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ON THE TERTIARY VOLCANIC ROCKS OF THE BRITISH ISLANDS.

BY

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[FIRST PAPER.]

[PLATE XIV.]

IN the present communication I propose to offer to the Society the first of a series of papers descriptive of those latest of the British volcanic rocks which intersect and overlie our Palæozoic and Secondary formations, and which, from fossil evidence, are to be regarded as of miocene, or at least of older Tertiary, date. Materials for this purpose have been accumulating with me for some years past. In bringing forward this first instalment of them, I wish to preface the subject with some general introductory remarks regarding the place which the rocks seem to me to hold in British geology, and on the nomenclature which I shall use in describing them. These remarks will be followed by a detailed description of the first of a succession of districts where the characteristic features of the rocks are well displayed. Other typical districts will be described in future memoirs.

GENERAL INTRODUCTION.

1. *Area occupied by the Rocks.*

The rocks to which I propose to direct attention cover many hundreds of square miles in the British Islands. They spread over the north-east of Antrim, from Belfast to Loch Foyle, forming there a great plateau or series of plateaux, with an area of fully 1200 square miles and an average thickness of 550 feet. From Ireland the same rocks are prolonged northwards through the Inner Hebrides. They form nearly the whole of the islands of Mull, Rum, Eigg, Canna, and Muck. They cover fully three-fourths of Skye, and extend even as far as the Shiant Isles. But far beyond our own area they reappear with all their characteristic features in the Faroe Islands, and again in the older volcanic tracts of Iceland. In studying the volcanic phenomena which these rocks present to us, therefore, we are not occupied with limited or local features, but with the records of perhaps the most remarkable period in the history of volcanic action in Europe—records which, in spite of the

vicissitudes of later ages, may still be gleaned at intervals over a length of nearly 800 miles. Throughout that great space volcanic activity has long been extinct, yet it remains in full force at the northern extremity in Iceland; and we may perhaps speculate upon the possible continuity of the present Icelandic volcanoes with those which, in Tertiary times, were in action from the Irish Channel far into the Arctic Ocean.

Nor is it merely by the vast basaltic plateaux which are left that the former extent and importance of this Tertiary volcanic activity is to be judged. From the main chain of the Antrim and Hebridean basalts there diverge innumerable dykes, which are found traversing Scotland and the north of England, even as far as the shores of the North Sea. I have elsewhere* given reasons for regarding these dykes as contemporaneous with the Tertiary volcanic series of the north-west, and I shall have much to say regarding them in a subsequent paper. Taken in connexion with the great basaltic plateaux, they furnish us with evidence of a prolonged period of great volcanic activity.

2. *Nomenclature of the Rocks.*

Although the petrography of the volcanic series falls to be described in detail with reference to the localities where the rocks are found, some general remarks are here required, more especially regarding the nomenclature which is to be followed†. For the purposes of a geologist a purely mineralogical or chemical arrangement of rocks is singularly unserviceable. He requires to take cognizance of the geological history as well as of the composition of the rocks; and indeed the latter branch of inquiry is chiefly of interest to him so far as it throws light upon the former. At the same time he cannot afford to dispense with the aid of chemistry and mineralogy; and yet this has only been too frequently the case in this country, where the nomenclature of our igneous rocks remains in much the same state as that in which it was half a century ago. In the course of the researches which are to be described in this paper, I have found it of great service to keep always prominently in view the fundamental geological subdivision of volcanic rocks into *Interbedded* or *Contemporaneous*, and *Intrusive* or *Subsequent*. Each of these two series indicates a distinct variety of volcanic action, the

* Proc. Roy. Soc. Edin. vol. vi. p. 74; Brit. Assoc. Rep. 1867, Address to Geological Section, p. 52.

† The word "trap" or "trappean" has been commonly used in this country as a general term for all these rocks. It has been employed, however, in such various significations that perhaps it had better be discarded as ambiguous, unless we agree to use it solely as a convenient synonym for all truly volcanic rocks which are found in our Palæozoic, Secondary, or Tertiary formations. As all the rocks which I shall have occasion to describe in this series of papers are of volcanic origin—either thrown out at the surface in the form of melted lava, or as loose dust and stones, or injected into different parts of the rocks lying beneath the surface,—I shall employ the word "volcanic;" only premising that if at any time, to avoid unmelodious repetition, the word "trap" is used, it is to be taken in the sense above indicated.

former bringing before us the results of that action as shown at the surface, the latter revealing to us, as no modern volcano can do, some of those features of the action which go on below ground. It will be found, moreover, that between the rocks of each series there is, on the whole, a well-marked petrographical difference. The same species of rock is sometimes found indifferently in either division; but when this occurs, as in the case of the dolerites and basalts, we often learn by practice to discover many little points of distinction, which, when combined, serve to give us a tolerably distinctive type for each of the two great series.

In both of these two leading divisions the rocks occur either as *Crystalline* or *Fragmental*. In the former section are included all the rocks which, like lavas, have been ejected in a melted state; in the latter those which have been thrown out, like ashes and scoriæ, in a fragmentary form.

The Crystalline Interbedded Rocks occur in the form of *sheets* or *flows*, either singly or in consecutive series; they are, in short, old lava-flows, and present the same general structural and textural varieties as modern lavas show.

The Fragmental Interbedded Rocks likewise occur in *sheets*, or *beds* or *layers*; they are the consolidated tuffs, conglomerates, and breccias arising from the ejection and deposition of ancient volcanic ashes and scoriæ.

In the case of the Crystalline Intrusive Rocks I have found the simplest classification to be one based upon the form of the space into which these rocks were intruded and in which they consolidated. Accordingly, I have classed them as 1. *Amorphous masses*, which have been thrust through irregular fractures, and show in consequence no parallel bounding surfaces; the syenites of Skye and Raasay are good examples. 2. *Sheets*, which were thrust between the bedding-planes of older rocks, and which differ from the sheets of the Contemporaneous Crystalline section in altering the beds above them, in showing none of the characteristic slaggy upper and under surfaces found in the contemporaneous flows, and in having some well-marked lithological differences, such as absence of amygdaloidal texture and greater compactness of grain towards the line of contact with the bounding surfaces of other rocks. 3. *Dykes and Veins*. These have resulted from the injection of melted rock along fissures. When the fissure was more or less vertical and straight, the intruded melted rock formed a Dyke; when the crack was on a smaller scale and ran irregularly or branched, either vertically, horizontally, or at any angle, the result was a Vein or series of Veins. 4. In some cases the original orifices remain, which served as the vents by which the volcanic rocks were erupted to the surface. These volcanic pipes are now filled with various kinds of volcanic materials, and are termed *Necks*.

The Fragmental Intrusive Rocks only occur as *Necks* or as *Veins* connected with necks. They consist of agglomerate and tuff, sometimes exceedingly coarse and unstratified, composed of fragments of crystalline volcanic rocks, older tuffs, or of the surrounding strata through which the neck has been blown out.

This general geological classification admits of and requires further subdivisions, according to the petrographical distinctions of the rocks. Thus the Tertiary volcanic rocks which occur as crystalline interbedded sheets may be grouped, according to their mineralogical composition, as *Felspathic* or *Augitic*. In the former group may be included the pitchstones, trachytes, and porphyrites; in the latter the dolerites, anamesites, and basalts. The fragmental interbedded rocks occur as basalt-tuffs or basalt-breccias. The crystalline intrusive series is represented by syenites, quartz-porphyries, pitchstones, felstones, dolerites, anamesites, and basalts. The fragmental intrusive series is shown by necks of basalt-agglomerate.

The dolerites, anamesites, and basalts form the great mass of the Tertiary volcanic rocks of Britain. They occur in vast plateaux, as in Antrim and the Inner Hebrides, also abundantly as dykes, veins, and intrusive sheets. They vary in texture from a coarse crystalline aggregate to fine black basalt, which, in turn, shades into the glassy variety known as tachylite. In interbedded sheets they are columnar or jointed, often amygdaloidal, and then full of zeolites. Closely related to these, and possibly a metamorphosed variety of them, are some rocks in which diallage occurs in place of augite*. Much less abundant are some pale grey rocks, sometimes amygdaloidal, occasionally very porphyritic, composed of a dull plagioclase base, with striated felspar crystals, and for which porphyrite is perhaps the most fitting name. They occur in interbedded sheets in Mull and Eigg. Of the more highly silicated igneous rocks, pitchstone occurs somewhat rarely, and always in the form of veins, except in the old coulée of the Scùr of Eigg, to be described in this paper. Felstone and quartziferous porphyry occur in veins and intruded masses. Syenite is found in veins, and also as huge hills disrupting and overlying liassic rocks in Skye and Raasay. That this syenite belongs to the Tertiary igneous rocks, and may be connected with the volcanic eruptions of the great basalt-plateaux, I hope to show in a future paper. A rock which has been called a trachyte-porphyry occurs in Antrim. I may add that around the syenite-hills of Skye, and possibly also in Mull, there has been developed a local but well-marked metamorphism of the surrounding rocks†.

The tuffs are comparatively small in quantity. They occur as thin lenticular layers between the sheets of dolerite forming the great plateaux, and sometimes, as at Ardtun Head, Mull, and in Antrim, contain recognizable remains of land-plants. In Mull also they are sometimes associated with local beds of black cherry-coal, not distinguishable by any external character from the ordinary fuel of our coal-fields. Necks of agglomerate are of still rarer occurrence. Between the sheets of dolerite thin irregular layers of

* These are seen to the south-east of Ben More, in Mull, and seemed to me to be a continuation of beds which, further west, were ordinary dolerites. In that area also masses of syenite occur; and the impression conveyed by a hasty examination of it was that the volcanic rocks had there undergone subsequent metamorphism, as has happened to the Lias limestones round the Tertiary syenite of Skye. But I propose soon to revisit this interesting district.

† See Quart. Journ. Geol. Soc. vol. xiv. p. 12 *et seq.*

red bole or earth not unfrequently occur. I have noticed similar partings between old lavas at Torre del Annunziata; and in the latter case, at least, they can hardly be regarded as other than the soil which had gathered over the older lava, and was burnt by the overflow of the newer one.

The following tabular arrangement will show at a glance the classification of the rocks which I have adopted:—

Classification of the Tertiary Igneous Rocks of Britain.

	Felspathic Series.					Pyroxenic or Augitic Series.					
	Syenite.	Felstone and quartz-porphyry.	Trachyte and trachyte-porphyry.	Pitchstone.	Porphyrite.	Dolerite.	Basalt.	Tachylite.	Diallage-rock, altered dolerite?	Felspathic tuffs.	Pyroxenic tuffs and agglomerate.
I. Interbedded or Contemporaneous.											
A. *Crystalline.*											
Sheets or beds	..	..	?	*	*	*	*	..	*		
B. *Fragmental.*											
Beds or layers	..	..	..	..	..	..	..	..	..	?	*
II. Intrusive or Subsequent.											
A. *Crystalline.*											
a. Amorphous masses	*	*	?	..	..	?					
β. Sheets	..	..	..	..	..	*	*				
γ. Dykes and veins	*	*	?	*	..	*	*	*			
δ. Necks	..	?	..	..	..	..	?				
B. *Fragmental.*											
Necks	..	..	..	..	..	..	..	.	..	..	*

In this Table are inserted only those rocks which I have myself, up to this date, found among the Tertiary series. The list will, no doubt, be enlarged as further investigations proceed†.

3. *Geological Age of the Rocks.*

A few words are needed here in support of the view that all the rocks now to be described are of Tertiary age. In Antrim the well-known position of the basalt above the chalk, and its association with layers containing miocene plants—in Mull the occurrence of a thick bed of chalk-flints, and of the Ardtun miocene leaf-beds‡, at the base of the whole volcanic series, the evident prolongation of the Mull volcanic rocks through the other islands of the Inner Hebrides§,

† I have given a more detailed account of this classification of volcanic rocks, and of the grounds on which it is based, in Chapter xiii. of the forthcoming edition of Jukes's 'Manual of Geology.'

‡ See Quart. Journ. Geol. Soc. vol.vii. p. 90.

§ Following Edward Forbes, I formerly regarded the volcanic rocks of Skye as of Oolitic age, being misled by the way in which the basalts at their base seem

the passage of the great system of divergent dykes across faults of every age and through the different geological formations up to and including the chalk—these are facts which make it sufficiently evident that in the north-western part of the British area, along the great hollow stretching from Ireland northwards between the chain of the Outer Hebrides and the Scottish mainland, volcanic action was abundantly manifested in miocene times. Whether the eruptions took place wholly within the miocene period, or whether they extended beyond it, into later ages, remains yet uncertain. That the time during which the eruptions continued was of enormous duration, is shown by several considerations:—(1) The plateaux are made up of many successive sheets, each of which marks at least one, and sometimes more separate eruptions. In Antrim these sheets rise one over another for a thickness of sometimes 900 feet; and how much thicker they may have been cannot now be determined, seeing that the upper part of the series has been removed by denudation. In Mull there is a visible thickness of more than 3000 feet of volcanic beds; yet there, too, the upward continuation of them has been worn away, and there are now no means of measuring what the original total thickness may have been. (2) There occur among the basalts intercalated layers of tuff, clay, and coal, indicating pauses between the eruptions of long enough duration for the growth and accumulation of vegetable matter sufficient, when compressed, to form two or three feet of coal*. The leaf-beds of Mull likewise indicate long and tranquil intervals between the outflow of successive sheets of basalt. (3) But the most striking evidence of the long continuance of this volcanic period is furnished in the island of Eigg, by the occurrence of ancient hollows worn by river-action out of the basalt plateaux, and subsequently filled by the outpouring of fresh lava. The latter bears thus the same relation to the more ancient eruptions that the later coulées of Auvergne do to the old denuded basaltic plateaux of that region.

But not only have the last-erupted rocks been worn away, and all evidence removed as to the time when volcanic action ceased to manifest itself in our area; denudation has since then been so constant and so potent, that even of the whole mass of erupted matter only disconnected fragments remain. Out of the great basaltic tablelands long and wide valleys have been carved to a depth of

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regularly intercalated with the oolitic strata. As pointed out in a subsequent page, I have now learned, however, after continued surveys of the other islands, that this intercalation is deceptive, and that the basalts of Skye are only a prolongation of the miocene basalts of Mull.

* Such beds of coal occur in Mull (see Proc. Roy. Soc. Edin. vol. vi. p. 72). All the coal associated with the volcanic rocks of the Inner Hebrides is of contemporaneous, that is of miocene, date. The so-called oolitic coal of Skye I have now no doubt is of this age; and hence the intercalated strata shown to occur in the volcanic series of Skye on the map of Scotland published by Sir Roderick Murchison and myself, and meant to indicate the strips of coal and associated strata, must be regarded not as oolitic, but as miocene. Their size was necessarily greatly exaggerated, with the view of expressing the bedded character of the igneous rocks.

more than 1000 feet. Some of the noblest hills of the Inner Hebrides are but solitary outliers left standing amid the ruin of the great sheets of solid rock of which they once formed a part. Ben More, in Mull, though more than 3000 feet high, is only a magnificent fragment of the huge pile of volcanic material which formerly swept over what are now the deep glens and fjords of Mull. The long lines of imposing cliff with which the basalt plateaux front the Atlantic all through these islands, from the Fair Head of Antrim to the far headlands of Skye, tell everywhere the same tale of vast and continuous denudation. Great, therefore, as the area is over which these rocks are now to be traced, it covers but a small part of its original extent.

These prefatory remarks may suffice to show the general nature of the subject of which I propose to treat, and I shall now proceed to describe in some detail a district in which some of the phenomena are typically displayed. The area which I have selected for this purpose is the island of Eigg, partly on account of its simplicity of structure, and partly because it presents to us a more striking picture of the vast duration of the Tertiary volcanic period in Britain than any other space of like size with which I am acquainted. My observations are the result of a survey made by me of the island in the year 1864. In this excursion I was accompanied by my friend and former colleague Professor Young, of the University of Glasgow, who devoted himself to the palæontology of the island. It was our original intention to combine our observations in a joint memoir. Circumstances having occurred, however, to delay the proper examination of the fossils, it has been judged expedient to publish, in the mean time, my own observations on the volcanic geology of the island, leaving the oolitic strata and their fossils to form the subject of a future communication.

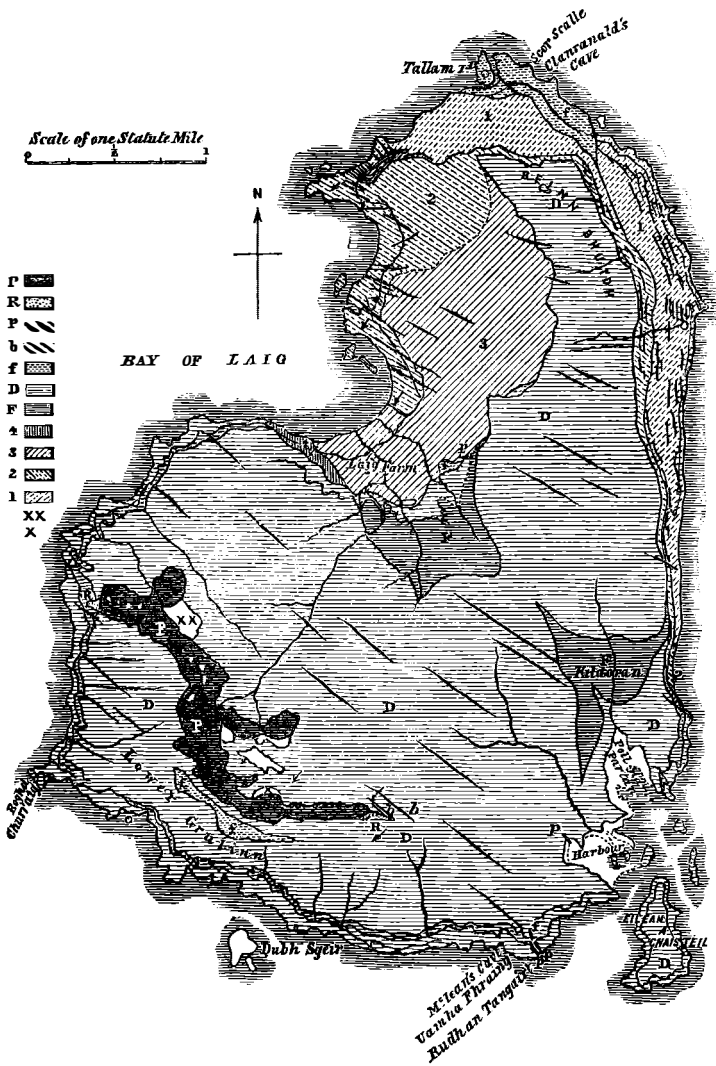
THE ISLAND OF EIGG*.

A. Physical Features and Geological Structure.

In the chain of the Inner Hebrides, broken as it is in outline and varied in its types of scenery, there is no object more striking than this island. Though only about five miles long and from a mile and a half to three miles and a half broad, and nowhere reaching a height of so much as 1300 feet, this little island, from the singularity of one feature of its surface, forms a conspicuous and familiar landmark. Viewed in the simplest way, Eigg may be regarded as consisting of an isolated part of one of the great basaltic plateaux which, instead of forming a rolling tableland or a chain of hills with terraced sides, as in Antrim, Mull, and Skye, has been so tilted that, while it caps a lofty cliff about 1000 feet above the waves at the

* The spelling of the Gaelic names on the map and in this memoir has been kindly revised for me by my friend Mr. Alexander Nicolson, advocate, whose name will be a sufficient guarantee for their accuracy.

Fig. 1.—*Map of the Island of Eigg.*



P. Pitchstone-porphyry *coulée* of the Scùr. R. Outcrop of ancient river-gravel under pitchstone of Scùr. P. Small veins of pitchstone. *b*. Dykes, veins, and intrusive sheets of basalt-rocks. The short black lines traversing the map in a N.W.–S.E. direction are basalt dykes. *f*. Intrusive quartziferous porphyry. D. Bedded basalt rocks with occasional tuffs. F. Bedded porphyrite.

Oolitic Series.
4. Clay with *Ammonites*, *Belemnites*, &c.
3. Shales and Limestone bands with *Cyprids*, *Cyclas*, *Ostrea*, &c.
2. Thick white and yellow Sandstones with plants.
1. Shales and Limestone bands with *Cyprids*, *Cyclas*, *Mytilus*, and teeth and bones of Reptiles.

×× Loch Beinn Tighe. × Loch a Bhealaich.

➡ General dip of the rocks.

north end, it slopes gently along the length of the island to the south end. In the southern half of the island, however, the ground rises, owing to the preservation of an upper mass of beds, which denudation has removed from the northern half of the island. On this rising part of the plateau stands the distinguishing feature of the island, the strange fantastic ridge of the Scùr of Eigg. Seen from the north or south, this portion of the island looks like a long steep hill-crest, ending in a sharp precipice on the east. But when we get to the east side, the precipice is seen to be the end of a huge mountain-wall, which rises vertically above the basalt plateau to a height of more than 350 feet. It will be seen from the accompanying map (fig. 1) that this ridge of the Scùr corresponds with the area occupied by a mass of pitchstone, and that while the basaltic rocks cover the whole of the rest of the southern half of the island, they gradually rise towards the north, and successive beds of the oolitic series make their appearance until, at the cliffs of Dunan Thalasgair, the latter cover the greater part of the surface, and leave the volcanic rocks as a mere stripe capping the cliffs.

In the accompanying section (fig. 2) the general structure of the island is represented.

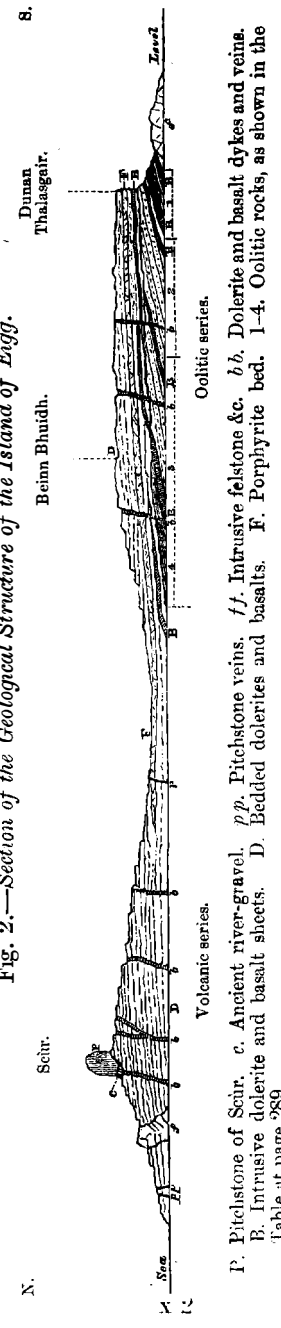


Fig. 2.—*Section of the Geological Structure of the Island of Eigg.*

P. Pitchstone of Scùr. *c.* Ancient river-gravel. *p p.* Pitchstone veins. *t t.* Intrusive felstone &c. *b b.* Dolerite and basalt dykes and veins. B. Intrusive dolerite and basalt sheets. D. Bedded dolerites and basalts. F. Porphyrite bed. 1–4. Oolitic rocks, as shown in the Table at page 289.

B. Literature of the Subject.

Several geologists have published descriptions, more or less detailed, of the mineralogy and geology of this interesting island. In the year 1800 Professor Jameson gave a brief account of the different rocks noticed by him in Eigg; but he did not attempt any description of its geological structure, further than to notice that one variety of rock occurred above or below another. He was then full

of belief in the theories of Werner; and as he had found fossil-shells in one of the sandstones of the island, he went on to speculate on the probability that the basalt, which alternated with these sandstones, would eventually be found to contain fossils*. The most detailed account of Eigg which has yet appeared, is that published by Dr. Macculloch in 1819†. He pointed out the clear order of succession of the rocks shown by the cliff-sections, and noticed some of the more marked varieties, both among the stratified and the igneous series. He showed also the relation of the secondary rocks to those of Skye and the rest of the western islands, and connected the igneous masses with those of the surrounding regions. Although he visited the island at least twice, he seems to have contented himself with the examination of those portions which were easiest of access. Hence some of the most interesting features of the island escaped his notice. About twenty years later Mr. Hay Cunningham communicated to the Wernerian Society a short but interesting paper upon the geognosy of Eigg. He gave some details as to the petrography of the igneous rocks, but added nothing to our knowledge of the geology, his remarks on the origin and position of the igneous rocks being founded on a misconception of the twofold interbedded and intrusive character of these masses‡. Hugh Miller, in the course of a cruise among the Western Islands, spent some time at Eigg. His attention was more particularly directed to the fossil-contents of the oolitic strata, of which he made a collection, and which he has to some extent described. He did not add any new facts to the known geology of the island§.

C. Oolitic Series.

Although the detailed account of the Oolitic rocks of Eigg falls to be given in a subsequent paper, some brief reference to them may be inserted here. Measured from the sea-level at Tallam to the base of the overlying sheets of basalt in the cliff at Dunan Thalasgair, the stratified rocks attain a thickness of probably not less than 600 feet; though, owing to the way in which they are split up by intruded sheets of basalt, and concealed by landslip-rubbish, their depth cannot be precisely determined. As the general

* Jameson's 'Mineralogy of the Scottish Isles,' vol. ii. pp. 36–47.

† Macculloch's 'Description of the Western Islands of Scotland,' vol. i. pp. 507–522.

‡ Hay Cunningham, Mem. Werner. Soc. vol. viii., 1839. This author insists that the igneous rocks of Eigg, as well as those of Scotland generally, were erupted and consolidated beneath the surface, there being no proof, according to him, that any of the basalts ever flowed out as a stream at the surface. With regard to the Scùr of Eigg, he says, "it can be confidently asserted that it exists as a great vein, which has been erupted through the older plutonic rocks"—a statement which has generally been accepted, but which, as will be shown in this paper, is wholly inadequate and incorrect.

§ See his 'Cruise of the Betsy,' p. 31 *et seq.*; 'Sketch-Book of popular Geology,' p. 137. Several foreign geologists and mineralogists have noticed the rocks of Eigg. Necker de Saussure gave a detailed description of the mineralogy of the Scùr ('Voyage en Ecosse,' ii. p. 449 *et seq.*).

dip of the rocks of the island is from north to south, the Oolitic series is best seen at the north end, whence its different groups of strata slope northward, until they finally disappear under the volcanic series at the Bay of Laig. The following section shows the order of succession among these rocks :—

Dolerites, basalts, &c. of the plateau.
(4) Clay, with ammonites, belemnites, &c., seen for a short space on the beach of the south side of Laig Bay.
(3) Estuarine shells and limestone with *Cyclas*, *Cyprides*, *Ostrea*, &c.
(2) Thick white and yellow sandstones, in some places abounding with fragmentary plants, and at other parts strongly calcareous, with numerous casts of *Cyclas*, &c.
(1) Estuarine shales and limestones, with fossils similar to those in No. 3, and with reptilian bones.
Base of series not seen.

From the general character of these beds, I am inclined to regard them as on the same horizon with the estuary beds of Loch Staffin, and with those which in Raasay come in between the Lias and the Tertiary volcanic rocks—that is, as belonging to the Lower Oolites. But this subject will require further consideration when the fossils have been determined.

D. Volcanic Series.

The Oolitic strata of Eigg are overlain by a cake of igneous rocks, which, though it caps the northern cliffs, dips southward with the underlying strata, until it reaches the sea at Laig Bay on the west side, and at Kildonan on the east. North of a line drawn between these two places the igneous capping has been reduced by denudation to a mere narrow strip, forming the tableland of Beinn Bhuidh; south of the same line, it covers the whole breadth of the island. Yet, although the general inclination of the igneous and aqueous rocks is in the same direction, a careful survey of them shows that the former lie unconformably upon the latter. At the south side of the Bay of Laig, the basalt-rocks rest upon the clays of group No. 1. As the former are inclined at a slightly less angle than the latter, they soon creep over their edges, so as to lie upon the shales and and limestones No. 2. These continue as far as Dunan Thalasgair; but there the basalts, after slowly creeping over their denuded edges for nearly two miles, overlap them, so as to come upon the massive sandstones of group No. 2. The apparent conformity, therefore, of the volcanic rocks with the Oolitic strata of the inner Hebrides, which has led to the belief that the volcanic phenomena were of Oolitic age, is in reality deceptive. I shall on other occasions have to point out the varied horizons on which these volcanic masses rest.

The igneous rocks of Eigg may be most conveniently described under three heads :—

1. The Basalt-plateau, marking the oldest eruptions.
2. Intrusive bosses, sheets, dykes, and veins.
3. The pitchstone *coulées* of the Scùr, a relic of the last eruptions.

1. The Basalt-Plateau.

The cake of volcanic rocks which has been referred to as overlying the Oolitic strata consists of a succession of beds, varying in thickness individually from a few feet to at least 50 or 60 feet, and having a united depth of not less than 1100 feet. They consist of dolerites, anamesites, and basalts, porphyrites, and tuffs or breccias. That they are the result of the outpouring of volcanic material at the surface, and not of its intrusion among the other rocks beneath the surface in other words, that they are interbedded or contemporaneous and not intrusive or subsequent masses, is shown by the internal texture of the crystalline rocks, and by the associated tuffs. Admirable sections are everywhere obtainable along the line of cliffs by which the island is almost continuously girdled.

a. *Dolerites, Anamesites, and Basalts.*

By much the larger part of the beds of the basalt-plateau consists of basaltic rocks (dolerite, anamesite, or basalt). These varieties of the same great family of volcanic rocks possess the same characters in Eigg which they retain throughout the Inner Hebrides and Antrim. The dolerite usually appears as a crystalline granular mass, passing on the one hand through anamesite into basalt, and on the other into a coarse aggregate, which shows on its weathered surfaces large crystals of augite. It is seldom that the rock becomes so black and compact as to deserve the name of basalt, except in the dykes to be afterwards described. Examined microscopically, these rocks fully bear out the observations of Zirkel on the presence of a non-crystallized matrix in basalt-rocks*. They occasionally abound in minute needles of apatite, which, along with the beautifully striated felspar, form a matted network of crystals, through which olivine, augite, and titaniferous iron are scattered. In some specimens the decomposition of the minerals is well illustrated. It may be added that these rocks very closely resemble, in composition and texture, the crystalline intrusive augitic rocks in the Scottish Carboniferous series—so closely, indeed, that no line of separation, so far as I have yet seen, can be drawn between them.

The bedded arrangement of the basalt-rocks, so characteristic of the vast miocene volcanic region from Antrim to Iceland, is well seen in Eigg. Along the cliffs at the north end of Beinn Bhuidh, and again along the south-western shore, the succession of beds is shown in noble vertical sections, while all over the southern half of the island the terraced or step-like hill-sides, formed by the outcrop of the beds, are everywhere visible. Even from a distance, therefore, the interbedded nature of these volcanic rocks can be readily determined. The beds range in thickness from perhaps 20 to 50 or 60 feet. They seem quite continuous when looked at from the sea, as they band the precipices with parallel stripes of darker and lighter

* See his Mikroskopische Untersuchungen über die Basaltgesteine. Bonn, 1869.

brown; and their continuity is still further indicated by the slender lines of bright herbage which have taken root along the decaying upper or under surfaces of the flows. Yet, on closer examination, we find them not unfrequently to die out, the place of one bed being taken by another, or even by more than one, in continuation of the same horizon. This is particularly noticeable along the cliff-line on the east side of Beinn Bhuidh. There is considerable diversity in the colour and texture, as well as the structure, of the different beds. Some of them, in which the rock is more compact and weathered, are divided by vertical joints, which in some cases increase in number till the rock acquires a rudely columnar structure. This may be admirably seen along the coast north of the harbour, where a long line of columnar cliff shows in some places curved and radiating columns. Other beds are formed of a dark compact amorphous mass, usually amygdaloidal, and occasionally very markedly so. A not infrequent variety occurs in the form of a dull green amygdaloidal and scoriaceous rock, in which balls of more compact material are wrapped, as it were, in a softer decomposed base. At the south end of the island, a peculiar band of rock occurs, in which the process of weathering reveals a succession of layers, a few inches thick, formed of nodular pieces of compact blue anamesite or basalt, with a bright red crust. These layers lie a few inches apart, in a soft, dirty-green, crumbling, and often highly amygdaloidal rock. The band in which these features are seen runs as an intercalation, about 3 or 4 yards thick, among the sheets of hard crystalline anamesite.

As an illustration of the bedded arrangement of these rocks, and of the way in which they succeed each other along the same horizontal plane, reference may be made to the accompanying diagram (fig. 3) of part of the cliff-section north of Kildonan, on the east side of the island.

Fig. 3. *Diagram of interbedded Volcanic Rocks on the east side of Island of Eigg.*

g. Compact jointed dolerite. *f*. Dull dirty-green decomposing amydaloidal dolerite. *e*. Compact crystalline dolerite, more finely jointed than bed *g*. *d*. Pale grey porphyrite. *c*. Dolerite, which a little further north is formed of several beds. *b*. Columnar dolerite. *a*. Oolitic strata.

The tests by which the true interbedded or contemporaneous character of the flows of the doleritic plateau can be determined are well exposed in Eigg. 1st. The upper and under surfaces of the successive flows have very commonly a rough slaggy character, even when the central portion is compact and crystalline. In this respect they perfectly resemble sections of recent lava-streams, such, for example, as those exposed along the Bay of Naples, around Torre

del Annunziata. In some cases the slaggy upper part of one bed and the corresponding lower part of the bed above it seem to pass into each other, although the general bedded structure of the whole remains very marked at a little distance. Here and there, as at the north end of Beinn Bhuidh, illustrations are afforded of the elongation of the cavities along the upper surface, showing the direction in which the lava was moving before it finally cooled and consolidated.

2nd. Some of the beds are coarsely amygdaloidal throughout. In the kernels are found the usual minerals which result from the decomposition of basalt-rocks—mesotype, stilbite, calc-spar, amethyst, chalcedony, quartz-crystals, &c. And it is to be remarked, in Eigg as elsewhere throughout the Western Islands, that the abundance of the amygdaloidal minerals is proportioned to the amount of alteration which has been undergone by the general matrix of the rock in which they lie.

3rd. Although the interbedded sheets are sometimes seen to die out along the line of cliff, they never penetrate or otherwise disturb each other. This feature is one which has not been recognized by previous writers on the igneous rocks of the Inner Hebrides. It has been lost sight of among the proofs of intrusion furnished by so many of the basaltic sheets; and thus the "trap" or "overlying rocks" of Skye and the other islands have come to be regarded as typical examples of intrusive igneous masses, and described and figured as such in innumerable text-books. Yet no fact is more absolutely certain than that the vast mass of the basaltic rocks of these regions consists of interbedded sheets, which flowed out, one over another, at the surface, and have no intrusive characters. They are traversed, however, by intrusive sheets and dykes, as will be pointed out in the sequel.

4th. The occurrence of intercalated tuffs, volcanic breccias, and layers of burnt soil in Eigg, and of shales with remains of land-plants and seams of coal in the other islands, completes the proof that the basaltic beds forming the great plateaux, must be regarded as of interbedded or contemporaneous origin—that is, sheets which were poured out as lava above ground, and not injected among older rocks below.

β. Porphyrite.

Under this term I include a well-marked bed, forming a conspicuous band along the range of cliffs which flank the plateau of Beinn Bhuidh (see figs. 2 and 3). It lies near the base of the volcanic series. Owing to the flatness of the beds and to denudation, it has been uncovered, so as to stretch over most of the bottom of the hollow between Kildonan and the Bay of Laig. But I did not find it in the southern half of the island. This rock is of a pale grey colour. It consists of a finely crystalline felspathic base, through which a few small plagioclase crystals and grains of titaniferous iron can be seen with the lens. Examined with the microscope by

transmitted light, it is found to consist of a base of plagioclase felspar, in minute, somewhat decomposed crystals, with abundant black grains of titaniferous iron, and a brown, much decayed mineral, which may be augite. The higher part of the bed, at Dunan Thalasgair is darker in colour, and, when examined microscopically, has much the character of an anamesite. Indeed the whole rock might be regarded as a highly felspathic basalt-rock in which the ferruginous silicates are poorly developed.

This rock is, as a whole, strongly amygdaloidal, the cavities in the upper part of the bed being sometimes so flattened and elongated as to impart a kind of fissile texture to the mass. This is more particularly to be noted at the precipice of Dunan Thalasgair. Throughout a considerable part of the bed, the calc-spar and zeolites of the kernels have disappeared, and the rock has resumed its original vesicular aspect.

γ. *Tuffs, Breccias, &c.*

One feature which distinguishes the Tertiary volcanic series of Britain from those of earlier geological periods is the comparative paucity and thinness of the intercalated beds of fragmentary materials. Among the contemporaneous igneous masses of the Silurian, Old Red Sandstone, Carboniferous, and Permian periods we find within our own borders enormous beds of tuff and volcanic breccia or conglomerate; but among the great basalt-plateaux of our north-western tracts such intercalations are represented by mere thin infrequent layers. This appears to be the case at least from the south of Antrim to the north of Skye—the most important tuffs in that extended area, so far as I am aware, being those of the cliffs at the Giant's Causeway. In Eigg this comparative insignificance of the fragmental as contrasted with the crystalline or lava-form rocks is characteristically maintained. Throughout the greater part of the cliff-sections one bed of dolerite or basalt follows another without the intervention of any dividing layer of tuff or other deposit. Here and there, indeed, between the beds, we not unfrequently meet with a thin irregular seam of red earth, which, when fine, might be called bole. In the cliff below Dunan Thalasgair, for example, several of the dolerite-beds are not only covered by this substance, but seem to pass into it. This may be observed also throughout the Inner Hebrides, and conspicuously along many parts of the Antrim coast-line. I have recently observed a precisely similar red parting between several of the lava-streams which have been laid open by the sea, and by artificial excavations, between Naples and Pompeii; and I may add that it is likewise to be observed between the sheets of melaphyre interbedded with the lower carboniferous rocks of Kinghorn, in Fife. In all these cases I regard this red layer as marking a surface of the igneous rock, decomposed into clay or soil by exposure, and subsequently heated and altered by the overflow upon it of the next sheet of molten material.

At the north end of Eigg, along the cliffs of Beinn Bhuidh, a bed of coarse doleritic or basaltic breccia is interstratified with the other

volcanic rocks of the plateau. It consists of a red gravelly matrix of dolerite débris, in which are imbedded angular and subangular fragments of various igneous rocks, sometimes a foot and a half long. Again, at the south end of the island, opposite the rock called Dubh Sgeir (Black Skerry), the dolerites contain a breccia which swells out rapidly from a few inches to 6 or 8 feet in thickness; it is a rough nodular bed, varying in colour from a dirty green to a dull red, and consisting of rude angular and subangular pieces of various dolerites, but more particularly of that on which it lies, imbedded in, or wrapped round by, a greenish more or less crystalline paste, veined with calc-spar.

2. Intrusive Bosses, Sheets, Dykes, and Veins.

The Oolitic rocks, as well as the basalt-plateau which lies upon them, are pierced by many intrusive masses of igneous rock. These are all crystalline rocks, no example of any intrusive fragmental mass, such as the agglomerate of necks, having yet been noticed. While in the interbedded series the order of superposition furnishes us at the same time with the relative age of the volcanic beds, among the intrusive rocks we have no certain guide to relative antiquity, save the obvious examples where one rock cuts through another. Nor is it easy to discover any means of ascertaining how far the intrusive masses were coeval with, posterior, or anterior to those of the plateau. The dykes, indeed, must be newer than the interbedded rocks already described; for they are found cutting through even the highest of the sheets of the plateau, as well as the intrusive sheets near or at the base. There is reason to think that the pitchstone-veins are yet more recent. But without attempting any chronological arrangement, let me here describe the intrusive rocks of Eigg, in accordance with the nomenclature above proposed, as capable of classification after the character of the mould into which they have been intruded.

α. Amorphous Masses or Bosses.

Only three amorphous intrusive masses were observed by me in Eigg; but they possess considerable interest, inasmuch as they serve to throw some light upon the age of similar masses in Skye. They consist of felstone (that is, a supersilicated felspar rock, with a little free quartz), and thus stand out strongly marked from the surrounding basic basalt-rocks. The largest and most characteristic forms a range of bold cliff, from 150 to 200 feet high, at the extreme north end of the island. It appears to have risen approximately along the bedding of the Oolitic strata, and thus to form of itself a large rude bed. It consists of a pale grey quartziferous porphyry, traversed by horizontal and oblique veins of basalt. It is quite columnar in places; and as the sea has here and there hollowed out caves at the base of the cliff, the roofs of these recesses expose the truncated ends of the columns. This rock closely resembles some of the finer-grained parts of the quartziferous porphyries of Skye and

Raasay. On the southern declivity, which shelves away from the base of the Scùr, the interbedded dolerites are traversed with an irregular band of intrusive rock, which weathers into a succession of rounded knolls along the slope above the ruined hamlet of Lower Grulinn. This rock varies considerably in different places. For the most part it has a grey porphyritic base, resembling that of the grey porphyry of the Scùr; in some places, however, it becomes darker and heavier, and assumes more the character of a doleritic rock. Possibly more than one variety of rock may here have been erupted along the same line. The third intrusive mass of porphyry is shown on the map a little to the east of Laig farm. It is a compact, yellow, quartziferous rock, resembling some parts of the first-named mass, and weathering with a platy texture. Its exact relations cannot be here made out; but it cuts through the basalt-rocks, and is thus later than they are.

Although the full importance of the intrusive bosses of felstone and quartziferous porphyry in the Tertiary volcanic series cannot be properly understood from the structure of Eigg, yet the examples which occur there are of interest, inasmuch as they are found associated with and penetrating the basalt-rocks, and thus serve to indicate the true relations of other masses which have invaded the Liassic and Oolitic strata of the Inner Hebrides at a distance from the main mass of the basalt-plateau.

β. Sheets.

Geologists are familiar with the often-quoted illustrations given by Macculloch of the way in which the trap-rocks of Skye have been thrust between the planes of the secondary strata, so as to run for a long way strictly parallel to them, appearing as regularly interstratified beds, and then to break across the strata, thereby revealing their true intrusive character*. I have already remarked that these features, which are characteristic of a certain horizon in the volcanic series, have been very commonly transferred to the whole of that series, which is cited in consequence as a kind of classical example of the intrusive nature of trap-rocks. In reality, however, the intrusive sheets are almost wholly confined to the lower portion of the igneous series, and they are quite subordinate in number and extent to the great interbedded sheets of the plateau.

So far as I have yet been able to ascertain, it is only the basalt-rocks which are ever found counterfeiting the parallelism of the true flows. The petrographical character of these rocks does not, then, differ essentially from that which they manifest when they occur as interbedded sheets. Yet, as a rule, they are more compact and closer-grained, never slaggy, and seldom amygdaloidal. Although the rock is finely crystalline thoughout, the upper and lower edges of each sheet are more close-grained than the central

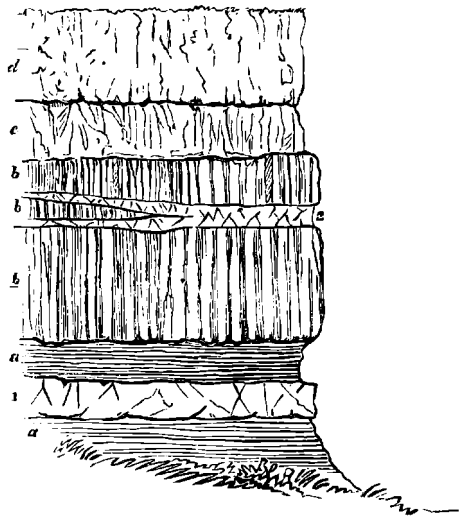
* See in particular plate xvii. of his 'Western Islands,' where numerous illustrations are given from the east coast of Trotternish.

parts. The abundant vertical joints only rarely assume a prismatic or rudely columnar arrangement. Hence, though it would often be difficult or impossible to discriminate the intrusive from the interbedded rock in hand-specimens, the distinctions between them are well maintained when we have a cliff-section before us. This similarity and difference become readily intelligible when we regard the two forms as in reality and originally proceeding from the same source, their distinction being due to the different conditions under which they were respectively consolidated; and we then perceive why the intrusive sheets should lie chiefly at the base of the interbedded series. The former are portions of the Tertiary lava which, unable to force their way to the surface, escaped laterally along the lines of least resistance. The increasing mass of the great overlying sheets of the plateau would oppose more and more the rise of the fluid lava, save from the main volcanic vents. Such portions of the latter as were driven up through cracks would often meet less resistance in trying to force their way along the bedding-planes of the secondary strata, or between these strata and the overlying igneous series, or between the lower beds of that series, than in breaking through the thick and compact volcanic mass above. Hence it is that, in nature, the intrusive sheets are in reality found where we might expect to meet with them. These statements involve, no doubt, only the most elementary knowledge. Yet the want of a due appreciation of this knowledge, and of its application in the field, has led to grave misconceptions as to the age of the volcanic rocks of the Inner Hebrides—misconceptions in which I have myself fully shared. I am naturally anxious, therefore, to point out that, while their intrusive relations have been fully recognized, the pseudo-interbedded character of the intrusive sheets at the base of the great basaltic plateaux of our west coast has been confounded with the true interbedded character of the sheets forming the plateau above, and that hence the inference regarding the intercalation of contemporaneous volcanic rocks among the secondary rocks of the Hebrides is without foundation. There is no evidence of any truly contemporaneous volcanic rock, so far as I have yet ascertained, in any of the Liassic or Oolitic rocks of that region. The basalt-plateau, viewed as one great sheet, rests alternately on Cambrian, metamorphosed Lower Silurian, Liassic, Oolitic, and Cretaceous rocks, and unconformably upon them all, from Antrim to the north of Skye. Here and there, where it happened to be laid down upon more or less horizontal strata, it shows at its base intrusive sheets which seem to run parallel with it, as well as with the secondary strata, between which they have been thrust. And thus has arisen the apparent gradation of the Oolitic groups of Skye into an upper volcanic series—a gradation, however, which is quite deceptive, and which disappears when, after wider examination, we come to recognize the true intrusive character of the intercalated sheets, and the real unconformability of the basalt-plateau alike upon Palæozoic and Secondary formations*.

* The suggestion of Edward Forbes regarding the probable Oolitic date of the

In Eigg the intrusive sheets at the base of the volcanic series are much less strikingly exhibited than in Skye, Raasay, and Mull. Some good sections occur, however, at the north end. In the lowest group of the Oolitic series, as exposed on the shore and on the low cliff to the east of Blarmor, there is an abundance of thin sheets of anamesite, which, sometimes coincident with, sometimes traversing the bedding-planes of the shales and limestones, harden the strata along the line of contact. At that locality the succession of the rocks is somewhat obscured by the effects of some large landslips; and similar disturbance extends all along the eastern flanks of Beinn Bhuidh. In one of the streamlets, coming down from that side of the plateau,

Fig. 4. *Section of Interbedded and Intrusive Volcanic Rocks, on the East Coast of Eigg.*



1. Sheet of intrusive basalt, 4 to 6 feet thick.
2. Sheet of fine-grained anamesite, 2 to 4 feet thick.
a. Calcareous pale yellow shelly sandstone (Oolite).
b. Columnar fine-grained anamesite or basalt, traversed by intrusive sheet (2).
c. Dull amorphous fine-grained anamesite.
d. Pale grey porphyrite.

near the Rudh nan tri Chlach, and which is known as the Ault na horsta mian, more than twenty intrusive sheets of dolerite, anamesite, or basalt may be counted among the shales and limestones. They are sometimes mere thin horizontal veins, not six inches thick; and they

igneous rocks of Trotternish, in Skye, must thus be abandoned (see Quart. Journ. Geol. Soc. vol. vii. p. 104). I adopted his views in my first examination of Skye; and my reference of the volcanic rocks of Skye to an Oolitic date must likewise be set aside (Trans. Roy. Soc. Edin. vol. xxii. p. 648; see also Proc. Roy. Soc. Edin. vol. vi. p. 72, where this change of view is indicated).

seldom exceed six or eight feet. But perhaps the best examples are to be seen along the cliffs to the south of Rudh nan tri Chlach. At this part of the coast, owing to the southward slope of the surface of the tableland of Beinn Bhuidh, the greater part of the overlying basalts is absent, and only the porphyrite and the underlying beds form the capping of the cliffs above the Oolitic rocks. The section (fig. 4, p. 297) represents the succession of rocks there to be seen, and shows how the intrusive sheets may be intercalated either with the Oolitic strata or with the older parts of the doleritic series.

γ. *Dykes and Veins.*

Another mode of escape to the pent-up molten rock was furnished by long straight fissures and by irregular winding cracks—the former giving rise to dykes, and the latter to veins. I reserve for a future paper a full consideration of that remarkable feature of the Tertiary volcanic rocks, the long parallel dykes. With regard to those which occur in Eigg, I may remark that they are not remarkable for numbers or other peculiarities, but that they exhibit many of the characteristic features of the dykes which range from the basaltic plateaux of the Hebrides across Scotland and the north of England. They run, as a rule, persistently from north-west to south-east, varying in breadth from a few feet to a few yards in breadth. They consist either of a close-grained anamesite or of basalt, and sometimes contain large grains of olivine. They cut across even the newest of the sheets of the plateau, as may be seen along the terraced slopes that descend from the Scùr. But in some of the cliff-sections, as, for example, below Bideann Boidheach and on the east side northwards from Kildonan, they may be seen rising through the lower, but stopping short of the higher beds of dolerite. That truncation may not indicate that where it occurs the dykes are older than the interbedded flows which cover them, but only that the fissures through which they rose did not extend further upward, or at least did not receive an injection of lava into their upper parts. At the same time, there can hardly be any doubt that the dykes as a whole are contemporaneous with the eruptions of the plateau, some of them belonging to earlier, others to later stages in the long volcanic history. No dyke has been observed cutting the pitchstone of the Scùr; but several are covered unconformably by that rock (see fig. 10).

The igneous veins by which the rocks of Eigg are traversed do not differ in origin from the dykes; but their smaller size and irregular form enable us to group them by themselves, and to note among them some characteristic features which are not found, or at least found much less distinctly, among the dykes. The veins may be arranged in two groups, according to their component rock, viz.:—1st. Basalt veins; and, 2nd. Pitchstone and Felstone veins. This classification may be regarded as also a chronological one, since there is reason to believe that the former group is older than the latter.

1. *Basalt, Anamesite and Dolerite Veins.*—These are closely connected both with the dykes and with the intrusive sheets, into either of which any vein may pass, or from which any vein may proceed. They commonly consist of a very compact finely crystalline rock, often paler in colour than that of the interbedded basalt-rocks, even where these are most close-grained. These features may be well seen along the coast-sections to the north of Kildonan. Among the veins of that as well as of other localities, a minutely amygdaloidal texture is occasionally observable, the small kernels being arranged in lines parallel with the sides of the vein and most marked along its centre. The grain of the rock usually becomes very close towards the edge of the vein, passing sometimes through various stages of flinty basalt into bright black lustrous tachylite. The most perfect example which I observed of this difference between the texture of the central and outer parts of a vein occurred in a vein which traverses the basalts on the east side of the Beinn Tighe—one of the outlying hills of the Scùr ridge. The rock is of a dark, very fine-grained basalt, which along the walls of the vein assumes a vitreous aspect, and sends out a loop or thread of black pitchstone-like tachylite into the surrounding interbedded basalt (fig. 5). The marginal crust of tachylite varies in thickness in different veins, ranging from one-third to about one-eighth of an inch. Sometimes it shades into the basalt within; in other cases it forms a pellicle, which cracks off in weathering. It is one of the most opaque rocks I have ever encountered; in several slices of it which I have had prepared for microscopic examination and reduced to extreme thinness, I am unable to get any light sent through, even at the edges.

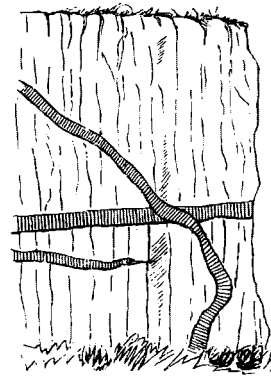
Fig. 5. *Plan of Basalt Veins with Tachylite edges, East Side of Beinn Tighe, Eigg.*

The veins run vertically, horizontally, or at any angle, and branch or unite, swell out or diminish, in a capricious manner. Their close texture and abundant joints make them weather differently from the rocks which they traverse. This, added to a frequent difference of colour, renders them a conspicuous figure along the coast-cliffs of Eigg (see fig. 6). Some striking illustrations occur on the east side of the island north of Kildonan, and also on the great precipice below Bideann Boidheach, where the pale thread-like veins may be distinguished even from a distance as they rise along the sombre face of the cliffs.

2. *Pitchstone and Felstone Veins.*—Although nearly the whole of the veins in Eigg are protrusions of doleritic rock, there occur a few in which the rock is pitchstone and, in one case at least, felstone. That these veins are, on the whole, later than those just described

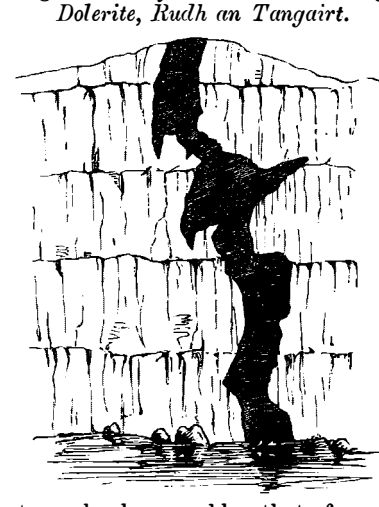
may be inferred from the fact that the pitchstone of the Scùr, as will be shown in the sequel, is much younger than the rocks of the basaltic plateau. The pitchstone of most of the veins differs, indeed, microscopically from that of the Scùr; but the latter varies greatly even within itself, so that, though no evidence exists of any pitchstone vein having ever been connected with the rock of the Scùr, we may, provisionally at least, class all the pitchstones together as the latest of the igneous rocks of Eigg.

Fig. 6. *Basalt Veins traversing interbedded Dolerites, Kildonan, Eigg.*



Four separate veins of pitchstone have been noticed in Eigg. The best-known and most clearly exposed veins are two which traverse the dolerite beds at Rudh an Tangairt, near the famous Uamha Fhraing, or Frank's Cave, on the south side of the island. The eastern vein (fig. 7) consists, in its upper part, not of pitchstone, but of a pale compact quartziferous porphyry or felstone, like that of Scorr Scalleadh*. It is exceedingly hard, splintering under the hammer with a metallic sound. It weathers with a yellowish or reddish tint, which extends for an inch or two into the stone, and shows numerous cavities, resulting apparently from the decomposition of felspar crystals. Towards the margin of the vein it assumes a laminar texture, in plates which are in a general sense parallel to the walls of the vein. Examined in thin section with the microscope, this rock shows a curious confused mass of minute needle-like or hair-like bodies, with opaque partially decomposed grains of pyrites, or possibly titaniferous iron, and a still more decomposed brown mineral. The texture closely resembles that of some of the pitchstones. The vein has a thickness of about $2\frac{1}{2}$ feet, and

Fig. 7. *Vein of Pitchstone traversing Dolerite, Rudh an Tangairt.*

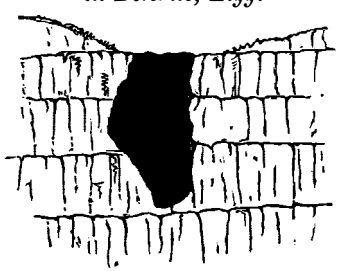


* An engraving of this vein is given by Jameson in his work already cited, vol. ii. p. 45. The felspathic rock he terms "hornstone;" it is called "chert" by Macculloch, and "porph ritic compact felspar" by Hay Cunningham. It differs in minute structure from evey other rock with which I am acquainted, and, as stated in the text, more nearly resembles pitchstone.

runs across the dolerite beds with a trend from N. 10° W. Descending the upper part of the cliff, the vein continues downward; but the porphyry is replaced by pitchstone, which descends to the beach. A detached portion of the former rock is involved in the latter; but it is hardly possible to decide here which is the newer mass, or if they are not of contemporaneous origin*.

The portion of the vein filled with pitchstone runs with a much less even course and regular thickness than the part filled with porphyry. The pitchstone suggests the idea of intense liquidity, as it seems to have thrust itself into every minute crevice of the crack in the dolerites up which it rose. Its path is somewhat tortuous; and its width varies from a few inches to 2 feet or more. Sometimes its walls are upright and parallel like those of a dyke; but in a little distance this feature disappears, and the pitchstone bends now to one side, now to the other, along the irregularly jointed surface of the dolerites. At the margin of the vein it is deep jet-black, and as glassy and lustrous as bottle-glass, but much more brittle; away from the edge it assumes the ordinary dull resinous lustre of pitchstone, while in the middle, where the vein is broadest, the rock takes a porphyritic texture. Examined microscopically, the outer or jet-black obsidian-like part of the vein is a perfect glass, of a pale brown colour, this hue being equally diffused as a tint through the mass, and not arising from the abundance of coloured crystals. I have not been able, even with a magnifying power which renders an object one five-thousandth of an inch in diameter clearly visible, to resolve this coloured matrix into component crystallites, grains, hairs, or any other structure. It is traversed by minute cracks, which, along with elongated cavities, run in one general direction parallel with the sides of the vein. On either side of these cracks the colour has in some cases been bleached out of the rock for a short distance; in others the colour is intensified into a deep brown. The cavities vary from one two-thousandth of an inch or less up to one fiftieth of an inch or more, sometimes empty, sometimes filled with a brown colouring-matter.

Fig. 8. *Pitchstone filling a cavity in Dolerite, Eigg.*



About four yards west from the vein just described a second vein of pitchstone is seen traversing the compact close-grained dolerite or anamesite of the cliffs. At the upper part of the cliff a detached portion (which, however, is probably only a part of the vein) fills up a cavity like a pot-hole, about a foot broad (fig. 8). It is traversed by numerous divisional planes, which run parallel with the sides of the cavity, and converge towards its bottom in such a way as to look

* Hay Cunningham found liquid bitumen in cavities of this rock.

like a mass of rather viscid pitch which had been spilt at the top of the cliff, and had slowly flowed into and filled a cavity in the rocks. This detached portion of pitchstone has the same bright deep jet-black or bluish-black colour and obsidian-like texture noticed in the previous vein. A little below it the main portion of the vein descends the lower part of the cliff, and crosses the beach from N. 25° W. to S. 25° E., with an average width of 1½ to 2 feet. Its external parts, as in the previous example, are black and quite glassy; the central portion possesses the common dull resinous lustre and dark-green colour characteristic of pitchstone. A thin section of the latter part of the vein, placed under the microscope, shows that the base of the rock is a nearly colourless homogeneous glass, through which are scattered abundant black or greenish hairs of some ferruginous silicate arranged singly and in oblong tufts. The individual hairs of each tuft are not feathered, like those of the Corriegills pitchstone of Arran. It is to the abundance of these particles that the dark colour of the rock is due.

A third, less distinctly traceable vein of pitchstone traverses the dolerites on the beach at the harbour. There is the same difference of texture in it as in the Rudh an Tangairt veins. The black brittle obsidian-like portion, when examined microscopically, shows a deep rich-brown homogeneous glass, with numerous small kernels, some of which are filled with an amber-coloured substance (bitumen?). Except for its much deeper colour and the presence of coloured kernels instead of much more minute elongated vesicles, the minute texture of this rock is analogous to that of the east vein. The dull dark-green portion is markedly porphyritic, and is mixed up, even in hand-specimens, with the more glassy variety. Under the microscope it shows considerable opacity, but on extremely thin edges and in certain less deeply coloured portions is found to consist of a thickly aggregated mass of minute black hairs, less distinctly separated than those of the Rudh an Tangairt vein, and imbedded in a glass mostly of a dark-green or black colour, but here and there colourless. The colouring-matter is therefore not entirely dependent in this rock upon the abundance of the hair-like particles. Large crystals of a beautifully striated felspar are scattered through the rock, also kernels filled with a brown or amber-coloured substance, as in the black part of the vein.

A fourth pitchstone occurs on the roadside, a little to the east of Laig Farm, and seems to be connected with the intrusive boss of quartziferous porphyry there. It differs considerably in external aspect from the other veins, being of a pale-green or greenish-grey colour, and thus resembling at first sight the pale slag of an iron-furnace. The base is minutely granular, and shows a few scattered felspar crystals. Under the microscope this rock appears as a pale-brown glass, through which are scattered abundant minute cavities, short dark bodies resembling the "hairs" already described, but less definitely formed, and crystals of an orthoclase felspar.

Petrographically considered, the pitchstone veins of Eigg present us with three varieties:—1st, those formed of a colourless glass and

owing their dark hue to the abundant included hair-like aggregations of a ferruginous silicate; 2nd, those formed of a coloured glass in which the colouring-matter is impalpably diffused; and, 3rd, those formed of a coloured glass where the hue is further intensified by the abundance of included "hairs."

3. Pitchstone and Porphyry Coulées of the Scùr.

That feature of the island of Eigg which renders it so remarkable and conspicuous an object on the west coast is the long ridge of the Scùr. Rising gently from the valley which crosses the island from Laig Bay to the Harbour, the basaltic plateau ascends south-westwards in a succession of terraces, until along its upper part it forms a long crest, from 900 to 1000 feet above the sea, to which it descends on the other or south-west side, first by a sharp slope, and then by a range of noble precipices. Along the watershed of this crest runs, in a graceful double curve, the abrupt ridge of the Scùr, terminating on the north-west at the edge of the great sea-cliff (975 feet), and ending off on the south-east in that strange well-known mountain-wall (1272 feet high) which rises in a sheer cliff nearly 300 feet above the basalt-plateau on the one side and more than 400 feet on the other. The total length of the Scùr ridge is two miles and a quarter, its greatest breadth 1520, its least breadth 350 feet. Its surface is very irregular, rising into minor hills and sinking into rock-basins, of which nine are small tarns, besides still smaller pools, while six others, also filled with water, lie partly on the ridge and partly on the basaltic plateau. No one, indeed, who looks on the Scùr from below, and notes how evenly it rests upon the basalt-plateau, would be prepared for so rugged a landscape as that which meets his eye everywhere along the top of the ridge. Two minor arms project from the east side of the ridge; one of these forms the rounded isle called Beinn Tighe (968 feet), the other the hill of A chor Bheinn.

Singular as the Scùr of Eigg is, regarded merely as one of the landmarks of the Hebrides, its geological history is not less peculiar. The natural impression which arises in the mind when this mountain comes into view for the first time is, that the huge wall is part of a great dyke or intrusive mass which has been thrust through the older rocks *. It was not until after some time that the influence of this first impression passed off my own mind, and the true structure of the mass became apparent.

The ridge of the Scùr, though formed of one great mass of rock

* Hay Cunningham, in the paper before quoted, remarks:—"In regard to the relations of the pitchstone-porphyry of the Scùr and the trap-rocks with which it is connected, it can, after a most careful examination around the whole mass, be confidently asserted that it exists as a great vein which has been erupted through the other Plutonic rocks—thus agreeing in age with all the other pitchstones of the island." Macculloch leaves us to infer that he regarded the rock of the Scùr to be regularly interstratified with the highest beds of the dolerite series ('Western Isles,' i. p. 522). Hugh Miller speaks of the Scùr of Eigg as "resting on the remains of a prostrate forest."—*Cruise of the Betsy*, p. 32.

very different from those around it, in reality consists of two distinct varieties of rock, pitchstone and felstone-porphyry, arranged in distinct and, in a general sense, horizontal beds. Looked at from the east side (Pl. XIV. fig. 1) this feature is not clearly marked; for the great cliff seems then to consist of one homogeneous mass, except a marked columnar band running obliquely along the base of the precipice. If, however, the side is viewed from the south, the bedded character of its component rocks becomes a conspicuous feature. Along the noble cliffs on that side the two varieties of rock are strongly distinguished by their contrasting colour and mode of weathering, the sombre-hued pitchstone standing up in a huge precipice striped with columns, and barred horizontally with bands of the pale-grey porphyry, which seems sunk into the face of the cliff. At the south-east end of the ridge the beds are very distinct. Further west of the precipices to the south of the Loch a Bhealaich, the dark pitchstone which forms the main mass is divided by two long parallel intercalations of grey porphyry, and two other short lenticular seams of the same material (see Pl. XIV. figs. 2 & 3). It is clear from these features, which are not seen by most travellers, who pass Eigg merely in a steamer, that the Scùr is in no sense of the word a dyke.

But although the Scùr is thus a bedded mass, the bedding is far different from the regularity and parallelism of that which obtains among the interbedded basalt-rocks below. Even where no intervening porphyry occurs, the pitchstone can be recognized as made up of many beds, each marked by the different angle at which its columns lie. And when the porphyry does occur and forms so striking a division in the pitchstone, its beds die out rapidly, appearing now on one horizon, now on another, along the face of the cliffs, and thickening and thinning abruptly in short distances along the line of the same bed. Perhaps the best place for examining these features is at the Bhealaich, the only gully practicable for ascent or descent, at the south-eastern face of the ridge.

By much the larger part of the mass of the Scùr consists of pitchstone. As a rule this rock is columnar, the columns being much slimmer and shorter than those of the basalt-rocks. They rise sometimes vertically, and often obliquely, or project even horizontally from the face of the cliff. They are seldom quite straight, but have a wavy outline; and when grouped in knolls here and there along the top of the ridge, they remind one of gigantic bunches of some of the palæozoic corals, such as *Lithostrotion*. In other cases they slope out from a common centre, and show an arrangement not very unlike that of a Highland peat-stack.

The pitchstone of the Scùr differs considerably in petrographical character from any other of the pitchstones of the island, and indeed from any other pitchstone which I have yet met with in Scotland. Its base is of a velvet-black colour, and is so much less vitreous in aspect than ordinary pitchstone as to have been described by Jameson and later writers as intermediate between pitchstone and basalt*.

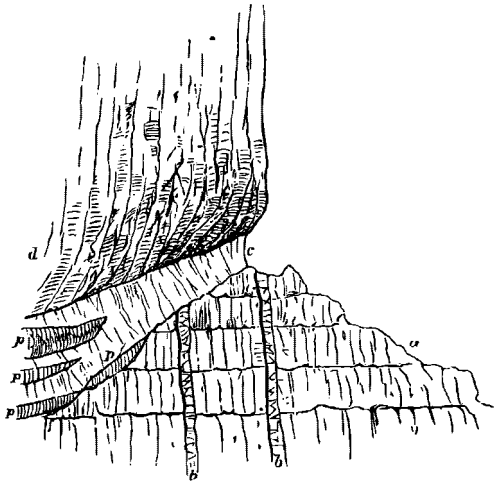
* 'Mineralogy of the Scottish Isles,' vol. ii. p. 47. See also Macculloch, 'Western Isles,' vol. i. p. 521, and Hay Cunningham, 'Mem. Wern. Soc.' vol. viii. p. 155.

It has a minutely granular texture, and is usually strongly porphyritic, with crystals of orthoclase, sometimes a quarter of an inch in length.

That portion of the mass which forms the eastern end, or Scùr proper, shows under microscopical examination a much less perfect glass than any of the veins above described. With a $\frac{1}{5}$ object-glass the rock seems to be made up of a confused aggregate of short pale fibres or hairs matted together. These are much more minute, and proportionally thicker than the hair-like bodies in the veins, and they are so abundant as to form apparently the whole or nearly the whole of the rock. At the opposite extremity of the ridge, the rock of Beinn Bhreac is less porphyritic. Examined with the microscope it shows a similar, but rather coarser texture, through which, in addition to the orthoclase, there are diffused small crystals of a delicately striated felspar*.

The grey porphyry, which occurs in beds and forms a subordinate part of the mass of the Scùr ridge, is usually a somewhat decomposed rock. Where a fresh fracture is obtained it shows a fine-grained, sometimes almost flinty, grey felspar base containing clear granules of quartz, and facets of a glassy felspar, probably orthoclase. In some places the rock is strongly porphyritic. Although the line

Fig. 9.—*Section at the base of the Scùr of Eigg (east end).*



of separation between this porphyry and the pitchstone is usually well defined, it is sometimes so obscure, and the two rocks so shade

* The notes given above of the microscopic structure of the Eigg pitchstones are the results of merely a preliminary examination. I hope to be able eventually to form materials for an essay on the minute structure of the pitchstones of Scotland.

into each other, that it is then difficult to regard the porphyry as other than a peculiar and decomposed modification of the pitchstone. This is particularly to be observed under the precipice at the east end of the Scùr. At that locality the pitchstone is underlain by a band of very hard flinty porphyry, varying in colour from white through various shades of flesh-colour and brown into black, containing a little free quartz and crystals of glassy felspar. Where it becomes black it passes into a rock like that of the main mass of the Scùr. Such pitchstone parts of the bed look like kernels of less-decomposed rock. The lower six feet of the porphyry are white and still more decomposed. The relation of the mass is shown in fig. 9, where the basalt-rocks of the plateau (*a*) are shown to be cut through by basalt dykes (*b*, *b*), and overlain by the porphyry (*c*) and the pitchstone (*d*). In the porphyry are shown several pitchstone kernels (*p*, *p*). It is deserving of remark also that in different parts of the Scùr, particularly along the north side, the bottom of the pitchstone beds passes into a dull grey earthy porphyry, like that now under description. Reference has already been made to the occurrence of the pitchstone vein at Laig road along with quartziferous porphyry, and also of similar porphyry and pitchstone filling the same vein at Rudh an Tangairt. Hence, between these two rocks there appears to be in Eigg a close relationship both as to origin and age.

Although the Scùr of Eigg is thus evidently the product of different flows, subsequent to the eruption of the highest of the now visible basalt-beds, it was separated from these latter eruptions by an enormous lapse of time. This point, which is as yet a unique feature in Hebridean Geology, I was so fortunate as to ascertain during my survey; and though I have elsewhere* announced the fact, I wish now to adduce the evidence upon which the conclusion is based. My observations show that what is now the great ridge of the Scùr was formerly a river-valley, that this valley was filled with successive flows of pitchstone-lava, that this river-silt, gravel, and drift-wood were buried under the eruptions, and that after long subsequent denudation the surrounding hills have been worn away, and the river-valley, by virtue of the superior permanence of the vitreous lava which occupied its course, has been left standing now as the highest ridge of the district.

A little attention to the form of the bottom over which the rocks of the Scùr have been erupted suffices to reveal the fact that between the basalt-beds of the plateau and the pitchstone sheets of the Scùr there is a marked discordance, since the latter lie upon a denuded surface of the former. Let us take a section at any part of the ridge, and this feature will be made clear. At the little tarn of the Bhealaich, already referred to, a section may be seen, where the base of the pitchstone on the north side is at least 200 feet above its base on the south side. Here, as everywhere else, the basalt-veins are abruptly cut off along the denuded surface on

* See my 'Scenery of Scotland viewed in connexion with its Physical Geology,' p. 278.

which the pitchstone rests. Again, at the east end of the Scùr the pitchstone wall is placed not fairly on the crest of the dolerite-plateau, but on the south side of it. This cannot fail to arrest the notice of every observer, even from a distance (see Pl. XIV. fig. 1). It shows us not only that the rocks of the Scùr were erupted along a hollow or valley, but that only the north or north-eastern side of that valley is now preserved.

Allusion has been already made to two minor tongues of pitchstone which project to the north-east from the main ridge of the Scùr, and form small hills. Even in these offshoots the same evidence of want of sequence between the rock of which they are composed and the underlying basaltic sheets is clearly exposed. In Beinn Tighe, for instance, the northern projection, a section taken across the isle from east to west shows the basalts at a much higher level on the one side than on the other. These offshoots appear to have been originally either recesses of the main valley, or tributary valleys descending into it, and to have been buried and preserved under portions of the coulées of the pitchstone lava which overflowed from the main mass.

Underneath the eastern end of the precipice of the Scùr, on its southern or lower side, a bed of fragmentary materials is found to intervene between the pitchstone and the dolerites. The base of the pitchstone dips into the hill, forming the roof of a small cave. The under surface of the pitchstone is tolerably smooth, but undulating, and shows the ends of the columns as a polygonal reticulation over the roof. The breccia is a pale-yellow or grey felspathic rock, like the more decomposing parts of the grey porphyry of the same cliff. Through its mass are dispersed great numbers of angular and subangular pieces of pitchstone, some of which have a striped texture. Fragments of basalt, red sandstone, and other rocks are rare; and the bed suggests the idea that it is a kind of brecciated base or flow of the main pitchstone mass. A similar rock is found along the bottom of the pitchstone on both sides of the ridge (*c*, in fig. 9). At some points where this breccia is only a yard or two in thickness, and consists of subangular fragments of the various dolerites and basalts of the neighbourhood, along with pieces of red sandstone, quartz-rock, clay-slate, &c. The matrix is in some places a mass of hard basalt débris; in others it becomes more calcareous, passing into a sandstone or grit in which chips and angular or irregular-shaped pieces of coniferous wood are abundant*. A little further east, beyond the base of the Scùr, a patch of similar breccia is seen, but with the stones much more rounded and smoothed. This outlier rests against the denuded ends of the ba-

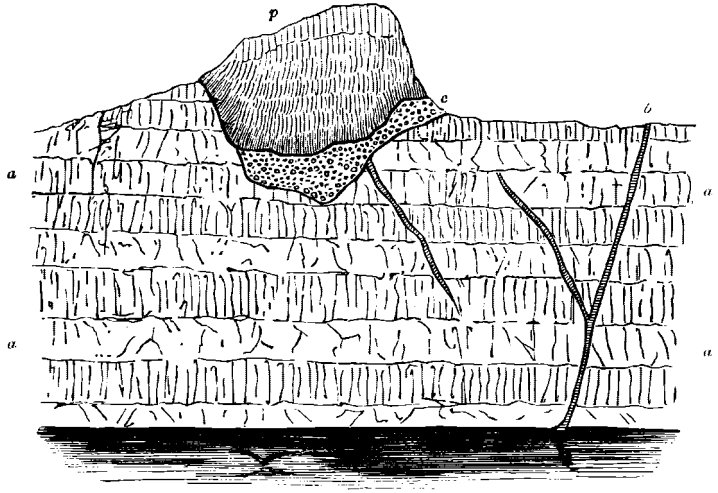
* The microscopic structure of this wood was briefly described by Witham (Foss. Vegetables, p. 37), and two magnified representations were given to show its coniferous character. Lindley and Hutton further described it in their 'Fossil Flora,' naming it *Pinites eiggensis*, and regarding it as belonging to the Oolitic series of the Hebrides—an inference founded perhaps on the erroneous statement of Witham to that effect. William Nicol corrected that statement by showing that the wood-fragments occurred, not among the "lias rocks," but "among the débris of the pitchstone" (Edin. New Phil. Journal, xviii. p. 154).

salt-beds forming the side of the hill. Its interest arises from the evidence it affords of the prolongation of the old valley eastward, and consequently of the former extension of the precipice of the Scùr considerably beyond its present front.

It is at the extreme north-western extremity of the pitchstone ridge, however, that the most remarkable exposure of the ancient river-bottom is now to be seen. Sweeping along the crest of the plateau the ridge reaches the edge of the great precipice of Bideann Boidheach, by which its end is truncated, so as to lay open a section of the gravelly river-bed along which the pitchstone flowed.

The accompanying diagram (fig. 10) represents the natural section there exposed. Rising over each other in successive beds, with

Fig. 10.—*Natural Section at the Cliff of Bideann Boidheach, north-west end of the Scùr of Eigg.*



a a. Bedded dolerites and basalts. *b b*. Basalt dykes and veins. *c*. Ancient river-bed filled with conglomerate. *p*. Pitchstone of the Scùr.

Hay Cunningham, in the paper already cited, states that the fossil wood really lies in the pitchstone itself! The actual position of the wood, however, in the breccia and conglomerates underlying the pitchstone is beyond all dispute. I have myself dug it out of the bed. The geological horizon assigned to this conifer, on account of its supposed occurrence among Oolitic rocks, being founded on error, no greater weight can be attached to the identification of the plant with an Oolitic species. Our knowledge of the specific varieties of the microscopic structure of ancient vegetation is hardly precise enough to warrant us in definitely fixing the horizon of a plant merely from the examination of the minute texture of a fragment of wood. From the internal organization of the Eigg pine, there is no evidence that the fossil is of Oolitic age. From the position of the wood above the dolerites and underneath the pitchstone of the Scur it is absolutely certain that the plant is not of Oolitic but of Tertiary date.

a hardly perceptible southerly dip of 2°, the sheets of dolerite, anamesite and basalt form a mural cliff about 700 feet high. Nowhere in the island can the bedded character of these rocks and their alternation of compact, columnar, amorphous, and amygdaloidal beds be more strikingly seen. They are traversed by veins and dykes of an exceedingly close-grained, sometimes almost flinty, basalt. But the conspicuous feature of the cliff is the hollow which has been worn out of these rocks, and which, after being partially filled with coarse conglomerate, has been buried under the huge pitchstone mass of the Scùr. The conglomerate consists of water-worn fragments, chiefly of dolerite and basalt, but with some also of the white Oolitic sandstones, imbedded in a compacted sand derived from the waste of the older volcanic rocks. The grey porphyry, so conspicuous at the east end of the Scùr, here disappears and leaves the conglomerate covered by one huge overlying mass of pitchstone.

An examination of the fragments of rock found in the conglomerate on which the great pitchstone ridge of Eigg stands, affords us some indication of the direction in which the river flowed. The occurrence of pieces of red sandstone, which no one who knows West-Highland geology can fail to recognize as of Cambrian derivation, at once makes it clear that the higher grounds from which they were borne could not have lain to the south or east, but to the north-west or north. From the fragments of white sandstone we may with some probability infer that the course of the stream came from the north, where the great white Oolitic sandstones rise to the surface. In short, there seems every probability that this old Tertiary river flowed southward through a forest-clad region, of which the red Cambrian mountains of Ross-shire and the white sandstone cliffs of Raasay and Skye are but fragments, that it passed over a wide and long tract of the volcanic plateau which has been so worn away that it now remains in mere islets left standing out of the deep Atlantic, that since then mountain and valley have alike disappeared, and that in Eigg a fragment of the river-valley has been preserved solely because it has been sealed up under streams of vitreous lava which could better withstand the progress of waste. Thus the Scùr of Eigg, like the fragments of the older basalt-plateaux of Auvergne, remains as a monument, not only of volcanic eruptions, but of a former land-surface, now effaced, and of the irresistible march of those slow and seemingly feeble agencies by which the denudation of a country is effected.

4. Summary of the Volcanic Geology of Eigg.

In conclusion let me briefly summarize the more important contributions made by the geology of Eigg to the history of the Tertiary volcanic rocks of Britain.

1. The volcanic rocks of this island rest unconformably upon strata of Oolitic age.

2. They consist almost wholly of a succession of nearly horizontal interbedded sheets of dolerite, anamesite, and basalt, forming an

isolated fragment of the great volcanic plateau which stretches in broken masses from Antrim through the Inner Hebrides.

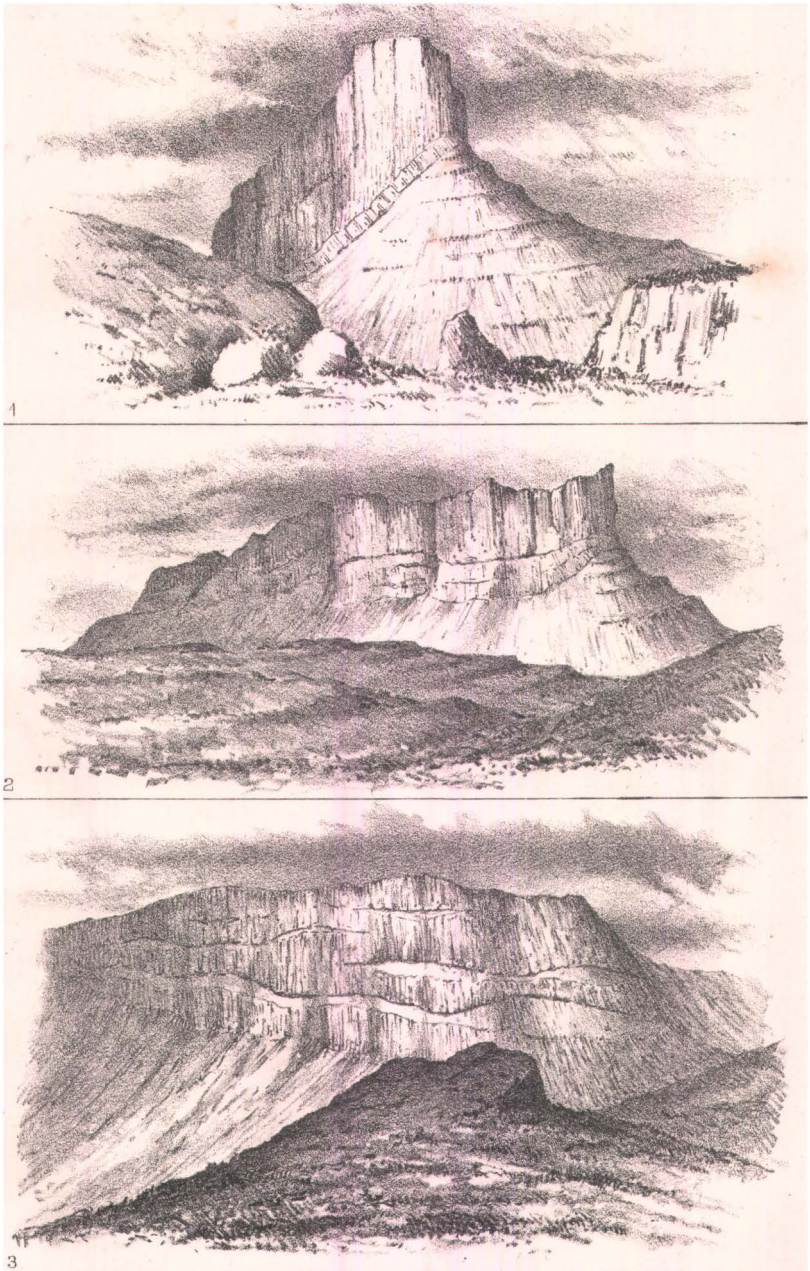
3. These interbedded sheets are traversed by veins and dykes of similar materials, the dykes having the characteristic north-westerly trend with which they pass across the southern half of Scotland and the north of England. Veins of pitchstone and felstone, and intrusive masses of quartziferous porphyry, like some of those which in Skye traverse or overlie the lias, likewise intersect the bedded basalt-rocks of Eigg.

4. At least two widely separated epochs of volcanic activity are represented by the volcanic rocks of Eigg. The older is marked by the bedded basalts and by the basalt veins and dykes, which, though, strictly speaking, younger than the bedded sheets which they intersect, yet probably belong to the same continuous period of volcanic action. The later manifestations of this action are shown by the pitchstone of the Scùr. Before that rock was erupted, the older basaltic lavas had long ceased to flow in this district. Their successive beds, widely and deeply eroded by atmospheric waste, were here hollowed into a valley traversed by a river, which carried southward the drainage of the wooded northern hills. Into this valley, slowly scooped out of the older volcanic series, the pitchstone and porphyry *coulées* of the Scùr flowed. Vast, therefore, as the period must be which is chronicled in the huge piles of volcanic beds forming our basalt-plateaux, we must add to it the time needed for the excavation of parts of those plateaux into river-valleys, and the concluding period of volcanic activity during which the rocks of the Scùr of Eigg were poured out.

5. Lastly, from the geology of this interesting island we learn, what can be nowhere in Britain more eloquently impressed upon us, that, geologically recent as that portion of the Tertiary period may be during which the volcanic rocks of Eigg were produced, it is yet separated from our own day by an interval sufficient for the removal of mountains, the obliteration of valleys, and the excavation of new valleys and glens where the hills then stood. The amount of denudation which has taken place in the Western Highlands since Miocene times will be hardly credible to those who have not adequately realized the potency and activity of the powers of geological waste. Subterranean movements may be called in to account for narrow gorges, or deep glens, or profound sea-lochs; but no subterranean movement will ever explain the history of the Scùr of Eigg, which will remain as striking a memorial of denudation as it is a landmark amid the scenery of our wild western shores.

DESCRIPTION OF PLATE XIV.

Fig. 1. View of the Scùr of Eigg from the east.
2. View of the Scùr from the south.
3. View of the precipice of the Scùr to the south-west of the Loch a Bhealaich.



G.R. DeWilde. del. et lith. Minterne Bros imp

VIEWS OF THE SCUR OF EIGG.