# Royal Society of Victoria.

## BASALTIC BARRIERS AND OTHER SURFACE FEATURES OF THE NEWER BASALTS OF WESTERN VICTORIA.

BY

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AND

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Read 10th December, 1936.



Reprinted from Proc. Roy. Soc. Victoria, Vol. XLIX., Pt. II. (New Series).

Issued separately 19th July, 1937.

658. H. J. Green, Government Printer, Melbourne.



[Proc. Roy. Soc. Victoria, **49** (N.S.), Pt. II., 1937.]

## Art. XVI.—*Basaltic Barriers and Other Surface Features of the Newer Basalts of Western Victoria.*

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## Contents.

## I. Introduction.

### (a) *Areas examined.*

The areas discussed in this paper consist of the Stony Rises of Porndon, the breached barriers of Dreeite, and the volcanic rocks of Byaduk. The area of the Stony Rises, wholly volcanic, has Mount Porndon near its western boundary, Lake Corangamite to the north, and Pirron Yallock near its eastern extremity. The centre of the area is about 14 miles west of Colac and 107 miles west of Melbourne.

The second and much smaller area near Byaduk, and lying about 16 miles south of Hamilton, which is about 200 miles west of Melbourne, is concerned with basalt flows from Mount Napier, partially filling valleys.

### (b) *Special interest of the surface in these areas.*

The special interest of these areas consists of the surface features of the basalts, the crowding of basaltic barriers (with intervening valleys), basins and knolls in the Stony Rises, and, in the Byaduk district, remarkable steam blisters, barriers and caves in lavas restricted to valleys. These features stand in marked contrast to the features of the basaltic plains commonly met with in Western Victoria, where monotonous plains of basalt extend over wide areas, diversified only occasionally with small isolated ridges or shallow depressions, apart from the numerous small, extinct scoria or lava cones or puys.

### (c) *References to similar features.*

Ridges or barriers of basalt, often breached, and in some ways similar to those of Western Victoria, occur in other parts of the world. Geikie (1) has figured and described such features from the Snake River plains of Idaho. Stearns (2) has also described them, and they occur on a small scale among the recent lavas of Hawaii, where they are known as pressure domes or schollen-domes.

One of us (E.W.S.) paid a visit to Hawaii in 1934, and examined these breached pressure domes in the Kau desert, south of Kilauea. These features, developed on some of the recent lava flows, are much smaller and far less crowded together than the breached barriers of the Stony Rises, and are generally developed on a slope of much steeper gradient.

### (d) *Previous references to the Stony Rises.*

James Bonwick (3) in 1858, refers to the Stony Rises, and describes the basalt as "reared up as waves petrified in their rise. Huge barriers meet the eye on all sides, of heights from ten to sixty feet." He recalls that Darwin compared a similar scene he beheld to a sea petrified in a storm, but that no sea could present such irregular undulations, or could be traversed by such deep chasms.



J. W. Gregory (4) refers to the "lava streams, which have come from Mount Porndon . . . . . an area of about 50 square miles, which is covered by ridges of piled lava blocks. These ridges are so rough and boulder strewn that they are known as the Stony Rises."

The authors (5) gave a very brief and preliminary description of the Stony Rises to the British Association (Centenary Meeting), 1931. More detailed work has led the authors to adopt a different view, presented in this paper, as to the methods of formation of the breached barriers. Apart from the above brief descriptions, the Stony Rises have not been scientifically described, and the Byaduk area, so far as we can find, has never been described.

### (e) *Sub-surface geology.*

This paper is primarily concerned with the surface features of the basalts, and only brief reference need be made to the sub-surface geology.

In the Stony Rises, basalt covers nearly the whole area. Among the ejectamenta included in the scoria beds of Glen Alvie, near Red Rock, are fragments of plant bearing, freshwater, Jurassic felspathic sandstones, and of marine Cainozoic sediments. A small outcrop of fossiliferous Cainozoic (Barwonian) calcareous sandstone occurs just within the ring of Mt. Porndon at an elevation of about 650 feet, and similar rocks occasionally outcrop round the shores of Lake Corangamite at about the 400 foot contour line. The abundance of xenoliths, consisting of angular fragments of vein quartz, in the basalts of the Stony Rises, suggests the presence beneath the area of Ordovician sediments. Bedded tuffs somewhat older than the basalt flows are also met with round the shores of Lake Corangamite, and appear to be associated with a volcanic centre known as Vaughan's Island. At Byaduk the basalt from Mt. Napier flows in a valley where Cainozoic marine limestone is exposed on the lower slopes, and is overlain by basalt considerably decomposed.

### (f) *Acknowledgements.*

The Air Force, through the courtesy of Wing Commander Cobby, took a series of air photographs of parts of the Stony Rises. A photo (Plate XIV A), provided by Wing Commander Swinbourne, of a small area about 1½ miles south-east of Stonyford, near the Pirron Yallock Creek, shows the forms of the breached barriers and associated valleys. The maps and sketches reproduced in this paper have been re-drawn by Mr. J. S. Mann, of the Geological Department of the University of Melbourne. Mr. G. Harman, of Byaduk, has been very helpful in facilitating field work in the Byaduk district.

## II. The Stony Rises South and East of Lake Corangamite.

*(a) Boundaries and area.*

The Stony Rises occur in two areas, one to the south-west, and the other to the east and south-east of Lake Corangamite (Fig. 1). The former area, covering about 80 square miles, is dominated by Mt. Porndon, and extends for 12 miles in an east-west direction from Pirron Yallock (101 miles west of Melbourne) to Weerite, and in a north-south direction for 8 miles from Lake Corangamite to Carpendeit. The southern shore of Lake Corangamite forms its northern boundary, while Pirron Yallock creek forms the southern and eastern boundaries. The eastern area around Dreeite covers about 100 square miles, and is dominated by the Warrion group of volcanoes. It extends for 15 miles in a north-south direction from Cundare to Robertson's Hill near Colac, and for 10 miles in an east-west direction from Beeac to the eastern shores of Lake Corangamite.

*(b) Altitude.*

The contours of the Military Map of the area (Fig. 1) show that around Mount Porndon, 949 feet, the surface of the basalt sheets reaches an elevation of 600 to 650 feet, and slopes gently away from the mount in all directions down to the 400 feet contour around the shores of Lake Corangamite. It is clear that the lavas in this area came from the neighbourhood of Mount Porndon. On the south-east side of Lake Corangamite, similar levels of the basalt sheets are noticeable. The 600 to 650 feet contour line defines the base of the volcanic centre of the Warrion Hills, and from this area of eruption the surface slopes away in all directions. In a westerly and north-westerly direction, through Dreeite to Lake Corangamite, the level falls from 650 feet to 400 feet. In this region it is clear that the basalt flows came from the direction of the Warrion Hills.

*(c) Centres of eruption.*

The two main centres of eruption in this area are Mount Porndon and the Warrion Hills. The central cone of Mt. Porndon, which rises to 949 feet, consists of a central scoria cone with smaller scoria and lava cones, all later in origin than the main basalt sheets proceeding from this centre. Warrion Hill, 922 feet high, however, consists almost entirely of basalt. Other centres of eruption lie south from Warrion Hill and consist of the scoria cones of Alvie and Red Rock (Plate XII.A). The latter includes a number of collapsed craters of fine grained ejectamenta, while Lake Coragulac, just south of Red Rock, another centre of eruption, is a caldera of collapse. Robertson's Hill, 722 feet, about 6 miles south of Glen Alvie, consists of basalt. The two Nalangil Basins are also collapsed calderas. Vaughan's



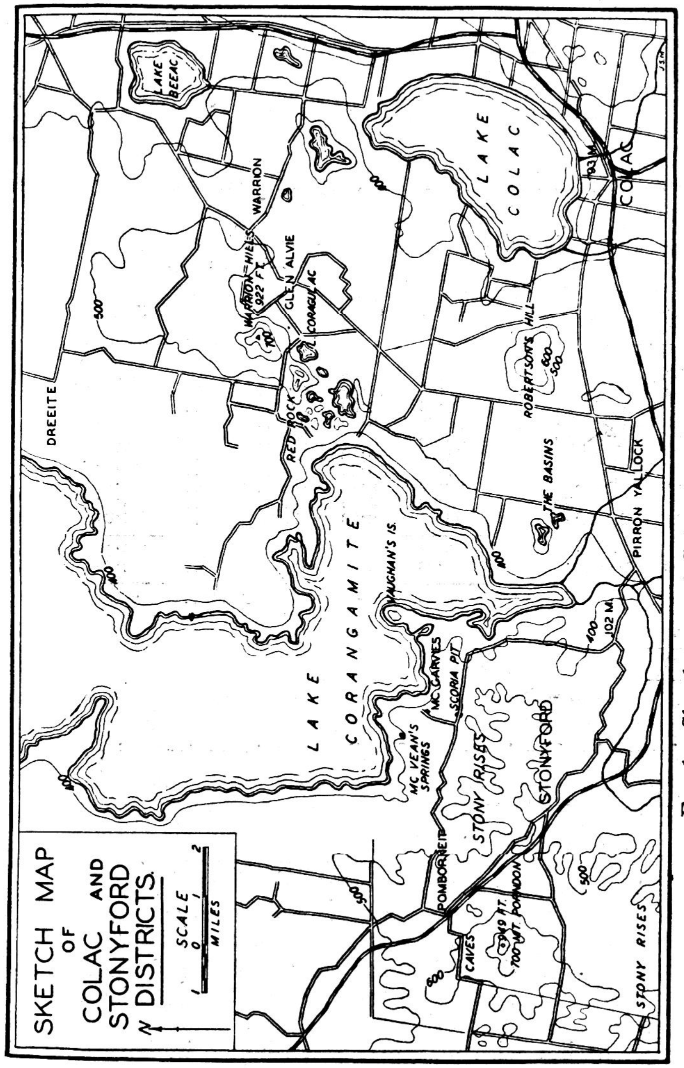



FIG. 1.—Sketch map of Colac and Stonyford District.

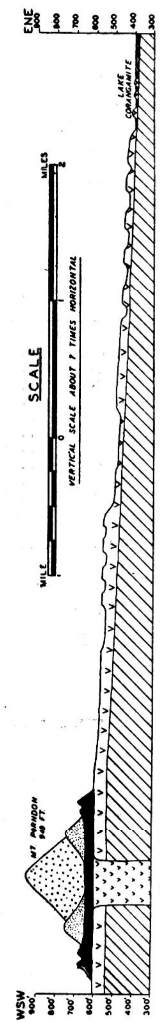



FIG. 2.—Section from Mount Porndon to Lake Corangamite, showing basaltic plateaux and lava tongues.

Island, projecting into the south end of Lake Corangamite, is another centre of eruption, and consists of coarse scoria passing outwards along the lake shore into fine grained tuffs, which appear to antedate the lava tongues projecting into the lake.

(*d*) *Composition and texture of the lavas.*

Since this paper is chiefly concerned with the surface features of the basalts, their petrography is important only in so far as it contributes to the development of these features. A brief statement of the textures and chemical composition of the basalts will suffice.

Two chemical analyses have been made by Mr. G. Ampt.

| — | I. 102 mile post W. of Pirron Yallock. | | | II. Later basalt from within Mt. Porndon ring. | | |
|---|---|---|---|---|---|---|
| | Chem. Anal. | — | Norm. I. | Chem. Anal. | — | Norm. II. |
| $SiO_2$ .. | 46·87 | Quartz .. | .. | 51·36 | Q .. .. | .. |
| $Al_2O_3$ .. | 12·42 | Orthoclase .. | 7·40 | 13·05 | Or .. .. | 5·01 |
| $Fe_2O_3$ .. | 2·34 | Albite .. | 21·18 | 2·36 | Ab .. .. | 24·80 |
| FeO .. | 10·54 | Anorthite .. | 14·68 | 8·89 | An .. .. | 19·99 |
| $TiO_2$ .. | 2·99 | Nepheline .. | 4·38 | 2·04 | Ne .. .. | .. |
| MnO .. | 0·15 | Diopside .. | 21·95 | 0·12 | Di .. .. | 18·24 |
| CaO .. | 8·43 | Hypersthene .. | .. | 8·56 | Hy .. .. | 20·97 |
| MgO .. | 10·31 | Olivine .. | 20·27 | 9·45 | Ol .. .. | 2·88 |
| $K_2O$ .. | 1·25 | Magnetite .. | 3·40 | 0·85 | Mgt .. .. | 3·42 |
| $Na_2O$ .. | 3·45 | Ilmenite .. | 5·67 | 2·93 | Il .. .. | 4·84 |
| | | | 98·88 | | | 100·15 |
| $H_2O$ .. | 1·08 | Water .. | 1·08 | 0·38 | $H_2O$ .. | 0·38 |
| | | Total .. | 99·96 | | Total .. | 100·53 |
| $P_2O_5$ .. | tr. | | | tr. | | |
| Total .. | 99·83 | | Total . | 99·99 | | |
| | | Sp. gr. = 2·974 | | | Sp. gr. = 3·063 | |

The basalt from the barrier at 102 mile post is typical of all the basalt of the Stony Rises. It is a fairly coarse grained, somewhat cellular, holocrystalline, dark-grey andesine basalt, crowded with fairly large felspar phenocrysts. Under the microscope, R.S. 2844 [Numbers of rock sections apply to the collection in the Geology Department, University of Melbourne], the texture is coarse, and the abundant plagioclase phenocrysts, with symmetrical extinction angles of the lamellae, range from 14°-25°, indicating oligoclase to basic andesine. Some of the felspars have external growths or zones of later formed felspar of the composition of oligoclase (extinction angle 12°–15°). Olivine, in clear fresh crystals but with marginal alteration to iddingsite, is also plentiful. Numerous small, pale green augites are present, and long plates of black ilmenite are fairly conspicuous.

Rock section 2845 is a specimen from a tachylytic basalt selvage of a similar felspar basalt from a quarry near McGarvie's. It differs mineralogically from the previous rock in the absence of augite, and in the fact that the bulk of the section consists of brown tachylytic glass. In this are set numerous phenocrysts of basic andesine (extinction angles 25°-28°) and fresh, but in places, corroded olivine. It is clear that both plagioclase and olivine are intratelluric in origin, and that the composition of the glass is such that augite would have crystallized from the fluid part of the magma but for the sudden chilling at the surface.



Rock section 2846 is a specimen of a dense black olivine basalt from a younger lava of a ridge inside the Mt. Porndon ring and opposite to the Porndon Caves. Under the microscope the fine grained texture is noticeable, and additional evidence of rapid solidification is yielded by the presence of a considerable amount of brown glass in the matrix. The plagioclase is not nearly so abundant or conspicuous as in the basalt of the Rises, consisting of minute crystals with symmetrical extinctions up to 30°, i.e. acid labradorite. There is abundant quite fresh olivine, a fair number of small brown augite crystals, and numerous minute octahedra of magnetite.

Rock section 4896 is a specimen of a dense basalt flow over a scoria pit on the eastern side of Porndon (No. 2 analysis). The rock is a fine grained dense olivine basalt. Under the microscope the fine grained texture is noticeable. Fresh porphyritic olivines are abundant, and a few of the crystals have margins of iddingsite. The felspar is plentiful, consisting of small lath-shaped plagioclases with symmetrical extinction angles up to 25°-27°, indicating basic andesine. A fair quantity of brown augite, partly in brown phenocrysts, but mainly in small crystals and grains, is present, together with numerous minute cubes of magnetite. A fair amount of brown glass is present as groundmass.

Innumerable fragments of reef quartz occur as xenoliths in the basalt and in the scoria fragments throughout the Stony Rises. It is angular and fractured, and the pieces vary from a half inch to three inches in length (6).

Molten basalt has penetrated many of the cracks in the quartz fragments, and the rounding off of the solid angles indicates corrosion and a certain amount of assimilation by the liquid lava. It is probable that during the eruptions of Porndon and Warrion, quartz reefs in the underlying Older Palaeozoic rocks were reduced to fragments, and incorporated in the flood of lava that poured over this area. No waterworn quartz inclusions have been seen in the basalt, and therefore the Cainozoic gravels are excluded as a possible origin. It is, however, rather surprising that no fragments of sedimentary rocks have been found in the basaltic lavas of the district.

(*e*) *General surface features.*

It has already been indicated that for the western part of the Stony Rises the site of Mount Porndon is the source of supply of the lavas. The average surface slope of the basalts is very low. From the 650 feet contour round Mt. Porndon in an ENE. direction to the 400 feet contour at Lake Corangamite near McGarvie's, the distance is about 5 miles, and the average slope is only about 1 in 105, or 48.5 feet per mile. From the same centre in an ESE. direction towards Pirron Yallock, the distance to the 400 feet contour is about 7 miles, and the average slope is therefore about 1 in 150, or 34 feet per mile. It should be noted, however, that two plateaux with short, steeper slopes connecting them, occur within these limits, so that for considerable distances the average slope of the basalt surface is much less than the figures quoted above. Between the 650 feet contour at the base of the Warrion and the 400 feet contour at Lake Corangamite near Dreeite, a similar drop in level of the basalt surface occurs in about 4 miles, an average slope of 1 in 84 or 61 feet per mile.

The surface of the basalt in the Stony Rises is characterized by open polygonal joints, so that all the rainfall over the area readily sinks through the basalt to the underlying Cainozoic sediments. In consequence of this there is not a single flowing surface stream in the whole area, but hundreds of windmills provide the dairy farmers with water from the underground storages. The Pirron Yallock Creek defines the southern and eastern limits of the Rises, and flows into Lake Corangamite. The underground drainage from the Stony Rises enters by springs and seepages into the Pirron Yallock Creek and into Lake Corangamite. The most important of these are McVean's, Oliver's, and Carey's. Five million gallons of fresh water emerging from beneath the basalt daily enter Lake Corangamite from McVean's springs.

Between the striking and crowded basaltic barriers occur depressions of various shapes and sizes, sometimes funnel shaped, more generally elongated, and often with smaller eminences as hummocks or knolls rising from them. While no flowing surface water traverses these depressions, the bottoms of many of them, owing to the accumulation of basaltic soil, have become alluviated. This alluvium has a flat surface, and often partially covers the hummocks or knolls. In consequence, such areas are retentive of surface water, and in wet weather become small lakes or swamps.

These depressions below the basaltic barriers are often elongated and sinuous, and superficially simulate erosion features. Their longitudinal gradient, however, is undulating, not regular, and many of these depressions are closed basins not infrequently funnel shaped (Plate XII.B). They are, therefore, clearly not erosion features, but part of the solidified surface of the original basaltic sheets, and their present positions and attitude are to be attributed to subsequent sagging and fracture of the basalt crust, and not to erosion.



The barriers, valleys and funnel shaped depressions all constitute part of the original crust of the basalt sheets which have developed their present aspects by subsequent undulations of the crust. This is clearly indicated by the fact that the original polygonal jointing of the basalt crust developed in cooling is everywhere evident on the surface, the joints always being at right angles to the cooling surface, so that they are vertical on the crests of the barriers and at the bottom of the valleys or depressions, and are inclined towards the barriers in the slopes between barriers and valleys (Plate XIII.A). Very little scoriaceous or ropy basalt occurs in the Stony Rises; it is nearly all columnar, but in a few places a tachylytic selvage to the basalt is present. All of the flows are of the Pahoehoe type of basalt.

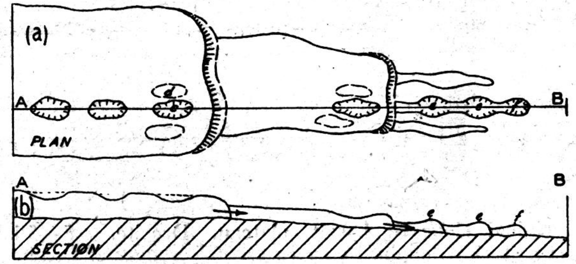
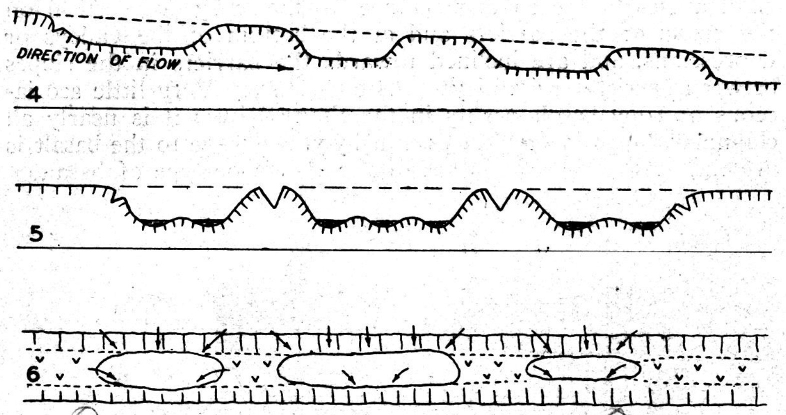



**Fig. 3.—Plan and section of basalt plateaux and lava tongues.**

Thousands of barriers occur in the Stony Rises, and every one examined by us is more or less breached. Sometimes this process is only slightly evident. The top of the basalt dome or barrier is either slightly flattened or has sagged a foot or more between prominent open columnar joints. In very many spectacular cases of breaching, a very definite minute "graben" or sharp depression represents a collapse of the top of the barriers which in some cases amounts to over 20 feet in depth. At the base of the trough there is generally an accumulation of deep red basaltic soil. In a few cases near McGarvie's, on the shores of Lake Corangamite, hardened tuff is present in the trough. At the 102 mile post from Melbourne on the main road, a basaltic barrier is exposed in section in the road cutting. This barrier of solid basalt is about 30 feet in height, and has collapsed only slightly between two major joints or cracks which are about 2 to 3 feet wide above, and gradually close below. The space between the joints is filled partly with basalt fragments, and partly with bright red, fine grained tuff. In places this baked tuff is in contact with the gaping joint surface of the basalt which here has a selvage of tachylyte about 1 inch in thickness.

At the eastern end of this barrier the sloping surface of the basalt has a definite tachylytic selvage, and red, fine grained baked tuff is in contact with it, and a definite prismatic structure in the tuff is developed for about 3 inches from the tachylytic basalt (Plate XIII.B). The inference is here drawn that a shower of tuff must have fallen on the basalt surface, so soon after its extrusion that while gaping joints had already developed, the surface of the basalt must have been still so hot as to have baked and prismatised the tuff.




FIGS. 4.—Original slope of basalt plateau, Dreeite. 5.—Plateau and barriers at same height, Stony Rises. 6.—Suggested origin of barriers and depressions, Stony Rises.

### (*f*) *The Stony Rises around Mount Porndon.*

East and south-east of Mount Porndon, outside the Ring, and starting from above the 600 feet contour line, a broad plateau extends for about a mile and a half (Fig. 2). This plateau is diversified with one very large breached barrier about 40 feet in height, and about 600 yards long on the north-east side of Mt. Porndon, and having an extension in a north-easterly direction. Apart from this prominent feature, only small domes and flat ridges rise above the plateau, and shallow depressions sink beneath the plateau level. Near the outer edge of the plateau large breached barriers, closely spaced and irregular in shape and direction, are a prominent feature. East of this rugged area the basaltic level falls rather abruptly about 30 to 40 feet, and further east another lower basalt plateau continues. In this case the plateau level is defined by the tops of the numerous breached barriers spread closely and irregularly over the area (Fig. 5). The plateau descends to about 450 feet near Lake Corangamite, and below this, fingers of basalt descend to lake level and enter the lake (Plate XII.c). The road about a mile west of Pirron Yallock also descends this plateau edge, and the easterly limit of the basalt ridges descends here nearly to the 400 feet contour. In the areas where the breached barriers are most closely crowded, they attain their maximum height, one of those measured reaching



a height of 65 feet above the adjoining depression. Probably the average outer slope of such barriers is about 25°, but in some cases it is very much steeper, up to about 50°-60°, and occasionally the walls of a few barriers may have an outer slope of 70°-80°. In all cases, whatever the slope or size of the barrier, it is always more or less breached, and the basalt is always columnar with the long axes of the columns at right angles to the basalt surface. A variety of hypotheses have from time to time been put forward to try to explain the formation of these barriers or apparently similar features. Lateral pressure on the solid crust of a lava sheet has been invoked. Some small features seen within the Halemaumau crater on Hawaii, and very small anticlinal arches in the basalt on the shores of Lake Corangamite (Plate XIII.c) appear to have this mode of origin. But a lateral thrust on a crust due to pressure of molten basalt from a higher level would develop asymmetrical slopes and varying heights, while the slopes of these barriers are normally symmetrical, and the crests of the barriers are at a fairly uniform height. Irregularities, amounting to submerged ridges in the topographic surface beneath the molten basalt, leading to an upthrust of molten basalt against the buried ridge and causing a bending up of a solid but somewhat plastic crust, have also been suggested as likely to develop breached barriers. This seems a quite feasible explanation for isolated or occasional and widely spaced domes or barriers rising from a basalt plain, especially where such barriers rise to varying heights. Some such isolated features seen on the Newer Basalt sheet at South Morang, north of Melbourne, may owe their origin to such a cause. But the presence of closely spaced breached barriers in hundreds within a few square miles would seem to necessitate the appeal to a buried surface of such extraordinary irregularity as to exclude it as a possible reason for the development of the barriers, apart from other objections.

The authors, in an earlier brief preliminary statement, suggested that the barriers may have marked the position of very numerous small fissures up which a limited amout of basalt was injected, but such a view is now seen to be untenable. The hypothesis now favoured and put forward with some confidence is one of partial collapse of the solid crust of a basaltic sheet due to the withdrawal of molten basalt from beneath, as a result of ruptures of the temporarily solidified front of the basalt sheet. Such ruptures occurring in a number of places would allow of large withdrawals of molten basalt from beneath the crust of the plateau, and lead to subsidences of the crust where withdrawal of lava occurred. Undulations are started, the surface area of the crust is increased, tensional stresses are set up, and fractures along the polygonal joints occur, especially at those parts of the crust of the plateau which do not sink, and therefore form the crests of the domes or barriers. In this way the breaching of the barriers accounts for much of the increased length of the cross section of the basalt crust, and general small openings of the universal polygonal joints account for the remainder (Figs. 5 and 6).

Reference is made above to the picture of a temporary stoppage of the front of the basalt sheet as a result of surface solidification, causing the front of the sheet to stand as a rampart with a fairly steep slope. The continued outflow and downflow of molten lava from the vent or source at a higher level, however, causes pressure, leading to rupture in many places at or near the base of the solidified front. Molten basalt pours outwards and downwards from such ruptures, the streams become confluent and a second and slightly younger sheet or plateau of basalt is formed at a lower level (Fig. 3).

The topography of the Stony Rises, as mentioned above, shows the existence of two such plateaux at levels between the 600 and 400 feet contours, and close examination at the junction of the higher with the lower basalt plateau surface, especially north of the road about a mile west of Pirron Yallock, confirms the view that such ruptures of a basalt front have occurred, and later flows have developed a plateau at a lower elevation.

While this paper was being written, a paper by Robert L. Nichols (7) came to hand, in which basalt flows in New Mexico are described. The consolidation of the front of a flow, the rupture where the crust is weak, and onflow of the molten basalt at a lower level, are described and figured. It is clear from this account that somewhat similar conditions attended the flowing of basalts in New Mexico as those which are met with in the Stony Rises. In this paper two depressions on the surface of the flow similar to those in the Stony Rises are figured in diagram but not discussed.

The reasons for the development in the Stony Rises of plateaux at different levels, the abundance and crowding of barriers and valleys, and their large dimensions, are no doubt complex, and the conditions must be different from those obtaining in other parts of Victoria where basaltic lavas are poured out in a succession of comparatively thin sheets with a comparatively level surface.

The very gentle slope of the pre-basaltic land surface in the Stony Rises favours slow movement of the lava, but normal basaltic lava is very fluid and would move rapidly in thin sheets. But all of the basalt of the Rises is crowded with porphyritic felspars of intratelluric origin, and this must impart a certain amount of viscosity to the flows. Again, the field evidence suggests that the basalt poured out from the source in a single flow about 80 feet in thickness. The peculiarities of the basalt surface which are such a striking feature of the Rises appear to have developed as a result of the combination of several causes, including the eruption of a thick sheet of lava over a gently sloping surface, and the rapid formation of a solid crust and front assisted by the abundance of felspar crystals. The great thickness of the lava sheet, however, enabled it to maintain internal fluidity, and this led to numerous ruptures at the base of the snout of the main flow and the extrusion of a series of subsidiary flows at a lower level. These later flows united to form a lower plateau, and the draining away of the liquid lava from under the solid crust in the higher plateau led to the development in it of numerous depressions and sinks, and to the crowding between them of breached barriers.



Valleys, etc.—The picture, developed above, of the formation of a lower basalt plateau in front of a higher plateau by rupture in many places of the solidified front of the flow, involves the withdrawal of large quantities of molten lava from beneath the crust of the upper plateau. Where the withdrawal is over a wide area, a general sagging of the solidified basalt surface may occur, leading to the formation, within the basalt plateau, of a broad area of subsidence which, if the subsidence and sub-surface are uniform, develops into a flat basin with marginal rims whose sides are opened by tension cracks (Figs. 5 and 6). Sometimes the broad collapsed area will have occasional undulations, and the fixation of the positions of the relatively elevated parts may be brought about in at least two ways. In the one case the basalt crust may vary in thickness, and the position of the ridge above the general level of the basin may be determined by the thickest part of the basalt crust. On the other hand, irregularities in the sub-basaltic topography are likely to be present. If so, the position of a sub-basaltic ridge is likely to locate the positions of a basaltic ridge on the surface of the depressed area, for away from such ridge there will be a greater thickness of molten basalt which is likely to be drained away, causing the basalt crust over such an area to sink to a lower level than over a buried ridge.

Where the breached barriers are most closely spaced and irregular in shape the intervening valleys are correspondingly restricted in width and irregular in plan. The removal of most of the molten basalt from under a wide area will tend to develop crumpling of the solidified basalt crust with the consequent formation of irregular valleys as well as breached barriers. Not only are these valleys often irregularly shaped or winding in plan, but also in thalweg or longitudinal profile. This at once distinguishes such valleys from those produced by erosion (Plate XIV.A). Inequalities in the amount of subsidence of the crust from point to point are the cause of such a profile.

A remarkable type of valley which is fairly common in the Rises is one which is irregularly ring-shaped, with a central knoll or ridge often connected to the side of the valley by a low connecting ridge. It is difficult to picture the precise mechanism of formation of such a feature.

In several parts of the basalt plateau the depressions are elliptical in plan and arranged in a linear direction. Sometimes they are circular in outline and constitute inverted cones. The shapes and linear direction of such features almost certainly mark at the surface, the positions beneath the basalt crust of "lava tunnels," or narrow valleys along which molten basalt has been drained away (Fig. 7). Such funnel shaped depressions carry down rain water easily; in places there are open joints, enabling one to see that beneath the apex of the cone caverns occur. The Pomborneit butter factory used to get rid of all its effluent by piping it to one of these conical depressions.

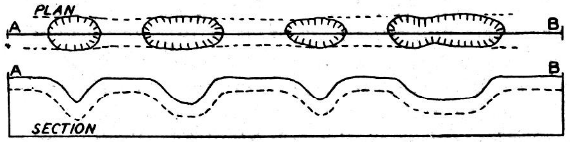



FIG. 7.—Plan and section of elliptical depressions over collapsed lava tunnels.

Gas Explosion Crater.—Near the caves of Mount Porndon a remarkably symmetrical surface feature occurs. It is a ring, about 50 yards in diameter, of basalt and basalt blocks raised about 10 feet above the level of the basalt outside. Within the ring the columnar basalt has its joints radially disposed. The central level depression of reddish soil is just below the level of the basalt outside the ring (Plate XV.A). It seems probable that the formation of this feature is due to the development of a large gas blister beneath the solid crust, causing it to be domed up, and later, when the joints developing downwards weakened the crust of the dome sufficiently, a small gas explosion occurred sufficient to form the slight rim or ridge around the central depression (Fig. 8).

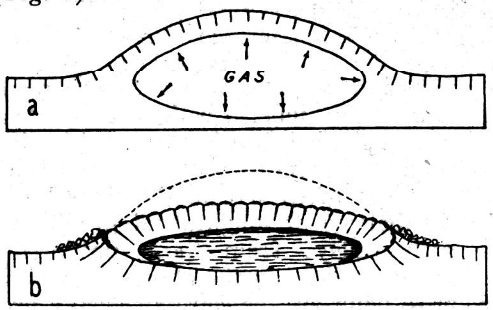



FIG. 8.—Gas explosion crater near Porndon Caves—(*a*) early development, (*b*) present appearance.

Caves.—Just outside the Porndon ring are two basalt caves. Each of these is situated beneath a broad, low dome of basalt.



The more southerly cave (Plate XVII.A) has a collapsed area in front with a natural arch formed of the basalt crust between the collapsed area and the mouth of the cave which is a natural arch (Figs. 11 and 12). The arch is interpreted as a swelling due to gas pressure between the molten basalt and the solidified crust, forming a cupola on the walls of which are small, pendent lava stalactites about $1\frac{1}{2}$ to 3 inches long. This cave, trending due

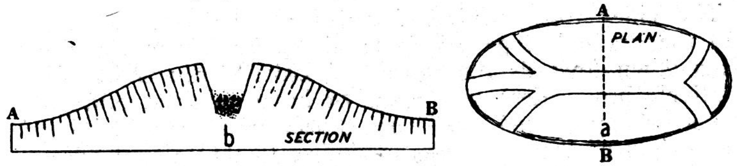



FIG. 9.—Plan and section of breached barrier, Dreeite.

north, has a flat floor, and against the walls at the base is a basaltic ridge about 2 feet high constituting the frozen edge of the lava which has since withdrawn along the lava tunnel.

The second cave is about 300 yards north-west from the one just described. This cave has no arch at the entrance, but collapse of the roof has yielded a fairly flat hole. The cave formerly could be penetrated for over 200 yards, but collapse of part of the roof basalt about six years ago has now restricted the

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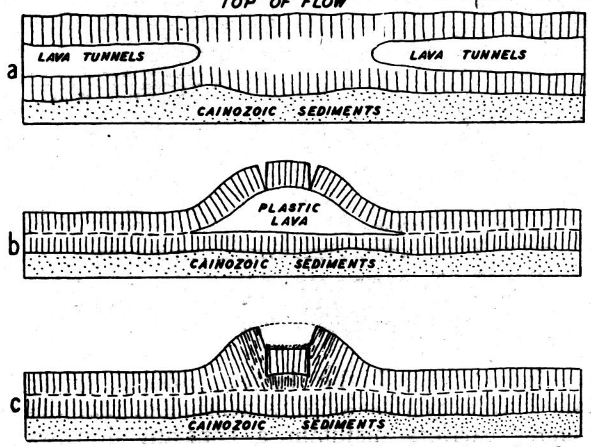



FIG. 10.—Probable origin of deeply breached barrier, Dreeite—(*a*) Flow with lava tunnels; (*b*) Subsidence of lava above tunnels; (*c*) Collapse of arch of barrier.

underground passage to about 50 yards in length. From the roof of this cave, small, pendent lava stalactites are to be seen. The floor is arched, with a central breach. Not only are there marginal frozen edges to this cave, but the walls of the lava tunnel are smeared with residual ropy basalt left by the retreating molten lava. Along the length of the roof of the cave two dome-shaped gas cupolas are developed, whose apices rise about 40 feet above the floor of the cave, and 20 to 30 feet above the roof of the lava tunnel, which is about 30 feet in width.

(*g*) *Dreeite.*

The chief topographical features of the Dreeite area are, (1) the gradual slope of the basalt surface from the Warrion Hills down towards the shores of Lake Corangamite, (2) the relatively broad, depressed areas of basalt surface, and (3) the rather widely spaced, but very conspicuous, breached barriers. The origin of these features is similar to that already described for the Stony Rises around Porndon. The chief interest centres in the breached barriers, many of which are of large dimensions. The central breach or minute "graben" may have a depth exceeding 20 feet (Plates XIV.c, XV.B, Figs. 9 and 10).

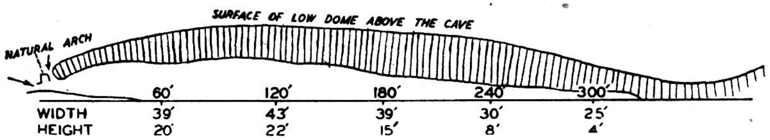



FIG. 11.—Longitudinal section of S.-E. cave near Mount Porndon.

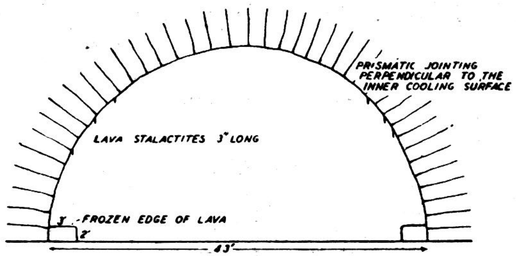



FIG. 12.—Transverse section of S.-E. cave near Mount Porndon, with lava stalactites and frozen edge of lava.

A view from one of the larger barriers towards Lake Corangamite shows by theodolite measurement that the summits of intervening barriers maintain a constant downward slope towards the lake (Fig. 4), probably indicating the original level and slope of the top of the lava crust before subsequent subsidence of the surrounding depressed areas.

At the base of the breach in each barrier there has accumulated red basaltic soil to a thickness which in some cases reaches 3 feet. From the western boundary of the basalt plateau, tongues or fingers of basalt, themselves usually breached, have flowed towards and into Lake Corangamite.



## III. The Southern and Eastern Shores of Lake Corangamite.

(*a*) *The Ridges.*

The main sources of supply for the basalt reaching Lake Corangamite came from Mount Porndon, moving in a north-north-easterly direction, from Robertson's Hill, moving in a north-westerly direction, and from the Warrion Hill, moving in west and north-west directions. From the edge of the main flows at about the 450 feet contour, molten lava breaking from the base of the flows poured lakewards in a series of small, linear, finger-like protrusions down to the lake shore, and project in some places for several hundred yards into the lake. The general direction of these small flows is radial to the shore line and their longitudinal profile is undulating. Temporary solidification of the snout of the flow occurred, the pressure of molten lava from behind developed a bull nosed knoll or ridge, and rupture at the base led to the continuation of the flow at a lower level. This is sometimes repeated several times before final solidification terminated the movement. The surface of these small flows is, in places, marked by tranverse ridges and joints, and in places it is clear that opening of these joints occurred while liquid lava, under some pressure, was moving beneath, for in several cases a small amount of ropy and scoriaceous lava has been squeezed out through the original joints (Plate XVI.A). Many of these small ridges show small true breaches at their summits, but in addition, a number of ridges occur on the lake shore and up to an elevation of 15 feet above it, constituting pseudo-breached barriers (Plate XV.c and Fig. 13). There is clear evidence that at one time the lake level was from 5 to 15 feet higher than at

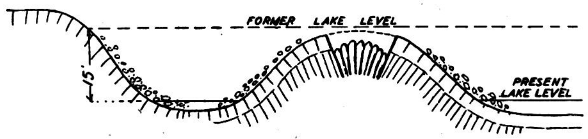



FIG. 13.—" Pseudo breached barrier " and basalt shingle on slopes, with former lake level, shores of Lake Corangamite.

present, and wave erosion has removed the rather vesicular upper crust of the crests of these ridges, exposing basalt with a distinct joint system beneath. In addition, the eroded material has accumulated on the slopes of these barriers as a waterworn basaltic rubble. This is abundant up to 5 feet above the present lake level, and in some places has been noticed up to 15 feet above the present lake surface. It has been flung into breaches of the barriers and along pockets of the shore line. A noticeable feature of nearly all the small lava tongues on the shores of Lake Corangamite is that the original tachylytic selvage, up to 1½ inches thick, common to Pahoehoe flows, has been preserved.

### (*b*) *Lake Corangamite, Dimensions and Salinity.*

The lake has a maximum length of 20 miles, a maximum width of 7 miles, a minimum width of 1½ miles, its area is 81 square miles, and it has a perimeter of 81 miles. It is remarkably shallow; one of us (A.J.) has made hundreds of soundings, and nowhere has it a depth greater than 5 feet, though, in the south-west, there is a thick deposit of soft silt over the floor of the lake. This can be penetrated by a stick to a depth of 9 feet. Although the lake in recent years has varied little in depth, there is evidence to show that there have been considerable variations during its past history. Local residents remember a time when cattle, to reach Vaughan's Island, had to be taken there by punt, although it is now a tied-island connected to the mainland by a neck of land 5 feet above the present water level. To the south-east of the lake, there is a plain of tuff and alluvium nearly 2 miles wide, and so level that there is little doubt that it was at one time part of the lake bed. The name given by the aborigines to this area is Pirron Yallock, which means "shallow water."

Lake Corangamite, containing 10.5 lb. of salt per 100 lb. of water, is three times more saline than the sea. This great salinity is due, not only to the fact that the lake is a basin of internal drainage, but also to its shrinkage in volume. Shrinkage has occurred in all the lakes examined throughout the district.

### (*c*) *Tuffs and their Relation to the Lava Barriers.*

Extending along the southern margin of the lake are tuffs, mostly very fine grained. They extend from below water level to about 5 feet above the present surface of the lake. Nowhere are tuffs found in this area at higher levels, and as they are widespread along the lake shore within the limits given above, it is reasonably safe to conclude that these tuffs were laid down in the lake when it was 5 feet or so higher than at present. The presence of numerous shells of *Coxiella* embedded in the tuff 1 mile north-north-west of J. McGarvie's strengthens the belief that the tuffs are of lacustrine origin. The tuffs extend far out into the lake on all sides of Vaughan's Island.

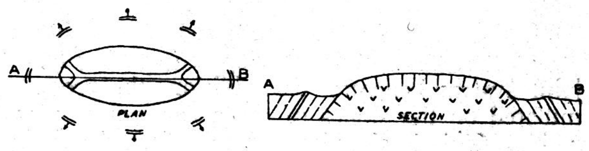



FIG. 14.—Plan and section of barrier with tuffs dipping away from it, near McGarvie's.

In the Red Rock, Warrion, and Porndon areas, there are thick beds of tuffs which are unquestionably younger than the felspathic lava ridges, for their undisturbed strata cover the broken surfaces



of the ridges. Along the southern shores of Corangamite, however, the lava ridges are younger than the tuffs, for in several places near McVean's Springs the lava ridges rest on the tuffs, while near McGarvie's there are two localities where small shoots of tachylytic lava are seen invading the tuffs (Fig. 15c). In most cases the tuffs are found completely or partially surrounding the lava ridges and knolls (Fig. 14), but inclined away from them, as though the barriers had been gently raised through the horizontal tuffs and had uplifted them bodily on their flanks. The inclination of the beds in these instances is the opposite to what it is where the lava barrier is resting on the tuffs (Fig. 15). In the latter case the tuffs are inclined towards the lava as though the weight of the lava mass was bending down the beds. In several places the tuff near the front of the ridge was seen to be puckered and to be neither inclined towards nor away from the lava. Generally there is, at the surface, a gap of one or two feet between the lava and the tuff outcrop. This is probably due to drainage upwards of the underground water from the Rises, altering the tuff to a black clay. All stages in this alteration have been observed by making a shallow trench between the basalt and the exposure of dipping tuff.

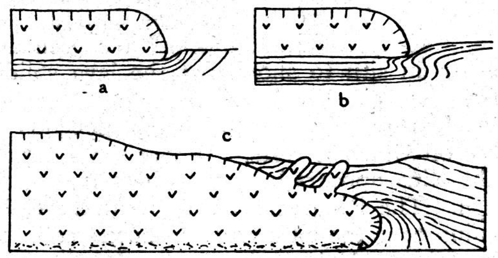



FIG. 15.—Section of basalt flow pressing down tuffs, Lake Corangamite; (*a*) with inward dip; (*b*) with crumpling; (*c*) with intrusion of basalt "squeeze up" into contorted tuffs.

It is likely that the tuffs were derived from the Vaughan's Island volcano, and that they formed thick unconsolidated strata in the coastal waters of Southern Corangamite. While they were in this state, the lava tongues from Porndon and Warrion poured into the lake. Some lava tongues flowed over the tuff and compressed it, but most of them appear to have flowed against the soft beds and pushed them ahead, or ploughed through and under them. In the last case, beds of tuff were left resting on the sides of the barriers and inclined away from them. Some low knolls are completely surrounded by tuff beds. They are parts of a lava tongue, the lower portions of which lie beneath the tuff. The tuff found within the breaches of some barriers is probably redistributed material as it is not stratified.

## IV. Mount Porndon.

*(a) General Outline.*

The centre of eruption within the Mount Porndon ring has probably played a more important part in the geological history of the district than have higher neighbouring volcanoes such as Leura and Noorat. Mount Porndon is surrounded by a remarkable lava ring barrier about 2 miles in diameter (Plate XIV.B). Within this ring are lava plains, deep depressions, and groups of low scoria cones and lava domes. Outward from the ring there is a general fall of level in all directions, therefore this centre of eruption is to be looked upon as the source of most of the lava south of Corangamite.

*(b) The Ring Barrier.*

This remarkable basaltic ridge (Fig. 16), standing generally 50 to 80 feet above the plains and ridges outside, extends in an almost unbroken line around Mount Porndon. It is 8 miles in length, is roughly circular in shape, and on all sides presents a steep outer slope with an angle of rest about 30°–40° (Plate XVI.c). That this outer face of the barrier is the original cooling surface is shown by the presence of lava columns perpendicular to its surface. Many columnar blocks have been displaced, but sufficient remain in situ to show that the lava solidified in that position. The external height of the Ring varies from place to place. One feature on which this height depends is the nature of the surface on which it rests. Where the Ring Barrier rests on a ridge, the Ring appears low, but where it is above a depression it is high. The Ring reaches its greatest height (84 feet) above the plains near the Stonyford-Cobden road. The internal height of the Ring, which varies from place to place, is considerably less than the external. Around the outside base of the Ring Barrier there is generally a depression some yards in width and a few feet deep, apparently made by the compression of the underlying lava while in a semi-solid state, by the mass of rock above it.

The inner face of the Ring Barrier is invariably fractured along one, two, three or four curved lines, two being the most common, and more or less concentric with the outer margin of the Ring. In some cases there has been considerable collapse along these fracture lines, extensive areas subsiding 30 feet or more (Plate XVI.B). Whereas the outer slope of the Ring exposes the transverse polygonal tops of the basalt columns, longitudinal sections are shown on the fractured inner face. The effects of gravitational collapse along tension cracks are everywhere apparent along the inner slope of the Ring. Cracks several feet wide and 20 feet or more in depth are common. Underground gaping joints are numerous.

For Caves, see p258-260



The ring barrier is composed of the same coarse felspathic basalt as is met with in the Rises. Little scoriaceous or ropy lava is present, though there is one locality where small scoriaceous fragments extend from the top to the bottom of the outer slope, a distance of 60 feet. Dr. A. Wade (8) has referred briefly to extinct volcanoes in Madagascar, and in a personal communication states that great walls surrounding some of the extinct cones in Madagascar appear to be similar in nature to the Porndon Ring.

*(c) The Lava Sheet and Depressions within the Ring.*

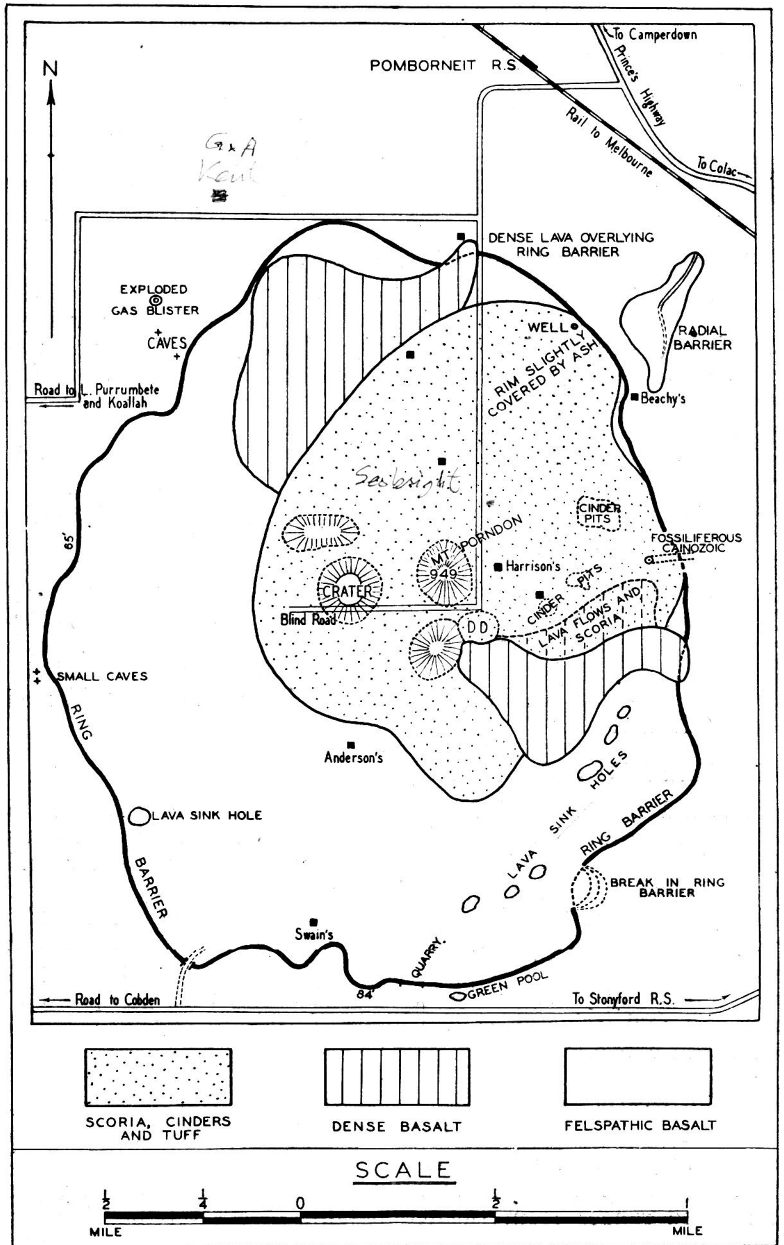
The basalt surface inside the Ring Barrier has similar features to the lava sheet outside the Ring, i.e., it is not flat but hummocky, and is composed of the same kind of lava as the Ring and the plains outside. From the fractured face, the sheet slopes inwards until it meets the more recent accumulations of lava and scoria within the Ring. In the south-west, and more particularly in the north-east, there occur depressions, circular or elliptical in outline, and 40 to 50 feet in depth. The largest, 100 yards in diameter, occurs fairly close to the Ring south-east of Porndon. Three of these large inverted cones are within two or three hundred yards of one another (Fig. 16). All have columnar jointing perpendicular to the surface, and all have severely fractured rims, the fractures being about 10 feet in depth. Contrasted with these is the depression D.D. on the map, which is formed by the confluence of the edge of a lava flow and the sloping flanks of two scoria cones. It is therefore not formed by subsidence.

*(d) Lava Hills within the Ring Barrier.*

Around the foot of Mount Porndon and the small scoria cones are several low basalt hills from which short lava streams have issued, in two instances reaching the Ring Barrier and overwhelming it. This basalt is quite distinct from the coarse highly felspathic and lighter coloured basalt of the Ring. It is very fine grained, rich in olivine, and dark in colour. As it overlies the felspathic basalt of the Ring and the plain inside it, it is obviously younger than these. The chemical composition, texture, and mineral composition of this basalt have been described above.

*(e) The Scoria Cones.*

The four highest hills within the Ring Barrier are all scoria cones, only one of which, to the west of Mount Porndon, 949 feet, has a crater. The fragmental material of which they are composed ranges from isolated basaltic blocks on the sides of the cones to the finest ash. Several pits have been opened up to obtain scoria for railways and roads. In these pits olivine bombs, which range in length from 2 inches to 2 feet, are plentiful.




PLAN OF MOUNT PORNDON AND RING BARRIER

FIG. 16.



Fragments of both the earlier felspathic lava and the later dense type are found among the ejectamenta in the pits and on the sides of the cones, thus showing that the explosive phase of Porndon was its last. The north-eastern portion of the Ring is partially hidden beneath the ashes from Porndon. Here the outline of the Ring can be seen, but its contour is smooth and flattened out. A temporary railway line was made many years ago into the cinder deposits on the eastern slopes, and excavations revealed a marine Cainozoic deposit beneath the ashes and lapilli at an altitude of about 650 feet. It is reported by local residents that they obtained many shells from it. Though the authors found there marine Cainozoic polyzoa, and shell fragments, no whole shells were found. The exposure has been buried beneath discarded materials from neighbouring pits, and consequently it is difficult to reach and examine the Cainozoic calcareous deposits. Some beds of lapilli have been so cemented by calcareous deposition around each grain that the beds have been consolidated and greatly hardened. Considerable quantities of Cainozoic gritstone and ironstone are found about the slopes of the scoria cones, thus showing that the underlying rock consists of Cainozoic sediments.

### (*f*) *Radial Barrier outside the Porndon Ring.*

Midway between the Pomborneit railway station and Mount Porndon is a conspicuous barrier outside but close to the Ring, and radial to it. It stands well above the hummocky plains around it. In plan it is roughly triangular, with the narrow base separated from the Ring by a valley-like depression. It is about 600 yards long. A deep trench extends along the crest of the ridge, and fractures also occur along its south-eastern margin. Basaltic ridges and depressions, higher than the low hummocky plains but lower than the radial barrier, occur along its sides. The general slope of these is away from the high triangular ridge. The whole area, plains and barrier, is composed of the same type of rock as the Ring Barrier, i.e., coarse felspathic basalt.

### (*g*) *Geological History of the Porndon Series.*

Before the high scoria cones existed, the Porndon area was a centre of eruption from which thick sheets of felspathic lava covered about 80 square miles of the surrounding district. Belonging to the first eruption was the radial barrier referred to in (*f*) above. It was possibly on an earlier water parting, for the lava surfaces on all sides slope away from it. As the movement of the lava within the sheet continued towards the lower levels around Corangamite, so the crust of the basalt about the radial barrier sank to its present level, but the basalt now constituting the barrier being, on this hypothesis, on a divide, did not sink. Owing to the subsidence along its sides, deep trenches were formed along its crest. Other hummocky areas were formed by differential subsidence in many parts of the district. The next phase was the formation of a sheet of lava up to 84 feet in thickness, which issued from a vent or vents within the present Porndon Ring. This thick sheet, flowing on irregular ground with little outward slope in any direction, moved forward only slowly. The front of the sheet solidified, and owing to the pressure of the lava from the source, it became exceptionally steep and high. At this stage the lava pancake is pictured with a slightly domed surface and a steep convex front (Fig. 17A). Withdrawal of molten lava from beneath the crust of the thick sheet is then pictured as having taken place. In a few cases this withdrawal appears to have been caused by the liquid lava breaking through the front of the pancake (Fig. 16), but it is probable that most was withdrawn through the vent or vents up which it rose (Fig. 17B). Several features resulted from the

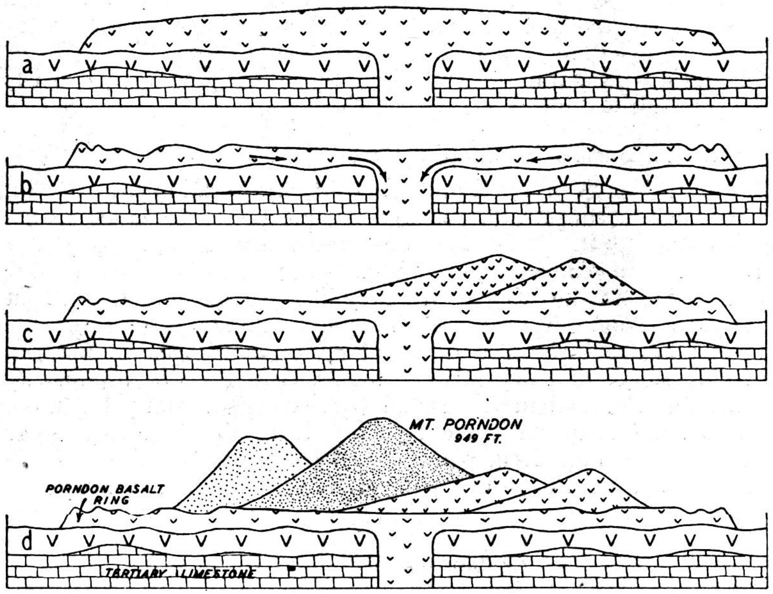



FIG. 17.—Four stages in the development of Mount Porndon, other cones, and Porndon Ring Barrier.

removal of lava from beneath the surface crust. In the first place, a somewhat irregular surface was formed which everywhere sloped inward from the edge of the pancake; secondly, deep depressions resembling huge sink holes were made by the local removal of support from beneath the crust; thirdly, fractures developed concentric with the solidified outside edge. The state of tension set up resulted in the separation of the



columns from one another, and deep crevices were formed. Lastly, a roughly circular ridge was left along the front of the thick sheet. The pressure of this sheet of lava on the partly solidified earlier flow, is probably the cause of the shallow depression noticeable around the outer foot of the Ring Barrier.

At a later stage small lava domes rose near the centre of the Ring, and from these, tongues of dense, dark olivine basalt flowed out. The supply was so limited that seldom did they reach the Ring Barrier (Fig. 17C).

Almost concurrently with this effusion of dense olivine lava, an explosive phase took place, which created the smaller scoria and cinder cones, for there is evidence in the scoria pits of this lava being intercalated between layers of scoria. The last chapter in the history of Porndon was the explosion which formed Mount Porndon, an eruption which by its steadily diminishing intensity, formed a high conical peak without a crater (Fig. 17D).

## V. Byaduk.

(*a*) *Lava Flows.*

Surrounding Mount Napier (1,453 feet), which is the source of the lava flows here described, there is an extensive area covered by sheets of basalt at a high level. From this thick widespread accumulation, there flowed considerable quantities of basalt into former river valleys which drained the Napier area. Three of these valleys, the Harman valley, Scott's Creek, and Weerangourt Creek, all now partially filled with basalt, occur in the neighbourhood of Byaduk, but only the Harman valley, which drains to the west into Lake Condah, is dealt with in this paper (Fig. 18). It is a young valley in Cainozoic limestone which underlies partially or wholly decomposed basalt that covers considerable areas in this district. The width of the Harman valley varies from 300 yards to half a mile.

There is no surface stream, the whole drainage taking place in or under the basalt. The jointed and broken nature of the surface rock provides an easy access for surface water into subterranean channels. In all the lava-filled valleys of this district, the same phenomenon occurs, i.e., the drainage of the area through underground channels. In Scott's Creek valley, adjacent to the Harman valley, a stream of considerable size flows alternately above and below the lava surface. In Harman's valley the stream does not appear on the surface at all until the valley widens out at Wallacedale, and there many springs unite to form a creek flowing into Lake Condah.

The lava flowing down the Harman valley completely blocked Scott's Creek and the Lyne, which were tributary streams. In the latter the stream, on reaching the lava which blocked the outlet, disappears into and underneath the wide open joints of the basalt. There is no sign of swamp deposits upstream from the barrier. The lava barrier across the junction of Scott's Creek and the Harman valley resulted in the formation of a swamp or lake, and in this water-logged area sediment and vegetation accumulated. This deposit has now been drained, and an exceedingly rich stretch of land known as "The Louth," has been made available for cultivation. At the western end of "The Louth," in the neighbourhood of Christie's selection, the Harman valley becomes very wide, and the lava flow, instead of being confined between comparatively steep valley sides 300 yards or less apart, widens into a sheet about 1½ miles in width.

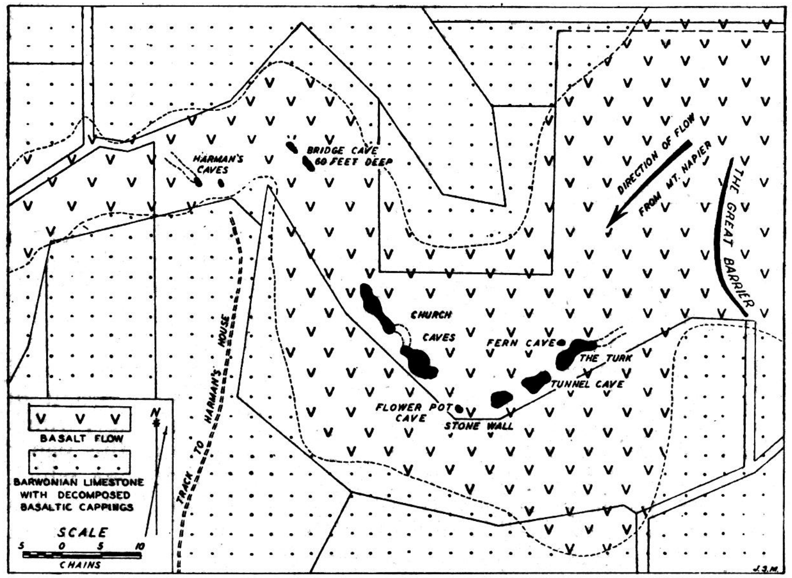



FIG. 18.—Caves and collapsed caverns in Harman's Valley, Byaduk.

(*b*) *The Barriers.*

Much of the surface of the basalt in the Harman valley is made so rough by deeply fractured basalt barriers and depressions, that it can be traversed only with great difficulty. The barriers or ridges are of two distinct types—single transverse barriers and twin barriers longitudinal to the direction of the flow.

Twin barriers are seen in several places on the well defined lava flow at Byaduk North, while near Wallacedale, there is an example, diagrammatic in its perfection. The Byaduk twin



barriers are about 400 yards in length. The barriers stand from 10 to 20 feet above the valley floor, and are separated from each other by 40 or 50 feet at the summits. Each ridge has columnar jointing perpendicular to the surface slopes, and in every instance the columns along the crests of both ridges are displaced to form V-shaped trenches 10 to 12 feet in depth (Plates XVII.C, XVIII.A).

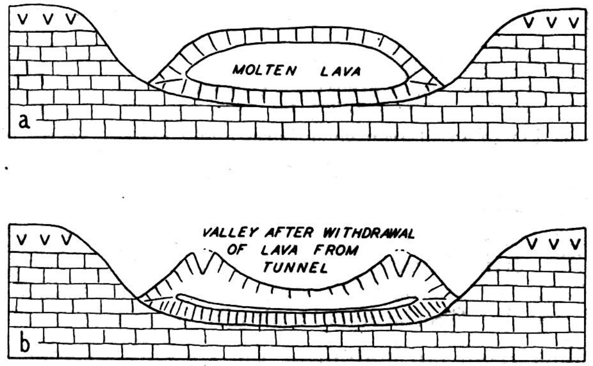



FIG. 19.—Section of basalt flow from Mt. Napier in Harman's Valley, Byaduk. a. Early stage. b. Showing present development of twinned breached barriers.

It is evident that the molten basalt beneath the solidified crust of an individual lava tongue occupying only a part of the total width of the basalt covered valley (Fig. 19A), was withdrawn probably through a break at the snout of the flow, and the crust being unsupported, collapsed, but left the solid edges in their original position. As polygonal jointing had at that time already developed, the fractures took place parallel to the sides of the lava tongue, and in this way twin ridges or barriers developed (Fig. 19B).

Barriers transverse to the direction of the lava movement are of different origin. They appear to have been the halting places of the basalt where solidification of the front offered temporary resistance to the pressure of the molten lava within. Crescentic barriers, steep and convex on the down-valley side, were consequently formed above the level of the lava sheet (Fig. 18). When at length the lava escaped at the base of the front of the flow, a deep trench was formed immediately behind the transverse barrier. The formation of this trench caused a fracture along the crest of the barrier. The largest of the transverse barriers occurs near the junction of the Napier lava plateau with the Harman valley. It is 500 yards in length, has a fracture 20 feet deep along the whole of the crest, and has a trough behind it 45 feet in depth. The edge of the flow behind the trough has two lines of fracture probably caused by the collapse of the trough in front of it (Fig. 20).

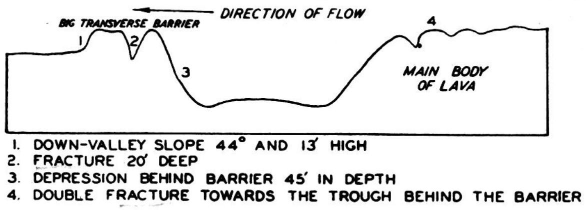



FIG. 20.—Section of great transverse barrier and trough, Harman's Valley, Byaduk.

### (c) *The Caves.*

Between Harman's and the big transverse barrier are several caves with vertical sides, up to 60 feet in depth (Fig. 18 and Plate XVII.B). On the floor of each cave is a tumbled mass of columnar basalt. Scoriaceous basalt also is abundant.

Extending from the bottom of the aperture of each cave are one or two large tunnels on whose roofs are exposed the broken ends of prismatic columns. These indicate that the tunnels are not entirely original formations like the caves at Porndon, but have been modified by lava blocks falling from the roof into a tunnel-like cavity at a deeper level. Owing to the difficulty of climbing over the heaps of fallen blocks which are wet and slippery, all the tunnels were not examined along their entire length, but one (Harman's) was explored for about 200 yards, when fallen blocks over the floor prevented further progress. All the tunnel caves inspected showed the same characteristics—floors covered by a jumble of huge rock masses, roofs made of scoriaceous basalt or the broken ends of prismatic columns, generally 20 to 30 feet above the floor, and with a width of 20 to 40 feet.

The caves are of various sizes. One of the Bridge Caves is 60 feet deep, 130 feet long, and 70 feet wide, while the Turk
doline length? Cave is 500 feet in length, 80 feet wide, and it is connected by a natural tunnel with Tunnel Cave, 260 feet long and 100 feet wide. Caves such as Fern Cave and the Flower Pot, with their pretty shrubs and trees that reach the surface, are small compared with those mentioned above, being less that 60 feet in diameter. Besides the caves and tunnels mentioned in the text and shown on the map, there are many more, some of which are tiny pits with vertical sides, and others, areas suffering collapse.

The sides of the caves reveal much of the volcanic history of the valley. Six flows are exposed, each averaging about 10 feet



in thickness. In one of the caves is seen a veneer of lava from a later flow, covering the fractured edge of an earlier one. This suggests that at the time the caves were formed or partly formed, at least one of the later flows had not completely solidified.

An examination of the map (Fig. 18) shows that the tunnels and caves lie along a well defined line which probably represents the course of the stream formerly draining the Harman valley. The facts available, such as at Harman's Cave, suggest that the first lava flow from the Napier plateau into the Harman valley was very thick. It overwhelmed the stream, and in doing so, created enormous quantities of steam which, imprisoned within the lava, caused the development of many steam blisters or cupolas beneath a thin crust. After the formation of the blisters or cupolas, the onflow of the molten lava, by bursting through ? the crust at the snout of the flow, developed lava tunnels. Later outpourings of basalt flowed around these hollow hills and ridges, until the surface presented a relatively uniform appearance. The last eruptions flowed right across the steam blisters. At length the thin crust of the caverns gave way, and then the vertical prismatic jointing of the upper flows offered little resistance to a general collapse into the caverns below (Fig. 21). As before stated, it is evident that collapse took place before solidification of the upper flows was complete.

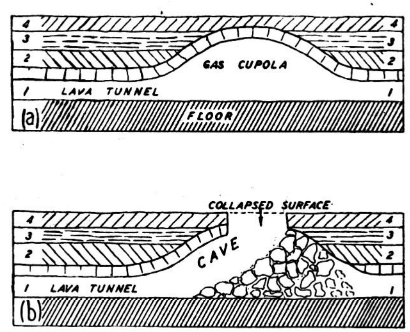



FIG. 21.—Harman's Cave, Byaduk. a. Development of gas cupola, lava tunnel, and later basalt flows. b. Formation by collapse of surface at apex of gas cupola.

### (d) *Steam Blisters.*

At the junction of the Harman valley and Scott's Creek, the lava sheet is about $1\frac{1}{2}$ miles in width. The surface is generally flat, but on the southern side, about fifty isolated basalt cones project spectacularly above the plain. They are from 20 to 30 feet

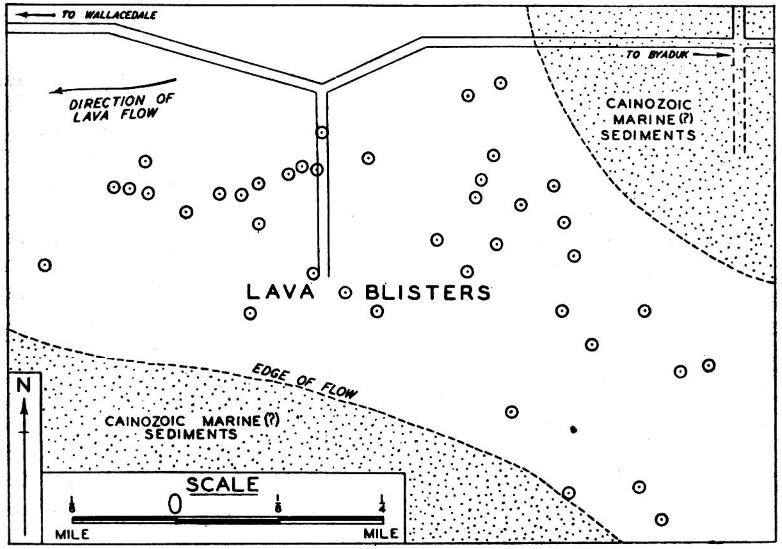



Fig. 22.—Plan showing lava blisters near Christie's, Byaduk.

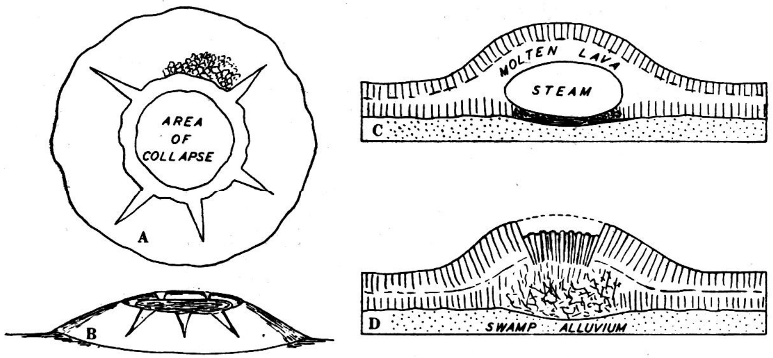



Fig. 23.—Basalt blister, near Christie's, Byaduk. A. Plan showing central collapse. B. Profile sketch showing radial cracks. C. Early stage of development by steam from swamp. D. Present stage after gas explosion, showing central collapse.



in height, and about a chain in diameter (Plate XVIII.B, Fig. 22). That they formed part of the original surface is shown by the continuity of the prismatic jointing from the plain to the sides of the cones. Columnar jointing is strikingly fresh and perfect over the whole surface of these knolls, and scoriaceous or ropy structure is either absent or rare. All the columns are vesicular towards the surface. An examination of these basalt cones reveals that every one is severely fractured. Several radial fractures from 1 to 4 feet in width and about 6 feet in depth, are found on every knoll, and most have also one or more concentric fractures on the upper half. On the crest of each cone is a basin-like depression (Fig. 23A), in the centre of which there is sometimes a small deep hollow (Fig. 23B), and sometimes a conical pile of columnar boulders. The interior of none of the knolls has been fully exposed, but the gaping joints which penetrate them give one the impression that the cones are hollow. ?

From a distance these low lava domes appear to be centres of eruption, but a closer inspection disposes of that suggestion. It seems probable that each is a steam blister. The lava from the Harman valley, flowing as a fairly thin sheet into a marshy flat on which were isolated pools and quantities of swamp vegetation, would imprison huge steam bubbles. These probably ? lifted the solidifying surface, and formed cones such as are seen there now (Fig. 23C). That the surface was solid when the cones were formed is shown by the concentric and radial fractures that occur on the surfaces of all the knolls. This suggests that the steam was imprisoned in the plastic lava beneath the contracting crust. As the prismatic joints perpendicular to the cooling surfaces penetrated deeper and deeper with continued cooling, the resistance to the pressure of the steam within slowly decreased. Eventually the formation of the prismatic columns weakened the crust so much that the steam was able, by a slight explosion, to burst open the top of the cones and escape, leading to the partial subsidence of the centre of the arch (Fig. 23D).

## VI. The Age of the Basalts.

Neither the age of the surface features of the Newer Basalts in the areas described above, nor the period of time during which vulcanicity remained active, can be determined with anything like precision.

In the Porndon-Corangamite area the slightly earlier explosive phase of Vaughan's Island was followed by the main effusive stage during which some evidence of contemporaneous tuffs has been recorded. It is certain, however, that the main explosive phase terminated the activity, as the scoria cones overlie the basalts at Porndon, Red Rock and Alvie, although a thin basalt flow is interbedded with scoria in one of the scoria pits of Mount Porndon. In the scoria pits at Alvie, Mr. D. J. Mahony, about 14 years ago, obtained a mineralized fragment of a bone believed to be from a kangaroo [personal communication]. If the identification is correct, it would suggest that the scoria may be as old as Pleistocene, if the bone was from an extinct kangaroo. We have, however, no definite evidence as to when such a marsupial became extinct. The scoria fragments in this and other pits have an iridescent lustre and an extremely fresh appearance. Most of the basaltic barriers appear to have suffered scarcely any erosion, and on some of them the original tachylytic selvage is still preserved. No noticeable topographical changes appear to have occurred in this district since volcanic activity ceased. In the Byaduk area, too, the basalts, whose surface features are fresh and remarkably preserved, partly occupy valleys whose characters seem to have otherwise remained unmodified since the lava poured down them from Mount Napier.

In this respect the Newer Basalts of Western Victoria seem to be much younger than those near Melbourne, which are referred to the same period. In the latter district, valleys up to nearly 200 feet in depth have been excavated by streams since the basalt flows formed the lava plains near Melbourne.

The lack of subsequent erosion and the fresh appearance of both basalt and scoria in the areas described in this paper, are consistent with the possibility that the volcanic activity occurred within geologically recent times. In addition, it seems to be possible, if not probable, that the volcanic activity in the Porndon area was restricted to a very limited period, such as a few years or even less. The evidence cited in the body of the paper suggests that the formation of the two basaltic plateaux, the lava tongues running into Lake Corangamite, and the somewhat later outpouring of the basalt of the Porndon Ring, all belonged to a single phase of eruptivity during which, while a crust solidified, the greater part of the basalt from the thick sheet remained molten and mobile.

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## Explanation of Plates.

### Plate XII.

(*a*) Collapsed craters of Red Rock, Lake Corangamite with lava tongues, Vaughan's Island on further side of lake, and Mt. Porndon in background.

(*b*) Inverted conical sinks due to subsidence of basalt crust, Prince's Highway, near Stonyford.

(*c*) Lava tongues with humped surface, Lake Corangamite.

### Plate XIII.

(*a*) Sloping edge of basalt flow. Prismatic columns at right angles to the surface, Dreeite.

(*b*) Baked columnar tuff at eastern edge of barrier in contact with basalt with tachylytic selvage, 102 mile post west of Melbourne, Prince's Highway, 1 mile west of Pirron Yallock.

(*c*) Small fold in basalt crust, near McGarvie's, Corangamite.

### Plate XIV.

(*a*) Air photograph of Stony Rises, about 1 mile S.-E. of Stonyford. Meandering barriers and valleys in centre, basalt plain to the north, Pirron Yallock Creek to the south.

(*b*) Mount Porndon and Ring Barrier, looking east.

(*c*) Breached barrier, Dreeite.

### Plate XV.

(*a*) Gas explosion crater, near Porndon Caves.

(*b*) Breach, 23 ft. 6 in. deep in barrier, Dreeite.

(*c*) "Pseudo breached" barrier, vesicular basalt eroded from the crest of the barrier, near McVean's Springs, Lake Corangamite.

### Plate XVI.

(*a*) "Squeeze up" of basalt through transverse joints of a barrier, near McGarvie's, Corangamite.

(*b*) Internal fractured edge of Ring Barrier of Mount Porndon.

(*c*) External steep slope of Ring Barrier of Mount Porndon.

PLATE XVII.

(*a*) The south-east cave near Mount Porndon.

(*b*) Church cave, Byaduk ? Looks like "Bridge Cave"

(*c*) Breached edge of basalt flow, between Christie's and Lake Condah, near Byaduk.

PLATE XVIII.

(*a*) Breached edges of basalt flow, between Christie's and Lake Condah, near Byaduk.

(*b*) Basalt blisters, near Christie's, Byaduk.



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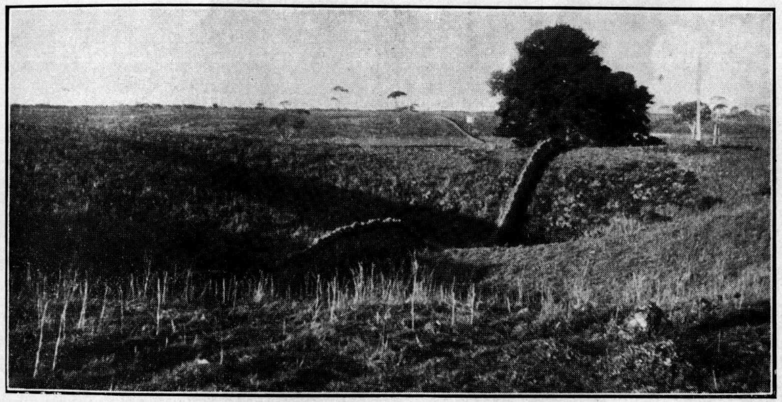

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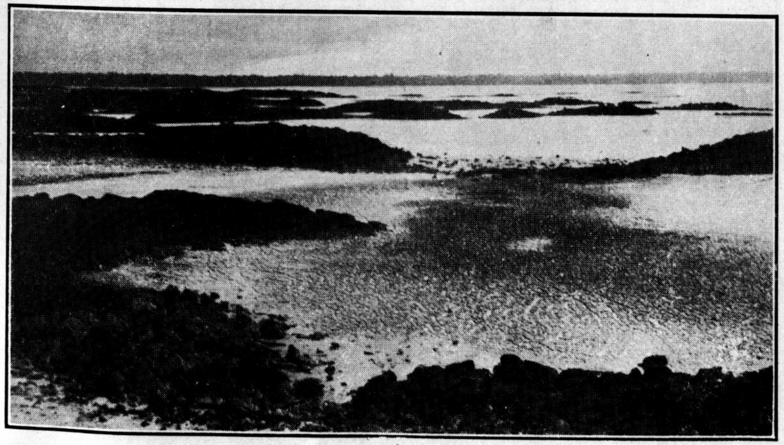

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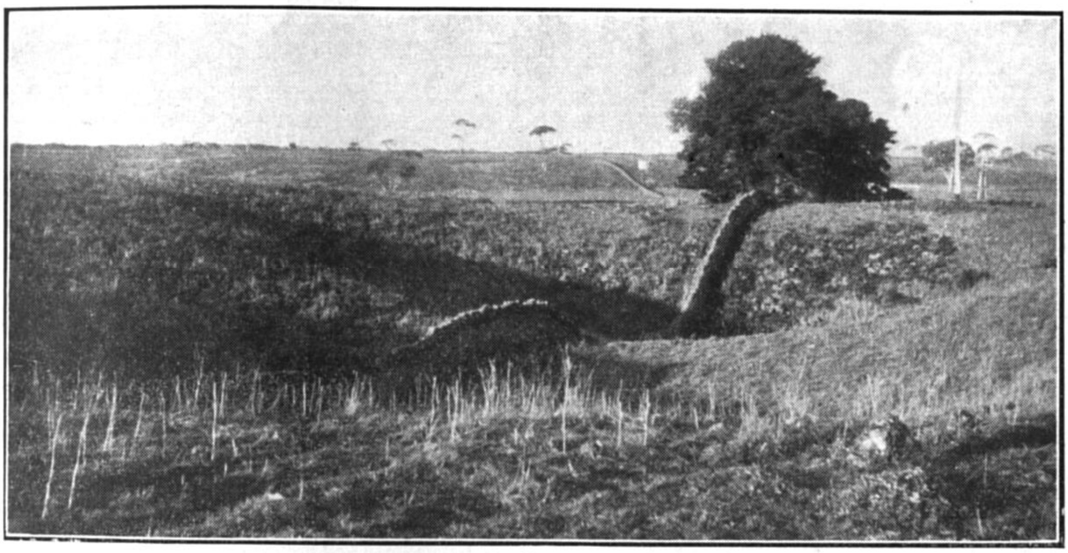

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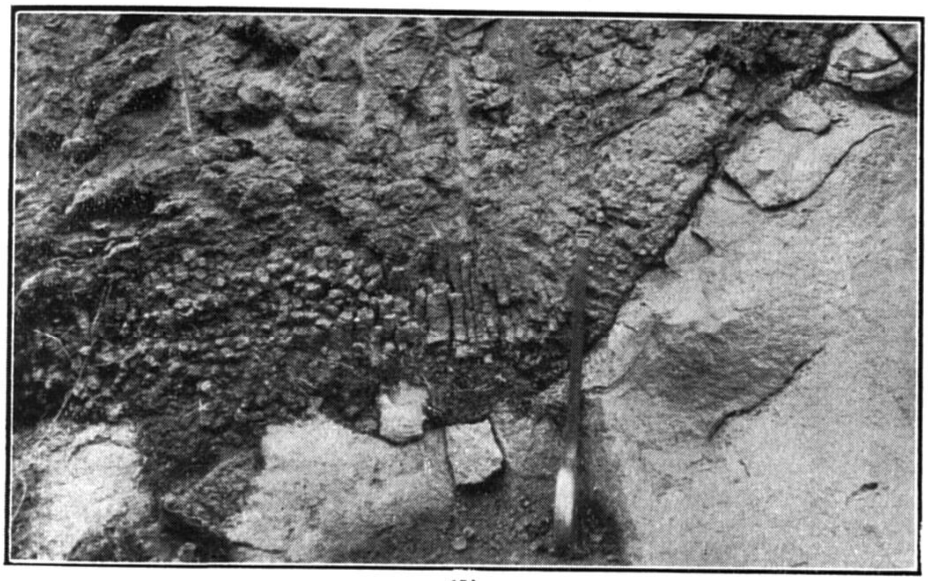

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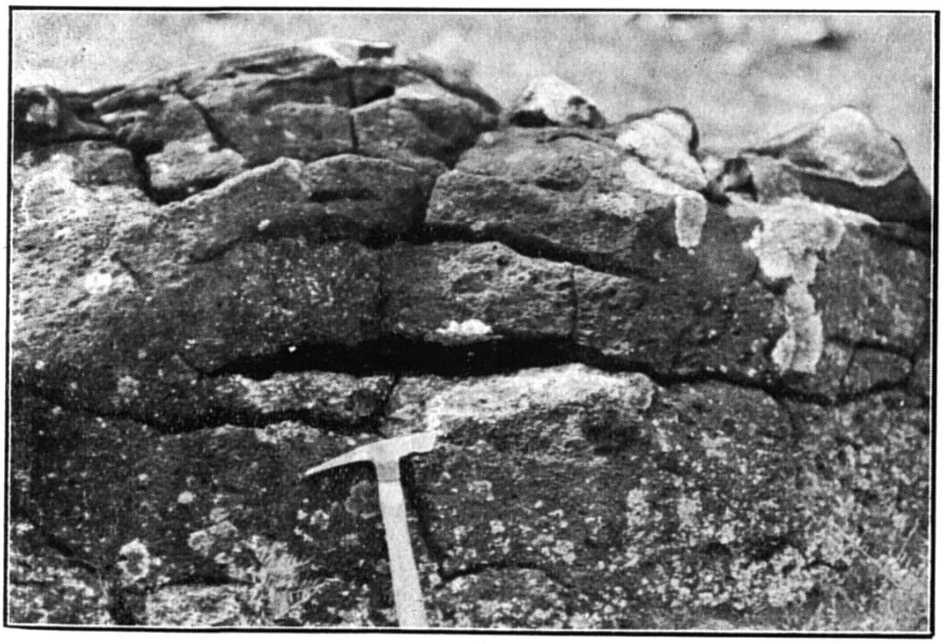

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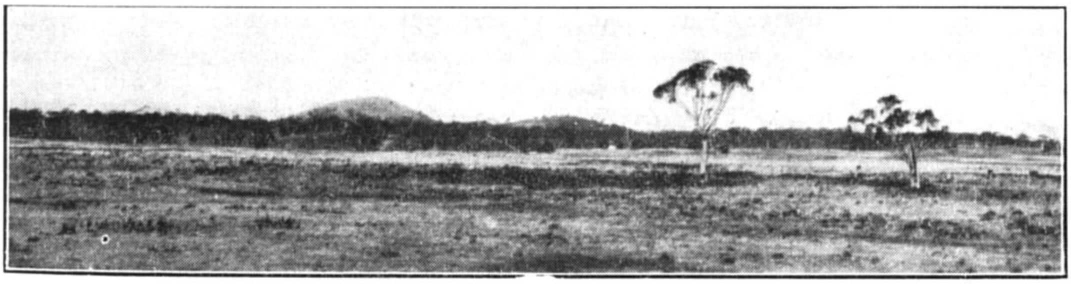

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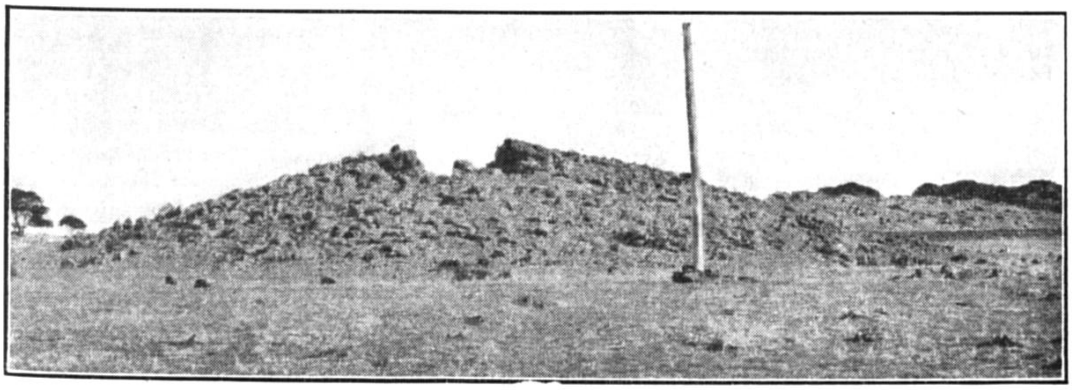

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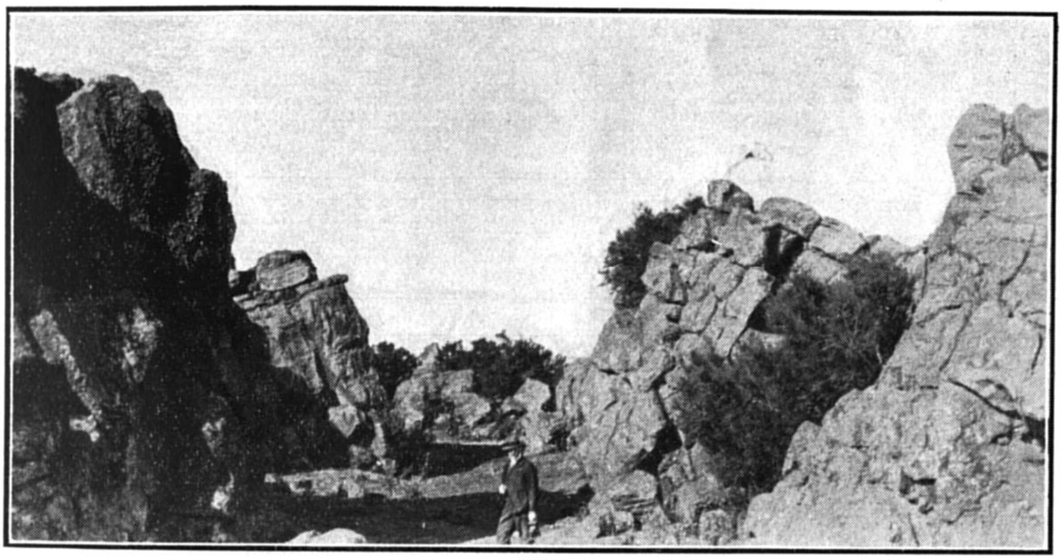

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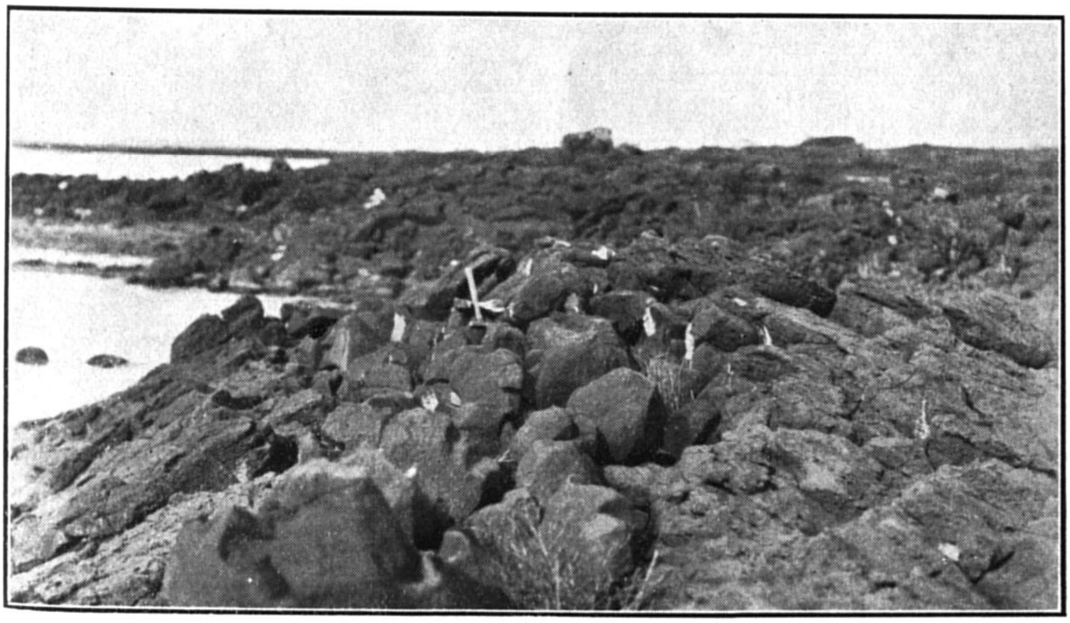



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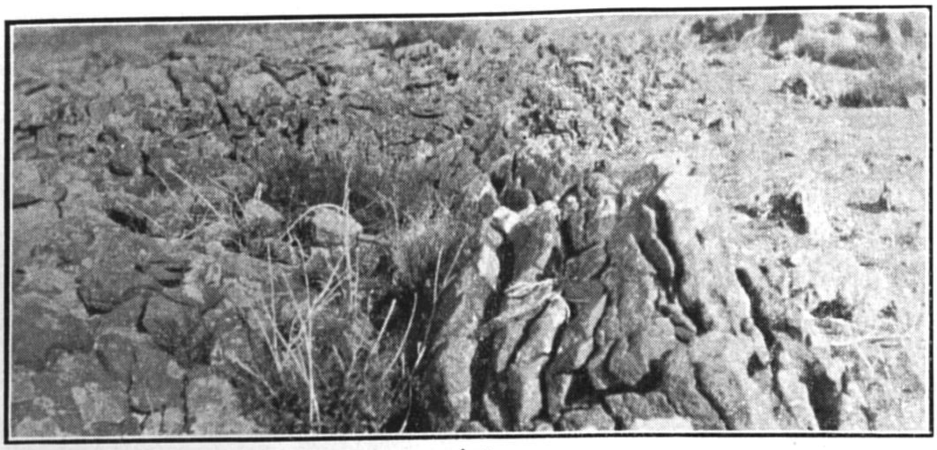

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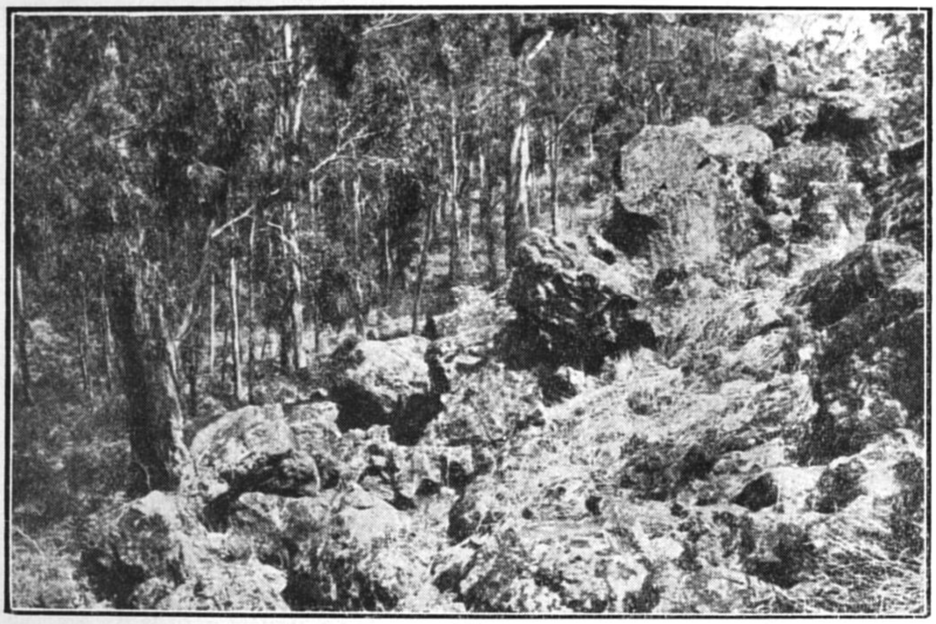

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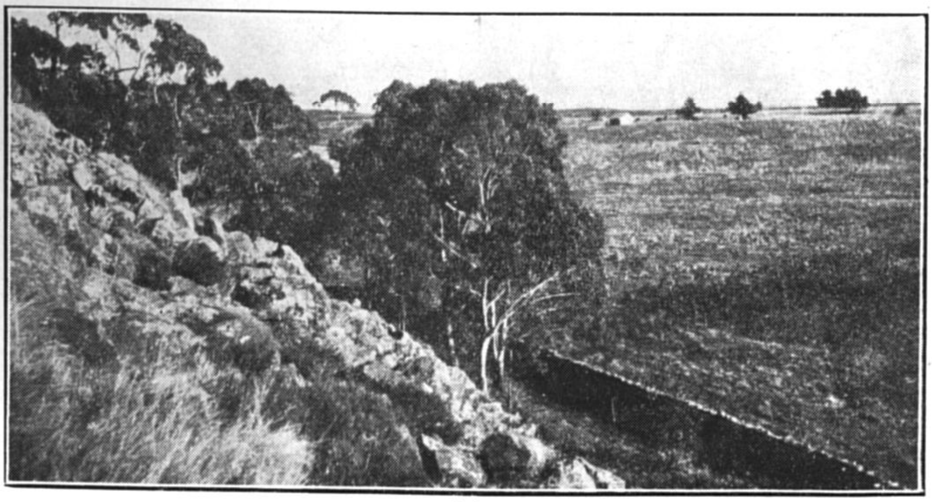

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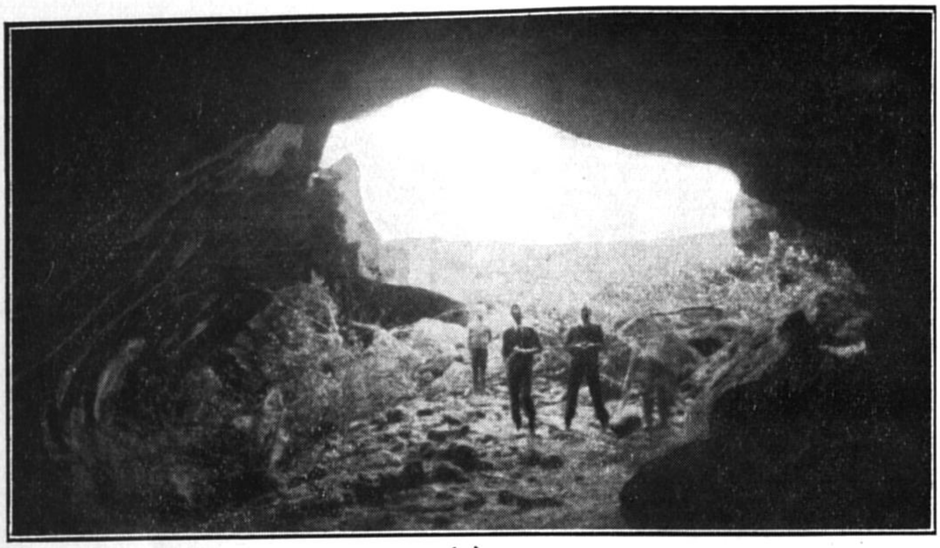

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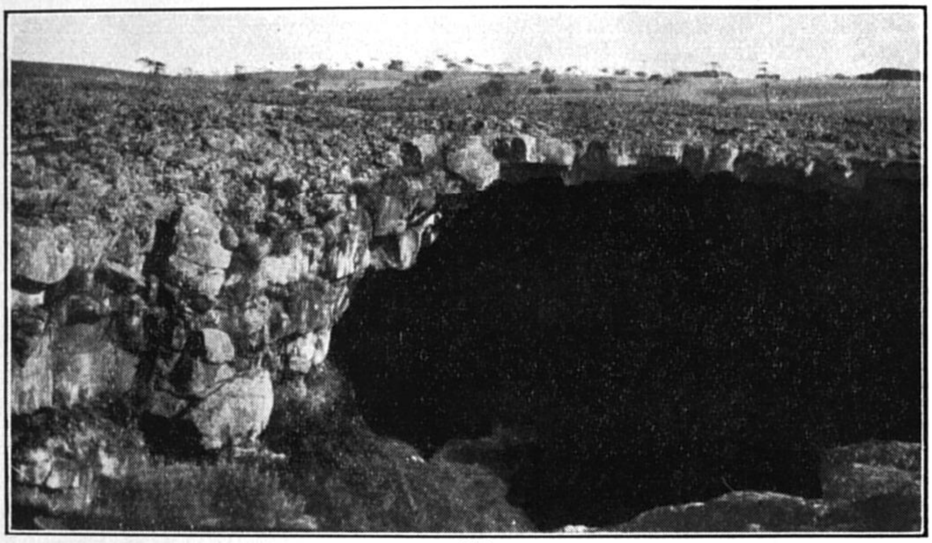

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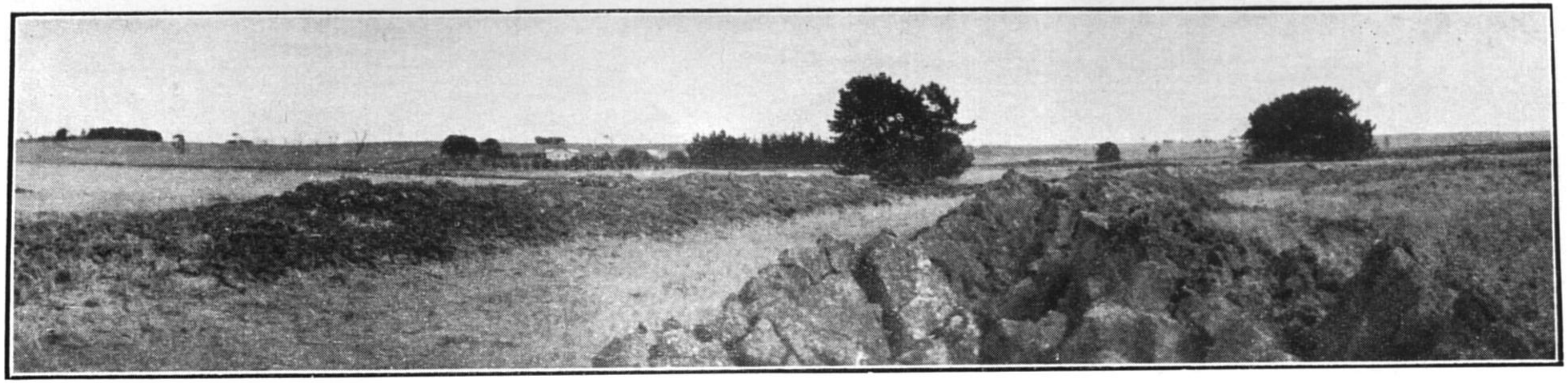

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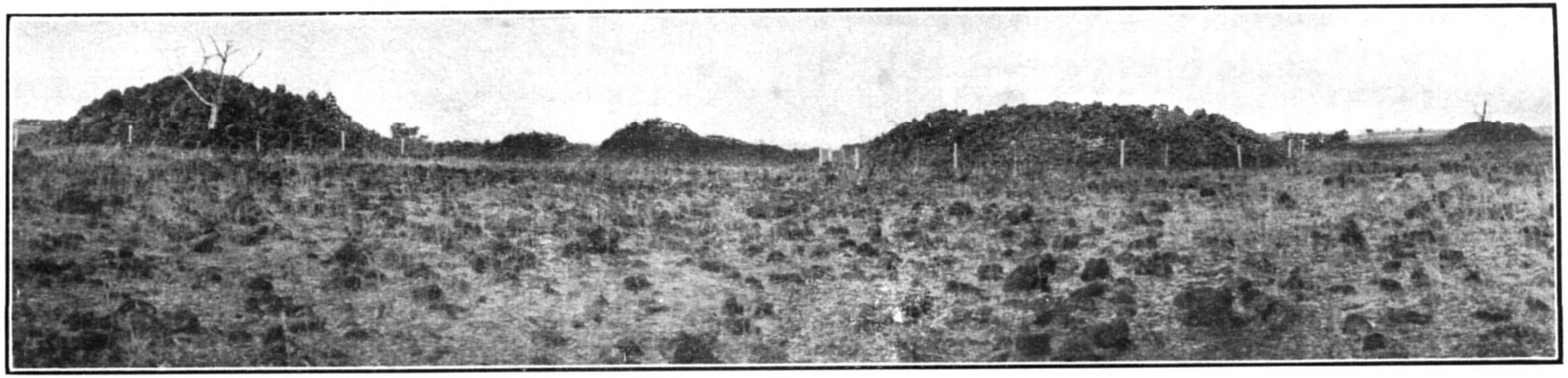

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