell and near Camperdown are also probably of this age, as they form a mantle over the countryside like those of Tower Hill, and overlie clays from which an artefact was obtained at the Pejark Marsh (Walcott), 1919).

The older lavas of this district, which are characterised by more extensive weathering, the development of buckshot gravels, and by their dissection by streams have been referred to the Lower Pliocene by Sussmilch, and an even earlier age, perhaps Miocene or older, by Walcott (1920). The evidence adduced by these authors is afforded by the leaf beds at the Glenfine Extended Mine at Pitfield, the Haddon and Nintingbool fruits, and the supposed termination of the Pitfield wash along a Miocene shoreline running westerly from Rokewood. The evidence of the Glenfine leaf beds has already been discussed, and it is clear that they have no bearing on the age of the superficial lavas of the area. If, however, the sub-basaltic Pitfield wash is really coeval with the Miocene beds further south, then the basalts might conceivably be of an age not far removed from the Miocene. This, however, I would deny, for the evidence from boring shows that the Pitfield wash forms a thin sheet beneath the upper basalts, resting on a planed down bedrock surface that was undoubtedly cut by streams after the uplift of the "Oldest" drifts. These drifts have been compared with the uplifted Kalimnan and Barwonian sands and gravels in the Melbourne district, and may be littoral deposits of Miocene or Lower Pliocene age. The Pitfield wash is younger than these gravels, and Krausé has shown (1886) that the Haddon fruit-bearing leads are also younger than them. Fossil fruits have recently been obtained from the Pitfield Plains, and I regard the Pitfield wash as similar in age to the Haddon and Nintingbool fruit-bearing leads. The basalts, therefore, are Post-Miocene, and may be Pliocene or even younger.

The Geelong and Melbourne Districts.

At the Moorabool Viaduct, flows from the Anakies, which although warped along the Lovely Banks axis, are not deeply dissected (except along their western edge by the Moorabool) overlie calcareous sands, referred by Mulder (1902) to the Werrikooian. Jutson and Coulson (1937) have compared these sands with Pleistocene or Recent shell beds at Portarlington (see below), and Singleton (1935) is doubtful of their Werrikooian age, but the fauna has not been critically reviewed, and their Upper Pliocene age may be accepted for the present. Thus the Anakies flows are either very late Pliocene or younger, and as their dissection by the Moorabool indicates that they are not Recent, they may be either late Pliocene or Pleistocene. Physiographically they resemble the flows from Mt. Duneed that are overlain by Pleistocene dunes at Barwon Heads, and overlie Lower Pliocene sands (Coulson, 1938). I therefore regard them as late Pliocene or early Pleistocene. For further details concerning the Geelong district the paper by Coulson (1938) should be consulted.

In regard to the basalts of the Melbourne district, it is necessary to review the radical changes that Coulson and Jutson have suggested in the interpretations of the Melbourne Tertiaries. They argue from the supposed fact that beds at Portarlington, regarded by them as Pleistocene, grade into ferruginous sands resembling lithologically certain of the Red Beds (Hall, 1911) in the Melbourne district, that these Red Beds are therefore Pleistocene and not Barwonian and Kalimnan, as formerly believed. On this interpretation the basalts of Footscray, Essendon, and the Yarra Valley must be Middle, or, more probably, Upper Pleistocene, as they occupy valleys eroded through the Red Beds.

I have examined the sections described by these authors at the Pier and at Steele's Rock, Portarlington, and can find no evidence of the supposed merging of the calcareous and sandy beds one with the other. At the Pier it appears to me that the shell beds were artificially laid over the ferruginous series, a possibility that was noted and rejected by Jutson and Coulson. The dark, shell-bearing sands merely form a plaster on the old cliff face, and cannot be seen to pass into the sands. At Steele's Rock the shell bed is a true geological stratum, but it is only necessary to indicate the dips of the ferruginous beds on the section given by Jutson and Coulson to see that any merging of the two series is impossible. The ferruginous sands are current bedded and, also, at the eastern end of the section, warped about an axis running southwards, so that their dip is variable, but the shell bed forms a superficial layer overlying the truncated bedding planes of the red sands, on the top of the cliff. These two sections, therefore, do not necessitate any change in the accepted interpretation of the age of the Red Beds of the Geelong and Melbourne districts.

In the Melbourne district the youngest flow is that which occupies the Yarra Valley. Here, young features such as the Gardiner's Creek and Templestowe Flats, which represent alluvium deposited in lakes caused by lava barriers, are still preserved, and in its upper parts the basalt has been but slightly trenched by streams.

As shown by Kitson (1902), the marine deposits recorded beneath the creek alluvium at Forest Hill by Coates (1860) are best explicable on the hypothesis that the basalt cut off an arm of a pre-existing estuary, representing a tributary of the drowned valley of the pre-basaltic Yarra. If the drowning that produced this estuary were correlated with the post-glacial rise of sea level, then the Yarra basalt would be Recent, but its physiographic features indicate a greater antiquity than this, and it may be that the estuary was formed during an inter-glacial epoch, so that the basalt can be assigned to some part of the Pleistocene.

Since the extrusion of the Tertiary basalts of the Keilor Plains, the Maribyrnong River has cut a young valley through them. After this valley was first incised, erosion was temporarily superseded by deposition near the coast, and an alluvial filling was deposited on the valley floor, which was later entrenched, giving the paired terraces of the 40-ft. level at West Essendon and Maribyrnong. Similar paired terraces occur along the lower course of the Moonee Ponds Creek. At a later date still, the mouths of the rivers draining into Hobson's Bay were drowned, causing tidal influences to be felt for a distance of about 9 miles up the Maribyrnong. It is clear from this sequence of events that these flows dissected by the Maribyrnong are considerably older than those which occupy the valley of the ancestral Yarra, but there is nothing to indicate whether they are Pleistocene or Pliocene. There is no doubt, however, that they are post-Kalimnan.

In regard to the age of the basalts of the Bacchus Marsh district, which overlie sands of doubtfully Upper Miocene age, containing *Cinnamomum*, a little-known paper by Brittlebank (1900) has some significance. By embedding wires of different lengths in the rocks exposed in the bed of the Werribee River, Brittlebank estimated the time that has elapsed since that river began to cut its present gorge. The results from three different stations showed a remarkable agreement, averaging 1,040,000 years. No allowance was made in this estimate for possible higher rainfall during past times or for the effects of undercutting of hard rocks underlain by soft Tertiary sands or glacial deposits, so that the estimate might possibly be more correct if the values given were halved. If this is done, the value of 520,000 years so obtained would place the date of the Rowsley fault somewhere near the beginning of the Pleistocene, so that the basalts are almost certainly Pliocene.

V. Summary and Conclusions.

In this paper the data available for the determination of the ages of the various Cainozoic volcanic rocks of Victoria have been critically reviewed. The *Cinnamomum* Flora has been shown to have a probable range in this State from Oligocene to Lower Pliocene, and the consolidated dune series, which is here correlated with the *Helicidae* Sandstones of the Bass Strait islands, is considered to range throughout the Pleistocene. Use has also been made of physiographical analogies with occurrences of known age, in dealing with the lavas of the Eastern Highlands.

Those volcanic rocks whose ages can be determined with some degree of precision fall into two groups—an Older Series, of Oligocene to Lower Miocene age, and a Newer Series, of Middle Pliocene to Recent age. It is possible that some of the flows that overlie beds containing members of the *Cinnamomum* Flora may bridge the gap between these two series, but no flow that can be dated by marine fossils or other means actually does so. Thus, the suggestion (Walcott, 1920; Edwards, 1938) that volcanic activity may have been continuous from Oligocene to Recent times, with a marked lull in the Middle and Upper Miocene and the Lower Pliocene still remains to be confirmed, and I consider it preferable, as a working hypothesis, to regard the two series as distinct.

Appendix.

Petrological Descriptions.

1. *Morass Creek.*

All the described specimens were obtained from sections along the road from Benambra to Corryong, between Uplands and the Gibbo River. Numbers in brackets refer to slides catalogued in the collection at the Department of Geology, University of Melbourne.

Olivine-iddingsite basalt [5259].—This is a highly vesicular and absolutely fresh rock with a bluish "bloom" in the vesicles. It consists of micro-phenocrysts of partially iddingsitized olivine set in a fine-grained intergranular groundmass of pale greenish-grey augite prisms, laths of basic andesine (Ab_{56}), and iron ore grains. Numerous minute apatite needles are included in the felspar and also in interstitial isotropic or weakly polarising colourless material, which is probably a felspathic glass.

Olivine basalt [5260, 5261].—These are non-vesicular but porous rocks, rather coarser in grain than the vesicular type. They contain micro-phenocrysts of unaltered olivine set in an intergranular groundmass of pale green and greyish augite with pale violet and greyish violet titan-augite, olivine granules, and plagioclase laths, some of which are zoned from a central core of andesine-labradorite (Ab_{50}) to an outer rim of oligoclase (Ab_{20}). Interstitial yellow-green serpentine [5262], rare iddingsite [5261], apatite needles, granules and plates of iron ores, and turbid glass are also present. A "pipe vesicle" [5258], contains fewer olivine phenocrysts than the average rock, and has larger felspar laths, which are shot through with long apatite needles. Rare xenocrysts of quartz in [5262] and [5263] are surrounded by rims of green augite, and in [5263] the texture is much coarser than usual, in the neighbourhood of the quartz inclusions. There, large skeletal crystals of pale green augite are associated with dendritic platy steel-grey iron ores, and large plagioclase grains. Near the xenocrysts the olivine is iddingsitized, and interstitial brown glass, calcite, and radial aragonite occur.

2. *Gelantipy.*

Most of the described specimens were collected from sections along the Buchan-Woolgulmerang Road. Numbers in parenthesis indicate distances in yards either north (N) or south (S) of the most northerly bridge over Butcher's Creek, about 3 miles south of Gelantipy. Other specimens were obtained from a natural section along Butcher's Creek about a mile north of this bridge.

Porphyritic olivine basalt (1862 S.) [5271].—This is a dense rock containing acicular glassy phenocrysts of plagioclase up to about 5 mm. long, a few amygdales of calcite, and rare turbid phenocrysts of anorthoclase. The plagioclase phenocrysts are labradorite Ab_{35}, and are twinned on the Carlsbad, albite, and pericline laws. A few partially serpentinized micro-phenocrysts of olivine are present, and the groundmass consists of an intergranular aggregate of colourless augite prisms, iron ore grains, and plates and laths of andesine-labradorite, Ab_{50}. Green and smoke-grey glass, the latter full of minute specks of iron ores, fill the interstices, together with a few small apatite needles. The anorthoclase phenocrysts are each composed of an aggregate of distinct individuals, which have evidently passed through a stage when they were not in equilibrium with the magma, as their cores are spongy, containing numerous small inclusions of augite and iron ore grains.

Olivine basalts.—The other basalts from this district are not macroscopically porphyritic, and most of them are dense and fine-grained, containing a few amygdales of calcite. They contain micro-phenocrysts of fresh olivine (550 N. [5267]) or pseudomorphs of serpentine after olivine

(2556 S. [5269]; 3033 S. [5264]) set in an intergranular groundmass of colourless augite granules, basic andesine (Ab_{60-65}) laths, and iron ores. In [5264], which is tachylitic, the mesostasis is a black glass full of specks of black iron ores, and the usual granular or platy iron ores are absent from this rock. In [5267] the glassy mesostasis is pale green, and in [5266] (713 N.) both black and green glass occurs.

[5265] (519 N.) is a vesicular and porous type, similar to the others except that it contains a red to red-brown mineral which is probably iddingsite, although in part it appears to have crystallized directly from the magma, as it has in places a banded colloform structure. A colourless isotropic mineral, of low refractive index, occurs as well defined interstitial grains. This is probably analcite.

The specimens from Butcher's Creek are both olivine basalts, but are richer in olivine than those above described, this mineral occurring both as micro-phenocrysts and as granules in the groundmass. The latter contains prisms of pale green and colourless augite, iron ore grains, and laths of basic andesine (Ab_{55}). In [5268], which is the lower flow at this point, green and yellow-green glass occurs in the mesostasis, while in the upper flow, [5270], the glass is black.

Throughout all the slides interstitial calcite is common, and minute apatite needles and rods occur in the felspars and the mesostasis.

3. *South Buchan.*

All the specimens were collected from a low hill on the west of the South Buchan-road, about 4 miles south of Buchan. Slides [5273-5276] are serpentinized olivine basalts, in which serpentine occurs both as pseudomorphs after olivine and as interstitial patches. The pyroxene is either green or a pale violet titanaugite, and the plagioclase basic labradorite, Ab_{35}. Black glass containing specks of iron ores is common.

No. [5272] is a dense black rock consisting entirely of small iddingsite granules, plagioclase laths (basic labradorite), interstitial pale green serpentine, and black glass, the latter being practically opaque, owing to the crowding of minute specks of iron ore within it.

4. *Seven Creeks, Euroa.*

[5277], from a stony knoll east of the confluence of Wombat Creek and Seven Creeks, and [5278], from the east side of Seven Creeks, about 2 miles downstream from the above, are both limburgitic basalts containing numerous phenocrysts of olivine, marginally iddingsitized, set in a fine-grained intergranular to sub-ophitic groundmass consisting of rods of colourless augite with much interstitial turbid glass and a few ill-defined large plagioclase laths. Large grains of black iron ores are plentiful. [5279], from a hill on the west side of Seven Creeks, in Allotment 27, Gooram Gooram Gong, is a true limburgite consisting of phenocrysts of unaltered olivine and colourless augite, some grains of which, however, have purple margins which are titaniferous. These are set in a dense groundmass consisting of augite rods with interstitial black glass. [5278] is a vesicular type; the others are dense.

Remarks.

Comparing the above lavas with the petrological types established by Edwards (1938), it will be noted that characteristic Older Volcanic types such as crinanites, ophitic titanaugite dolerites, and nephelinites are absent. The porphyritic olivine-poor basalt from Gelantipy appears to be tholeiitic in nature, although it cannot be established under the microscope that the pyroxenes are pigeonitic, as the grains are too small to enable 2V to be determined.

Iddingsite occurs in both Newer and Older Volcanic rocks, and its presence at all the above localities therefore has little significance. Nevertheless, this mineral is commoner in Newer Volcanic rocks than in Older.

Bibliography.

Brittlebank, C. C., 1900.—The Rate of Erosion of some Victorian River Valleys. *Geol. Mag.*, Dec. 4, n.s., vii., pp. 320-322.

Chabanaud, P., 1931.—Affinitiés morphologiques, répartition stratigraphique et géographique des poissons fossiles et actuelles de la famille des Gonorhynchides. *Bull. Soc. Géol. de France*, Ser. 5, i., pp. 497-517.

Chapman, F., 1928.—The Sorrento Bore, Mornington Peninsula. *Rec. Geol.. Surv. Vic.*, v. (1), pp. 192.

Chapman, F., and F. A. Singleton, 1925.—The Tertiary Deposits of Australia. *Proc. Pan. Pac. Sci. Congr. (Australia)*, 1, pp. 985-1024.

Coates, J., 1860.—On a Deposit of Diatomaceae at South Yarra. *Trans. Roy. Soc. Vic.*, v., pp. 158-164.

Coulson, A., 1935.—Geological Notes on Lake Connewarre, near Geelong. *Proc. Roy. Soc. Vic.*, n.s., xlviii. (1), pp. 1-10.

————, 1938. The Basalts of the Geelong District. *Ibid.*, n.s., 1 (2), pp. 251-257.

Daly, R. A., 1935.—The Changing World of the Ice Age. Yale Univ. Press.

Darwin, C., 1876.—Geological Observations on the Volcanic Islands, &c., 2nd Edn. London.

David, T. W. E., 1932.—Explanatory Notes to Accompany a New Geological Map of the Commonwealth of Australia. Australasian Medical Publishing Co.

Deane, H., 1902.—Preliminary Report on the Fossil Flora of Pitfield, Mornington, Sentinel Rock (Otway Coast), Berwick, and Wonwron. *Rec. Geol. Surv. Vic.*, 1 (1), pp. 13-14.

Dennant, J., 1887.—Notes on the Post Tertiary Strata in South-western Victoria. *Trans. and Proc. Roy. Soc. Vic.*, xxiii., pp. 225-243.

Dunn, E. J., 1907. Limestone Deposits at Wombat Creek and the Mitta Mitta River. *Rec. Geol. Surv. Vic.*, ii. (2), pp. 123-124.

————, 1907. Geological Notes on the Mitta Mitta River, North-east District. *Ibid.*, ii. (2), pp. 122-123.

————, 1914. The Tamleugh Quartz Reef and the Basalt Area near Euroa. *Ibid.*, iii. (3), p. 276.

Easton, J. G., 1937. Gibbo River.—Alluvial Deposits. *Ibid.*, v. (4), pp. 507-509.

Edwards, A. B., 1934.—Tertiary Dykes and Volcanic Necks of South Gippsland, Victoria. *Proc. Roy. Soc. Vic.*, n.s., xlvii. (1), pp. 112-132.

————, 1938.—The Petrology of the Tertiary Older Volcanic Rocks of Victoria. *Ibid*, n.s., li. (1).

Ferguson, W. H., 1899.—Report on Geological Survey of Snowy River Valley. *Geol. Surv. Vic., Prog. Rept.*, No. 9, pp. 20-22.

————, 1920.—Limestone at Aringa, near Port Fairy. *Rec. Geol. Surv. Vict.*, iv. (2), pp. 105-106.

Griffiths, G. S., 1887.—The Geology of the Portland Promontory, Western Victoria. *Trans. Roy. Soc. Vic.*, xxiv. (1), pp. 61-80.

Hall, T. S, 1911.—Victorian Hill and Dale. E. W. Cole, Melbourne.

Hills, E. S., 1934.—Tertiary Fresh Water Fishes from Southern Queensland. *Mem. Queensland Mus.*, x. (4), pp. 157-174.

———, 1935.—Section on Physiography in the *Handbook for Victoria, A.N.Z.A.A.S.*, Melb., pp. 78-89.

Howitt, A. W., 1875.—Notes on the Geology of part of the Mitchell River Division of the Gippsland Mining District. *Geol. Surv. Vic., Prog. Rept.*, No. 2, pp. 59-73.

———, 1879.—Notes on the Physical Geography and Geology of North Gippsland. *Quart. Journ. Geol. Soc.*, lv., pp. 1-41.

Hunter, S., 1898.—Dargo High Plains. *Geol. Surv. Vic., Prog. Rept.*, No. 9, pp. 50-54.

———, 1901.—The Pitfield Plains Goldfield. *Special Reports Dept. Mines, Vic.*

———, 1909.—The Deep Leads of Victoria. *Mem. Geol. Surv. Vic.*, No. 7.

Johnston, R. M., 1888.—Systematic Account of the Geology of Tasmania. Government Printer, Hobart.

Jutson, J. T., and A. Coulson, 1937.—On the Age of certain Marine Deposits at Portarlington, Victoria, with a Proposed Subdivision of the Post-Tertiary Rocks of the Port Phillip Bay District. *Proc. Roy. Soc. Vic.*, n.s., xlix. (2), pp. 314-326.

Keble, R. A., 1918.—The Significance of Lava Residuals in the Development of the Western Port and Port Phillip Drainage Systems. *Proc. Roy. Soc. Vic.*, n.s., xxxi. (1), pp. 129-165.

Kenny, J. P. L., 1937.—Dam Sites at Hinnomunjie and Morass Creek. *Rec. Geol. Surv. Vic.*, v. (4), pp. 461-465.

Kitson, A., 1902.—Further Notes on the River Yarra Improvement Sections at the Botanical Gardens, Melbourne. *Proc. Roy. Soc. Vic.*, n.s., xv. (1), pp. 41-46.

———, 1906.—Report on the Diatomite Deposits and General Geology of the Portland District. *Rec. Geol. Surv. Vic.*, i. (4), pp. 251-256.

Mahony, D. J., and H. J. Grayson, 1910.—The Geology of the Camperdown and Mount Elephant Districts. *Mem. Geol. Surv. Vic.*, No. 9.

McCoy, F., 1878.—In R. A. F. Murray's Report on the Geological Survey of Portions of Dargo and Bogong. *Geol. Surv. Vic., Prog. Rept.*, No. 5, pp. 96-117 (plants on p. 102).

Mulder, J. E., 1902.—Newer Pliocene Strata on the Moorabool River. *Proc. Roy. Soc. Vic.*, n.s., xiv. (2), pp. 82-84.

Murray, R. A. F., 1875.—Reported in Brough Smyth's *Prog. Rept.*, No. 2, *Geol. Surv. Vic.*, p. 5.

———, 1877.—Progress Report on Geology of Portion of Country between the Thomson and Wonnangatta Rivers, North Gippsland. *Ibid.*, No. 4, pp. 52-57.

Murray, R. A. F., 1908.—Basalt along the Gibbo River. *Rec. Geol. Surv. Vic.* ii. (4), pp. 195-198.

Pritchard, G. B., 1895.—The Sand-dunes of the Coast. *Geelong Naturalist*, iv. (3), pp. 40-44.

Sanders, M., 1934.—Die Fossilen Fische der alttertiären Süsswasserablagerungen aus Mittel-Sumatra. *Verh. Geolog.-Mijn. Genootsch. Nederland en Koloniën. Geol. Serie*, xi. (1), pp. 1-144.

Sayles, R. W., 1931.—Bermuda during the Ice Age. *Proc. Amer. Acad. Arts and Sciences*, lxvi., pp. 380-467.

SINGLETON, F. A., 1935.—Section on "Cainozoic" in *Handbook for Victoria, A.N.Z.A.A.S.*, Melbourne Meeting.

SKEATS, E. W., 1910.—The Volcanic Rocks of Victoria. *Pres. Addr. Sect. C, Rept. A.A.A.S., Brisbane*, 1909, pp. 173-235.

SKEATS, E. W., and A. V. G. JAMES, 1937.—Basaltic Barriers and other Surface Features of the Newer Basalts of Western Victoria. *Proc. Roy. Soc. Vic.*, xlix. (2), pp. 245-278.

SMYTH, R. B., 1858.—On the Extinct Volcanoes of Victoria, Australia. *Quart. Journ. Geol. Soc.*, xiv., pp. 227-235.

————, 1875.—*Progress Report*, No. 2, *Geol. Surv. Vic.*

STIRLING, J., 1888.—Second Progress Report on Preliminary Geological Traverse of the Western Boundary of County of Benambra. *Repts. of Mining Registrars*, Quarter ended 31st Dec., 1887; Appendix D (with map).

SUSSMILCH, C. A., 1937.—The Geological History of the Cainozoic Era in New South Wales. *Proc. Linn. Soc. N.S.W.*, lxii., pp. viii-xxxiii.

TATE, R., 1879.—The Natural History of the Country around the Head of the Great Australian Bight. *Trans. and Proc. Roy. Soc. South Aust.*, ii., pp. 94-140.

THOMAS, D., 1937.—Lake Omeo. *Rec. Geol. Surv. Vic.*, v. (4), pp. 569-575.

WALCOTT, R. H., 1919.—The Origin of the Volcanic Tuff of Pejark Marsh, Victoria. *Proc. Roy. Soc. Vic.*, n.s., xxxii. (1), pp. 1-10.

————, 1920.—Evidence of the Age of some Australian Gold Drifts, with special reference to those containing Mammalian Remains. *Rec. Geol. Surv. N.S.W.*, ix. (2), pp. 66-97.

WHITE, E. I., 1926.—On the Occurrence of the Genus *Epiceratodus* in the Upper Cretaceous Rocks of New South Wales. *Ann. Mag. Nat. Hist.*, xvii., pp. 677-682.

WILKINSON, C. S., 1865.—Report (relative to the Otway country). *Parl. Paper, Geol. Surv. Vic.*, No. 44.

WOODWARD, A. S., 1901.—British Museum Catalogue of Fossil Fishes. Part 4, pp. 498, 499.