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OF THE

GEOLOGICAL SURVEY OF VICTORIA

(E. J. DUNN, F.G.S., Director),

ISSUED BY

W. DICKSON, SECRETARY FOR MINES, UNDER THE AUTHORITY OF THE HON. PETER McBRIDE, M.P., MINISTER OF MINES.

No. 9.

THE GEOLOGY OF THE CAMPERDOWN AND MOUNT ELEPHANT DISTRICTS,

Descriptive of Geological Quarter-Sheet Maps Nos. 8 N.E. and 17 S.E. (New Series),

BY

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CONTENTS.

PREFATORY NOTE.

The maps of the areas described in this Report were made under the supervision of Professor Gregory by a number of senior students attending his classes in Geology at the Melbourne University, together with the writers of this Report. The field work was completed during the long vacations of 1902–3 and 1903–4.

The mapping was based on the parish plans, scale 2 inches to 1 mile, issued by the Lands Department. These were divided up into areas of about 4 square miles, with easily-found boundaries, such as fenced roads or water-courses or lake shores, and the geology of each of these areas was mapped in by a party of two men, who worked independently of those in the adjoining areas. The maps when completed were handed to the heads of the surveying party, and checked by comparing the boundaries with those of adjoining areas. Numerous specimens were collected, and typical examples chosen for petrographical examination and analysis.

Certain difficulties occurred in tracing the boundaries of formations in parts of the area which was dealt with, the ground often being quite flat and featureless and the rocks hidden with soil and buckshot gravel and a thick growth of grass. Many wells have been sunk, but at the time most of them were inaccessible. Records had been kept in some instances, but the terms used were so vague as to render them useless for geological work, the harder strata, for instance, often being called "rock" with no other description.

The report was originally prepared shortly after the completion of the survey, but publication was deferred owing to changes in the staff of the Geological Survey Branch, and to allow more pressing publications to be issued. In the meantime subsequent visits to the district and the examination of fresh sections exposed in road cuttings, &c., and comparison with other districts, such as Tower Hill, Koroit, have led to the extension and recasting of the whole Report.

On behalf of all the members of the field party, we desire to thank the many gentlemen in the district who assisted us by their kindness in allowing free access to their properties, and in supplying much valuable information as well as facilities for camping. We have also to thank Mr. Coakley, Chief Draughtsman to the branch and his staff for their care in accurately producing the quarter-sheet maps from the parish maps supplied to them. Professor Skeats and Mr. Stanley Hunter assisted us with friendly criticism, and to the former we are indebted for some of the views illustrating the occurrence of the Hampden tuffs. Mr. F. Chapman, A.L.S., palæontologist to the National Museum, has kindly revised the list of fossils and identified the foraminifera.

The remaining photographs of views and rock sections were taken by Mr. H. J. Grayson.

THE CAMPERDOWN AND MOUNT ELEPHANT DISTRICTS.

POSITION AND RELATION TO THE SURROUNDING COUNTRY.

The area described in this Report and geologically coloured in quarter-sheet maps Nos. 8 N.E. and 17 S.E., new series, is situated almost in the centre of the great volcanic plains of Western Victoria. These plains stretch from near the Glenelg River on the west to Port Phillip on the east, a distance of 160 miles, and are continued in a north-easterly direction for another 60 miles into the Melbourne Basin. The southern boundary of the volcanic series between the Glenelg River and Warrnambool lies near the coast from which it is separated by sand dunes and Cainozoic sedimentary rocks, and then continues easterly in a fairly straight line as far as the Barwon River. To the south of this portion extends a large area of late Cainozoic sands covered with heaths and forests, and the Cape Otway Ranges which consist of felspathic sandstones of Jurassic age. The northern boundary is more irregular. From its western extreme, near the Glenelg River, it first runs in a northerly direction till it almost reaches the southern end of the Victoria Range; it then trends south-eastwards past the Serra Range and the high-level Palæozoic rocks in the neighbourhood of Mount Stavely, where it again sweeps northwards as far as Ararat. From this point it skirts the highlands and extends as an irregular line as far as Maude, on the Moorabool River. Between Trawalla and Chepstowe a large branch passes northwards past Ballarat into the Loddon Valley. This branch rests on the ancient rocks of the plateau, and its general level is some 600 feet above the Western District plains. The difference of level is an original feature, and has not resulted from earth movements since the basalts were erupted. This is proved by the distribution of the marine Cainozoic beds, which were deposited prior to the extrusion of the basalt. The main volcanic plain is at its widest from Ararat southwards, where it measures 75 miles across, and its area is about 9,000 square miles. The rocks are all basaltic and occur either as lava flows or in a fragmental condition. It is the third largest plain of its kind in the world, and is exceeded in size only by the Snake River plains in the United States and the Deccan Plateau in India.

SURFACE CONFIGURATION.

The plains show little signs of denudation and are almost level, but they have a slight dip towards the south, a dip sufficient to determine the direction of the Hopkins River and the Mount Emu Creek, which traverse them. The fall between Darlington and Terang, a distance of 18 miles, is 86 feet. Numerous steep scoria cones rising 400 or 500 feet above the plains are striking features in an otherwise flat landscape. The whole region is like a broad smooth ocean turned to stone: the scoria cones are scattered islets, and the edge of the distant plateau an indented coast.

The following list of heights above sea-level of various scattered places indicates how flat the surface is:—

Weerite Railway Station ..	476 feet.	Bed of Lake Colongulac ..	432 feet.
Camperdown Railway Station	541 ,,	Darlington	503 ,,
Boorcan Railway Station ..	479 ,,	Hexham	432 ,,
Terang Railway Station ..	434 ,,		

Before going into details, a short general description of the area mapped as seen from the top of Mount Noorat will be attempted. Mount Noorat, which rises about 500 feet above the plains, is an isolated hill about 4 miles north of Terang. From the top almost the whole Western District is in sight. Its northern and western boundary can be traced by the distant hills on the horizon, and its southern limit is marked by the Otway Ranges and the forest country which separates it from the sea. The boundless plains are thinly timbered and dotted over with homesteads and long lines of plantations.

To the east, about 12 miles away, Bullenmerri forms a broad dome with gently-sloping sides, on which the town of Camperdown is partly built. Within this dome are Lakes Bullenmerri and Gnotuk, though they cannot be seen from this point of view. The shape detracts from the apparent height, for it is loftier than several of the more striking hills. The steep symmetrical cone of Mount Leura, the highest peak in the neighbourhood, is almost hidden behind it. To the south-west a low platform connects this dome with Ewan's Hill, which lies near the southern boundary of the map, about half-way between Camperdown and Terang, and is formed of a scoria heap whose steep sides merge into a long gentle slope, indicating an extensive lava flow. Behind it, some 40 miles away, are the Otway Ranges, which are very different in origin and character, having been sculptured by denudation from a thick mass of Jurassic sandstones and mudstones. Between them and the volcanic plains is the forest country, consisting of Cainozoic sands and clays. Mount Terang is low and inconspicuous, and the lake is only just visible. Between it and Ewan's Hill there is a hill resembling Bullenmerri, but it lies outside the area mapped. Lake Keilambete is the next feature which catches the eye. It is an almost circular sheet of blue water about a mile in diameter, and surrounded by a low rim whose gentle outer slope can scarcely be seen from this elevation, though its steep inner escarpment is plain enough. Beyond it lies Mount Garvoc, and, as the horizon is followed westwards, two other distant volcanic peaks—Mounts Napier and Rouse—are seen, and then Mount Sturgeon, a sandstone peak at the southern end of the Serra Range. These three peaks are all between 40 and 50 miles away. Twelve miles to the north-west, Mount Shadwell, a large composite volcano, rises to a height of 962 feet, and is a very conspicuous landmark. Far beyond it the serrated outline of the Grampians, which are formed from ancient sandstones, runs north and then east, to Mount William. The horizon then remains unbroken as far as the hills about Mount Ararat. Almost due north and about 20 miles distant is Mount Fyans, a low volcanic hill with gently sloping sides and its top covered with plantations. Just to the west of it another distant cone is visible, and beyond this again the granitic and sedimentary Ordovician rocks in the neighbourhood of Beaufort. Still tracing the horizon eastwards, the surface about 20 miles away is seen to swell gently upwards high enough to blot out the more distant mountains. This difference in level marks the position of some granitic rocks (mostly covered with basalt) which occur near Derrinallum. The next prominent hill is Mount Elephant, one of the highest and most conspicuous of all the extinct volcanoes in the Western District. It was named from its fancied resemblance to a kneeling elephant when viewed from the south. It is very steep-sided and symmetrical, and consists of a single large crater, whose northern wall has been breached by a lava flow. Mounts Koang and Kurtweeton (Cloven Hills) have the same general characteristics and the lava flow from the former is distinctly visible. Behind them and Mount Elephant, the distant scarp of the Ballarat Plateau looks like a mountain range, and Mount Warrenheip, a volcanic hill near Ballarat, 70 miles away, rises above it. Mount Meningoort is not so conspicuous as the Cloven Hills, although it is nearer. Beyond it and more to the east is Lake Bookaar, and still farther eastwards again is Lake Colongulac. Beyond the lakes are Mounts Myrtoon, Wiridgill, and the Warrions, all scoria heaps piled up on basalt platforms representing the lava streams which were erupted before the cones were formed. This completes the view obtained by slowly turning to the right till a complete turn is made. No river is seen for the Mount Emu Creek flows in a rather narrow trench or gorge, which it has cut to a depth of 30 or 40 feet below the general level of the plains.

GEOLOGICAL FORMATIONS.

The oldest group of rocks found in the area will first be described. These rocks are formed of sediments and the remains of marine organisms that collected on the floor of the sea which once occupied the whole district. They are almost completely covered by the later volcanic series, which has been subdivided in this Report for convenience of description, though no attempt has been made to arrange the groups strictly according to their relative age. It is very probable that the different types of volcanic phenomena which differentiated the various groups of rocks did not occur at the same time in all parts of the area, and that the sequence of events at the various centres of eruption was not always exactly the same.

Marine Cainozoic Clays and Marls.

The oldest rocks in the areas included in Quarter-sheets Nos. 8 N.E. and 17 S.E., new series, are marine Cainozoic clays and marls, which contain numerous fossils. These beds are exposed only at Lakes Bullenmerri and Keilambete, but fragments were also found amongst the material brought up from several bores scattered over the district. The colour is generally yellowish, and no marked stratification was observed in the exposed sections. The fossils have long been known, and the following is the list of identifications recorded by Messrs. Dennant and Kitson in their list* (the nomenclature has been corrected by Mr. Frederick Chapman, A.L.S.):—

Mollusca.

Gasteropoda—

Semiactæon microplocus, Cossmann.
Ringicula lactea, Johnston.
Terebra simplex, T. Woods.
T. additoides, T. Woods. (Prob. a syn. of *S. Johnstoni*.)
Conus cuspidatus, Tate.
C. heterospira, Tate.
C. extenuatus, Tate.
Bathytoma paracantha, T. Woods sp.
Pleurotoma murndaliana, T. Woods.
P. septemlirata, Harris.
Asthenotoma consutilis, T. Woods.
Drillia integra, T. Woods.
Daphnobela gracillima, T. Woods.
Clathurella bidens, T. Woods.
Cancellaria varicifera.
Olivella adelaidae, Tate sp.
Ancilla pseudaustralis, Tate sp.
A. ligata, Tate sp.
A. orycta, Tate sp.
Marginella wentworthi, T. Woods.
M. propinqua, Tate.
M. micula, Tate.
Volutilithes antiscalaris, McCoy sp.
Voluta weldii, T. Woods.
V. strophodon, McCoy.
Mitra atractoides, Tate.
Uromitra leptalea, Tate.
U. exilis, Tate.
U. ralphii, Cossmann. (Nom. mut., *U. semilaevis*, Tate.)
Conomitra ligata, Tate.
Columbarium acanthostephes, Tate.
Fusus simulans, Tate.
Latirus murrayanus, Tate.
L. linteus, Tate.
Siphonalia longirostris, Tate.
Zemira præcursoria, Tate.
Nassa tatei, T. Woods.
Columbella funiculata, T. Woods.
Typhis maccoyi, T. Woods.
T. acanthopterus, Tate.
T. laciniatus, Tate.
Murex velificus, Tate.
M. lophoessus, Tate.
Lotorium woodsi, Tate sp.
L. annectans, Tate.
L. tortirostre, Tate.
Morio gradatus, Tate.
Trivia avellanoides, McCoy.
Newtoniella cribarioides, T. Woods sp.
Triforis wilkinsoni, T. Woods.
Turritella tristira, Tate.
T. acricula, Tate.
Natica hamiltonensis, Tate.
N. subnoœ, Tate.
N. substolida, Tate.
N. polita, T. Woods.
N. perspectiva, Tate.
N. subinfundibulum, Tate.
Scalaria leptalea, Tate.
Eulima danae, T. Woods.
Niso psila, T. Woods.
Turbonilla liraecostata, T. Woods.

* Records of the Geological Survey, Victoria, Vol. I., Pt. 2, 1903.

MOLLUSCA—*continued.*

Scaphopoda—
Dentalium mantelli, Zittel.
D. subfissura, Tate.
D. aratum, Tate.

Lamellibranchiata—
Placunanomia sella, (?) Tate.
Dimya dissimilis, Tate.
Pecten hochstetteri, Zittel.
P. yahliensis, T. Woods.
Amussium zitteli, Hutton.
Barbatia crustata, Tate.
Plagiarca cainozoica, Tate.
Cucullaea corioensis, McCoy.
Glycimeris cainozoicus, T. Woods sp.
G. maccoyi, Johnst. sp.
Limopsis forskali, Adams.
Nucula tenisoni, Pritchard.
N. morundiana, Tate.
Leda vagans, Tate.
L. woodsi, Tate.
L. huttoni, T. Woods.
Trigonia tubulifera, Tate.
Cardita delicatula, Tate.
Crassatellites communis, Tate sp.
Meretrix eburnea, Tate sp.
Corbula ephamilla, Tate.
C. pyxidata, Tate.
Lucina araneosa, Tate.
Tellina masoni, Tate.
Myadora tenuilirata, Johnston.

MOLLUSCOIDEA.

Magellania insolita, Tate.
Terebratulima scoulari, Tate.
Magasella compta, Sow.
Magasella woodsiana, Tate.

ACTINOZOA.

Flabellum gambierense, Duncan.
F. victoriæ, Duncan.
Placotrochus elongatus, Duncan.
P. deltoideus, Duncan.
Sphenotrochus australis, Duncan.
S. emarciatus, Duncan. (Syn. *S. excisus*, Duncan.)
S. alatus, T. Woods.
Deltocyathus viola, Duncan sp. (?)
Conosmilia anomala, Duncan.
Bathyactis lens, Duncan.
Trematotrochus fenestratus, T. Woods.
Notophyllia gracilis, Dennant.

Some of the beds are particularly rich in Foraminifera. The protozoa obtained are practically all confined to this order, and, though generally distributed throughout the area, were found to be more plentiful and in a better state of preservation in some localities than in others. The following is a list of species whose determination was generously undertaken by Mr. Frederick Chapman, A.L.S., of the National Museum. They were obtained from some clay at the site of a newly-sunk bore hole in allotment XXV., parish of Kilnoorat, which had been put down 90 feet and had bottomed in marine clay. The list is arranged alphabetically for convenience of reference :—

FORAMINIFERA.

Anomalina ammonoides, Reuss sp.
Anomalina rotula, D'Orb.
Bolivina punctata, D'Orb.
Bulimina sp.
Cassidulina subglobosa, Brady.
Cristellaria articulata, Reuss.
Cristellaria cultrata, Mont. sp.
Cristellaria schlœnbachi, Reuss.
Cristellaria tricarinella, Reuss.
Discorbina araucana, D'Orb. sp.
Discorbina bertheloti, D'Orb. sp.
Discorbina rarescens, Brady.
Frondicularia sp.
Globigerina triloba, Reuss.
Globigerina inflata, D'Orb.
Lagena acuticostata, Reuss.
Lagena crenata, P. and J.
Lagena gracillima, Seguenza sp.
Lagena hexagona, Will. sp.
Lagena hispida, Reuss.
Lagena lævis, Mont. sp.
Lagena marginata, W. and B.
Lagena orbignyana, Seguenza sp.
Lagena quadrata, Will.
Lagena quadricostulata, Reuss.
Lagena semistriata, Will.
Lagena striata, D'Orb.
Lagena, 2 spp.
Nodosaria consobrina, D'Orb. sp.
Nodosaria communis, D'Orb. sp.
Nodosaria obliqua, Linne. sp.
Nodosaria scalaris, Batsch. sp.
Nodosaria sp.
Nonionina scapha, F. and M sp.
Nonionina umbilicatula, Mont. sp.
Orbulina universa, D'Orb.
Polymorphina communis, D'Orb.
Polymorphina compressa, D'Orb.
Polymorphina elegantissima, P. and J.
Polymorphina lactea, var. *oblonga*, Will.
Polymorphina lanceolata, Reuss.
Polymorphina oblonga, Will.
Polymorphina regina, B. P. and J.
Polystomella macella, F. and M. sp.
Pulvinulina auricula F. and M. sp.
Pulvinulina elegans, D'Orb. sp.
Pulvinulina oblonga, Will. sp.
Pulvinulina sp.
Sphæroidina bulloides, D'Orb.
Truncatulina lobatula, W. and J.
Truncatulina reticulata, Czj. sp.
Truncatulina ungeriana, D'Orb. sp.
Truncatulina variabilis, D'Orb. sp.
Truncatulina wuellerstorfi, Schw. sp.
Uvigerina pygmæa, D'Orb.
Vaginulina sp.

Though this list is by no means exhaustive, the almost entire absence of one or two families is noteworthy. Very few of the Miliolidae are present, and those are too fragmentary for specific determination, being corroded and iron-stained as if attacked by some solvent in the water draining from the overlying rocks. Their absence is the more remarkable since the family is, as a rule, abundantly represented throughout the Cainozoic deposits of Victoria. The Arenacea and isomorphous forms are seldom seen, but this scarcity might be expected since there is an almost entire absence of other siliceous organisms such as Radiolaria and Porifera.

In the present state of our knowledge of the Cainozoic rocks of Victoria, it is impossible definitely to state the exact age of this marine formation, but it evidently belongs to the earlier part of the series.

Although the marine beds outcrop in only three localities in the area surveyed, the material lying at the side of bore holes and the fragments found among the scoria near points of eruption prove that they underlie the whole district. Similar beds, probably part of the same formation, have been examined at Birregurra, Shelford, Hexham, and near Rokewood. Private bores put down to prospect possible deep leads show that one mile south of Rokewood the marine beds, which rest on Ordovician bed-rock, are about 100 feet thick, and are covered by about 100 feet of basalt. A little to the north*, where extensive boring and mining operations have been carried out, the marine series is absent. At Portland a bore put down in 1899 passed through about 46 feet of what appears to have been late Cainozoic sands and clays, and then through about 2,200 feet of marine limestones and clays of the older Cainozoic series without reaching bed-rock. Summing up the information available from surface outcrops and bore records, it appears that the greater part of the basalt plains are underlain by Cainozoic clays, marls, and limestones. The northern boundary of this formation probably runs from Steiglitz to Rokewood in a fairly straight line, then curves southwards round the granite outcrop near Lismore (where the basalt directly overlies the granite), passes a little to the north of Hexham, turns westward to Hamilton, and then in a southerly direction not far from the junction of the basalt with the Jurassic series of the Merino district.

There is evidence in the road cuttings at Lake Bullenmerri (to be described later) that the surface of the marine series is irregular, and was subjected to a certain amount of denudation before the volcanic period began, showing that it had already been sufficiently raised above the sea to form a land surface at that time. The evidence, is, however, not sufficiently convincing to put the matter beyond doubt. It is possible that the irregularities of the surface of the marine beds were caused by subsequent volcanic action.

This formation, being at no great depth below the surface, is of great economic importance since it forms an impervious layer which prevents the further sinking of the waters that soak through the overlying rocks, and an underground reservoir is formed which can be tapped by boring to moderate depths and pumping. It is also important because it yields evidence indicating with some degree of certainty that there can be no deep lead gold mining within its boundaries. This has been proved by boring in the neighbourhood of Rokewood and Pitfield, where the deep leads were traced to the edge of the Cainozoic marine rocks and then lost. The ancient rivers evidently discharged into the sea at about this point, and their concentrating action on the auriferous sands came to an end. Similar conditions may reasonably be expected to hold all along the boundary.

THE VOLCANIC SERIES.

The volcanic series divides itself into two natural groups of rocks—the basaltic lava flows and the materials ejected in a fragmentary state.

THE BASALTS.

For convenience of description the basalts may be divided into two groups which differ in relative age and to a certain extent in character. All, however, belong to one cycle of volcanic activity, and no sharp line of demarcation separates the earlier from the later flows. The terms "earlier" and "later" have been used to avoid the connotation of the terms "older" and "newer" when applied to Victorian basalts.

(*a*) *The Earlier Basalts.*—The distinguishing features of the earlier basalts are their texture, which is rather coarse, their position relative to the other flows, and their surface configuration where exposed to the atmosphere.

The rock is dark-grey in colour, sufficiently coarse-grained for its crystalline structure to be easily seen with the naked eye, and usually solid and compact but traversed in various directions by irregular bands an inch or more in thickness which are more vesicular and coarser in texture than the main mass. Olivine is not a conspicuous constituent. Very little decomposition except in the olivine was noticed anywhere among these rocks, except in specimens from some wells. The underground water appears to act more quickly than the atmosphere in producing chemical effects. No spheroidal weathering was observed, and the formation of calcite and zeolites in the cavities has not been carried far.

The relation of the earlier basalts to the underlying marine beds is of interest as the idea naturally presents itself that they may have been submarine lava flows, but the facts when examined point to the flows having covered a land surface. Where the junction can be seen, as in some wells, there is evidence, though not clear enough to be convincing, that an ancient soil existed before the volcanic epoch. Above the basalt there are no strata containing marine fossils, nor are there any interstratified marine beds.

These basalts are exposed over very considerable areas. They cover the greater part of the Mount Elephant quarter-sheet map, and stretch southward into the parishes of Koort-koort-nong and Wooriwyrite, and occupy considerable areas in the parishes of Marida Yallock and Terang. Rock outcrops

* See Howitt, A. M., Report on Parish of Kuruc-a-Ruc, Mon. Prog. Rept. Geol. Surv., Vict., No. 10, pp. 13-14, 1900; and Hunter, S. B., The Pitfield Plains Goldfield, Spec. Rept. Dept. Mines, 1901.

are scarce in many places, and the evidence for mapping much of this formation was based on the material obtained from wells and bores, as well as on the configuration of the surface and the nature of the soil. A great part of it is covered with soil and buckshot gravel (pisolitic concretions of limonite). Many of the parts marked "buckshot" on the map are probably underlain by the earlier basalts.

The northern area is characterized by the abundance of the buckshot gravel on the surface and consists of rather bleak-looking plains, treeless for the most part and yielding a soil less fertile than that found to the south. The original surface of the lava has been denuded away, and the plains are traversed by a reticulation of natural shallow drainage channels and other depressions with gently-sloping sides, in which the water lies for long periods. They have probably been formed largely by the chemical action of the water. This action also is going on underground, and nearly all specimens obtained from the lower portions of bores were much corroded and decayed.

The flows appear to be of considerable thickness. A well situated in a depression in the parish of Dunnawalla passed through 90 feet of solid basalt before water was obtained.

In the southern area there are some points of difference. The exposures are not so extensive, the buckshot gravel is generally found at about a foot beneath the surface, and the soil is amongst the most fertile in this fertile district. Possibly the greater rainfall and better natural drainage may account for the difference in the position of the buckshot. The better drainage is due partly to the more pronounced slopes towards the Mount Emu Creek and to the cutting of drainage channels, and partly to the porous sub-soil to which the formation of the buckshot has given rise.

The origin of these basalts is very obscure. In the Mount Elephant district the vents from which they issued may be represented by some of the low rounded hillocks found on the plains, but there is no definite evidence on this point. Selwyn* suggested that in some instances it seems probable that the same hills have served as vents for eruptions at widely-separated intervals, and in the case of some of the scoria cones in the area under consideration this may be true. It is quite possible that the earlier basalts in the vicinity of Mount Wiridgill and Ewan's Hill were erupted from those centres, but in other cases the nearest scoria cone cannot be their place of origin. The earlier basalts to the north of Mount Noorat, for instance, have a surface sloping towards that vent, and therefore could not have flowed from it.

The earlier basalts provide a good, solid, impervious building stone of even grain and almost free from vesicles. It can be readily trimmed into any desired form.

(*b*) *The Later Basalts.*—The later basalts differ from those described above in several important particulars. They are always closely associated with a scoria cone, and there can be no doubt about their point of eruption. They are often slightly raised above the general level of the plains and form low platforms from which the volcanic hills arise. The surface often retains many traces of the irregularities which are characteristic of a newly-cooled lava flow, and where this is well marked we get "stony rises," such as occur to the north of Mount Noorat and around Mounts Elephant and Fyans. They differ from the earlier basalts in being finer grained, more generally vesicular, and darker in colour. Olivine is a conspicuous constituent, and may occur as nodules or masses measuring a foot across.

The later basalt flows are very limited in extent in many cases, as a glance at the map will show, and sometimes have not accompanied the explosion which formed the scoria hills. There is very little basalt among the material forming Mount Leura, but some is exposed, together with scoria, in the quarries at the eastern end of Manifold-street, Camperdown, and in two other quarries close to the Show Ground. A small stream evidently flowed in a northerly direction. The best section of the newer basalts is seen in the quarry near the top of Mount Terang (Pl. 5, Fig. 2). Four distinct flows, forming together a thickness of about 15 feet, are exposed in the face. The centre of each flow is dark-blue, fairly compact and crystalline, but the top and bottom surfaces are slaggy, and the rock here is tachylite or a very glassy basalt, and is much stained with iron oxides. This basalt is associated with unstratified scoria, which is generally composed of fairly small fragments, and is particularly interesting on account of the number of beautifully developed crystals of olivine and augite which occur loose amongst the rock fragments. The basalts rest on bedded tuffs. Both lava flows and tuffs dip outwards from the top of the hill at an angle of about 5° to 8°, and there appears to have been no denudation of the surface of the tuff before the basalt covered it. In some small caverns between the lava flows the old "ropy" surface of the flows has been beautifully preserved, and certain bosses projecting into the cavities may be termed stalactites. The accompanying photograph (Pl. 6) shows their shape and their beautifully preserved lace-like surfaces. Some have small olivine crystals with smooth bright facets projecting from the surface. The material of the stalactites is black glass full of vesicles about $\frac{1}{4}$ inch long and drawn out in a direction parallel to the nearest surface. There is no sign of these vesicles on the surface, and they cannot be seen till the stalactite has been broken away from the surrounding rock. It seems reasonable to suppose that the cavities were first surrounded by a crust of solidified lava, while the interior of the flow remained fluid or viscous, and that this solid crust was fractured either by unequal cooling or by movement, allowing some of the molten or viscous matter to find its way through and form the boss or stalactite. Similar stalactites are found in some of the quarries near Mount Leura.

The freshness of the surface features of the later basalts and the small amount of chemical change that has affected the rock point to a very recent origin. Though approximately of the same age, some of these flows are no doubt considerably older than others, and no sharp line can be drawn between them and the earlier basalts.

The later basalts are used for building purposes and for road metal. For building, the stone is not so good as the earlier basalts since it is more vesicular, and the abundance of olivine segregations in some flows makes them quite unsuitable for that purpose.

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* Physical Geography, Geology, and Mineralogy of Victoria. Intercolonial Exhibition Essays, 1866.

The Pyroclastic Rocks.

As in the case of the basalts, the pyroclastic rocks form two groups, the well-bedded tuffs and the unstratified scoria. Here again we find that the distinction is not so clearly defined as appears to be the case at first glance, for amongst the well-stratified tuffs beds of scoria are found, whilst amongst the scoria ill-defined stratification is often noticed, and sometimes a well-marked bed of material finer in grain than the surrounding scoria can be traced for some distance.

(*a*) *The Hampden Tuffs.*—This name was selected by Professor Gregory for the bedded tuffs on account of their typical development in the County of Hampden. They are locally called " sandstone," and the name sandstone-tuff has also been applied to them.

Professor Gregory gives the following definition.* A " volcanic tuff consists of volcanic material which occurs in layers. Volcanic tuffs are of three different kinds :—(1) Volcanic material which has fallen around a volcanic vent, and been deposited in beds owing to the action of rain ; (2) volcanic material which has fallen into water and thus acquired a well-marked horizontal bedding ; in this case, if the material has fallen into the sea, the beds may contain marine fossils, if into a lake, they may contain freshwater fossils ; (3) a bed of rock formed by the redisposition of fragments of volcanic rocks, especially scoria and dust, mixed with sand and pebbles." He also quotes† Prof. Judd's definition of a tuff " as the finely-divided materials, which, owing to the storms of rain which frequently accompany volcanic eruptions, 'descend in the condition of mud, which flows evenly over the surface of the growing cone and consolidates in beds of very regularly stratified tufa or tuff.' " Tuff may also be formed of fine volcanic ash accumulating in a dry condition in layers.

The material of which the Hampden tuffs are formed consists of semi-rounded fragments of scoriaceous basaltic rock with scattered fragments of felspar and hornblende crystals, generally comparable in size with the grains of a coarse sandstone or grit, but varying through a considerable range. It is assorted into layers of different degrees of fineness of texture varying from a quarter of an inch to several inches in thickness: in some cases as many as fifteen laminæ to the inch were counted. The fragments are rounded to a certain extent and may be described as lapilli.‡ The texture of each bed is fairly even, and the size of the grains makes the whole mass distinctly porous. The effect of the finer beds in stopping the soakage and forming a moist layer is shown in Pl. 3, Fig. 1, where plants have taken root along such a layer in a cliff face. The rock is brownish in colour from the oxidation of the iron-bearing minerals, and both in the rock and the soil derived from it bright cleavage surfaces of hornblende and to a less extent of felspar, are noticeable. The rock tends to form vertical faces where exposed to the action of the water on the lake shores.

The beds as a rule dip at a few degrees from the horizontal. Where they appear to be quite horizontal they may have a small dip either towards or away from the cliff face where they are exposed. The dip appears to be an original feature and not produced after the bed had been laid down horizontally.

A striking feature is the abundance, scattered irregularly through the formation, of masses of basalt, gabbro (essexite) and the marine beds on which the tuffs lie. No gabbro or diorite massif is exposed at the surface anywhere in this part of Victoria. These ejected blocks are angular or sub-angular, and measure from a few inches to several feet across. They have evidently been torn away from the parent mass and hurled from the volcano at the same time as the finer materials which form the bedded tuffs. Volcanic bombs which acquired their shape by revolving in the air while in a molten state were not found, although they are very common among the typical unstratified scoria. The ejected blocks are more common at Lake Bullenmerri than elsewhere, particularly in the lower beds.

The Hampden tuffs are widely distributed. They are exposed over a considerable area around Camperdown, on the floor of Lake Bookar, at Terang, and around Lake Keilambete, and in the northern part of the parish of Mortlake. They are proved by wells sunk through the basalt to the north of Mount Noorat and to the north of Kurtweeton, and outcrop from beneath the basalt in the bed of Mount Emu Creek, near the Marida Yallock homestead. There is no evidence to show that the various outcrops are part of one continuous sheet.

The best sections are seen in the cuttings along the road which crosses the neck of land between Lakes Bullenmerri and Gnotuk and in the cliffs around Lakes Terang and Keilambete. In each of these places, except at Terang, the tuffs rest on the marine Cainozoic beds, but they appear to be separated from them by an ancient soil.

The age of these beds cannot be definitely settled from the fossil contents. The only fossils in the tuffs about which there can be no possible doubt are impressions of fern fronds found during the sinking of a well at Marmre Station and kindly lent for determination by Mr. J. M. Peter, of Camperdown. Professor Ewart, D.Sc., Ph.D., F.L.S., Government Botanist, who kindly examined the fossil, says that the fern most closely resembles *Pteris aquilina*, Linn. (the common bracken), and seems to have the same marking on the fronds as well as the same shape. He remarks that this fern is cosmopolitan and probably an old type, so that unless the deposit is a very old one, the identification is very possibly correct. Fossil bones were found in the Pejark Swamp drainage channel, near Terang, but whether they are in the tuffs or really belonged to the outlying alluvium it was found impossible to determine on account of the water and the decomposed state of the rocks. The same remark applies to the bone beds at Blind Creek. Tuffs similar to these and of widely differing age occur elsewhere in Victoria. Messrs. Hall and Pritchard § have described a cliff section at Curlewis near Geelong, where bedded tuffs resembling those at Camperdown are overlain

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* The Geography of Victoria, p. 184. Melbourne [1903].

† Ibid., p. 183.

‡ Chamberlin and Salisbury, Geology, Vol. I., p. 386. " Fragments too large to be borne away by the air, but still small, are known as lapilli, especially if they are somewhat rounded and gravel-like."

§ Proc. Royal Society of Victoria, Vol. VI., n.s., 1894, p. 1.

by early Cainozoic marine beds, which they describe as Eocene ; while at Tower Hill, near Warrnambool, similar beds overlie sands containing modern shells. Mr. Brough Smythe* quotes a letter from the late Mr. A. R. C. Selwyn, dated 11th August, 1857, in which he says, " Tower Hill is certainly the most recent volcanic vent I have yet seen. It appears, at least during its later eruptions, to have emitted vast quantities of ash and scoriæ ; these are seen near Warrnambool, resting on beds of shell, sand, and earthy limestone, containing numbers of living littoral species of mollusca." Mr. Smyth also gives an account of the finding of the skull of a dingo in the same locality beneath the tuffs ; but from an examination of Selwyn's note accompanying some bones found in the locality and at the time mentioned, it appears that Smythe's record is an error, and that the bones were really found in a cave in the tuffs. The bones are now in the National Museum.

The origin of the tuffs is a matter of considerable interest since their well-bedded structure makes them very different from the confused heaps of scoria round the well-preserved craters of the district. The whole of the material from which they are formed is of volcanic origin, and the ejected blocks which are scattered through the beds prove that the stratification was developed while the volcano from which the lapilli and the blocks were ejected was in active eruption.

Several theories have been advanced to explain the formation of these beds. It was suggested by the Rev. J. E. Tenison Woods, Mr. Selwyn, and Mr. Hart that similar deposits in other parts of Victoria were formed by volcanic ash falling into water and being sorted into layers of varying extent like ordinary sedimentary rocks. Dr. T. S. Hall suggested that the material fell on a land surface, and that the bedding was due to the wind sorting the scoria as it fell.

But there are several reasons why neither of these theories will satisfy the observed facts in the area under consideration. No marine or fresh water fossils have been found in the beds, but they enclose plant remains, and may possibly enclose marsupial bones ; the beds dip in various directions though the underlying rocks give no indication of having been folded since the tuffs were formed ; and the beds thicken and thin out unlike ordinary sedimentary rocks, while the relation between the thickness of the beds and the size of the grains forming them is unusual, thin beds often being formed of relatively coarse grains. The type of false bedding commonly found in æolian rocks does not occur.

We consider that the arrangement is due to the action of water condensed from the steam which accompanied the ejection of the lapilli and which was possibly augmented by water that accumulated in crater lakes during periods of repose. Under the supposed conditions the material would reach the ground as mud, or would be converted into mud very soon afterwards. It would be capable of flow like a viscous fluid, and a differentiation into layers of particles roughly of the same size would take place. If the water did not exceed a certain proportion in the mixture, these tuffs would come to rest on moderate slopes, and would be more or less parallel to the surface on which they were laid down. Any considerable mass is probably due to a succession of distinct explosions separated by longer or shorter intervals of time. Occasionally small lava flows occurred or beds of unstratified scoria were formed.

Bedded tuffs formed in this way have been described by several authors. Charles Darwin,† in describing some craters of tuff in the Galapagos Islands, remarks that the beds dipping regularly from 25° to 30° " are formed of tuff, appearing like a subaqueous deposit," and, further, " that the tuff must have flowed as mud." Sir Archibald Geikie speaks of " mud-lava " in his Text-book of Geology,‡ and Messrs. Chamberlin and Salisbury § give a good account of it :—" In violent eruptions, the steam, accompanied with much ash, is shot up to great heights, often rolling outwards in cumulus or cauliflower-like forms. . . . . In the phenomenal case of Krakatoa the projection was estimated at 17 miles. The steam . . . is quickly condensed, and prodigious floods of rain frequently accompany the eruption. This rain, carrying down a portion of the ash and gathering up much that had previously fallen, gives rise to mudflows, which in some cases constitute a large part of the final deposit. These mudflows chiefly lodge on the lower slopes of the volcano or adjacent to its base, and give rise to rather flat cones, sometimes designated tufa cones to distinguish them from cinder cones formed by the direct fall of fragmental material." As will be seen later, the Hampden tuffs, when exposed at the surface, are associated with dome-like hills.

The Hampden tuffs produce a soil unrivalled for dairy farming purposes.

(*b*) *Scoria and Bombs.*—The volcanic cones, which form so striking a feature in this district, are almost entirely composed of scoria and bombs. The scoria is only found close to volcanic vents.

The scoria consists of vesicular or honeycombed fragments of basalt torn away from the liquid or viscous underground mass during explosions, and hurled into the air. The molten lava itself is saturated with superheated water or steam, and this expands as soon as the fragment is released from the pressure of the surrounding rock, and a spongy mass is produced which solidifies as it cools. These rough angular fragments vary from the size of a pea to some inches across. Amongst them there are many angular pieces of more solid basalt and bombs.

The bombs are very remarkable objects on account of their symmetrical appearance. They vary in size from abour half-an-inch to 3 feet or more across. The most common form is spindle-shaped, consisting of a central protuberance prolonged into two more slender processes on opposite sides of the centre. These projections, which generally show signs of having been twisted while still plastic, are joined by a rim which divides the central bulb into two unequal parts. The photographs (Pl. 7) give a better idea of the shape than any description. There is a good deal of variation, and forms like a peach or apricot stone are common. The surface is generally rough and often cracked, but is not vesicular. When broken across the basalt is found to be vesicular, and the vesicles are arranged in concentric layers of differing degrees of fineness. The centre is often formed of an aggregate of olivine grains or other minerals. They were formed in the following way :—Masses of lava, or solid mineral aggregates with an adhering coat of

* " On the Extinct Volcanoes of Victoria, Australia." Quart. Journ. Geol. Soc., Lond., Vol. XIV., 1858, p. 227.

† Geological Observations on Volcanic Islands, Chap. V. 1844.

‡ Text-book of Geology, 4th edition, pp. 312 and 270. 1903.

§ Geology, Vol. I., p. 581. 1905.

liquid magma, were hurled into the air with a rotary motion. The solidifying mass conformed as nearly as possible to the shape most stable under these conditions of rotation and translation. The rim is probably due to the resistance of the air. The first to explain their internal structure was Charles Darwin, who gives an excellent description of some bombs from the island of Ascension.* He says—" This structure is very simply explained if we suppose a mass of viscid, scoriaceous matter to be projected with a rapid rotary motion through the air ; for whilst the external crust, from cooling, became solidified (in the state we now see it), the centrifugal force, by relieving the pressure in the interior parts of the bomb, would allow the heated vapours to expand their cells ; but these being driven by the same force against the already hardened crust, would become, the nearer they were to this part, smaller and smaller or less expanded until they became packed into a solid concentric shell. . . . . Geologists have remarked that the external form of a bomb at once bespeaks the history of its aerial course, and few now see that the internal structure can speak, with almost equal plainness, of its rotary movement." The structure of many angular pieces of basalt in the scoria pits shows them to be fractured portions of large bombs.

Green and red nodules of granular olivine are commonly found among the scoria, and are often covered with a thin skin of basalt. On close examination they are always found to contain grains of pyroxene or other minerals. In the scoria on the top of Mount Terang olivine occurs as very beautiful small crystals and groups of crystals in parallel positions, and small perfect crystals of augite are also found at the same place. Hornblende, either as cleavage fragments or as somewhat rounded pieces, is common in certain places, such as Mount Noorat, but is rare at others (Mount Leura). The rounded pieces have an exterior " skin " of light colour, and appear to have been partly remelted before they were ejected from the volcanic orifice. Cleavage fragments of colourless glassy felspar are very common, and are sometimes a couple of inches long. Pieces with the original crystal faces are rare, but are occasionally to be found.

In general freshly exposed scoria is almost black, but portions of it are always stained white or yellow by percolating water. It weathers to a brownish-red colour, due to the oxidation of the ferruginous minerals.

Large quarries have been opened in the scoria in several places. One on the roadside where the Camperdown-Geelong road crosses the shoulder of Mount Leura has been largely worked for years, and good sections are exposed. The great mass of the scoria consists of pieces an inch or so across, but amongst them are great numbers of bombs and irregular pieces of basalt of all sizes. In places there is a rough arrangement of the material into beds, and one bed of fine material a few inches thick can be traced very easily for some distance. It is more compact than the rest, and forms the roof of an artificial cave at the western end of the quarry. It is cut across by many small faults, evidently caused by the irregular settling down of the loose scoria and agglomerate beneath it. This bed and the less well-defined layers all dip away from the neighbouring crater in Mount Leura. Several smaller quarries are situated near this hill, and similar features are exposed. There are very large roadside quarries at Mount Noorat, and here well-shaped bombs of all sizes are very common. The coarseness of the scoria depends on the proximity of the vent, and it is often loose enough to make quarrying a matter of danger.

The scoria is used largely for roadmaking, for which it is particulary suitable, as it readily binds together, remains sufficiently porous to dry rapidly, and gives a good smooth surface. The roads made with it are amongst the best in Victoria. It has lately been used in concrete work, both for making solid concrete walls and concrete blocks for building purposes. The scoria weathers into a dark reddish soil of excellent quality.

ALLUVIAL DEPOSITS, WIND-BLOWN DUNES, AND BUCKSHOT GRAVEL.

Small alluvial plains are found along the course of the Mount Emu Creek, especially along that part mapped in the Camperdown Quarter-sheet. Alluvial deposits also fill depressions in the plains, such as Frenchman's Marsh and Pejark Marsh, which are closely akin to the numerous shallow lakes, as well as smaller depressions. The soil is very rich when the land is properly drained and has all been formed by the decomposition of the volcanic rocks. Quartz gravel was observed at the junction of Blind Creek with the Mount Emu Creek. It has probably been washed down from the sands and gravels which are exposed in the Stony Point P.R. (parish of Darlington), and known to extend under the basalts there. The latter deposit is of interest, as it may indicate that there is granite close to the surface. Granite is known to outcrop a few miles to the east.

It has already been stated that it is a matter of considerable difficulty to decide what was the original position of the marsupial bones which are numerous in certain places marked as "bone beds" on the map. At Blind Creek and Pejark Marsh they may quite possibly lie buried in the tuffs, and the bone beds around Lake Colongulac may contain only such bones as have been washed out of the tuffs. So far we must acknowledge that nothing definite has been proved, but the evidence at Blind Creek inclines us to believe that the bones come from the tuffs. It is quite possible that the animals which they represent continued to inhabit the country both during the deposition of the tuffs and the formation of some of the alluvium.

Fossil bones of the following species have been found at Lake Colongulac† :—

Thylacinus rostralis, De Vis.
Phascolomys pliocenus, McCoy.
Macropus titan, Owen.
M. magister, De Vis
M. pan, De Vis.
M. giganteus, Shaw.
Procoptodon goliah, Owen.
Canis dingo, Blumenbach.

* Geological Observations on Volcanic Islands, Chap. III. 1844.

† Dennant, John, and Kitson, A. E. Catalogue of the Described Species of Fossils (except Bryozoa and Foraminifera) in the Cainozoic Fauna of Victoria, South Australia, and Tasmania. Rec. Geol. Surv., Vict., Vol. I., Pt. 2. Melbourne, 1903.

On the southern and eastern sides of many of the shallow lakes there are often low rounded hills which have been formed by silt blown from the dry beds of these lakes during the summer. In places, as in the parish of Darlington, at Lake Barnie Buloke, and the lakes to the north of Mount Elephant white earthy limestone is developed in them. The soil is usually dark and very suitable for onion growing and other agricultural purposes.

A large part of the volcanic country is covered with a thin layer of small concretions of limonite, known as buckshot gravel. It sometimes forms a deposit beneath the surface or occurs in masses some feet in thickness, as along parts of the Mount Emu Creek. It consists of rounded grains about the size of a hazel nut, generally brown in colour, but sometimes black and highly polished. When broken the grains have the typical yellowish-brown colour of limonite. Fifty years ago Mr. G. H. Wathen* noticed it in the vicinity of Mount Porndon, and suggested that it is a volcanic ash. It appears, however, to consist of concretionary iron ore deposited by the evaporation of water which had dissolved some of the iron from the ferruginous minerals in the underlying rocks. It often causes great difficulty to the geological surveyor by hiding the underlying rocks in a featureless country. It appears to be best developed on the surface of the earlier basalts, but it is also found overlying the bedded tuffs. The shallow depressions which wander like narrow channels over the surface of the basalt and in which water often lies for considerable periods, seem particularly favorable for its formation. The grains are generally separate, but along the banks of the Mount Emu Creek they are in places cemented into solid masses. The conditions of its formation no doubt depend largely on the rainfall and the natural drainage of the surface. Occasionally lumps of cemented buckshot may be picked up and found to contain limonite pseudomorphs after hornblende, indicating that the original rock was probably scoria.

LAKES.

In the area surveyed there are 27 lakes, which vary in size from mere ponds to sheets of water 4 miles across. They form two distinct groups.

The Colongulac Type.

The first group, and the one containing the majority of the lakes, embraces the shallow basins, irregular in shape, and often dry in summer; they merge into the shallow depressions filled with alluvium, and some of them remain dry for long periods. No well-marked streams enter them, and there is no outflow. The water collects during wet weather, and is gradually lost by evaporation, and is in consequence salt or brackish. When it dries up it leaves a white incrustation on the lake bed, giving an appearance of water when none is present.

These shallow basins appear to occupy the natural depressions which occur between lava flows, and which have been deepened during times of drought by the wind blowing away the dry mud from their beds and increased in size by the action of the waves on their banks.

The largest lake of this kind is Lake Colongulac, whose bed covers 3,700 acres.

The Bullenmerri Type.

The other group consists of lakes that are roughly circular in shape, surrounded by a ring or rim of hills, and are generally deep and permanent. The outer slope of the ring of hills is gentle, but it dips steeply to the water. The catchment area is too small to account for the supply of water necessary to replace that lost by evaporation. There is no outflow, but Lakes Gnotuk and Terang are said to have risen sufficientlyto overflow their banks about 40 years ago. The water is either brackish or fresh. There are four lakes of this type in the area under consideration—Lakes Bullenmerri and Gnotuk, Terang, and Keilambete. They are all deep and permanent except Lake Terang, the level of which appears to be falling at the present time.

The most remarkable of this group are Lakes Bullenmerri and Gnotuk, which are situated near Camperdown. They lie close together, but as the accompanying diagram (Pl. 1) shows, the surface level of the water in the two lakes differs by 163 feet, while the floors of both are on about the same level. Their respective depths are 263 feet and 103 feet. The level of the water of Lake Bullenmerri is about 18 feet below the level of the Camperdown railway station.

The ring of hills round Lake Bullenmerri at its highest point rises 440 feet above the water. The lowest points occur at the south end of the lake and at the north end, where the narrow ridge separates it from Lake Gnotuk. There is evidence of changes of level in the surface of the lake. Indistinct traces of a raised beach about 12 feet above the present surface of the water tell of a time when the water level was higher, and the stumps of dead trees at some little distance from the shore prove that it has also been lower in past times. These stumps were mentioned by Mr. Brough Smyth† in 1869, so that the low water period is of no very recent date. The water is brackish, but it is quite fit for watering stock. Lake Gnotuk is very similar in its general features; the lowest part in its rim is at the northern end, and the water is said to have once risen sufficiently high since the district was settled to overflow at this point. On the beaches of the lakes are vast quantities of small shells. The water is sufficiently salt in both cases for stones within reach of the spray to be covered with a whitish incrustation.

The catchment area does not supply enough water to replace the loss by evaporation, and the chief source of supply is evidently the underground water so abundantly tapped by windmill pumps in the surrounding country. The hills surrounding the lakes are formed almost entirely of Hampden tuffs, and, at places along the shores of both, the underlying marine marls outcrop. Surface water filters through

* The Golden Colony, or Victoria in 1854, with Remarks on the Australian Gold-fields, p. 14. Lond., 1855.
† The Gold-fields and Mineral Districts of Victoria, 1869.

the tuffs till it comes to the impervious marl, and is guided by the junction of the two formations into the lake. Any considerable rise in the surface of the lake would probably check this supply, and the water would escape along the path by which it now comes. The surface of the marls around Lake Gnotuk do not rise to such a high level as those round Lake Bullenmerri, and therefore the high water mark is lower. The swampy spring between the two lakes shows that there is an underground discharge from Lake Bullenmerri into Lake Gnotuk, and this explains the difference in salinity, one having a discharge and the other not. Both supply and discharge are underground.

The sand found along the shores is exceedingly interesting, being largely composed of clear grains of green olivine and other basic minerals quite unlike the usual sand found on beaches, which is almost entirely made up of grains of silica and fragments of broken shells.

The other lakes belonging to this group—Lakes Terang and Keilambete—are not so striking. The surrounding ring is much lower, but has the same character, being largely composed of bedded tuffs, falling steeply towards the lake and sloping gradually away from it. Lake Keilambete is about 96 feet deep, but Lake Terang is apparently drying up, and is now partly a swamp. The large quantity of underground water pumped to the surface in the surrounding country is probably a factor in this desiccation, but the source of supply may have been affected in other ways by town improvements.

The origin of these lake basins is a matter of great interest, but its consideration must be deferred till the hills which form the surrounding rings have been described, and all the facts presented before any deductions are attempted.

THE HILLS.

Like the lakes, the hills (with the exception of the small dunes already mentioned) belong to two distinct classes—the scoria cones and the dome-like hills. The latter are the more ancient, but the scoria cones will be treated first since their origin is evident, and a description of them leads to a better understanding of the more involved questions relating to the other class.

The Scoria Cones.

The scoria cones are the most striking features in this flat country. They rise steeply from the plains and are often very symmetrical in shape. Most of them have one or more craters, some as perfect as they were at the time of their formation and others shattered by subsequent explosions or nearly obliterated by the hand of time. Mount Elephant is an example of a single crater with its surrounding rampart breached in one place, while Mount Noorat is a compound volcano, in which various orifices discharged at different periods of its history.

There are nine scoria hills included in the maps—Mounts Elephant (Clarke), 1,294 feet; Leura, 1,027 feet; Noorat, 1,026 feet; Koang, 894 feet; Meningoort (Meningorot, Miningorat), 766 feet; Kurtweeton; Wiridgill; Terang, 579 feet; and Ewan's Hill (Mount Gnarogein, Mount Emu), 893 feet. The names in brackets are those found in old publications and maps, and the heights above sea level were determined during the trigonometrical survey, for which the hills were used as trigonometrical stations. Mounts Koang and Kurtweeton are close together, and are often called the Cloven Hills; they are about the same height. The hills rise from about 140 feet (Mount Terang) to 780 feet (Mount Elephant) above the plains.

Mount Leura, on the north-west slope of which the town of Camperdown is partly built, is a typical scoria hill. The accompanying photograph (Pl. 2), taken from the crest of Bullenmerri, looking eastward, gives a very good general idea of its shape. It consists of what was once a well-defined crater wall. This was partly destroyed by an explosion, and only about a third of it now remains intact on the north-eastern side. It rises as a steep crescent-shaped rampart with a narrow top highest at the eastern end, the horns of the crescent pointing southwards. Between them, and evidently where the remainder of the crater rim once stood, a steep cone with a pointed top lifts its head a little above the highest part of the crater rim. The steepest parts of the sides slope at about 30°, and there is no sign of a crater on the top. The ruins of the crater rim extend around the southern side of the cone. The great explosion which caused this destruction, built up the cone partly on the site of the old rim and partly in the crater, which is now represented by the hollow between the cone and the northern crescent. It is a fairly deep hollow entirely surrounded by hills, but is of far less extent than the original crater. The irregular small hills to the south and east indicate other subsidiary explosions. The whole mass lies within a sort of amphitheatre, bounded on the south by a cliff 50 feet or so in height, in the face of which several massive basalt flows are exposed. This cliff faces the volcano, and between them is some low-lying ground. From the top of the cliff the land rises towards Bullenmerri. The escarpment separating the high area from the low appears to be the direct result of faulting. Subsidences in close proximity to volcanoes have often been observed, and are no doubt due to the adjustment of the conditions caused by the transference of great quantities of rock to the surface from some underground source.

The whole surface of the hill is covered with luxuriant grass, but many scoriaceous basalt boulders are seen. Good sections are exposed in the scoria pits which have been opened on its flanks. The scoria and bombs are generally piled together in confusion, but sometimes form ill-defined beds dipping away from the hill. The porous nature of the scoria explains why no water lies in the depressions. Just below the crest of the rim and on its northern slope a small basalt flow is exposed, but lava flows and dykes appear to form only an insignificant part of the hill. A lava flow can be traced in a northern direction, but, as in the case of practically all the other cones, it welled out before the explosions which piled up the hill began.

Mount Elephant is probably the most conspicuous hill in the Western District on account of its considerable height, its very symmetrical form, and its isolated position. It consists of a single crater breached on the north-eastern side. The rim is narrow on top, steep sided, and rises at three points somewhat above the average height of the top. The great mass consists of coarse scoria and bombs, some of them of great size, and there are some small interstratified basalt flows. There has been a considerable outpouring of lava during the earlier history of this volcano. It is clearly defined from the more ancient surrounding basalts by the steep slopes which bound it as well as by the rugged appearance of its surface. In places there are circular depressions caused by the escape of the steam which was entangled in the mass of molten basalt.

Mount Noorat, situated about 4 miles north of Terang, is the best example of a composite volcano, and is remarkable for its beautifully preserved principal crater, which is about a quarter of a mile in diameter, nearly circular, and surrounded by a rim with a fairly level top. At one point the rim rises about 60 or 70 feet above the general level, and is marked by an outcrop of basalt which forms an almost vertical cliff of considerable height on the inner side of the crater. The crater itself is smooth sided, funnel-shaped depression. Its depth is given by the trigonometrical survey as "200 feet to 300 feet deep," but Selwyn's note in his list of points of eruption*, "Noorat, 505 feet deep," is probably correct. This estimate would make the bottom of the hollow at about the same level as the surrounding plains. Its sides are largely composed of loose scoria and bombs, and are now thickly overgrown with grass and bracken. There are few trees left, but formerly they grew thickly on the sides. The bottom of the crater is quite dry. Close to the main crater and almost due north of it is another of smaller dimensions, but well defined, and close by it there appear to have been three other minor rents. On the southern side of the hill there are also traces of subsidiary vents. On the western flank, and separated from the main mass by a boat-shaped valley which is deeper in the middle than at either end there is an elongated mound of scoria, something like a railway embankment. In this the great roadside scoria pits have been dug, and the valley may mark the subsidiary vent from which it was ejected. The whole forms an imposing mass from any point of observation, more especially as there are no adjacent hills to dwarf it by comparison. The lava flows are of considerable extent, especially in a northerly direction, and have the kind of surface known as stony rises.

Hornblende and felspar fragments are common on the surface of the mountain, and pieces of quartz, some of them evidently rounded in a stream, are also found. This is at first rather puzzling, but on closer examination many of them prove to be artificially chipped, so that they were probably carried here by the aborigines, who doubtless used the mountain for a look-out station in early days.

The other cones present much the same features as those described. Mounts Koang and Kurtweeton show little signs of denudation, but the craters of Mounts Meningoort and Terang and Ewan's Hill have been greatly modified by wind and weather.

Mount Terang is interesting on account of the lavas from the modern vent resting directly on a surface of the bedded Hampden tuffs and lying parallel to the bedding of the latter. It would therefore appear that no great interval of time elapsed between the formation of the one and the extrusion of the other, and they may possibly have come from the same source.

The history of all these hills is the same. They began as vents from which liquid basalt quietly welled out and flowed over the surrounding plain. This phase was followed by an explosion or series of explosions caused by gases or vapours which hurled vast quantities of scoria and bombs into the air. This material fell around the orifice and formed a ring or rampart about it. Sometimes other subsequent explosions took place and partly destroyed the original cone and formed a new one, but it is quite possible that the main mass of many of the scoria hills may be the result of a single outburst. There are several well authenticated accounts of such occurrences. For example, Monte Nuovo, on the Bay of Naples, which rises to a height of 440 feet, and has a crater 420 feet deep, was formed in two days at a place where there was no hill. The eruption began at 1 a.m. on Sunday, 29th September, 1538, and was witnessed by the inhabitants of the neighbouring town of Puzzuoli, and contemporaneous accounts of it given by eye witnesses are extant.

The lava flows about whose point of origin there can be no doubt are of small extent, except those which came from Mounts Elephant and Fyans. Whether any of the earlier basalts came from the same vents we have no proof, but in certain cases it is evident that they did not originate at the site of the nearest scoria cone: for instance, the surface of the earlier basalts to the north of the Mount Noorat flow dips towards the hill, not away from it.

The Bullenmerri Type of Hill.

Quite distinct in their configuration from the scoria cones which have just been described are those hills surrounding Lakes Bullenmerri and Gnotuk. To this class belong the low rims surrounding Lakes Terang and Keilambete. In the district under consideration this particular form of hill is always associated with a particular kind of lake.

These hills are rounded and dome-like. They have gently sloping sides, and are quite unlike the steep scoria cones. They consist almost entirely of bedded Hampden tuffs, and in every case form a ring around a lake. Amongst the well bedded tuffs are layers of unassorted scoria, and there is an accumulation of ordinary scoria on the top of Bullenmerri and at Mount Terang close to the lake of that name. The Bullenmerri ring will be described as it is the most striking and best dissected by road cuttings. The others are much lower, but similar in other respects.

The circle of hills around Lake Bullenmerri varies considerably in height at different points, but everywhere rises well above the water and the surrounding plains. The lowest point is on the neck of land separating the two lakes, and is about 50 feet above the water. The highest point is occupied by the

* Notes on the Physical Geography, Geology, and Mineralogy of Victoria. Intercol. Exhibition Essays, 1866.

public gardens, and rises 960 feet above sea level, and 440 feet above the lake. The outer slopes are gentle. but there is a steep slope towards the water, somewhat modified by landslips. This steep slope is continued below the water, and ends in a flat floor. The shape of the basin is quite unlike the funnel-like craters in the scoria cones (see Plate I.).

It is almost impossible to judge the dip of the tuffs from outcrops on the escarpment, as they have been much modified by the slipping of the surface on the steep slopes where they are best exposed. Two road cuttings, which have been made since the completion of the map, expose good sections. One is on the northern side of the road which runs from the public park acr ss the low divide between the two lakes. The bedded tuffs dip towards the water at about 20° to 25°. Some are very fine in texture, and others consist of fragments ranging up to the size of a pea and rounded. The bedding is very distinct, and ejected blocks of basalt and more coarsely-grained basic rocks are common, ranging up to a couple of feet in diameter. No volcanic bombs were seen. Plate 3, Fig. 2, gives an excellent idea of the bedding, dip, and included fragments. Sometimes these included blocks are pieces of fossiferous marl from the marine series. We have already given our reasons for believing the stratification of the tuffs was caused by the condensation of the steam which accompanied their ejection. The lowest bed seen in the section is a massive marine clay.

From the lowest part of this road another is being constructed to the water's edge, and the tuffs here seem to be horizontal.

After crossing the lower ground the road continues up the western side of the rim. At the bottom of the hill the tuffs dip 12° E., but at this point no good sections are exposed. Further up the hill there is another cutting. The lowest beds are marine, with occasional fossils. Their junction with the overlying rock is hidden by grass. Above this is the following succession, beginning at the lowest :—Basalt, about 12 feet; agglomerate, rather coarse, and containing angular pieces of dolerite, through which runs a band of basalt, about 6 feet thick, and parallel to the general dip of the beds—it may be either a flow or a dyke ; bedded tuffs, about 5 feet thick ; a stratum of light-coloured, unstratified material, which may be an ancient soil, about 1 foot thick ; a considerable thickness of tuffs as far as the end of the cutting. All the beds dip about 10° W., away from the lake (Fig. 2, Pl. 5).

Another cutting traverses the outer slopes of the hill along the Camperdown-Cobden railway line, and a little to the west of the section just described. The cutting is parallel to the strike of the beds, but the dip can be estimated by comparing opposite sides. The section is much obscured by grass, but sufficient can be seen to prove that the tuffs seen at each end of the cutting and the basalt in the middle all dip westward at about 10°, like the beds just described. A feature of great interest is that the tuffs in places overlie an old land surface with obscure plant remains (Fig. 1, Pl. 5).

Several theories concerning these lake basins have been published. Brough Smyth,* in 1857, wrote—" Lakes Gnotuk and Bullenmerri, situated to the west of Mount Leura, are also, I believe, ancient craters." This explanation seems insufficient since they differ from the neighbouring depressions which are undoubtedly craters, in size, in depth, in shape, in the configuration of the surrounding hills, and in the materials composing them, and, moreover, the undoubted craters do not retain water.

In speaking of these lakes, Mr. Selwyn said† " some of these (such as Purrumbete, 150 feet deep, and only about 1¼ miles in diameter; Gnotuk, 300 feet deep, and still smaller; Terang and Keilambete, the banks of which are composed chiefly of beds of volcanic ashes) may perhaps have been the sites of old craters, but the evidence of their having been so is by no means so clear as it is respecting the hills. I am rather inclined to think that many of them are accidental depressions due to other causes." Again,‡ " that certain features exhibited by some of them, viz., that the walls of the craters are formed of stratified layers of ash, dipping outwards at a low angle, seem to indicate the probability of their having been sub-aerial vents, forming low islands in the Tertiary seas, under the waters of which the lava streams flowed and even consolidated."

Professor Gregory considered that they are depressions formed by subsidence in a widespread sheet of bedded tuff. He says,§ " The two best known lakes, which have been regarded as occupying volcanic craters, are Bullenmerri and Gnotuk, to the south-west of Camperdown. They both occur in steep-walled, flat-floored depressions in a down-shaped hill of bedded volcanic tuff. This volcanic material rests on a bed of clay that was formed beneath the sea. The volcanic tuffs have accumulated beneath water, and in most cases the material has been sorted and rounded by water action. The sides of the down-shaped hill, which encloses the lakes, do not represent the slopes of an old volcano. The hill is a remnant of a vast sheet of volcanic tuff that was once spread widely across the surrounding country. The existing slopes are simply due to denudation. The lake basins have been formed by a subsidence that has cut across the mass of tuff ; this subsidence has made three great depressions. The one to the south is dry ; the second is occupied by Lake Bullenmerri, and the northern one by Lake Gnotuk. The three basins are separated by narrow transverse ridges." Again (p. 130, footnote), " It may be suggested, from the occurrence of ejected blocks of old rocks on the shore of Lake Bullenmerri, that the lake covers an old volcanic vent, and that the lake basin should be regarded as a caldera. A caldera is a basin formed by subsidence in the surface of a volcanic mountain. The evidence in support of this view is, however, inadequate."

While fully realizing the weight which must be attached to the opinion of such an eminent geologist as Professor Gregory, we venture, in the light of the fresh evidence which has been collected since the publication of his valuable work, to offer the following criticism, and to suggest another theory.

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* On the extinct Volcanoes of Victoria, Australia. Quart. Journ. Geol. Soc., Lond., Vol. XIV., 1858.
† Notes on the Geography, Geology, and Mineralogy of Victoria. Intercolonial Exhibition Essays, 1866, p. 31.
‡ *Ibid.*, p. 34.
§ The Geography of Victoria, p. 127. Melb. [1904].

In the first place, we cannot accept the hypothesis that the country was once covered by a widespread sheet of tuff which accumulated beneath water, and which has been denuded away, leaving only the Bullenmerri hills to mark its former thickness. The dips of the tuffs exposed in the road cuttings are not consistent with this theory, for they are found to be inclined both towards the depression and away from it. Tuffs accumulated in the way suggested would be horizontally bedded, and the dip would be due to subsequent earth movements. The dip towards the lake might reasonably be considered to be caused by the sinking of its floor, if the basin was produced in that way, but the outward dip is quite another matter. There is no evidence of folding—such as the bedded rocks outcropping along their line of strike for any considerable distance anywhere in the district—and there is little or no evidence of folding in beds of the Newer Basalt period in other parts of Victoria.

Again, we failed to observe any signs of denudation amongst the volcanic rocks sufficient to remove almost totally a widespread sheet of rock whose surface must once have been at least 600 feet above the present plains. Even if this denudation did occur, there is no reason why the Bullenmerri hills should have been preserved from the general destruction, for they are composed of rocks which very easily decay, and they are not crowned by any hard, protecting layer.

Finally, the greatest objection to the theory is the constant association of the lakes of this type with a rim of bedded tuffs which rises above the general level of the plains. The origin of both basin and rim must be very closely connected. They cannot respectively be the result of such very distinct and independent causes as subsidence and denudation.

We consider that the Bullenmerri ring of hills is the basal fragment of a tuff cone. The reasons have already been given for believing that the tuffs were not laid down under water, but acquired their bedding and their dip during the temporary action of the water which converted them into mud at the time of their ejection or very shortly afterwards. Briefly, these reasons are—the interbedding of tuffs with layers of unbedded scoria or agglomerate; the peculiarities of bedding; the occurrence among them of old land surfaces with soils and plant remains; and the absence of freshwater and marine fossils.

Cones formed of such bedded tuffs, some of them dipping at angles up to 25°, and originating in the manner suggested, have been described by Darwin* and other geologists in several parts of the world. The size and great number of the ejected blocks in the tuffs, or weathered out of them and now lying round the shore of the lake, are irrefutable evidence of the close proximity of a volcanic vent. That Mount Leura is not the vent from which they were hurled is proved by many of them being rocks of a type never found amongst the scoria of Mount Leura or any other of the scoria cones.

The next point is the origin of the lake basins. Confining our attention for the moment to Lake Bullenmerri, the sinking which would produce this depression would be very remarkable, for the area affected is a little more than 2 square miles, and the floor lies 700 feet below the highest part of the rim and is bounded by steep sides. The formation of such a basin by the sinking of its floor has never been actually observed, but there are several historic instances of the formation of such depressions by great paroxysmal explosions blowing away the upper part of a volcano, destroying the crater properly so-called, and leaving the lower slopes as a ring surrounding a great cavity. The stupendous explosions at Krakatoa in 1883 and at Bandaisan in 1888 have shown how great cavities may be produced in a few hours. The Tarawera catastrophe, which destroyed the famous pink and white terraces in New Zealand in 1886, formed a chasm 2,000 feet long, 500 feet broad, and 300 feet deep on the slopes of the mountain.

We consider that this lake basin and the others similar to it have been produced by such explosions, and, in the case of the deeper lakes, that they have subsequently been modified by the sinking of their floors owing to the adjustment of the strains caused by such an outburst.

A similar explanation has been advanced by Mr. T. S. Hart to account for the formation of Tower Hill Lake.†

PETROGRAPHICAL NOTES.

The Basalts.

General Notes.

In a general survey of the basalts of the area described, the feature most apparent is that the earlier basalts are, on the whole, more coarse-grained than those which were erupted during the last stages of the volcanic activity of the district. There are, of course, many exceptions to this general statement, but it must be observed that, although the finer-grained types are not very rare among the earlier basalts, the coarser-grained varieties are much more exceptional in the latest series. It is quite possible that the structure of the rock depends largely on the volume of basalt ejected, and the earlier flows appear to have been much more extensive than the more recent lavas which emanated from the existing vents. The finer-grained types are more basic than the others. It is often extremely difficult to say in which group a basalt should be placed. The uppermost flow from Harvey's well (see below) and those interbedded with the Hampden tuffs are much more like the later than the typical earlier basalts, but have been classed with the latter since their origin cannot be traced to any existing scoria cone.

The minerals of which these rocks are composed are felspars, pyroxenes, olivine, and iron ores, and the decomposition products of these minerals are often present. In one slice taken from one of the latest lava flows from Mt. Kurtweeton grains of quartz occur.

The felspar most commonly present in all the basalts appears to be labradorite. It was determined in a number of sections by measurements of the angle of obscuration in the zone perpendicular to (010), and in several instances, felspars which were twinned on both the Carlsbad and albite laws were found cut in suitable positions to give concurrent extinctions and readings in the two halves of the Carlsbad twins. In some instances the angle was measured on (010). In some of the coarser types a zonary structure is present, and the outer zone then appears to be andesine. In one case the predominant felspar appears to be bytownite. All these felspars occur as well-defined lath-shaped crystals of various sizes, but in addition

* Geological Observations on Volcanic Islands, Chap. V. The Galapagos Islands: Craters of Tuff.
† *Vict. Naturalist,* XVII., 1901.

to them another felspar is very commonly present, though it is by no means abundant; it is allotriomorphic, untwinned or simply twinned, of low refractive index, and has no definite point of extinction, but is traversed by a dark shadow as it is revolved between crossed nicols. It has evidently been the last mineral to crystallize out. Since anorthoclase occurs commonly among the scoria of the cones, the idea suggests itself that this also may be anorthoclase or potash-oligoclase. The rock analyses present no objection to this view. Olivine occurs in all the rocks examined, except in a rather peculiar type of basalt from Harvey's Well, which lies near the cross roads, a little to the north of Lake Gnotuk, and one of the later basalts from a quarry in Allotment XVII., 3, parish of Glenormiston. It is generally very abundant, and occurs as well defined crystals, crystals that have been deeply eaten into by the magma, or angular grains. It is usually larger than the other minerals of the rock in which it is found. It varies from the clear unaltered mineral to the completely decomposed stages. The change usually begins with the appearance of a narrow rim of iron-staining around the edges; this extends until the whole mineral is converted into a red-brown substance, composed of parallel fibres or lamellæ, which is slightly pleochroic, and has a much lower refractive index than the original olivine. The pseudomorph becomes dark over its whole area at the same instant in polarized light, and is probably the substance known as iddingsite. The conversion of olivine into serpentine is rather uncommon in this district, but is occasionally observed. The augite of the basalts is commonly the violet-brown, titanium-rich variety; colourless forms also occur, but they appear to be confined to the phenocrysts in the later flows. The augite often forms the bulk of the ground mass in the fine-grained basalts, and it is then either granular or forms minute prisms. In the rocks of coarser texture it is either developed in irregular plates, which inclose the felspars, or it fills the spaces between them, and it also occurs as phenocrysts in which the crystal form is more or less perfect. Other ferro-magnesian minerals, such as hornblende and mica, do not occur. The iron ores are abundant as a rule, and are of considerable interest. Three distinct forms are found; little cubes and equidimensional grains; elongated forms; and skeleton crystals and fern-like growths, generally minute. The first variety, magnetite or titaniferous iron, is the most common, and occurs in practically all the basalts evenly distributed through the mass. The elongated forms in the basalt from Harvey's Well, Pl. 10, fig. 1, appear in the micro-section as slender black needles, which may be as much as ¼ inch long, and are sometimes grouped together as skeleton crystals. The thinnest parts are translucent and deep brown in colour, so that the mineral is ilmenite. In the drusy cavities in this basalt the ilmenite can be seen in the form of thin black polygonal plates. Ilmenite of this form occurs in many of the other basalts, but it is not so well developed. The little fern-like growths are most common in the fine-grained groundmass of the later basalts. Apatite is conspicuous in none of these rocks, although the analyses show that in some of them the phosphorous is considerably in excess of the average content for basalts. The occurrence of quartz is discussed with the fragmental rocks. It is rather curious that many of the minerals found in the bombs and amongst the scoria do not appear to occur in the basalts; hornblende, for instance, was not observed in any of them. In many of the basalts there are large "olivine secretions," which are almost identical with the nuclei of many of the bombs found among the scoria of the cones; they appear to be rather more abundant in the later than in the earlier types.

The coarser-grained varieties are generally dark-grey in colour, owing to the occurrence of little white felspar laths that can be easily seen with the naked eye among the darker minerals. On weathering they become stained with a coating of brown limonite, derived from the decomposition of the olivine, which is generally found to be the only mineral which has undergone any serious alteration. The finer-grained varieties are almost black, especially when fresh. The completely glassy forms (tachylite) are rare, although the original surfaces of the basalts, where preserved, are generally composed of very glassy rock. Some of the basalts, especially in the neighbourhood of Mts. Noorat and Elephant, have a peculiar variolitic aspect, due to the occurrence of light-coloured spots in the darker material. These spots are about the size of a split pea, but disappear when the rock is ground down for microscopic examination. When a little weathered, this basalt breaks into a gravelly mass when struck with a hammer.

An examination of the analyses given on p. 28, shows that the finer-grained varieties are more basic than those of coarser texture. The silica contents of these rocks is decidedly below that of the average olivine basalt; the silica contents of the coarser varieties is rather above it, but the mean of the six analyses is very close to the general average for rocks of this class. The fine-grained types are richer in magnesia and lime than the others, and very considerably richer in these substances than the average basalt. They approach limburgites in composition. The titanium is high, as it is in many Victorian rocks; it occurs partly as titaniferous iron or ilmenite and partly in the augites. The occurrence of an appreciable amount of nickel and cobalt in all the rocks analysed is worthy of remark.

In the following detailed description of thin slices of typical basalts, the specimens are grouped as earlier and later basalts, the terms being used in the sense already specified. Some of the coarser types might be described as dolerites.

The Earlier Basalts.

1. Harvey's Well, S.W. corner of Allotment XXVI., parish of Colongulac, a little north of Lake Gnotuk. —This well, which is 70 feet deep, exposes a section of three basalt flows, one above the other, underlying the Hampden tuff, which forms the surface bed, 15 feet thick. The flows are separated from one another by soft decomposed rock, leaving about 40 feet of solid basalt in all. The lowest flow consists of a coarse grained holocrystalline basalt, of even texture, composed of lath-shaped plagioclases, granular augite, olivine completely altered to iddingsite and often quite opaque from iron staining, and some iron ores, both of the equidimensional and elongated types. The untwinned felspar referred to above also occurs. In the lower part of this flow the decomposition has resulted in the production of green serpentine from the olivine. The overlying flow consists of a very striking rock (Fig. 1, Pl. 10). It is coarse-grained and holocrystalline, with ophitic structure, and under the microscope resembles an intrusive rather than an effusive rock. The felspars are lath-shaped, and reach ⅛ inch in length; they are sometimes twinned on both the albite and Carlsbad laws, and a suitably cut section of this kind gave concurrent readings of 10° and 30° for the extinctions on the two halves, and is therefore bytownite of about the composition

Ab_1An_4. The felspars readily gelatinize with acids, and contain many little acicular crystals, probably, for the most part, apatite. The untwinned felspar with the cloudy extinction also occurs. The augite is the titanium-bearing variety, and encloses the other minerals ophitically. The most remarkable feature is the abundance of rods of ilmenite up to ¼ inch long, evidently sections of crystals flattened parallel to the base; skeleton crystals of this mineral are also common. This rock is quite free from olivine. The topmost flow is quite distinct in character from those below it (see Fig. 2, Pl. 10, and Analysis No. 7). It is fine-grained and of even texture, and consists of a base of little felspar laths and granular augite through which larger crystals of olivine are scattered. The second felspar is fairly abundant, though not conspicuous. The olivine is, as a rule, perfectly fresh, and when it has been altered gives rise to green serpentine, and no iron staining. The iron ores are plentiful as little equidimensional crystals and grains evenly scattered through the rock. There is a little residual glass, which is in part devitrified and greenish. This basalt is compact and free from vesicles, unlike those below it. Its chemical composition, as well as its texture and freshness, ally it to the later basalts.

2. From the cliffs forming the south boundary of the depression in which Mt. Leura stands.—This basalt is porphyritic, with a very fine-grained groundmass consisting of an aggregate of granules of augite, a little felspar, and some glass with thickly scattered grains of iron ore. Through this are scattered larger lath-shaped felspars, grains and crystals of olivine, and some groups of augite grains. One of the felspars, with Carlsbad and albite twinning combined, gave concurrent obscurations of about 14.5° and 35°, corresponding to labradorite of the composition Ab_2An_3. The olivine is usually converted into iddingsite, and is sometimes quite opaque from staining with limonite.

3. From cliff on the east side of Lake Bullenmerri.—A rather fine-grained basalt, consisting of plagioclase, augite, olivine, and iron ores. The bulk of the felspar is in the form of small crystals in the base, but through this some larger crystals are scattered. The augite is granular and small. The olivine occurs as grains which are more or less altered to iddingsite. The iron ore occurs as small grains and elongated forms. Another slice from the same locality showed a similar basalt, a little coarser in texture, and with rather more abundant iron ore of the elongated form.

4. Near the southern end of Lake Gnotuk.—A holocrystalline coarse-grained basalt, of even texture. The twinned felspar laths are labradorite, giving symmetrical extinction angles up to 26°. The untwinned allotriomorphic felspars are fairly common; some of them evidently vary in chemical composition in different parts of the same crystal, one, for instance, extinguishing at about 0° near its periphery and at about 18° near its centre. The olivine, which is moderately abundant, is largely iron stained and altered to iddingsite. The augite is granular and plentiful, and the iron ore occurs both as grains and elongated pieces.

5. Quarry near Lake Colongulac (southern end).—A holocrystalline basalt, moderately fine-grained. The most abundant mineral is augite, which occurs in the granular form. The usual twinned felspar laths are plentiful, but the anhedral felspar is absent. Olivine is moderately abundant as grains, and is in part altered to green or iron-stained serpentine, especially along certain lines. The iron ore occurs as grains scattered evenly through the mass. One idiomorphic felspar crystal of considerable size compared to the other minerals occurs, but is unsuitable for exact determination.

6. Marida Yallock.—The next group of specimens to be described was collected from various parts of the large area of basalt, part of which forms the platform from which the scoria cone of Ewan's Hill rises, and which may have originated at or near the site of that hill. It occupies most of the parish of Marida Yallock, and gives rise to a very fertile soil.

(*a*) Terang-Camperdown road, Quarry near Allotment XV., parish of Marida Yallock, 3 miles from Camperdown. Slice No. 1312, Pl. 8, Fig. 2, Analysis No. 4.—A coarse-grained holocrystalline basalt, of even texture. The twinned felspar laths are labradorite, giving symmetrical extinctions up to 30°, and the untwinned felspar is fairly common. Olivine is abundant, both as crystals and grains, and, as a rule, is much iron stained and partly altered to iddingsite. The augite is granular, and not very plentiful, and occasionally encloses some felspar. The iron ores occur both as grains and elongated pieces.

(*b*) One mile from Boorcan Railway Station, on the Geelong-road.—A coarse-grained olivine basalt, with a little residual glass. The olivine is quite fresh, except for a narrow iron-stained selvage. It has crystallized out into well-shaped forms, and these have been subsequently deeply eaten into by the molten magma, so that they often appear to enclose the other minerals. The felspar is of the usual type, but there seems to be little or none of the untwinned variety. The augite is granular, and the iron ore elongated and in skeleton crystals; both these minerals are rather less plentiful than in the average basalt.

(*c*) Mt. Emu Creek, near southern boundary of the map.—The two slices of basalts from this locality are very similar to (*a*) above. The elongated iron ores are translucent in places, and are then clove-brown in colour; this shows that they are ilmenite.

(*d*). The old platform of Ewan's Hill.—This is probably a little younger in age than the basalts just described from the same area, but belongs to the same series. It is similar to (*a*) and (*c*), except that the augite (titaniferous) is larger and encloses the felspars ophitically.

(*e*) Quarry, near Water Reserve, Allotment XII., parish of Marida Yallock.—A similar basalt, with granular augite. The skeleton crystals of ilmenite, though not large, are striking.

Near Lake Terang.—(*a*) Quarry on east shore of Lake Terang. Slice No. 1292, Pl. 9, Fig. 1, analysis No. 5.—A moderately coarse-grained, holocrystalline, ophitic olivine basalt. The felspars are of the usual varieties, both twinned and untwinned forms being present, and the augite individuals are often of considerable size. The augite is practically all altered to iddingsite, and, as is the case in nearly all the specimens examined, is the only mineral that appears to have undergone a change. The iron ore is ilmenite in elongated forms, and is not particularly common. This stone has been used for building the church which stands near the quarry.

(*b*) A little south of Lake Terang.—Similar to No. 1292.

(*c*) Half-a-mile east of Lake Terang.—A moderately fine-grained basalt, containing residual glass.

The most abundant mineral is titaniferous augite, which forms minute prisms. The felspars appear to be the usual varieties, and crystals of olivine are plentiful and unaltered, except for a narrow iron-stained marginal rim. The iron ore occurs as grains and crystals, scattered throughout the slide. The glass is full of trichites. This slice has rather the appearance of the later basalts than of the earlier series.

7. Near Kolora, north-west of Mt. Noorat. Slice No. 1311, Pl. 8, Fig. 1, Analysis No. 6.—A holo-crystalline, moderately coarse-grained basalt. Both types of felspar occur, the untwinned form being plentiful. The lath-shaped plagioclase with repeated twinning is labradorite. The abundant olivine crystals and grains are in part converted into iddingsite. The augite is of a very light tint, and gives an extinction up to 40°, and the iron ores are abundant, and tend to assume an elongated form. This is a representative of the earlier basalts which occur largely in the parishes of Mortlake, Wooriwyrite, and Kilnoorat, and to the north, largely covered with buckshot gravel.

8. Quarry, Allotment XVII., 2, parish of Glenormiston.—Similar to No. 1311, but the olivine is sometimes deeply eaten into by the groundmass. From beneath the buckshot.

9. Parish of Kilnoorat, near north boundary (Allotment XXVI.).—Similar to No. 1311, but a litt finer in texture. From beneath the buckshot.

10. Brennen's Well, Allotment III., 15, parish of Glenormiston. See Pl. 9, Fig. 2.—This specimen was collected at a depth of 90 feet from the surface, and is from the basal part of the earlier basalts. It has been much altered, and the hand specimen, which is traversed with numerous fine veins of calcite, is greenish-black in colour, and resembles melaphyr or serpentine; felspar is recognisable on its surface, but the other minerals are obscure. The microscope reveals a basic felspar containing many needle-like inclusions, but very much decomposed. The olivine is completely altered into serpentine; calcite and other carbonates are also present as decomposition products. There are some scattered grains of iron ore. This rock has undergone more alteration than any of the others examined.

The Later Basalts.

1. Mt. Noorat Basalt Flows.—(*a*) Quarry, Allotment XII., 3, parish of Glenormiston.—A fine-grained basalt with few phenocrysts. It consists largely of an intimate admixture of minute prisms of titanium-bearing augite and felspar, a good deal of which is untwinned and ill-defined in shape and of later growth than the augite, which it often incloses; little cubes of iron ore are evenly and plentifully distributed throughout the rock. Olivine is rather rare, but there are a moderate number of grains and crystals of augite, larger than the other minerals, embedded in the groundmass. These grains are generally sub-angular, and in one place there is a mosaic of little augite grains which evidently represents a large crystal which has been shattered and partly absorbed. An example of the principal lava flows from Mt. Noorat.

(*b*) Mt. Noorat, north side.—A very fine-grained basalt. The groundmass examined with a high power appears to consist of a rather dense violet-brown substance (resolved by polarized light into glass and minute augites), through which are distributed abundant grains of iron ore and scattered felspar laths. Olivine is abundant as well-defined crystals, but more commonly as grains, the larger of which have been generally more or less re-absorbed by the magma. One phenocryst of felspar with rather fine repeated twinning is present, but it is unsuitable for more specific determination. In another slice a similar felspar occurs, whose centre is crowded with inclusions of iron ore and augite. An example of one of the latest flows; it took place during the explosive period. Such flows are generally quite small in extent, and have rugged surfaces. The basalts on the northern and western sides of Mt. Noorat are typical examples of them. These lavas are generally dark in colour and finely vesicular.

2. Camperdown.—Quarry immediately west of the Show Ground. Slice No. 1291, Pl. 11, Fig. 2, anlaysis No. 9.—A fine-grained basalt, with little or no residual glass. The groundmass consists largely of minute prisms and grains of titanium-bearing augite, with plentiful iron ores, which occur as minute skeleton growths and larger rectangular crystals, and a little felspathic matter. Through this are scattered numerous plagioclase laths, generally with fine twin striæ, a little untwinned felspar and augite, and plentiful olivine grains and crystals. A lath-shaped felspar, apparently nearly parallel to (010), became obscure at 29°, indicating bytownite.

3. Mt. Kurtweeton.—A fine-grained basalt, in which the finest part of the groundmass consists of minute augites and ill defined felspars, with plentiful grains of iron ore. Through this are scattered numerous little plagioclase laths, a little untwinned felspar, and small grains and crystals of olivine. The large constituents, of which olivine is very much the commonest, are moderately plentiful, and consist of olivine and faintly-coloured augite, rather rare felspar, and a couple of grains of quartz. All the olivine is surrounded by a narrow iron-stained zone; the augite is usually in the form of well-shaped crystals; most of the felspar is confined to a group of fairly large lath-shaped crystals; and the quartz grains are partly re-absorbed and are surrounded by a reaction zone. This occurrence of quartz in basalt is very interesting, and is again referred to on page 25.

4. Mt. Koang (Cole's Hill), Allotment XVIII., parish of Koort-Koort-Nong.—Very similar to the last, but contains no quartz.

5. Ewan's Hill.—A fine-grained, scoriaceous basalt, containing many phenocrysts. The ground mass consists largely of a dense glass of violet-brown colour, containing small augites and plentiful little plagioclase laths, and very abundant grains of iron ore. The phenocrysts are crystals and grains of olivine and augite; the latter mineral is considerably more abundant than the former. This is rather unusual in the basalts of this district. It generally exhibits sharply-defined crystal outlines, but may be more or less irregular in shape. It is almost colourless, and extinguishes at angles up to 42° in the sections from the prismatic zone which were measured.

6. Mt. Terang.—The quarry facing north, near the top. Slice No. 1290, Pl. 11, Fig. 1.; Pl. 5, Fig. 2, Analysis No. 8.—A fine-grained basalt. The groundmass consists largely of glass and little titanium-bearing augite, with some ill-defined felspars and plentiful iron ore, which occurs either as beautiful fern-like skeleton crystals or as larger, but still small, cubes. Through this are scattered felspar laths and plentiful olivine, generally in the form of well-shaped crystals, and usually surrounded by a narrow iron-stained border. Augite is rare among the phenocrysts. The development of the fern-like crystals of iron ore appears to have taken place most readily in the vicinity of the steam cavities which penetrate this rock.

7. Darlington-road, north-west of Terang.—Quarry. A fine-grained basalt, consisting of a groundmass composed of glass, granular augite, some allotriomorphic untwinned felspar, very numerous little lath-shaped plagioclases, and grains of iron ore. Through this are scattered fairly plentiful grains of olivine and a little augite. The interesting feature about this basalt is that it presents a pustular or variolitic appearance in the mass, the surface being covered with little spots lighter in colour than the general mass. No trace of this structure can be seen under the microscope.

8. Mt. Elephant.—A fine-grained basalt, of even texture. It consists of the usual minerals, but the untwinned felspar is rather abundant, and the rock has scattered through it numerous colourless needle-like crystals, which may be apatite.

The Fragmental Rocks.

General Notes.

In the preceding pages the fragmental rocks have been divided into two groups—the Hampden tuffs and the material of the scoria hills—and the petrological details will be given under the same two headings.

The main body of the Hampden tuffs consists of well stratified beds, ranging in texture from layers which resemble a fine sandstone to others in which the fragments are as large as a pea. They are soft rocks, dark grey in colour, and often iron-stained. The individual fragments seen by the naked eye are more or less rounded pieces of rock, with scattered cleavage flakes of black hornblende and white felspar. Under the microscope the rock fragments are seen to be basalts of various textures set in a more or less decomposed aggregate of volcanic dust, together with small mineral fragments. It is a noteworthy fact that some of these tuffs contain quartz-bearing basalt and numerous fragments of quartz scattered through the groundmass (see detailed description below).

In certain places the Hampden tuffs contain vast numbers of ejected blocks, ranging in size from an inch or two across to masses a ton or more in weight. Many of them are formed of basalt without any distinctive structural features to differentiate it from the surface basalt flows, but many of them are formed of essexite, an alkali gabbro which has not previously been recorded in Victoria. It is a dark-grey rock, which weathers to a lighter shade on the surface, and varies in texture from coarsely crystalline to aphanitic. The component minerals are orthoclase, labradorite, and monoclinic pyroxene, with varying minor proportions of hornblende and biotite, abundant apatite, iron ores in fairly large and well-developed crystals or skeleton growths, and an isotropic mineral, probably analcite. The analyses (Nos. 1 and 2) are given side by side with Washington's analysis (No. 3) of essexite from the type locality. It will be seen that the alkalies in the Bullenmerri rocks are comparatively low, but they come well within the limits given in analyses of rocks classified under this heading from other localities, and the soda exceeds the potash, as it does in the type rock. The relative proportions of lime and magnesia are also typical. A somewhat similar rock, from near Sölvsberget in the Christiania area, has been described by Professor Brögger* ; it forms part of the series in which sölvsbergite occurs. The idea naturally presents itself that the essexite may be torn from some deep-seated representative of the Macedon series of rocks, of which sölvsbergite is a typical example. Other ejected blocks, generally of smaller size, consist of peridotite and pyroxenite ; some of them may be basic concretions formed in the basalt magma. Masses of basalt are abundant. The beach at Lake Bullenmerri, which is a basin in these rocks, consists of grains of olivine, diopside, and other ferro-magnesian minerals, felspar, garnet, and a little quartz ; and in places contains many small fossil shells washed out from the Cainozoic beds, which outcrop along the shore line, as well as shells of the little molluscs which are now living in the waters in great numbers.

The Scoria hills consist for the most part of rough, angular pieces of vesicular basalt, which is formed largely of a purplish brown glass crowded with microliths of felspar and iron ores, and contains larger scattered crystals of augite and olivine. Amongst this are very numerous bombs, which generally have a nucleus of some material other than basalt forming a large proportion of their mass. The nucleus generally consists largely of olivine, with more or less augite, hypersthene, diopside, hornblende, garnet, and picotite ; sometimes the pyroxene may predominate or the nucleus may consist consist largely of felspar and quartz, of a single crystal of augite, or of an angular piece of sedimentary rock. Cleavage fragments of felspar, sub-angular granular masses of olivine, and other ferro-magnesian minerals are scattered among the bombs and scoria. The olivine nodules are either green or red in colour ; the red variety appears to be derived from the green by the alteration of the outer coating of the olivine into iddingsite. In all cases where the test was tried the olivine remained practically unaltered before the blow-pipe, neither fusing nor becoming magnetic, and is therefore the species chrisolite and not fayalite.

Ejected Blocks.

Essexites.—Slices Nos. 1288, 1307, and 1308. Ejected block about 3 feet across, north end of Lake Bullenmerri. Analysis No. 1.—The specimen from which these slices were cut is a coarse-grained essexite, in which the component minerals range from an eighth to a quarter of an inch in length. The most conspicuous mineral is black pyroxene, which is irregular in shape, but often roughly prismatic. It is rather less abundant than the felspars, the individual crystals of which are not very clearly marked off from one another, though numerous bright cleavage faces show that many of the felspars have a prismatic habit, and are zoned and sometimes simply twinned. Occasional grains of olivine can be distinguished.

* W. C. Brögger, Q.J.G.S., L., 1894, pp. 18, 19.

Under the microscope the rock is seen to be holocrystalline and hypidimorphic in structure, and to consist of ilmenite (or magnetite), olivine, augite, soda-augite, labradorite, orthoclase, analcite, a little biotite, and apatite. The first mineral to crystallize out was the ilmenite or titanic iron ore, which occurs as grains or skeleton crystal growths little inferior in size to the other minerals. It is fairly plentiful, and associated with it are the few small flakes of biotite which occur in this rock. This was followed by the apatite, which is plentiful and forms slender rods, some of them fairly large. Grains, or rather irregular crystals, of olivine are scattered through the rock, but it is by no means so plentiful as the pyroxene; it is a little iron-stained near the edges and along some of the cracks, but is otherwise practically unaltered. The pyroxene has the purplish-brown tint characteristic of the varieties containing titanium, is practically non-pliochroic, and obscures at angles ranging up to 33° from the vertical axis; it may, therefore, be identified as titanium-bearing augite. It generally forms rather irregular prisms, and sometimes surrounds felspars, so that, at least in part, it has crystallized out after them. A green, slightly pleochroic pyroxene also occurs, but is much inferior in size and quantity; extinction angles ranging up to 35° were measured in the prism zone, so that it is probably ægerine-augite. The felspars, which form the bulk of the rock, are of interest as amongst them is found the rather unusual combination of orthoclase and labradorite. The plagioclases are idiomorphic and elongated parallel to the albite twin lamellæ; twinning of the pericline and Carlsbad types also occurs. One section, twinned according to both the albite and Carlsbad laws, and cut almost perpendicular to the lamellæ, gave concurrent obscuration angles of 32° and 16°; the felspar is therefore labradorite of about the composition Ab_2An_3. Symmetrical extinctions measured in six sections cut perpendicular to the lamellæ, and in which albite twinning only was developed, ranged from 20° to 32°. These angles point to a felspar at least as basic as labradorite; but some of the crystals merge into a more acid variety around their periphery, and they are often surrounded by a zone of orthoclase, into which the albite lamellæ, of course, do not penetrate. Orthoclase occurs as anhedral crystals between the other minerals, and sometimes surrounding them, and is sometimes simply twinned. The isotropic mineral, which is not very abundant, is colourless and without cleavage, but is generally traversed by a reticulation of short cracks; its refractive index is about the same as that of sodalite. It shows no trace of decomposition, and is evidently not a secondary mineral. It usually occurs filling the space between two other minerals, often in the angle between two intersecting felspars, but some pieces show distinct traces of their crystal form. This is brought into prominence by treating the slice with dilute hydrochloric acid, which gelatinizes the surface of this mineral, and then staining with malachite green (Pl. 14, Fig. 1). The idiomorphic sections are about equidimensional, and have six or eight sides. In the stained preparation they are marked by zones of colour parallel to the edges, showing that the mineral is not homogeneous in composition, but consists of concentric shells which are gelatinized by the acid to various degrees; some of these zones are feebly bi-refringent. Micro-chemical tests were tried with negative results, for chlorine, which would indicate the mineral to be sodalite, and for SO_3, which would indicate hauyné or nosean. The only other mineral which it is likely to be is analcite; and the optical anomalies, the slight variations in chemical composition indicated by the varying degree of gelatinization, and the outline of the sections of idiomorphic crystals, all support this determination, although the refractive index seems, if anything, rather low. The chemical analysis of the rock (No. 1) also seems to exclude the members of the sodalite group, for the presence of 1 per cent. of these minerals in the rock (a moderate estimate, judging from the micro-slices) should give the following amounts* of chlorine or SO_3 in the analysis of the whole rock:—

1%.	Cl %.	SO_3 %.
Sodalite	0.03 to 0.07 ..	
Hauyne	.. ..	0.08 to 0.12
Nosean	.. ..	0.07 to 0.11
Actual result ..	Less than 0.01 ..	Less than 0.01

Even if the amount of the mineral present were only half of 1 per cent., the amount of Cl or SO_3 should be more than a trace (0.01 per cent. or less), unless it were sodalite exceptionally poor in chlorine.

Some of the isotropic mineral assumes a blue tint when stained, while the rest is green; this may indicate the presence of two minerals closely resembling one another. There does not seem to be any nepheline present.

Slice No. 1289. Analysis No. 2.—This also formed a part of an ejected block of considerable size near the north end of Lake Bullenmerri. It is rather a fine-grained rock, and the minerals can scarcely be distinguished in the hand specimen, but it can be seen to be composed largely of felspar and a dark ferro-magnesian mineral with fairly plentiful grains of yellowish olivine. Under the microscope the same minerals which occur in No. 1288 are observed. The olivine is fairly plentiful and very little decomposed, and forms larger crystals than the augite; and the latter mineral gives extinction angles up to 44°. Apatite needles are rather more plentiful than in the coarser-grained variety.

Several other specimens from the same locality were examined, and were all very similar, though there is a considerable range in the coarseness of their texture. Sometimes the pyroxene is purplish-brown shading off into a greenish tint towards the edge, or it may be wholly greenish. In both these cases the extinction ranges up to 44°, so that it is augite or diopside, and not ægerine. In some cases it is almost colourless. Twinning is sometimes met with. The olivine may be rather scarce or nearly as plentiful as the pyroxene, and the biotite may be absent, or very rare, but it is occasionally scattered all through the rock. The analcite may inclose needles of apatite and is evidently a primary mineral.

* Based on analyses of the minerals given in Dana's Text-Book of Mineralogy, 6th Ed.

Basalts.—Basalt occurs frequently as ejected blocks of all sizes. Many of them are aphanitic, but contain phenocrysts of felspar and ferro-magnesian minerals. A typical example contains rather scarce felspar and augite and scattered grains of olivine. The felspar is colourless and glassy, and up to $\frac{3}{8}$-inch across, and the hordblende is black, rounded, and partly re-absorbed. Under the microscope the bulk of the rock (Slice No. 297) consists of a rather opaque glass, through which is scattered a great number of little grains of magnetite or ilmenite, and larger grains or crystals of olivine and pyroxene. The felspar mostly occurs as very small microliths, but there is a rounded phenocryst of an unstriated and indeterminable felspar, and near the edge the shattered remains of a large augite crystal. A somewhat similar basalt (Slices Nos. 296 and 299), without the porphyritic minerals, contains occasional rather rounded grains of coffee-brown spinel (picotite) surrounded by an opaque black border, formed, at least in part, of grains of iron ore.

Picrite.—Picrite is not a very common rock in the Hampden tuffs. A typical specimen consists of a coarse-grained, almost black rock, composed largely of black pyroxene, with some green pyroxene and mica, and a very little felspar. In the small cavities these minerals present bright crystal faces. Under the microscope (Slice No. 312) it is seen to be holocrystalline, and to consist largely of a mosaic practically colourless augite, in which decomposition is beginning; moderately plentiful olivine, iron stained along the edges and partly decomposed to serpentine and calcite; light yellowish-brown basaltic hornblende or barkevikite, strongly pleochroic (yellowish-brown to deep brown), with extinctions up to 5°; and rather rare biotite, almost the same colour as the hordblende, but even more strongly pleochroic. The remains of a single large felspar occurs; it is untwinned, and gives a shadowy extinction in different parts when rotated, and is indeterminable; a few rather short prisms of apatite are included within it. Iron ores are practically absent.

Pyroxenite.—The specimen from which Slice No. 313 was cut is dark in colour, and consists of a granular aggregate of dark-green pyroxene, through which pink garnets are plentifully scattered. The grains are about one-twentieth to one-fortieth of an inch across. Under the microscope none of the diopside shows any trace of crystal outline; its colour is very faint green, and it is not pleochroic; its extinction ranges up to 45°. Most of the grains are optically uniform over their whole surface, but some are marked by repeated narrow twin striæ making an angle of about 70° with the prismatic cleavage in sections parallel to the axes *a* and *c*, and is therefore parallel to the basal pinacoid. The grains of garnet, which are very pale pink, are traversed by the usual characteristic cracks, but are quite unaltered and are free from optical anomalies. There is no sign of crystal outline, and they are free from inclusions. Iron ores and other minerals are absent. Attached to this rock, which is allied to eclogite, is a partial coating of basalt similar to that already described.

Peridotite.—A typical specimen (Slice No. 311) is holocrystalline and granular; practically the whole rock consists of a mosaic of olivine grains which are perfectly unaltered, clear, and colourless. Some pyroxene occurs as an allotriomorphic infilling between the olivine grains, and evidently embraces two species, one light green and the other colourless. The former is slightly pleochroic, from faint sea green to a more yellowish tint, and extinguishes between crossed nicols at angles ranging up to 37° for sections in the prism zone, and is therefore diopside. The colourless pyroxene obscures in the zero position, and is the rhombic species enstatite. Iron ores are absent. The rock might be described as lherzolite (Pl. 12, Fig. 2).

Another is a dark, coarse-grained, heavy rock, composed of yellow granular olivine and black pyroxene, which is generally irregular in shape. Under the microscope (Slice No. 293), about half the rock is seen to be formed of pyroxene, and the rest of olivine and basaltic hornblende, with a few large grains of iron ore, which is generally associated with the hornblende. The pyroxene is pale French grey in colour, faintly pleochroic, allotriomorphic, and traversed by numerous cracks; the cleavage is obscure, and the extinction angles range up to 44°. In some instances there appears to be a paramorphic change to brown hornblende, but the hornblende has, for the most part, crystallized out after the olivine and augite; extinction angles up to 10° were measured, and the pleohroism is extremely strong, ranging from light brownish yellow to almost black.

The Hampden Tuffs.

The well bedded Hampden tuffs from different localities examined microscopically bear a strong likeness to one another. A specimen from Section XIX., parish of Colongulac, north-east of Lake Gnotuk, may be taken as a typical example. It consists, for the most part, of small, more or less rounded fragments of basaltic rocks of various textures, dispersed through a groundmass of fine decomposed volcanic dust. Some fragments are fine-grained and glassy olivine basalt containing angular grains of quartz, around which in polarized light a narrow "reaction border" can be seen. Most of the rock fragments contain olivine, and vary from glassy forms to coarse-grained holocrystalline basalt. In addition, there are scattered through the groundmass of volcanic dust fragments of diopside, olivine, felspar, hornblende, and quartz, all more or less angular. The presence of the quartz is proved beyond all doubt by its interference figure, and it was noticed in the other tuffs examined (see below). Some of the quartz grains enclose sender rods, which do not transmit light, and which cross one another at angles of 60°, making a network like sagenite; they may possibly be rutile. In other specimens transparent prisms were observed, which were probably apatite. The presence of quartz in these rocks is strange, unless it represents the shattered fragments of some of the rocks through which the volcanic forces broke during the eruptive period, and from the nature of the inclusions the parent rock was evidently of igneous origin. Other samples of Hampden tuff examined microscopically came from the south-west corner of the Mt. Elephant Quarter Sheet, and from Mt. Terang. They are very similar, but contain, in addition, a secondary mineral as veins and streaks around the larger fragments; it is yellow in colour and glassy looking, and gives low polarization colours and wavy extinction, and is probably a zeolite. The deposit covering the marsupial remains at Blind Creek, parish of Kilnoorat, is similar microscopically, but it is uncertain whether this is an original tuff or one that has been redeposited.

SCORIA AND BOMBS.

The scoria from the cones generally consists of angular pieces of vesicular basalt of various sizes. Under the microscope the basalt consists largely of brown glass, rendered rather opaque through the presence of very numerous minute granules of iron ore, and in part iron-stained ; through this are scattered numerous small lath-shaped microliths of felspar, which appears to be labradorite, though no very satisfactory measurements were obtained. Augite occurs as microliths and larger crystals, together with olivine.

The bombs (Pl. 7) generally consist of an outer coating of similar basalt, surrounding a nucleus of some other substance. The arrangement of concentric bands of vesicles can be seen well in some of the micro-sections, but the following descriptions are confined to the nuclei. These may be classified as (1) ultrabasic concretions consisting almost entirely of olivine and pyroxene ; this is by far the most common type (2) Consisting of quartz and felspar ; these are rather rare. (3) Single crystals ; generally augite or a glassy felspar. (4) Pieces of sedimentary rock.

(1) Ultrabasic concretions.—Slice No. 301, Mt. Noorat, is cut from a small bomb, the centre of which consists of a granular aggregate of green olivine and black pyroxene. Under the microscope the most abundant mineral is seen to be olivine, but the pyroxene is also plentiful. It is practically colourless. All the extinction angles measured on it were less than 10°, except one, which was 32°. This indicates that there is some augite or diopside, but that most of the pyroxene is some species with a lower extinction. There are some opaque black grains with sub-metallic lustre, which are probably chromite. Other bombs contain similar nuclei, composed of the same minerals, including the two varieties of pyroxene, but they often contain more or less picotite in grains which look as if they had been partly re-absorbed.

No. 303, from the same locality, differs somewhat from the usual type. The bulk of it is formed of practically colourless diopside, and there are only a few grains of olivine. Plagioclase occurs as allotriomorphic plates enclosing apatite rods and the other minerals. Some of it shows twin striæ, but is not suitable for exact determination. Patches of yellow isotropic material, with a low refractive index, occur in the spaces between the diopside grains ; they show no signs of cleavage, and are always uniformly coloured throughout, and in places are crowded by a mass of microliths of iron ores and felspars, both very small. It is probably a glass.

(2) Quartz and Felspar.—No. 307, Pl. 15, is a small bomb with a white granular nucleus, which is resolved into a granitic admixture of quartz and felspar under the microscope. Some of the felspar is unstriated or simply twinned, and appears to be orthoclase. The greater part, however, consists of plagioclase, with rather fine striations of the albite and pericline types. A crystal cut perpendicular to the lamellæ gave symmetrical extinctions of 5°, but this is probably not approaching the maximum, since others cut nearly in the right direction gave extinctions of about 19°. The plagioclase may be oligocene or andesite.—Mt. Noorat. Bombs of this type are not very plentiful, but some were examined from Mt. Leura.

(3) Single large Crystals.—A small volcanic bomb, whose nucleus is formed of an angular piece of black augite, was sliced (No. 305) for microscopic examination. In the section, one set of cleavages can be seen, and the position of obscuration makes an angle of 33° with these. In parallel intergrowth with the augite is another colourless pyroxene, which can only be differentiated between crossed nicols. It forms short and narrow bands with ragged outlines, and its position of extinction is not far from zero. There are also present within the augite a few flakes of biotite and some brown basaltic hornblende, whose cleavages are generally parallel to those of the augite, but which are not always orientated in the same manner.—Mt. Noorat.

(4) Sedimentary Rocks.—A slice was cut from a small bomb whose centre is evidently an angular piece of sedimentary rock (No. 304.). Under the microscope it is formed of a fine-grained argillaceous sandstone which appears to have suffered very little change—Mt. Noorat. In others the sedimentary rock was rather coarser in texture.

LOOSE MINERALS IN THE SCORIA.

1. Felspar occurs very commonly on most of the scoria cones, generally as cleavage fragments, which range up to a couple of inches long ; sometimes they are partly surrounded by basalt and more or less rounded. The material used in making the analysis is given on page 28 was all part of the same individual crystal, which was transparent and quite free from decay and visible impurities. The large amount of potassium and the small quantity of lime show that it must be anorthoclase, and not, as might be expected, one of the plagioclases of the albite-anorthite series. Mr. Bayly, in discussing this analysis, says that the discrepancy in the summation is due to the estimation of the alkalies being a little low, but that he is quite sure of great accuracy in the other figures. The alkalies were unsatisfactory owing to fusion during the analysis, and there was not sufficient material left to repeat this estimation. Distributing the error, then, between the K_2O and the Na_2O in the proportion in which they occur, and working out the molecular formula, a very satisfactory result is obtained ; for comparison, an analysis by Penfield quoted by Dana from U.S. Geol. Surv., 7th Ann. Rept., p. 269, 1885–6 (1888), is computed in the same manner.

ANORTHOCLASE FROM MT. NOORAT.

—	%.	Molecular Proportions.		Orth.	Albite.	Remainder.
SiO_2	66.23	1.104	1,104	234	864	+ 6
Al_2O_3	19.97	0.196	199	39	144	+ 16
Fe_2O_3	0.49	0.003				
MgO	0.17	0.004	13	..	..	+ 13
CaO	0.50	0.009				
Na_2O	8.91	0.144	144	..	144	..
K_2O	3.71	0.039	39	39	..	..
H_2O	0.02	..	..	..	..	..
	100.00	..	..	39	144	..

ANORTHOCLASE FROM OBSIDIAN CLIFF, U.S.A.

—	%.	Molecular Proportions.		Orth.	Albite.	Remainder.
SiO_2	67.53	1.126	1,126	324	810	− 8
Al_2O_3	17.99	0.176	180	54	135	− 9
Fe_2O_3	0.60	0.004				
CaO	0.09	0.002	2	..	..	+ 2
Na_2O	8.36	0.135	135	..	135	..
K_2O	5.08	0.054	54	54	..	..
	99.65	..	..	54	135	..

The analysis of the Mt. Noorat specimen shows that orthoclase and albite molecules occur in the proportion Or : Ab. :: 1 : 3.7. Taking the lime into account, the composition of the felspar is approximately $Or_{6\cdot5}Ab_{24}An_1$ or $(OrAb_{3})_{\cdot5}An_1$. Its optical properties were determined on cleavage plates parallel to (001) and (010). The refractive index is close to that of orthoclase, and the acute bisectrix emerges nearly perpendicular to (010). The extinction on (001) is 5°, and on (010), 7°; the thicker parts of the cleavage plates parallel to (001) do not give any proper extinction, but remain more or less bright in all positions between crossed nicols. The thin edges, however, give a well-marked position of obscuration. There are some fine twin striæ on (001), but they are rather obscure. Other loose felspar fragments from Mt. Leura and other cones have similar optical properties, and are consequently anorthoclase.

The occurrence of this felspar, instead of one of the lime-soda species, is rather remarkable; the best known group of Victorian rocks in which anorthoclase has been determined are the Macedon series.* The presence of this felspar strengthens the hypothesis suggested by the finding of ejected blocks of essexite, that there is some connexion between the volcanic rocks of the Macedon series (dacites, solvsbergites, &c.) and the Western District basalts. Some of the unstriated felspars in the basalts and fragmentary rocks described may also be anorthoclase. Should any genetic connexion exist between these basalts and the Macedon series, the latter connot be of any very great antiquity.

2. *Olivine.*—This mineral generally occurs as a coarsely granular aggregate, mixed with other ferro-magnesian minerals, either with or without an exterior coating of basalt. These nodules are either red or green; the colour depends on what minerals are present, and the extent to which weathering has taken place. At Mt. Terang, among the fine scoria exposed in a quarry close to that shown in Pl. 5, Fig. 2, and in a road-cutting near the top of the hill, there are many very beautiful, though small, olivine crystals. They are either simple forms or consist of groups of parallel growths, and are generally about ⅛ inch long. The planes noted were the pinacoids (010) and (001), the prisms (110) and (120), and the domes (101), (011), and (021). They are sometimes flattened parallel to (010). The faces of the crystals are bright, but have generally been more or less altered by weathering. This makes it difficult to obtain satisfactory readings with the reflecting goniometer; the angles measured, however, closely approximated to those of chrysolite. The colour is greenish yellow. On analysis they were found to contain 15.80 per cent. of FeO, so that they are the species chrysolite. Before the blowpipe, minute pieces fuse with great difficulty and give good reactions for iron with the fluxes. Its specific gravity is 3.486 at 4° C.

3. *Pyroxene.*—With the olivine crystals just mentioned, there are found small bright crystals of black pyroxene. The three pinacoids (100), (010), and (001), the prism (110), the pyramid (111), and the domes (011) and (101) were observed, and doubtless other faces would be noticed if a larger amount of material were examined. The prisms are generally short and stout, but they are sometimes long in comparison to their thickness. In some cases twinned forms were noticed, and in others the distribution of the pyramid faces suggests that the mineral may possibly be a triclinic pyroxene, and not one of the usual monoclinic forms.

* See J. W. Gregory, Proc. Roy. Soc., Vict., Vol. XIV., n.s., 1900, p. 185.

ANALYSES.

—	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	—
SiO_2 ..	48.84	49.93	46.99	50.53	50.69	49.29	45.86	45.15	46.29	48.00	48.78	66.23	SiO_2
Al_2O_3 ..	14.95	15.99	17.94	15.13	15.64	13.99	13.19	12.93	13.71	14.11	15.85	19.97	Al_2O_3
Fe_2O_3 ..	2.79	1.56	2.56	5.26	9.64	7.54	2.82	5.26	3.03	5.61	5.37	0.49	Fe_2O_3
FeO ..	8.53	7.32	7.56	5.68	2.04	4.49	8.61	6.88	9.14	6.11	6.34	..	FeO
MgO ..	4.73	6.83	3.22	7.59	5.51	8.82	10.58	11.35	9.50	8.81	6.03	0.17	MgO
CaO ..	7.47	9.12	7.85	8.41	7.52	8.28	9.09	9.97	8.60	8.68	8.91	0.50	CaO
Na_2O ..	3.90	3.54	6.35	3.26	3.25	2.97	2.44	2.90	3.26	3.01	3.18	8.07	Na_2O
K_2O ..	2.01	1.54	2.62	0.94	1.05	1.04	1.00	1.76	1.62	1.25	1.63	3.36	K_2O
H_2O + ..	1.53	1.55	0.65	0.63	0.87	0.69	1.33	0.32	0.39	0.73	1.03	..	H_2O +
H_2O − ..	0.67	0.36	..	0.76	1.06	0.79	1.66	0.29	0.31	0.80	0.73	0.02	H_2O −
CO_2 ..	Nil	Nil	..	Nil	Nil	Nil	0.60	Nil	Trace	..	..	..	CO_2
TiO_2 ..	4.00	1.95	2.92	1.70	2.05	1.75	2.20	2.65	2.95	2.20	1.39	Nil	TiO_2
P_2O_5 ..	0.52	0.40	0.94	0.35	0.36	0.38	0.51	0.73	0.71	0.50	0.47	..	P_2O_5
SO_3 ..	Trace	Trace	..	Nil	Trace	Nil	Nil	Trace	Trace	..	..	..	SO_3
Cl ..	Trace	Trace	..	Trace	Trace	Trace	Trace	Trace	Trace	Trace	..	..	Cl
F ..	0.08	..	..	..	..	..	..	..	..	..	..	..	F
Cr_2O_3 ..	..	..	..	..	0.06	..	..	..	0.05	..	..	..	Cr_2O_3
MnO ..	0.13	0.07	Trace	0.10	0.12	0.15	0.24	0.16	0.14	0.13	0.29	..	MnO
NiO ..	0.03	0.03	..	0.02	0.06	0.06	0.03	0.01	0.01	0.03	..	..	NiO
CoO ..	Trace	Trace	..	Trace	Trace	Trace	Trace	Trace	Trace	Trace	..	..	CoO
Li_2O ..	Trace	Trace	BaO Nil	Strong Trace	Trace	Trace	Strong Trace	Nil	Nil	..	..	Nil	LiO_2
Correction for F ..	0.03	..	..	..	..	..	..	..	..	..	..	..	
Total	100.15	100.19	99.60	100.36	99.92	100.24	100.16	100.36	99.71	99.97	100.00	98.81	Total
Sp. Gr. ..	2.908	2.865	2.919	2.922	2.797	2.895	2.922	2.914	2.959	2.902	..	2.608	Sp. Gr.

1. Essexite (Alkali Gabbro); ejected block, north end of Lake Bullenmerri, Camperdown. See p. 23 and Pls. 13 and 14. Rock Slices Nos. 1288 and 1307; analysis by Mr. A. G. Hall (No. 347).

2. Essexite (Alkali Gabbro); ejected block, north end of Lake Bullenmerri, Camperdown. See p. 24 and Pl. 14, Fig. 2. Slice No. 1289; analysis by Mr. A. G. Hall (No. 348).

3. Essexite; Salem Neck, Essex County, Mass., U.S.A. Analysis by H. S. Washington, Journ. of Geology, Vol. VII., 1896, p. 57. Original analysis of type specimen.

4. Earlier Basalt.—Quarry, Camperdown-Terang road, near Allotment XV., parish of Marida Yallock. See p. 21 and Pl. 8, Fig. 2. Slice No. 1312; analysis by Mr. A. G. Hall (No. 623).

5. Earlier Basalt.—Quarry on east shore of Lake Terang. See p. 21 and Pl. 9, Fig. 1. Slice No. 1292; analysis by Mr. A. A. Topp (No. 351).

6. Earlier Basalt.—Near Kolora, north-west of Mt. Noorat. See p. 22 and Pl. 8, Fig. 1. Slice No. 1311; analysis by Mr. A. G. Hall (No. 622).

7. Earlier Basalt.—Harvey's Well (uppermost flow), allotment XXVI., parish of Colongulac. See p. 21 and Pl. 10, Fig. 2. Slice No. 1313; analysis by Mr. A. G. Hall (No. 624).

8. Later Basalt.—Quarry, near summit of Mt. Terang. See p. 23 and Pl. 11, Fig. 1. Slice No. 1290; analysis by Mr. A. A. Topp (No. 349).

9. Later Basalt.—Quarry immediately west of Camperdown Show Ground. See p. 22 and Pl. 11, Fig. 2. Slice No. 1291; analysis by Mr. A. G. Hall (No. 350).

10. Average composition of the six basalts mentioned above.

11. Average of 161 analyses of typical basalts (largely olivine-bearing) from various localities. R. A. Daly, Journ. of Geology, Vol. XVI., 1908, p. 409.

12. Anorthoclase.—Scoria pits, Mt. Noorat. See p. 26. Slices Nos. 1314, 1315, and 1316; analysis by Mr. A. G. Hall (No. 602).

NOTES ON THE ANALYSES.

Mr. P. G. W. Bayly, A.S.A.S.M., Government Metallurgical Chemist, has supplied the following notes on the analyses, which were made under his supervision:—

The analyses were made on the lines indicated in Dr. W. F. Hillebrand's publication, Bull. 305, Geol. Surv., U.S.A., with modifications which have proved satisfactory, and most of which are referred to below. According to the usual practice followed in the Geological Survey Laboratory, the analysis of each rock was made quite independently by two analysts, Messrs. A. G. Hall and A. A. Topp. The results were critically examined and compared, and the best analysis decided upon.

In the separation of manganese the basic acetate method was used by Mr. Hall, while Mr. Topp used the triple precipitation by alumina, dissolving the last time in nitric acid. When the results were compared it was found that the variation between the two sets of figures for manganese was very small, the greatest difference being 0.04 per cent. higher in one instance for the acetate method; in another case the result by the same method was 0.03 per cent. lower. The results indicate that, even for such highly basic rocks as these, the triple precipitation method for determining manganese is quite satisfactory, besides being much cleaner and safer for the important alumina-iron determination.

Fluorine was determined only in the case of No. 1 in the above table; the method of Berzelius was adopted. It is very long for so small an amount of fluorine (0.08 per cent.), and this result may be high, as it is more than would be required if all the phosphoric mineral in the rock were fluor-apatite. Fluorine, according to Washington, "is an essential constituent of most apatite, and, as an integral part of this mineral, is almost universally present. It occurs also in biotites and other micas, and in some hornblende and augite." The rock contains all these minerals, and the fluorine figure may be thus accounted for. On heating the final precipitate, CaF_2, with sulphuric acid, strong fumes of hydrofluoric acid were observed. Although not determined, this element is probably present in the other rocks.

Chromium was determined in the case of one coarse and one fine-grained basalt; the colorimeter method was used. The other rocks would probably also be found to contain chromium.

Combined water.—The method used was described by me in the Eleventh Report of the Australian Assn. Adv. Sci., Adelaide, 1907, p. 330; in this method the loss on ignition is corrected by a determination of the ferrous iron after heating. The results have been shown to be entirely satisfactory.

In the case of No. 12, the rather low summation is due under-estimation of the alkalies owing to fusion during the analysis. There was not sufficient to repeat this portion, but the error indicated may be regarded as in the alkalies, the other determinations in duplicate being very satisfactory.

The specific gravity was determined by the following method, described by Hillebrand, Bull. 305, Geol. Surv., U.S.A., pp. 39, 40:—

1. Specimen suspended in water, boiled, cooled, and weighed in water of known temperature.
2. Wire removed and weighed while immersed equally in same water.
3. Rock dried at 110° C., and after atmospheric cooling for some hours, weighed till constant.
4. Specific gravity calculated at 4° C.

LIST OF MINERALS FOUND IN THE CAMPERDOWN DISTRICT.

Mineral.	Remarks.
Analcite ..	.. Occurs as an original rock-forming mineral in the essexite.
Apatite ..	.. Fairly abundant as a rock-forming mineral in the essexite; present but not conspicuous in the basalts and fragmental rocks.
Amphiboles	.. *Basaltic hornblende* occurs as cleavage flakes in the Hampden tuffs, and is especially common near Lake Gnotuk; as partly fused rounded pieces amongst the scoria; as a rock-forming mineral in essexite and associated ejected blocks; and in some of the bombs from the scoria cones; not found in the basalt of the lava flows. A variety, which is probably *barkevikite*, was noticed as a rock-forming mineral in some of the basic ejected blocks from the Hampden tuffs.
Biotite ..	.. In essexite and some associated rocks from the Hampden tuffs, not common; enclosed in a large augite crystal forming the nucleus of a bomb; not found in the basalts.
Calcite ..	.. In the marine cainozoic rocks, generally as fossil shells, &c.; as veins and patches in decomposed basalt.
Chromite ..	.. Some small black grains with sub-metallic lustre found in the nuclei of some bombs are probably chromite.
Felspars ..	.. *Orthoclase*, in essexite and associated with quartz and plagioclase in certain bombs; *anorthoclase*, loose fragments, generally clear and glassy, but sometimes opaque, in the scoria (especially at Mt. Noorat and Mt. Leura); also possibly as a rock-forming mineral in the basalts; *oligoclase* or *andesine*, in small quantities in the basalts and other felspar-bearing rocks and associated with quartz and orthoclase in certain bombs; *labradorite*, the principal constituent of most of the basalts, and in essexite; *bytownite*, in some of the basalts.
Garnet ..	.. In some of the ejected basic rocks in the Hampden tuffs, and in the sand forming the beach of Lake Bullenmerri. It is always the pink variety.
Iddingsite	.. In many of the basalts as an alteration product from olivine.
Ilmenite ..	.. Skeleton crystals and rod-like forms common in the basalts; tabular crystals occur in the vesicles of some of these rocks.
Limonite	.. Abundant as concretions forming "buckshot gravel"; also as a coating on weathered basalt.
Magnetite	.. Small cubic crystals and grains abundant in the basalts.
Olivine ..	.. Abundant in practically all the igneous rocks of the district; generally as scattered grains or crystals, but occasionally occurs as granular masses in the basalt up to 1 foot across; forms the major part of many of the ejected blocks and bombs; abundant grains in the beach-sand of Lake Bullenmerri. Beautiful though small crystals in the scoria of Mt. Terang; these contain 15.80 per cent. FeO, and are the species *chrysolite*. Blowpipe tests of specimens from various localities all indicated the same variety of olivine.
Picotite ..	.. A few grains occur in the ejected blocks of basalt from the Hampden tuffs and in the "olivine bombs."
Pyroxenes	.. The pyroxenes are very plentiful. *Enstatite* or *hypersthene* occurs in the bombs and ejected blocks. Purplish-brown *augite* is the most abundant member of the group, and occurs in all the basalts, in the essexite, &c.; the colourless variety appears to be confined to some of the latest flows. *Diopside* occurs in the bombs and ejected blocks; it is sometimes traversed by narrow twin striae parallel to (001). Also found in the sand at Lake Bullenmerri. Some *soda augite* is found in the essexite. Well preserved crystals of pyroxene are found in the scoria of Mt. Terang.

Quartz .. .. Rarely in the basalt as grains surrounded by a "reaction border"; with felspar in the nuclei of certain bombs; as grains in the Hampden tuffs; occasionally as pebbles in Mt. Emu Creek; chipped flakes on Mt. Noorat, &c., where they have evidently been carried by natives.

Rutile .. .. The network of slender rods crossing one another at angles of 60 degrees in quartz grains in the Hampden tuffs are probably rutile.

Serpentine .. In basalt as an alteration product of olivine.

WORKS USED IN THE PREPARATION OF THIS REPORT.

No comprehensive geological description has yet been given of any particular area in the Western District, nor has any detailed map been published, probably because the wealth of this part of Victoria lies in its pastoral and agricultural richness, and because no gold mining has been attempted in the past or is likely to be tried in the future. The gold-bearing rocks are far below the surface, and even the depth at which they are likely to be found is quite unknown. The only geological maps dealing with the area are sketch maps of Victoria on a small scale (1 inch to 8 miles or smaller), or others of quite small areas, such as Tower Hill, Koroit.

The following list of works referring to the area under review or having a direct bearing on the problems which have to be faced there, makes no pretence at being an exhaustive bibliography of the district, and is merely a list of books and papers which have been examined during the preparation of the report. The descriptions given and theories advanced have been carefully considered and in some instances discussed.

The names of the authors are given alphabetically, and when more than one work is mentioned, the earliest publication is placed first:—

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Hart, T. S.—

"Notes on a Visit to Tower Hill, Koroit." Victorian Naturalist, Vol. XVII. Melbourne, 1901.

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Salisbury, Rollin D. *See* Chamberlin.

Smyth, R. Brough—

"On the Extinct Volcanoes of Victoria, Australia." Quart. Journ. Geol. Society, Vol. XIV. London, 1858.

"The Gold-fields and Mineral Districts of Victoria." pp. vi. + 644. Melbourne, 1869.

"Mining and Mineral Statistics: with Notes on the Rock Formations of Victoria; to which is added a Sketch of the New Geological Map of Victoria." Melbourne, 1872.

"A Descriptive Catalogue of Rocks, Minerals, and Fossils illustrative of the Geology, Mineralogy, and Mining Resources of Victoria, Australia." Melbourne-Philadelphia International Exhibition, 1876.

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DESCRIPTION OF PLATES.

Pl. 1.—Plan and section of Lakes Bullenmerri and Gnotuk, near Camperdown.

Pl. 2.—Mt. Leura, Camperdown, from the crest of the hills surrounding Lake Bullenmerri. The crescent-shaped northern portion of the original crater rim is very distinct, as well as the cone which was built up when the southern part of the rim was destroyed. The distant hill on the left is Mt. Wiridgil, and that on the right Mt. Porndon.

Pl. 3, Fig. 1.—Section of the Hampden tuffs exposed in the scarp surrounding Lake Keilambete; illustrates the well-bedded horizontal tuffs.

Fig. 2.—Section of the Hampden tuffs exposed in a road-cutting on the north-east inner slope of Lake Bullenmerri, near the Camperdown Park; tuffs tilted at a steep angle, well bedded, and enclosing ejected blocks.

Pl. 4, Fig. 1.—Another part of the same section, showing a large mass of fossiliferous marl of Cainozoic age, in the Hampden tuffs. It is 70 feet above the lake surface, and is an ejected block, or possibly a part of the irregular surface of the floor on which the tuffs rest.

Fig. 2.—Section on continuation of same road, west inner slope of Lake Bullenmerri; exposes scoria (A) overlain by the Hampden tuffs (B) with which is interbedded a light-coloured stratum (C) that appears to be an ancient soil. All he beds dip west at about 12°.

Pl. 5, Fig. 1.—Railway cutting, Camperdown to Timboon line, about ¼ mile west of Lake Bullenmerri; Hampden tuffs dipping westward towards towards the observer, and resting on an old soil containing ill preserved plant remains.

Fig. 2.—Basalt flows resting conformably on the Hampden tuffs; quarry near top of Mt. Terang.

Pl. 6.—Small basalt stalactites from cavities beneath the lava flows shown in Pl. 5, Fig. 2; about natural size.

Pl. 7.—Typical volcanic bombs from the scoria pits, Mt. Noorat; about natural size. Small specimens were chosen for convenience of illustration, but similar bombs range up to several feet in length. One has been sliced across to show the nucleus of granular olivine and the concentric arrangement of the vesicles in the basalt coating.

Pl. 8, Fig. 1.—Basalt, near Kolora, north-west of Mt. Noorat, × 48, ordinary light. Slice No. 1311, analysis No. 6. A holocrystalline, moderately course-grained basalt, consisting of lath-shaped plagioclases (white), and another felspar of irregular shape, olivine, augite and titaniferous i on. The greater part of the right hand half of the slice is occupied by olivine in large phenocrysts surrounded by a dark border, due to incipient decomposition. Augite is small and not very plentiful. The iron ores occur as grains and elongated pieces, but in the photograph are largely indistinguishable from decomposed olivine (iddingsite), which appears black, though really it is deep red-brown. The holes through the slice are due to steam cavities in the rock.

Fig. 2.—Basalt; quarry on the Camperdown-Terang road, near Allotment XV., parish of Marida Yallock; × 48, ordinary light. Slice No. 1312, analysis No. 4. A coarse-grained basalt composed of the same minerals. The olivine is almost completely altered to iddingsite, which appears in the photograph as a wide black band surrounding an unaltered core. The elongated iron ores are noticeable, and there are several steam cavities.

Pl. 9, Fig. 1.—Basalt; quarry on east shore of Lake Terang; × 48, ordinary light. Slice No. 1292, analysis No. 5. The same mineral composition, but with ophitic structure. The augite is developed as large plates, which enclose some of the felspars; the large black patches are olivine altered to iddingsite. Rather vesicular.

Fig. 2.—Basalt; Brennan's Well, Allotment III., 15, parish of Glenormiston, lowest flow at 90 feet from the surface; × 24, ordinary light. The bulk of the rock is composed of colourless felspar; the augite is granular or forms small prisms; the olivine is almost entirely altered to serpentine.

Pl. 10, Fig. 1.—Basalt; Harvey's Well, Allotment XXVI., parish of Kilnoorat, about ½ mile north of Lake Gnotuk, second flow from surface; × 24, ordinary light. Very coarse-grained, with ophitic structure and extreme development of ilmenite in hexagonal crystals flattened parallel to the base, which appear like rods in section. The rock contains no olivine.

Fig. 2.—Basalt; Harvey's Well; uppermost flow; × 48, ordinary light. Slice No. 1313, analysis No. 7. For comparison with Fig. 1, which immediately underlies it and which is magnified only half the amount. A fine-grained basalt; the larger crystals ars olivine.

Pl. 11, Fig. 1.—Basalt; quarry on top of Mt. Terang shown in Pl. 5, Fig. 2; × 24, ordinary light. Slice No. 1290, analysis No. 8. The same mineral composition; the fine groundmass consists of glass with small augites and iron ores, through this are scattered felspar laths and crystals of olivine surrounded by a narrow zone of incipient decomposition, which appears dark in the photograph. The colourless patches are steam cavities.

Fig. 2.—Basalt; quarry immediately west of the Camperdown Show Grounds; × 48, ordinary light. Slice No. 1291, analysis No. 9. The fine-grained groundmass consists of augite and iron ores. The larger crystal near the top of the figure is augite.

Pl. 12, Fig. 1.—Hampden Tuff; Allotment XIX., parish of Colongulac, near Lake Gnotuk; × 24. Shows the typical clastic structure of these tuffs; the dark portions are fragments of dense, fine-grained, vesicular basalt; the lighter coloured portions are formed of more or less decomposed volcanic dust.

Fig. 2.—Ejected block, Lake Gnotuk; × 24, polarized light. Slice No. 311. A mosaic of grains of olivine with a few cracks, and augite with well-marked cleavage, and a little felspar.

Pl. 13, Fig. 1.—Essexite; ejected block, north end of Lake Bullenmerri; × 36, ordinary light. Slice No. 1288, analysis No. 1.

Fig. 2.—Same portion of same slice; polarized light. The two photographs are given in order to show all the minerals, which are as follows:—(*a*) lath-shaped felspars, colourless in Fig. 1, but with twinning shown in Fig. 2, in which the outer untwinned zone of orthoclase can also be distinguished; (*b*) analcite, the mineral which forms the white area near the centre of Fig. 1, and the corresponding black area in Fig. 2; (*c*) augite occurs as large plates, which inclose felspar laths; (*d*) olivine, a large grains is cut by the circumference in the lower left-hand quadrant; (*e*) apatite, slender rods best seen in Fig. 1; (*f*) iron ores, generally elongated forms, black in both Fig. 1 and Fig. 2.

Pl. 14, Fig. 1.—Essexite; a slice from the same rock stained to bring out the structure of the analcite; × 36, ordinary light. A piece of analcite near the centre has absorbed the stain in such a way as to show its crystal outline, and that it consists of layers or zones, which offer various resistance to the action of dilute hydrochloric acid.

Fig. 2.—Essexite; a finer-grained variety from the same locality; × 36, polarized light. Slice No. 1289, analysis No. 2. Same mineral contents.

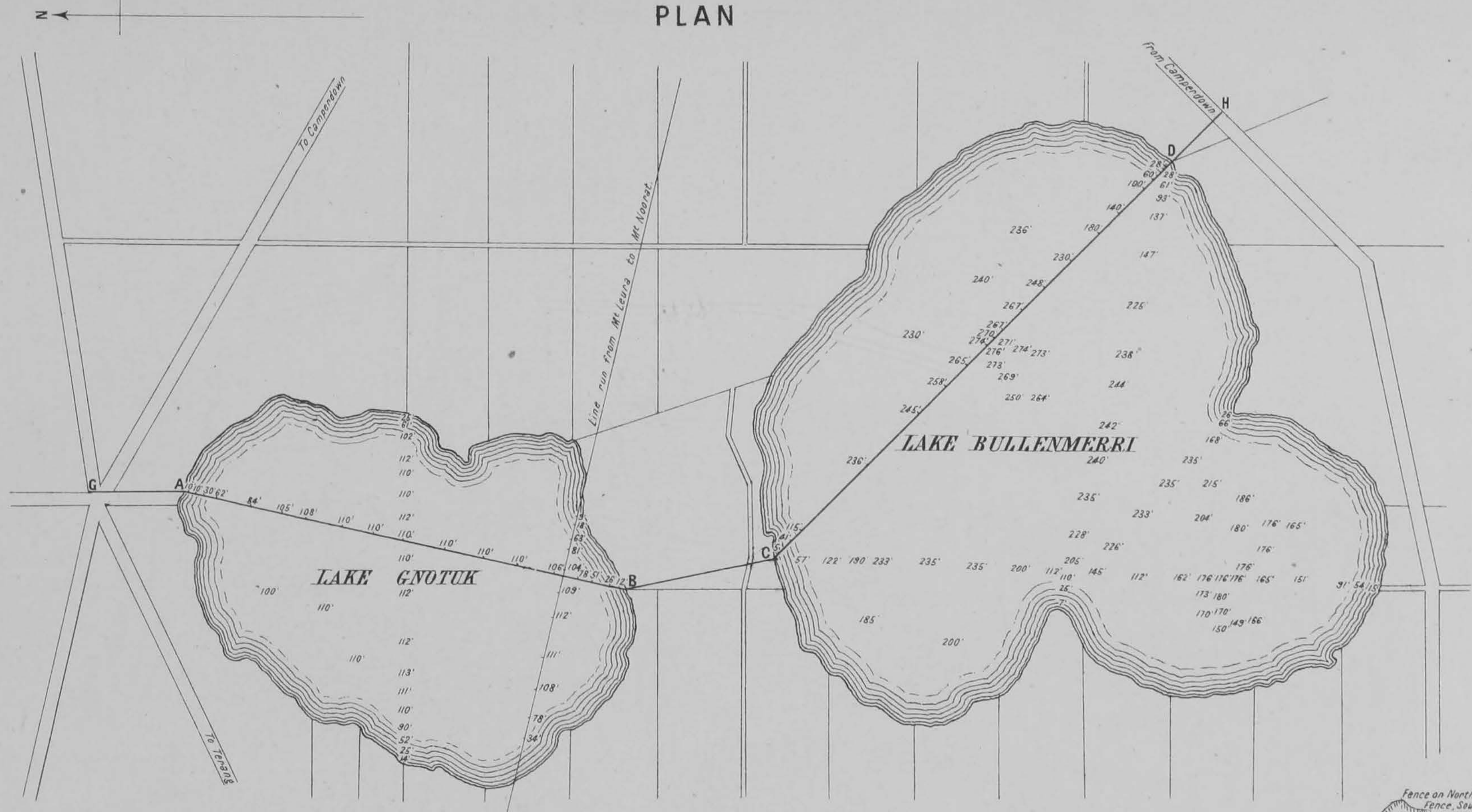
Pl. 15.—Nucleus of a bomb; Mt. Noorat; × 24, polarized light. Slice No. 307. This is one of the less common types; it consists of felspar and quartz. Most of the felspar is plagioclase with rather fine twin striæ, some is untwinned. The rest of the rock is quartz. Both minerals are allotriomorphic.

By Authority: J. KEMP, Government Printer, Melbourne.

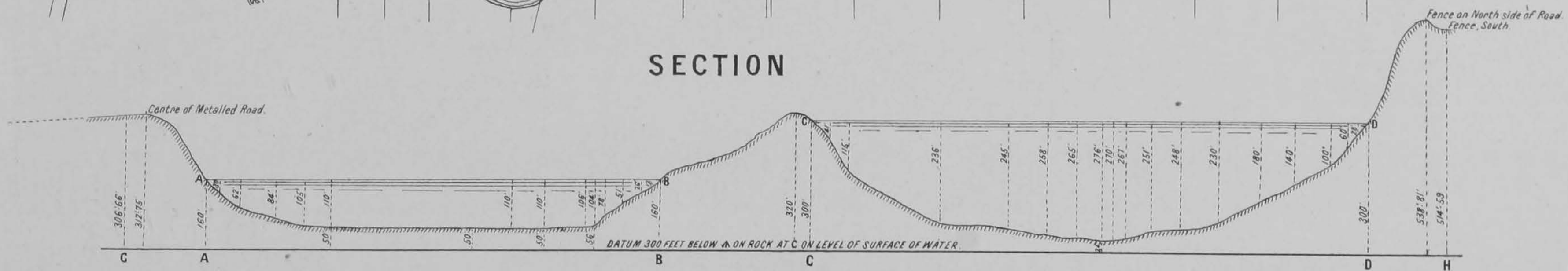
LAKES BULLENMERRI & GNOTUK

Scale, 40 chains to 1 inch.

PLAN



SECTION



Scale, — { Horizontal, 2640 feet to 1 inch. Vertical, 400 " " " "

Plate, I.

MOUNT LEURA, CAMPERDOWN.

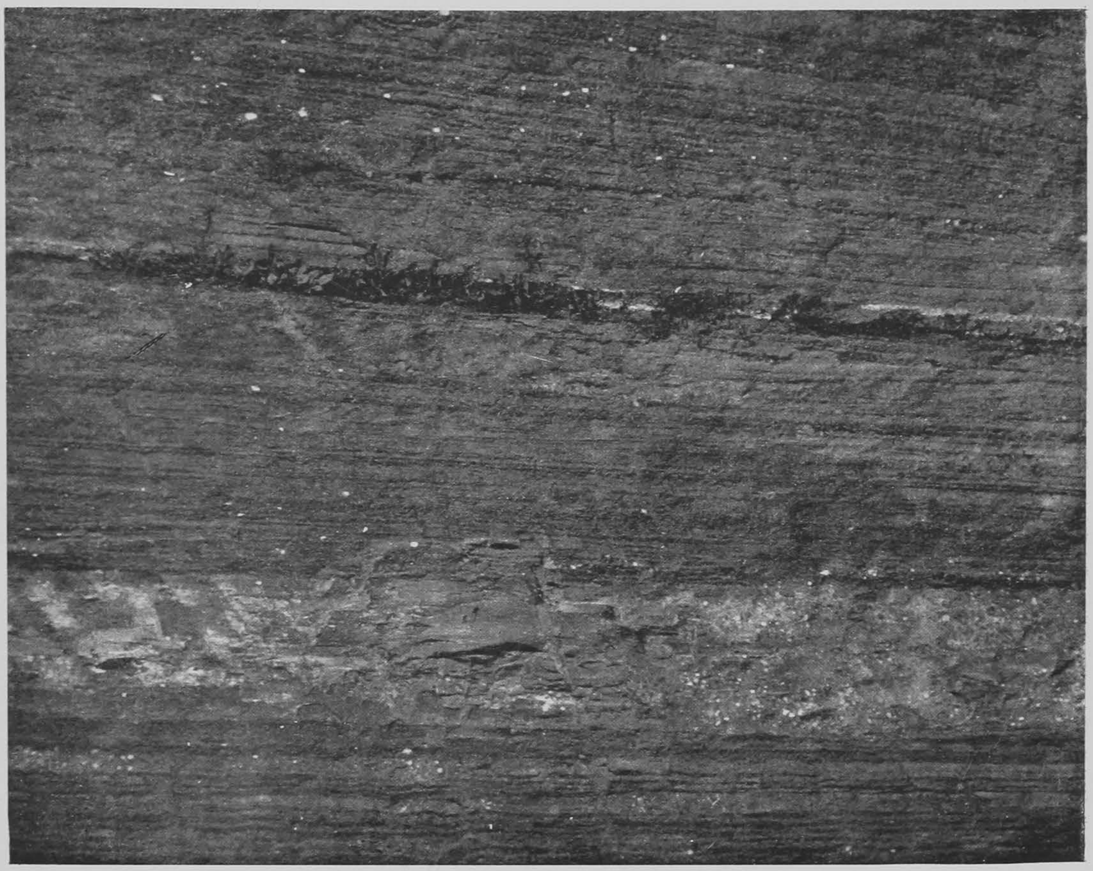


FIG. 1.—CLIFF FORMED OF THE HAMPDEN TUFFS, LAKE KEILAMBETE.

FIG 2.—ROAD-CUTTING, LAKE BULLENMERRI.

FIG. 1.—FOSSILIFEROUS TERTIARY LIMESTONE (A) IN BEDDED TUFF (B); ROAD-CUTTING, LAKE BULLENMERRI.

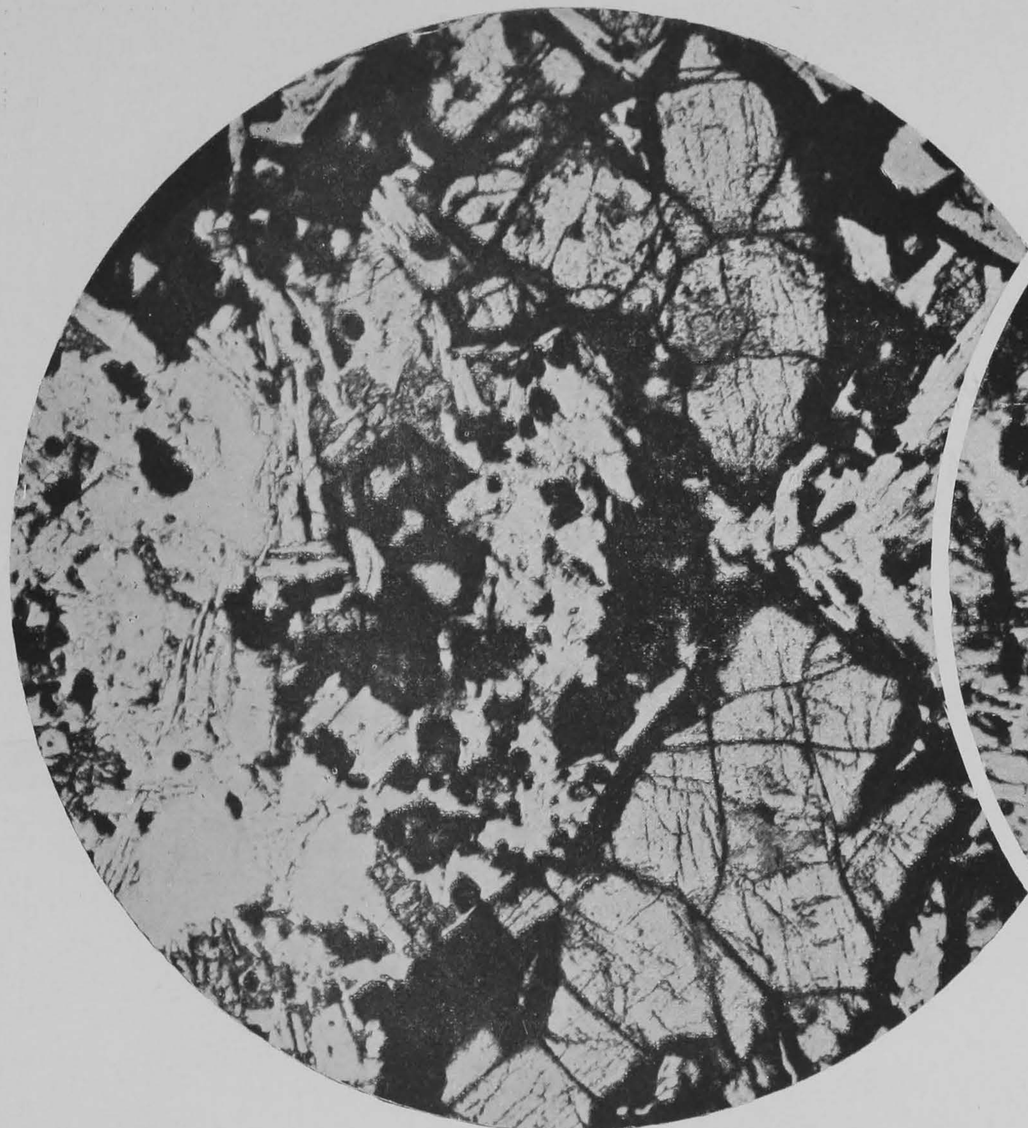
FIG. 2.—THE HAMPDEN TUFFS (B) OVERLYING AGGLOMERATE (A). THE LIGHT-COLOURED BED (C) IS POSSIBLY AN ANCIENT SOIL. ROAD-CUTTING, LAKE BULLENMERRI.

FIG. 1.—HAMPDEN TUFFS RESTING ON AN ANCIENT SOIL CONTAINING OBSCURE PLANT REMAINS. THE HAMMER MARKS THE JUNCTION, RAILWAY CUTTING, WEST OF LAKE BULLENMERRI.

FIG. 2.—QUARRY, MOUNT TERANG. THIN BASALT FLOWS RESTING CONFORMABLY ON BEDDED TUFFS.

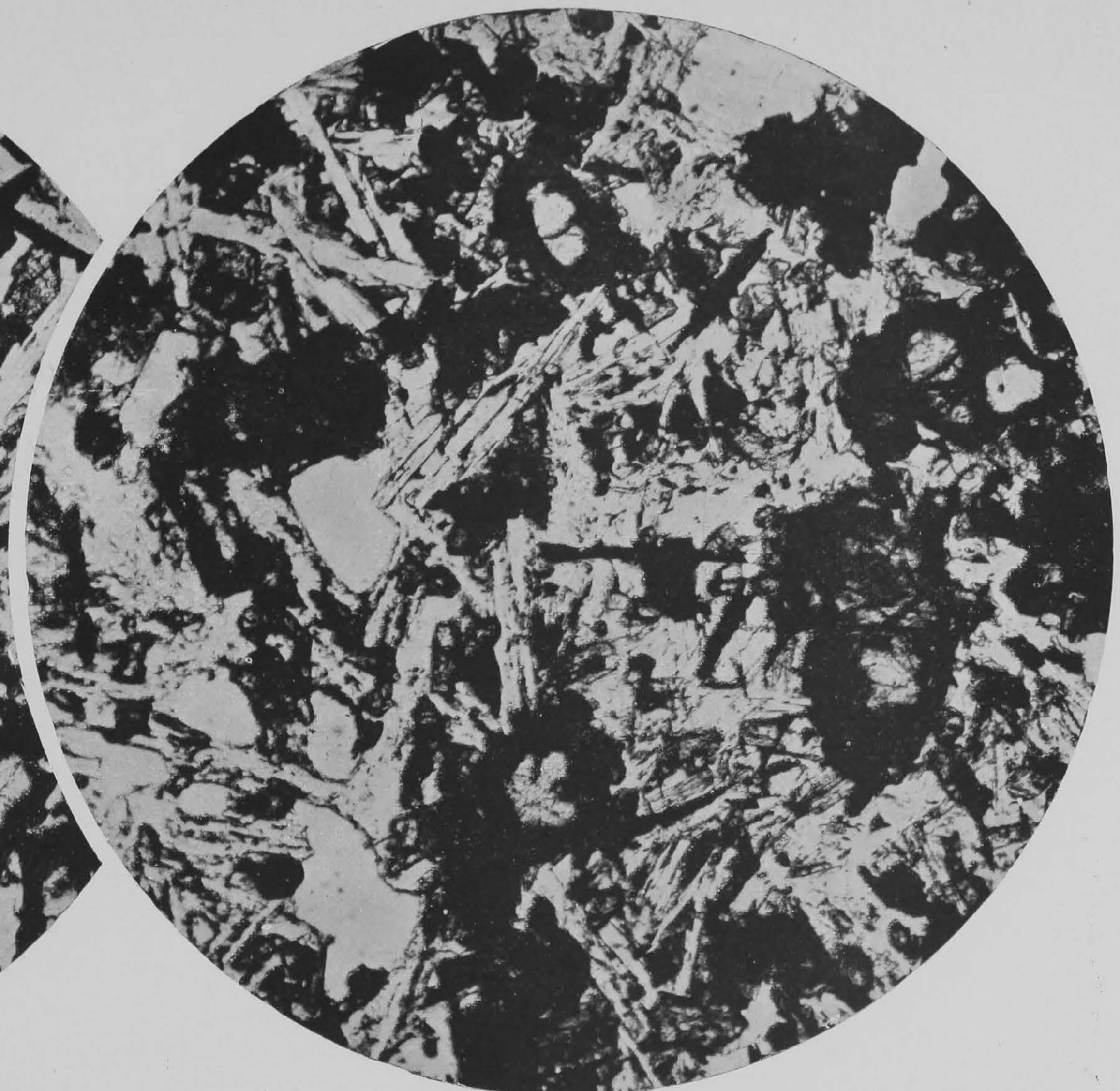
BASALT STALACTITES : MOUNT TERANG. ABOUT NATURAL SIZE.

VOLCANIC BOMBS: MOUNT NOORAT. ABOUT NATURAL SIZE.



H. J. Grayson, Photo-micro. × 48, Ord. Light.

FIG. 1.—BASALT: NEAR KOLORA, NORTH-WEST OF MOUNT NOORAT.

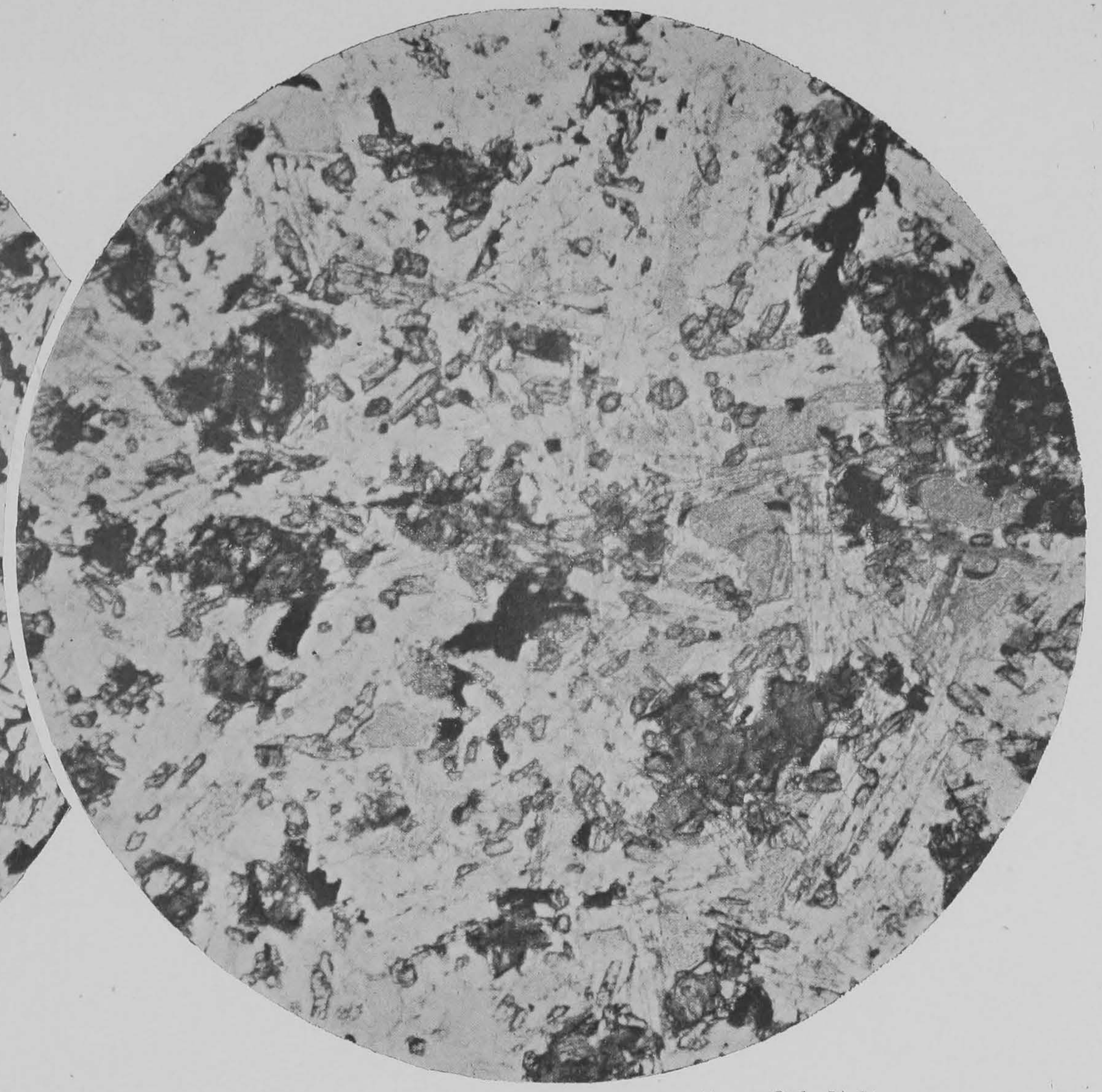


× 48, Ord. Light.

FIG. 2.—BASALT: QUARRY ON CAMPERDOWN-TERANG ROAD, NEAR ALLOT. XV., PARISH OF MARIDA-YALLOCK.

H. J. Grayson, Photo-micro. × *48, Ord. Light.*

FIG. 1.—BASALT: QUARRY ON EAST SHORE OF LAKE TERANG.

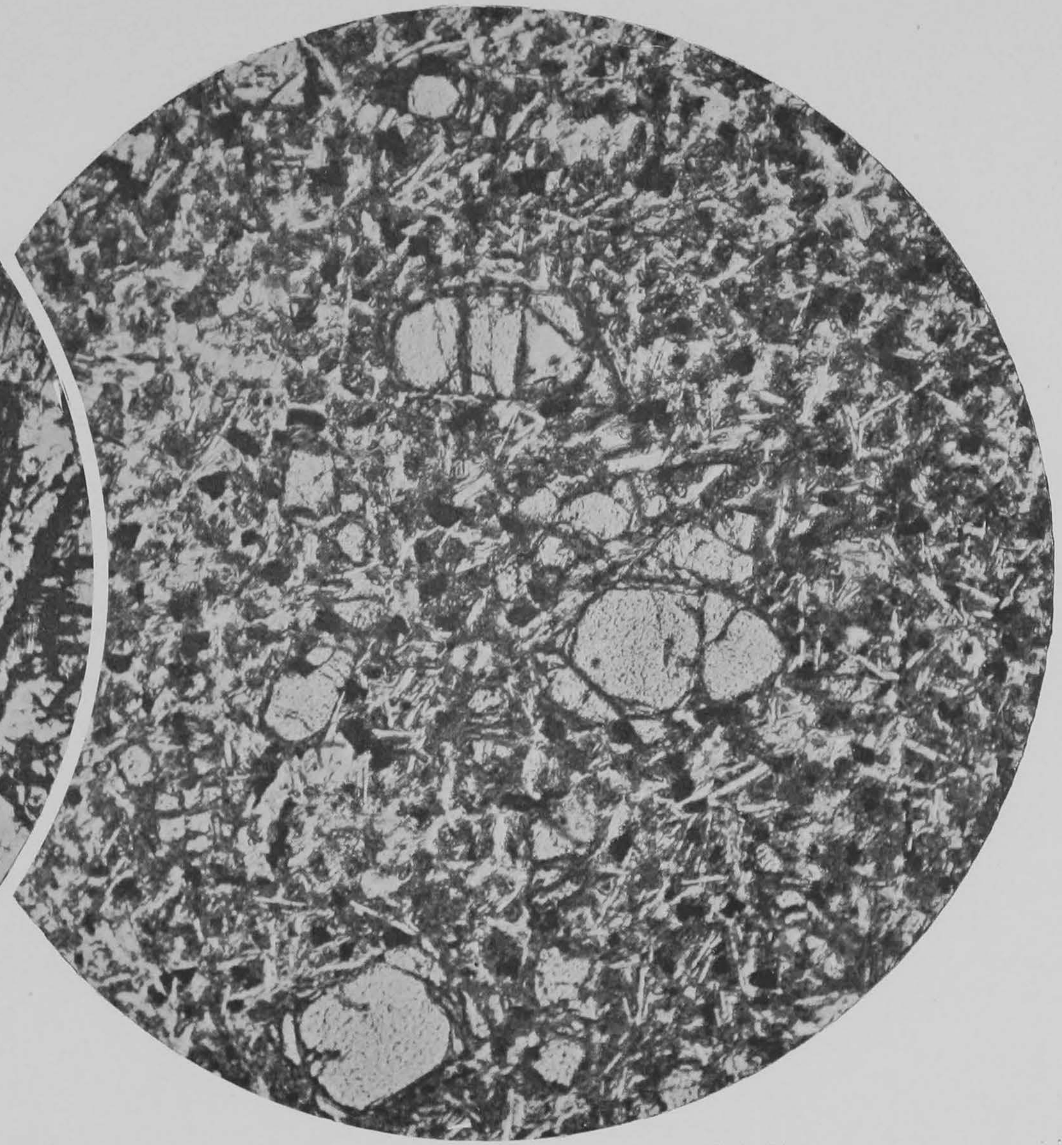


× *24, Ord. Light.*

FIG. 2.—BASALT: BRENNEN'S WELL, ALLOT. III., 15, PARISH OF GLENORMISTON.

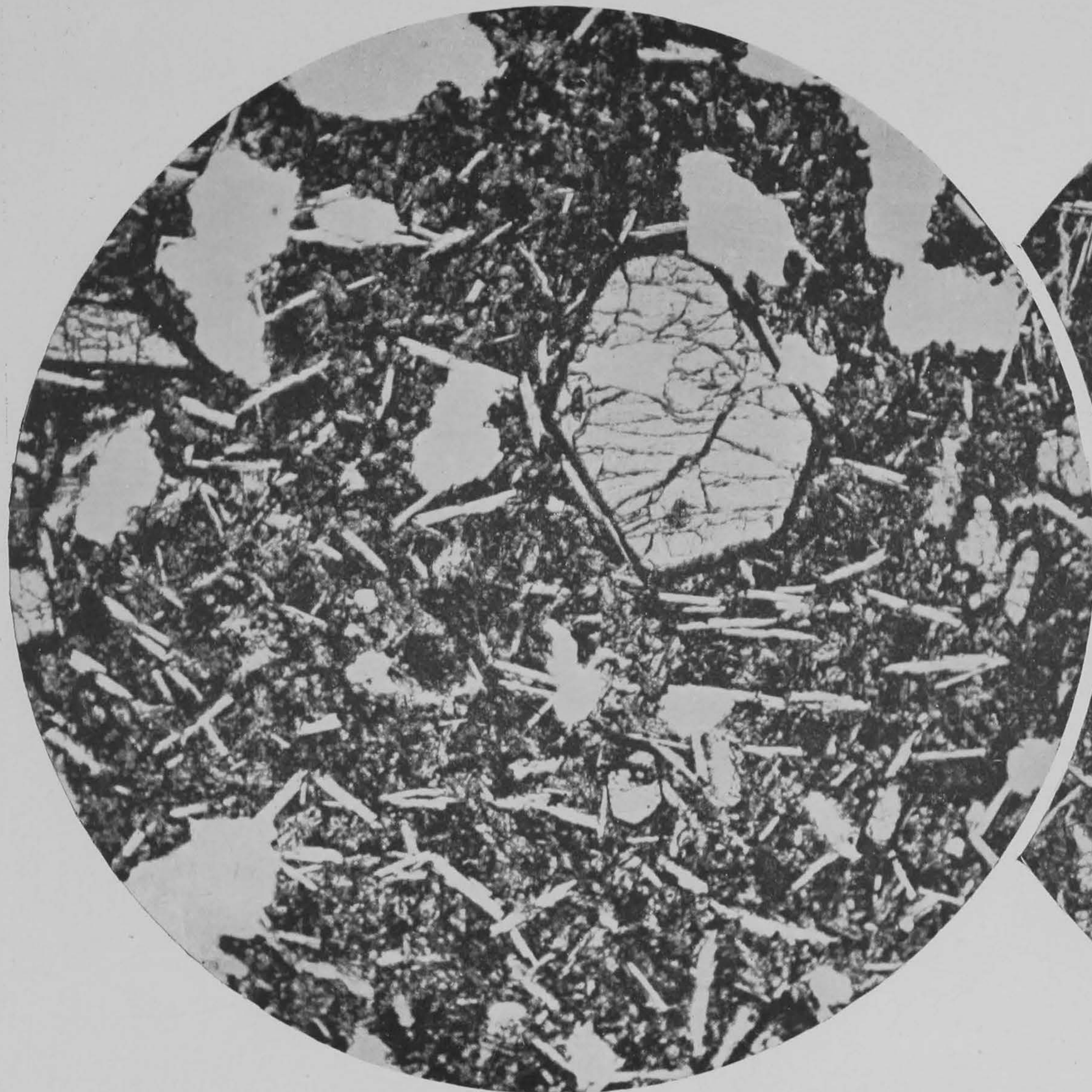
H. J. Grayson, Photo-micro. × *24, Ord. Light.*

FIG. 1.—BASALT : HARVEY'S WELL, ALLOT. XXVI., PARISH OF KILNOORAT, SECOND FLOW FROM THE SURFACE.



× *24, Ord. Light.*

FIG. 2.—BASALT : HARVEY'S WELL, ALLOT. XXVI., PARISH OF KILNOORAT, UPPERMOST FLOW.

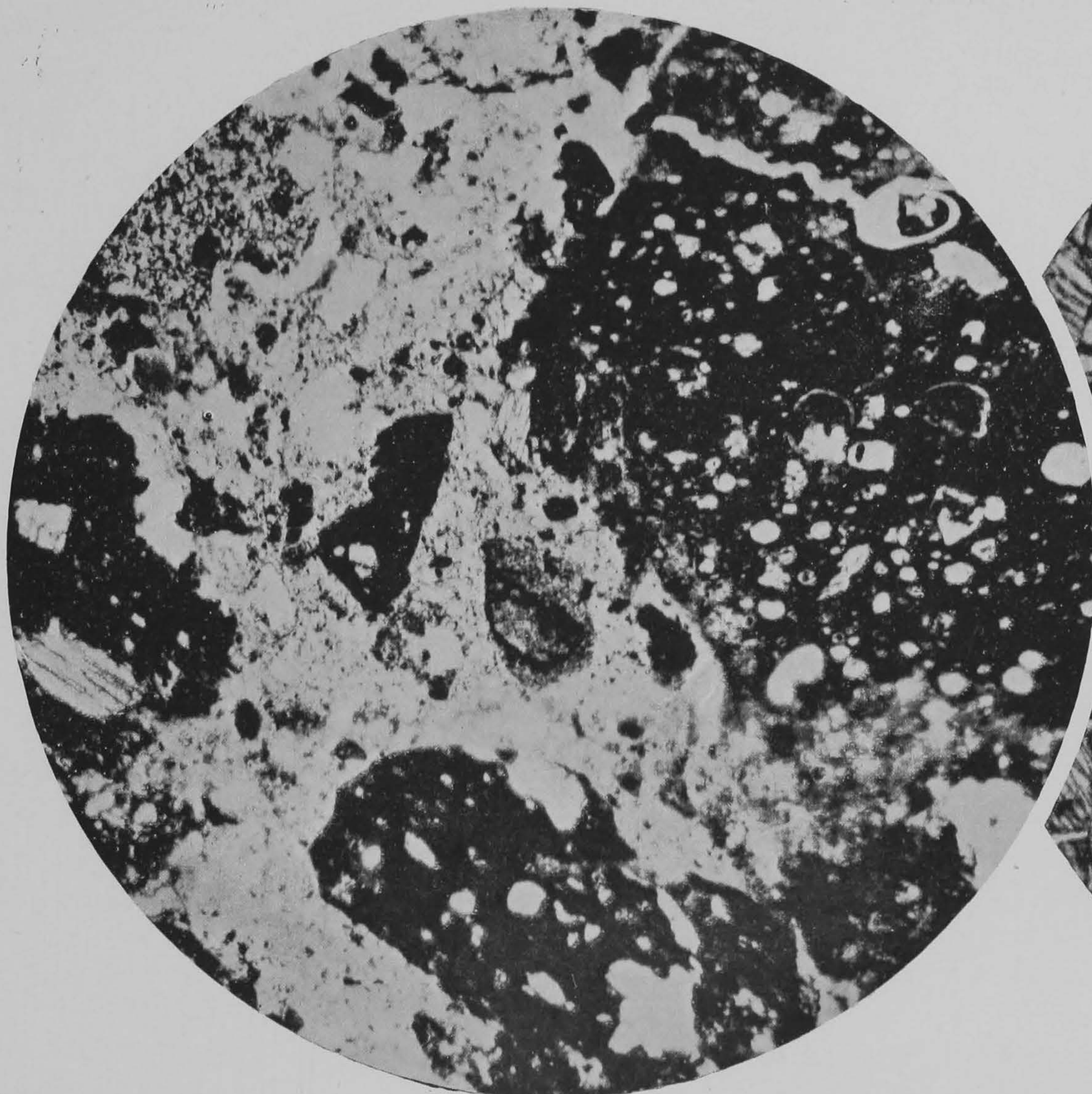


H. J. Grayson, Photo-micro. *× 24, Ord. Light.*

FIG. 1.—BASALT: QUARRY ON TOP OF MOUNT TERANG.

× 48, Ord. Light.

FIG. 2.—BASALT: QUARRY IMMEDIATELY WEST OF CAMPERDOWN SHOW GROUNDS.



H. J. Grayson, Photo-micro. × 24, *Ord. Light.*

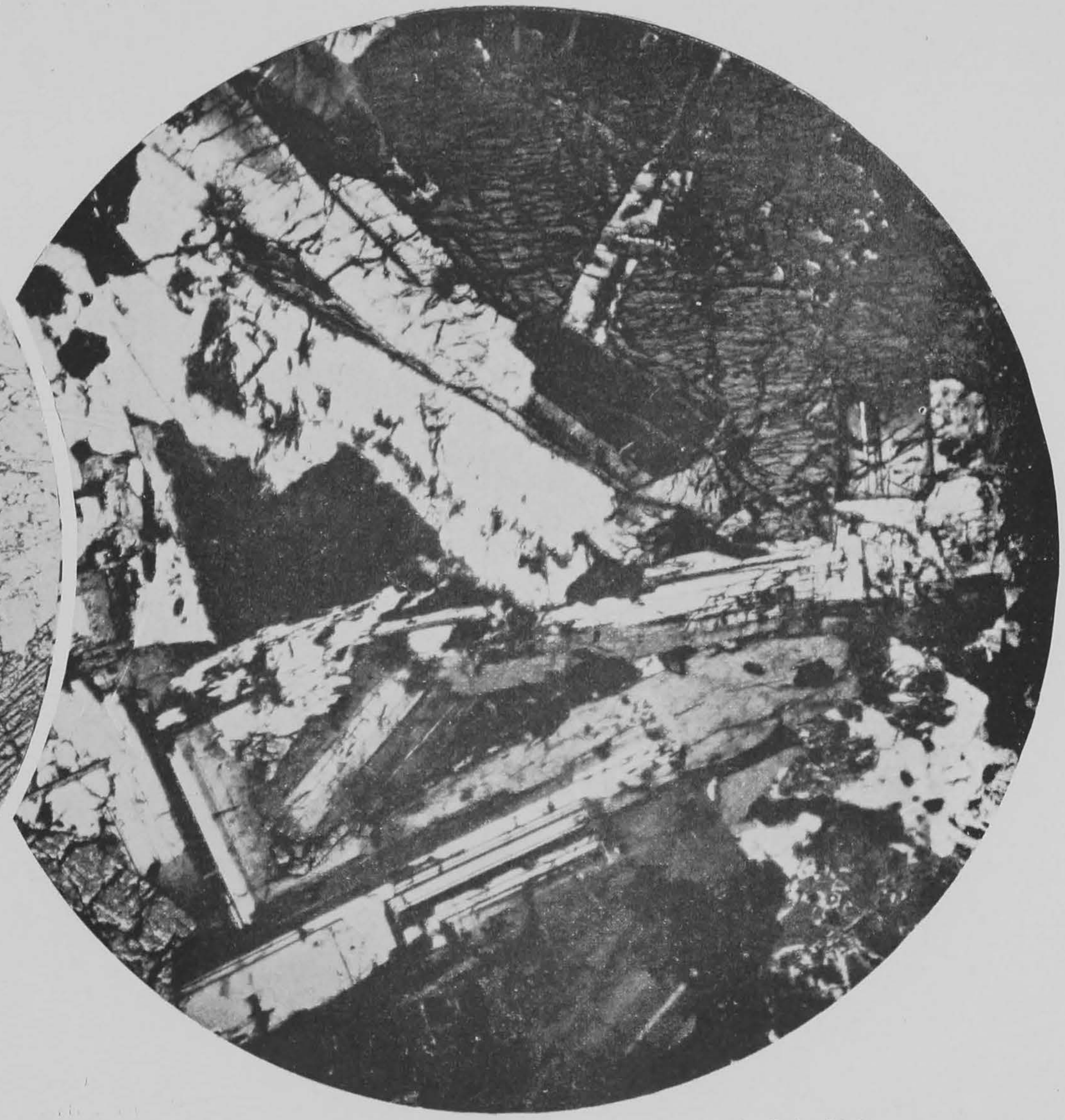
FIG. 1.—HAMPDEN TUFF: ALLOT. XIX., PARISH OF COLONGULAC, NEAR LAKE GNOTUK.

× 24, *Pol. Light.*

FIG. 2.—PERIDOTITE (LHERZOLITE): EJECTED BLOCK FROM THE HAMPDEN TUFFS, LAKE GNOTUK.

H. J. Grayson, Photo-micro. *× 36, Ord. Light.*

FIG. 1.—ESSEXITE: EJECTED BLOCK, NORTH END OF LAKE BULLENMERRI, IN ORDINARY LIGHT.



× 36, Pol. Light.

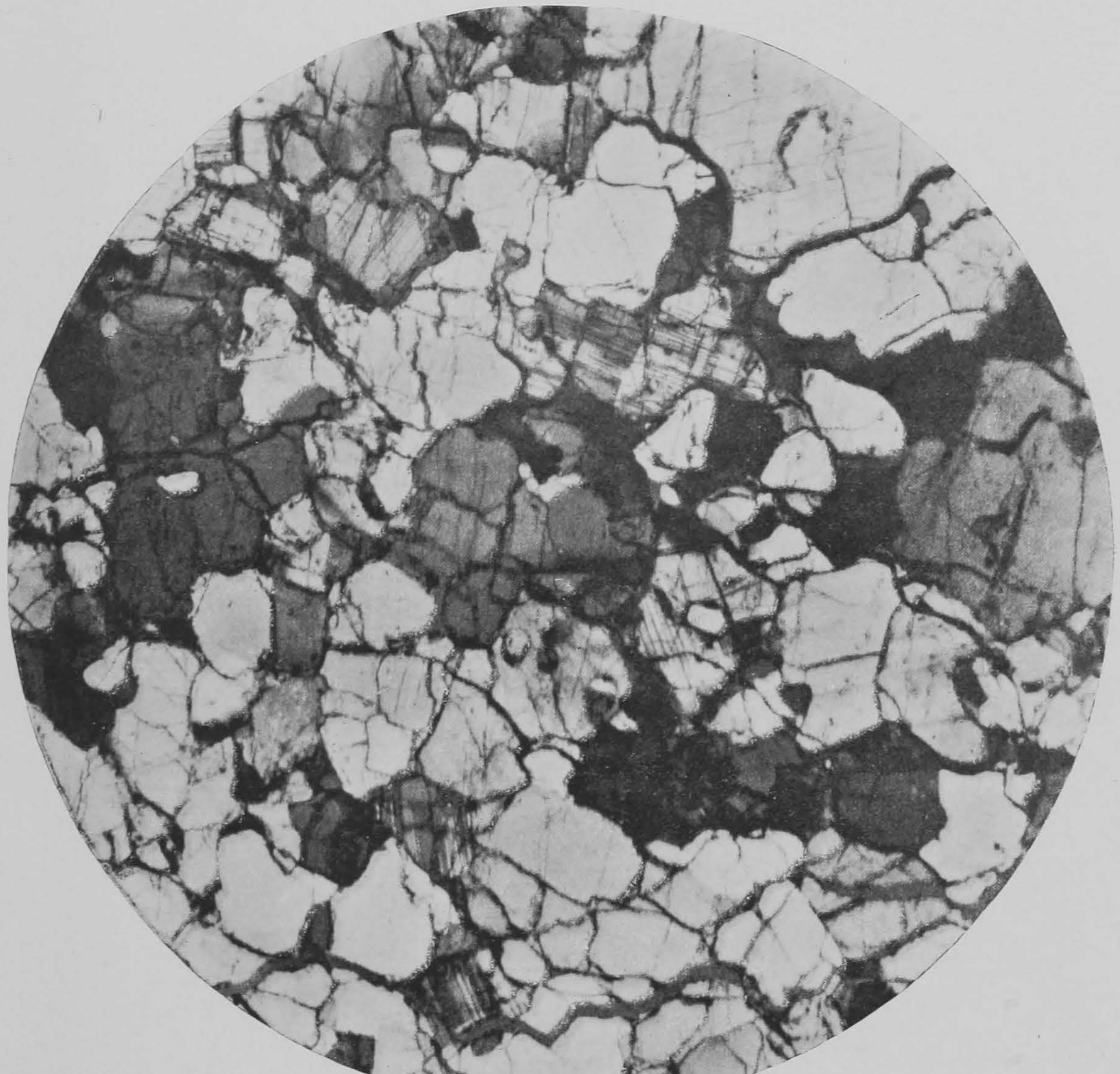
FIG. 2.—THE SAME PORTION OF THE SAME SLICE IN POLARIZED LIGHT.

H. J. Grayson, Photo-micro. × *36, Ord. Light.*

FIG. 1.—ESSEXITE : EJECTED BLOCK, NORTH END OF LAKE BULLENMERRI. TREATED WITH DILUTE ACID AND STAINED TO BRING OUT THE STRUCTURE.

× *36, Pol. Light.*

FIG. 2.—ESSEXITE : EJECTED BLOCK, NORTH END OF LAKE BULLENMERRI.



H. J. Grayson, Photo-micro. × *24, Pol. Light.*

NUCLEUS OF A BOMB : MOUNT NOORAT.