Chapter 1 Introduction, and general relations of the volcanic series.

As a region of igneous rocks the Western Isles of Scotland, with neighbouring parts of the Scottish mainland and of Ireland, have engaged attention since the early days of modern geology; and a considerable literature dealing with the various districts severally or collectively has grown up during the last hundred years. The special features of the region are the grand scale on which igneous activity has here operated, the completeness of the record, and the manner in which the inner mechanism of igneous action has been brought to light by profound erosion. The clear recognition of the Tertiary age of the whole has added a further feature of interest, more especially as regards the rocks of deep-seated origin. In few other parts of Europe is there any similar exhibition of plutonic rocks of this comparatively late geological date, and the study of the British area has contributed in no small degree to dispel the misconception of radical differences supposed to distinguish pre-Tertiary from Tertiary igneous rocks. In all the aspects indicated Skye is fully equal, and in some particulars superior, to other parts of the region in the advantages which it offers to the geologist, and the island has received a corresponding amount of attention at the hands of observers.

In view of the frequent references contained in the following pages and the full Bibliography given as an appendix, no formal review of the literature of the subject is called for. Among the earlier writers Macculloch may claim the chief place. His great work, published in 1819, is a monument alike of accurate observation and of acute generalisation, and it contains much which, after more than eighty years, is still valuable. Boue's "Essai geologique sur 1'Ecosse" (1820) should also be mentioned, and a memoir published in 1829 by von Oeynhausen and von Dechen. A brief but important paper by J. D. Forbes in 1845 marked a decided advance in the geology of the Skye mountains. The results of Sir A. Geikie's earliest geological work in Skye were presented to the Geological Society in 1857, and forty years later he embodied in his "Ancient Volcanoes of Great Britain" the results of many valuable researches in the same district. Professor Zirkel was the first to apply to the igneous rocks of Skye, in 1870, the methods of modern petrology; while our fuller knowledge of this side of the subject is due principally to an important series of memoirs from the pen of Professor Judd. The mineralogy of Skye, as of Scotland in general, owes most to the late Professor Heddle, whose many contributions are collected in his posthumous publication "The Mineralogy of Scotland" (1901).

In this chapter we shall offer a few introductory remarks upon the Tertiary igneous rocks of Britain in general, and also some observations concerning the general relations of the volcanic rocks of Skye, which here, as elsewhere in the region, constitute the earliest members of the whole suite. It should be mentioned that in the south-eastern part of Skye there are igneous rocks of much greater antiquity, with which we shall have no concern. Apart from those older than the Moine crust-movements, and accordingly much disguised in character, there are various pre-Tertiary dykes both acid and basic, the latter chiefly of lamprophyric affinities. Few of these are found beyond the limits of the Sleat district. The most north-westerly example observed is a much decayed mica-lamprophyre dyke intersecting the Cambrian limestones in Coire Beithe, on the south side of Beinn na Caillich, near Broadford. Although the immediate subject-matter of this memoir is limited to the Isle of Skye, it is important to bear in mind constantly that the Tertiary igneous rocks of Britain have a much wider distribution. Bedded basalts comparable with those which build the plateaux of Skye occur in many other parts of the Inner Hebrides, besides some patches on the adjacent coast of Scotland and a large area in the north-east of Ireland (*see* sketch-map, Fig. 1); the Tertiary age of these rocks being proved in several localities by the discovery of an Eocene flora in intercalated bands of tuff and lignite.<ref>See especially Starkie Gardner, *Proc. Roy. Soc.,* vol. xxxviii., pp. 14–23: 1885, and vol. xxxix., pp. 412–415: 1886.</ref> On petrographical and other grounds it seems probable that the area of distribution of Tertiary igneous rocks in Britain may be further extended to include the gabbros and granites of St. Kilda, Arran, the Mourne Mountains, Carlingford, and perhaps other districts.<ref>The intrusions at Carrock Fell, in Cumberland, may possibly come in here. Mr. T. Davies made a like suggestion for the granite of Lundy, off the north coast of Devon (see Judd, *Quart. Journ. Geol. Soc.,* vol. xxx., p. 275: 1874); but the specimens of this rock which we have examined lend no support to the supposition.</ref> There is moreover a very numerous system of basic dykes throughout the western and southern parts of Scotland and the northern parts of Ireland and England, which are with good reason inferred to belong to the same general period of igneous activity.<ref>See map by Sir A. Geikie in *Trans. Roy. Soc. Edin.,* vol. xxxv., Pl. I.: 1888. The later dykes of Anglesey are also referred, with considerable probability, to a Tertiary age (Greenly, *Geol. Mag.,* 1900, pp. 160–164). </ref>, Such an inference seems to be warranted by the petrographical characters of the dykes, their bearing and behaviour in the field, and the fact that

some of them traverse Mesozoic strata. Thus the Cleveland dyke near Whitby (about 300 miles from Skye) cuts through the Oolites; and, since no igneous outburst is known to have occurred between Permian and Eocene times, this fact affords a strong probability of the Tertiary age of the dyke.<ref>On this question, see more particularly Sir A. Geikie, *Trans. Roy. Soc. Edin.,* vol. xxxv., p. 30: 1888.</ref>

The British area thus embraced is still but a small fraction of the whole "petrographical province", which extends northward for more than two thousand miles, to far within the Arctic Circle, and includes not only Iceland and the Farber, but Jan Mayen, a portion of Greenland, Spitzbergen, Franz Josef Land, etc. Throughout this great area the volcanic rocks are marked by common characteristics, such as the great preponderance of basic lavas, the prevalence of the fissure type of eruption, and other features, geological as well as petrographical. At certain centres, notably in Iceland, volcanic activity has been prolonged down to the present time, or, as some geologists would prefer to say, has been revived upon the old lines and with the old characteristics. The southern and western boundaries of this "Brito-Icelandic province" are probably rather sharply defined, for on Rockall, some 250 miles west of Skye, and at the Wolf Rock, off the Cornish coast, we meet with igneous rocks of a very different kind. Although the Tertiary age of these two occurrences cannot be proved, their petrographical nature leads us to attach them to another great province, characterised especially by rock-types rich in alkalies, which embraces most of the Atlantic basin.

Subsequently to the cessation of igneous activity within the British area, the volcanic tract has been subjected to extensive crust-movements, generally in the sense of subsidence, and to erosion on an enormous scale; and it has thus been reduced essentially to a certain number of islands rising from the hundred-fathom continental platform. Some of the larger questions on which we might desire to have assurance have thus become matters of speculation; among others the question to what extent basaltic districts now separated by the sea have once been continuous. Professor Judd is of opinion that the lavas were poured forth from great central volcanoes comparable with Etna at the present day. Of these he has specified five, in. Mull, Skye, Rum, Ardnamurchan, and St. Kilda, their sites being marked by the occurrence of considerable masses of plutonic rocks, which in his view represent the denuded cores or basal wrecks of these hypothetical volcanoes. The detailed survey of Skye has led to quite other conclusions, and has endorsed the view, first enunciated by Sir A. Geikie in 1880, that the basaltic lavas issued, not from great volcanic vents, but from innumerable small fissures. There would thus be no narrow limit to the possible extent of a continuous lava-field. That of the Snake River Plains in Idaho stretches for much more than 300 miles, the total area being still undetermined, while the "Deccan traps" in India cover at least 200,000 square miles. There is therefore nothing of inherent improbability in the supposition that a basaltic tract once extended continuously from Antrim to Skye and much farther.

The *volcanic*<ref>Throughout this memoir we use the term "volcanic" in its strict sense, i.e. limited to eruptions at the surface of the earth's crust. The plutonic and later intrusions in our area had no connection with volcanoes, other than the lax connection which unites all the extrusive and intrusive rocks as members of one great suite, for which we may infer a remote common parentage. t Prof. Judd, in his earlier papers, dealing with the Western Isles as a whole, referred the latest igneous eruptions to the Pliocene. This, however, was when the flora of the basaltic group was believed to be of Miocene age. (See Quart. Journ. Geol. Soc., vol. xxx., p. 274: 1874.) </ref>phase, doubtless representing in itself a prolonged lapse of time, was followed by a *plutonic* phase, in which the manifestations of igneous activity assumed a new form. The energy, instead of being diffused over a vast region, became localised about certain centres within that region, and one such plutonic centre or focus was situated in what is now the mountain district of Skye, including the Cuillins and the Red Hills. Here large bodies of molten magma, first of basic (including ultrabasic) and afterwards of acid composition, were intruded immediately below and among the volcanic rocks, and consolidated beneath a very considerable superincumbent mass. There is evidence that this was effected by many distinct intrusions, and the building up of these complex plutonic masses must have been a gradual and prolonged process.

To the plutonic phase there succeeded a third and final phase of activity characterised by *minor intrusions* in the form of sills, sheets, and dykes. This third phase embraced numerous distinct episodes, the history of which has been partly, but not in every case completely, deciphered. We shall show that certain groups of these minor intrusions are probably common to the whole great region or "petrographical province"; others affect a very large area of that region, including Skye or a considerable portion of Skye; while others again stand in relation to the special centre of activity already established during the plutonic phase, and have a distribution limited accordingly. The groups which fall into this last category are as a rule very definitely characterised, and it has been found possible to follow out the succession of events

connected with the special Skye focus in sufficient detail. The rocks belonging to groups of regional extension present much less variety in their petrographical characters; and, for this and other reasons, it is not possible to decipher their succession in any thorough fashion.

The succession of events from the breaking out of igneous action in the area considered to its final extinction implies a very extended length of time, but its actual duration is a question concerning which we have little certain knowledge. The only precise datum is supplied by the botanical evidence which assigns the volcanic rocks to some part of the Eocene. Since the volcanic phase covers only a fraction of the whole time demanded, we might be led to suggest that succeeding events were prolonged into some of the later divisions of Tertiary time.<ref>On this point, see Judd, *i.e.;* also Geikie, *Quart. Journ. Geol. Soc.*, vol. lii., pp. 402–405: 1896.</ref> Against this, however, we have to set the consideration of the enormous amount of erosion+ which has affected our Tertiary igneous districts, and which was mainly accomplished before the Glacial Epoch. The lavas, it is true, may have been undergoing erosion concurrently with the later phases of igneous activity; but the great basic sills intercalated among the lavas, and belonging to a much later episode, expose their truncated edges throughout a thickness of rocks amounting to hundreds and indeed thousands of feet. The gabbro, too, which must certainly have consolidated under a considerable cover,<ref>Michel-Tavy's remarks on this point (*Structures et classification des roches eruptives,* Paris, 1889, p. 9) seem to be based on a misunderstanding of Sir A. Geikie's writings. The same conception, that the gabbros and granites of the Hebrides can be explained as extrusive rocks, has also been put forward by Reyer upon a misunderstanding of Judd's description (*Theoretische Geologie,* Stuttgart, 1888, pp. 369–372).</ref> has been carved into lofty mountains. Such considerations dispose us to throw back the period of igneous activity so far as is consistent with the varied developments of which the record gives evidence, and without further knowledge the balance of probability cannot be more precisely stated.

In describing the various rocks, geologically and petrographically, we shall treat them, so far as is possible, in chronological sequence. As regards the dykes, however, the imperfection of the record, or of our reading of it, sometimes precludes such orderly treatment, and the account will then be given in a more collective form. For convenience, and to avoid repetition, certain features of special interest will be discussed in separate chapters; and some general considerations, which turn upon a comprehensive review of the observations recorded, will find their most appropriate place near the end of the volume. In accordance with this plan, the volcanic rocks will be first described, then in due sequence the several plutonic rocks and, partly in chronological order, the various minor intrusions of the area.

The *volcanic rocks* still preserved in Skye, together with the numerous sills of basic rocks intruded amongst them, occupy, roughly speaking, the whole of the north-western half of the island, *i.e.* all the country to the north and west of the central mountains, which consist essentially of gabbro and granite. It is quite clear, morever, that they have once had a considerable extension south-eastward; for, besides numerous patches of the volcanic rocks enclosed in the plutonic masses of the mountain district, we find outliers of some extent in the Strathaird peninsula, and other areas both north and south of the Beinn na Caillich massif, the most easterly of the granitic or "Red" Hills. These last-mentioned relics of the volcanic group are let down by faults, and owe partly to this cause their preservation from destruction. Prior to the great erosion of later Tertiary times these rocks must have overspread the greater part, if not the whole, of Skye. Nor is it to be supposed that even this area, nearly 50 miles in length, represents the full extent of country which they covered; for there is nowhere any sign of thinning away of the group, and the truncated edges of the basalt sheets are seen, often to a thickness of many hundreds of feet, in the precipitous cliffs which form the coast-line in the north and west of the island.

Apart from local variations, the volcanic group has, throughout the large continuous area which it occupies in the north-western half of Skye, a *general dip to westward* or to some point south of west. In accordance with this we find that, while on the east side Jurassic rocks are almost everywhere seen beneath, and are exposed near Broadford and Portree to some distance inland, on the west coast the volcanic rocks descend in most places below sea-level, though probably to no great depth.<ref>On Loch Harport Jurassic sandstones were brought up as cores in boring for the foundations of the new pier, about 500 yards beyond the Talisker Distillery at Carbost. The spot is covered by about 21 feet of water at high tide, and the borings were only 6 or 7 feet deep.</ref> But although the general decline of the base westward, and the principal exceptions to this, are the results of subsequent disturbance, many of the minor irregularities are to be attributed to the unevenness of the old land-surface upon which the earliest volcanic rocks were erupted. Prior to the volcanic epoch the pre-Tertiary strata had been both disturbed and deeply eroded. The volcanic rocks thus repose in different places on different members of the Jurassic and older systems. In the north of the island they rest on the

Oxfordian group and the Great Estuarine Series; farther south on the Lower Oolites, and then on the Lias. At Sconser on one side of the island, and near the Sound of Soay on the other, they pass from Jurassic strata to Torridon Sandstone: then to the east of Blaven they rest on Jurassic rocks again, and in the Strathaird peninsula on higher members of the Jurassic. At Creag Strollamus, north of Beinn na Caillich, the volcanic rocks are again seen on Torridon Sandstone, and in some of the patches enclosed in the Beinn na Caillich granite there are little outliers resting on the Cambrian limestones. Only three-quarters of a mile from Creag Strollamus, on the opposite side of the Sound of Scalpay, the bedded basalts lie on strata of Cretaceous age, and this is the case also, as Mr Clough has discovered, at one point on the Sound of Soay.

The volcanic series of Skye, so far as it is preserved, consists almost wholly of lavas of *basic and sub-basic composition.* At one place only, on the northern border of the Cuillins, do we find the relics of a group of sub-acid and acid lavas and tuffs. Excluding these from present consideration, the uniformity of general characters from base to summit of the series is very striking. At the base of the whole, certain local accumulations of volcanic agglomerates and tuffs prove that the volcanic era was ushered in, in places, by outbursts of a paroxysmal kind; but the great succession of lavas above is practically unbroken by any pyroclastic deposits worthy of notice.

The *thickness of the group,* or rather of that portion of it which has survived the energetic erosion of later Tertiary times, must be very considerable; but there are serious difficulties in the way of framing even an approximate estimate of it. These difficulties arise chiefly from the monotony of lithological characteristics, which makes it by no means easy to detect the faults which certainly intersect and displace the rocks, and impossible in general to determine the throw of such faults. If we could overcome this obstacle and calculate the thickness of the whole pile which builds the moorland plateaux, we should still have to restore in imagination the portion removed, and then to deduct from the total the aggregate thickness of the intruded sills, which in many parts of the district surpass in importance the lavas themselves. From the altitudes attained by the group in such places as the Quiraing, the Storr Rock, etc., we may at least infer that the total thickness of lavas and sills together considerably exceeds 2000 feet, and of the lavas alone 1000 feet. This is not the full thickness of the group, and there are places, such as the Isle of Scalpay (Figure 2), where lavas free from sills mount up to a thickness of 1500 or 1600 feet.

The impossibility of compiling any estimate, from horizontal sections may easily be made apparent. The base of the volcanic series is exposed at Peinchorran and Balmeanach, north of Loch Sligachan. From thence, following the direction of dip, viz. W. by S., we arrive at Carbost pier on Loch Harport in about 9■ miles. The dips along this line vary usually between 10° and 20°, with an average of about 16°, and hence, if the succession were an unbroken one, we should have crossed a thickness of some 14,000 feet. Nevertheless, at Carbost pier the base is again found only a few feet below sea-level. Making any reasonable allowance for the uneven form of the old land-surface on which the lavas were poured out, it is still manifest that in the traverse specified we must have crossed faults with a downthrow towards the east amounting in the aggregate to many thousands of feet. A section across the northern part of the island would bring out the same point, for it is evident that the observed dips would, if the succession were unbroken, carry the basalts far below sea-level on the west coast. The faults, the existence of which is thus proved, may often evade notice in mapping, owing to the impossibility of distinguishing horizons in the series and to the concealment of much of the ground by drift and peat. Along the coast northward from Loch Sligachan, where Jurassic strata are exposed below the basalts, such faults as occur can of course be verified and their effect esti mated; but, since this coast runs nearly along the strike of the volcanic rocks, it contributes no information germane to the question. In places where the circumstances are most favourable to investigation, as in the Talisker district, numerous strike-faults can be verified, the downthrow being in general towards the east (Figure 3); and it is safe to assume that the essential structure of the whole plateau country is that of a succession of gently tilted strips separated in this way by strike-faults. This is the type to which Powell<ref>*Amer. Journ. Sci.* (3), vol. xii., p. 419: 1876.</ref> has given the name of "Kaibab Structure"

The same reasons which make it impossible to frame a just estimate of the thickness of the volcanic series also preclude its subdivision. Excepting only some rather important accumulations of volcanic agglomerate which occur at the base of the series in the central mountain district, all intercalations of pyroclastic and stratified deposits among the lavas are minor and strictly local incidents which cannot be correlated with one another. The lavas themselves show on the whole a remarkable uniformity of general characters, and such varieties as occur we have not been able to connect with different horizons in the series. Even the division into a Lower and an Upper group, well marked in Antrim, cannot be made out in

Skye. More accurately, it can be made out in one locality only, where a group of acid volcanic rocks is interposed in the midst of the basalts, and may possibly correspond with the rhyolites, etc., which in Antrim occur between the two divisions of the basalts.

It has long been recognised that the British Tertiary volcanic rocks were *of subaerial origin.* Professor Judd and Sir A. Geikie have both pointed out in more than one place the abundant evidence of this offered in all parts of the region; and the contrast with undoubted submarine volcanic series, such as those of Lower Palaeozoic age in North Wales and elsewhere, is sufficiently marked. In the Tertiary area we find on the one hand no marine deposits interbedded among the lavas, and on the other hand, what is even more convincing, the direct evidence that at many stages, which represent short pauses in the long succession of eruptions, individual flows remained as actual land-surfaces for sufficient time to allow of the formation of a soil and the growth of terrestrial vegetation. The only detrital and sedimentary accumulations which occur are certain river-gravels and lacustrine deposits, always of local distribution.

The evidence of terrestrial conditions afforded by the contemporaneous weathering of the basalts and the growth of vegetation is particularly well marked in Antrim; and in that district a continuous group of clays, lithomarges, pisolitic iron-ores, etc., including a tuff with good plant remains, is traceable throughout a large part of the area. In Skye, where the lavas are perhaps thicker, they seem to have been poured out with fewer, or at least shorter, pauses. Clays are found, however, in some parts of the area, as will be noticed below, and vegetable remains are also known in numerous places. The plant-beds of Skye have not yielded specimens comparable in perfection with those from Ballypallidy in Antrim, Ardtun Head in Mull, and the Isle of Canna, by which the Eocene age of the volcanic series has been determined;<ref>See Starkie Gardner and von Ettingshausen, *Monograph of the British Eocene Flora,* vol. *ii., Palaeontograph. Soc.:* 1883–1886.</ref> but thin beds of lignite and coal are found not infrequently in some parts of the island. Coal has been worked at Portree Harbour, Camastianavaig, Strathaird, etc.,<ref>At several places in Skye, including Strathaird, inconstant seams of coal in the Jurassic have also been worked.</ref> but only on a small scale, the beds, though sometimes as much as a foot thick, having no great lateral extent. The coal is usually impure, but this is not always the case; at An Ceannaich, south of Dunvegan Head, for instance, Sir A. Geikie has remarked a seam of coal, about a foot thick, of remarkable purity. He cites this as an example of a mode of occurrence not infrequent, the carbonaceous band forming the highest member of a small group of sediments intercalated between two flows of basalt.<ref>*Quart. Journ. Geol. Soc.,* vol. lii., p. 341: 1896.</ref>

Concerning the accumulations of vegetable origin, we have nothing to add to the brief accounts given by Macculloch,<ref>*Descr. of West. Isl. Scot.,* vol. i., pp. 360–362: 1819.</ref> Sir A. Geikie,<ref>*Quart. Journ. Geol. Soc.,* pp. 341, 342: 1896.</ref> and others. It is a fact perhaps worthy of notice that the carbonaceous deposits associated with the basalt group are quite as much mineralised as some of those in the Jurassic strata (*see* analyses), and seams from 1 to 3 inches thick in some places consist of very pure coal. Coal of less pure nature may form beds of six inches or even a foot in thickness. These carbonaceous deposits are often associated with thin stratified (lacustrine) tuffs, or again with volcanic (fluvia-tile) conglomerates, as already noticed.

	I	A
Water	10.00	11.494
Gas	36.40	35.077
Residual Carbon	50.16	45.183
Ash	3.44	8.246
	100.00	100.000
Specific gravity		1.373

I. Lignite, Ardmore Point, Vaternish; "in a bed 18 inches thick, mostly tree trunks, overlaid by a bed of amygdaloid, with an intervening bed of red clay one foot thick": anal. Heddle, *Mineralogy of Scotland,* vol. *ii.*, p. 183: 1901.

A. Lignite, Brora, Sutherland; in Jurassic strata: *ibid.*

It has been stated above that the basic lavas were poured forth, not from large orifices, with their external apparatus of cone and crater, such as in popular parlance are connoted by the term volcano, but from *fissures,* the insignificance of

which individually was more than compensated for by their vast number. The grounds for this statement are, in brief: the enormous volume and extent of the extravasated lavas as a whole, in contrast with the limited dimensions of the several flows which collectively build up the pile; the almost total absence of the pyroclastic accumulations which are the chief products of most volcanic vents of the central type; and the fact that the lavas, as a group, show no indication whatever of thickening towards particular centres and dying out as we recede from such points. They show, indeed, as has been remarked above, no sign of dying out at all: the area which they now occupy in Skye is certainly only a part of their original extent, and probably but one relic among others of a continuous lava-field of vastly greater dimensions.

It is necessary to say a few words about the supposed basal wrecks of large central volcanoes, upon which Professor Judd has laid much stress in developing his views of British Tertiary vulcanicity. One of these is situated in Skye, and consists of the large masses of gabbro and granite which constitute the mountain tract, these representing, in that geologist's view, the core of a volcano which once rose 12,000 or 15,000 feet above a base about thirty miles in diameter. Professor Judd's papers, as well as those by Sir Archibald Geikie combating his conclusions, are cited in the Appendix. It will be sufficient in this place to say that our survey proves these plutonic rocks, both gabbro and granite, to be *younger* than any extravasated lavas in Skye. Partly they break abruptly through the older strata, though without any indication that their molten magmas ever found exit at the surface above; partly, and more usually, they are intruded as large irregular sheets or lacolites at or near the base of the volcanic group. In both modes of occurrence they produce intense metamorphism in the volcanic rocks in their neighbourhood, and enclose numerous patches of those rocks, also in a highly metamorphosed condition. We shall have occasion to remark below that there are both gabbros and granites, nowhere exposed at the surface, belonging to an earlier date; but, as the evidence for the existence of these is their occurrence as fragments in the agglomerates at the base of the volcanic series, they are manifestly *older* than any of the volcanic rocks. If, as is possible, there do exist plutonic rocks of the same general age as the basaltic and other lavas, representing the unexhausted portion of a great subterranean reservoir from which those lavas were drawn, they must be situated at a great depth, and must have an enormously greater extent than the gabbro and granite masses of the Skye mountains. Also, in view of the great predominance of basic types among the lavas both of Skye and of other parts of the "petrographical province", it is clear that, among such hypothetical plutonic masses, granite can play at most a very subordinate role.

We may picture the channels through which the lavas rose to the then surface as ordinarily straight vertical fissures, which would naturally be occupied, when volcanic activity finally died out, by the latest uprise of the molten magma: in other words, they must be represented now by dykes of the same general composition as the extravasated lavas themselves. Such dykes are often seen in profusion where the lavas have been stripped by erosion from the adjacent rocks. They are of moderate width, a few feet at most, running in nearly straight lines in directions which do not vary much from N.N.W.–S.S.E., or N.W.–S.E., and composed of basalt and dolerite. It is not to be assumed that all dykes in the district answering to this description represent feeders of the lava-flows: we shall have to point out below that some were possibly feeders of the intrusive sills, while very many — probably the majority — are of still later date. Generally speaking, the number of dykes which traverse the lava-series becomes smaller, in any given locality, as we pass upward. This is very largely due to the resistance offered by the often massive intruded sills to the passage of later dykes; but no doubt it is owing also in some degree to the fact that those dykes which represent the feeders of the lavas necessarily terminate each at its appropriate flow.

It would be satisfactory to verify in some instances by ocular demonstration the presumed continuity of dyke and lava-flow, but no undoubted example of this has come under our notice. There would be in any case small chance of the relation being often displayed, and it is to be remembered that the lavas, in consequence of their proneness to disintegration under subaerial agencies, are rarely well exposed. All the salient features in the basalt country are formed by the intrusive sills, and for long distances the lavas themselves are never seen except perhaps in the bed of an occasional burn.

It appears that the form of the upward channels, while in the great majority of cases a straight fissure, was liable to some modification in form in traversing certain rocks. An interesting illustration of this occurs to the south of Creag Strollamus, in the Broadford district. The base of the lavas is here seen resting on the Torridon Sandstone, which in this part of Skye is a massive close-grained grit, and very near this spot passes locally into quartzite. This rock, as we shall have occasion to note in a later chapter, is of a singularly obdurate nature as regards admitting the passage of dykes. At this place,

extending for 500 yards along the N.W. side of Allt Fearna, we have a surface of Torridon Sandstone from which the lavas have been stripped away. With the sandstone we see little patches of basalt, the largest not much over a hundred yards in length. They resemble the lavas which come on in force a short distance away, but they are not outliers of them. They do not lie on the surface of the sandstone, but traverse it and are involved with it in an intricate fashion. The larger outcrops are long in comparison with their breadth, and their long axes have the direction of the dykes of the district. They are too irregular in outline to be termed dykes, but we must regard them as the analogues of the dykes seen in other kinds of country-rock, and as representing the channels by which the lavas rose through the Torridon Sandstone at this place. It is noteworthy that in this neighbourhood, *e.g.* N.E. of Loch Cùil na Creag, the lavas occasionally enclose fragments of sandstone. In general the lavas of the district are remarkably free from inclusions of any kind.

Another locality which exhibits remarkable relations between the lavas and the rocks through which they have been erupted is the northern slope of Creagan Dubha,<ref>The Ordnance Survey does not place the name correctly: on the six-inch map the crags are called Coire Garbh, this name belonging to the corrie on the east.</ref> the basaltic crags immediately north of Beinn Dearg Mhòr (of Strath). Here several small patches of grit, probably Liassic, are involved in the lavas. As they are found up to about 200 feet from the base of the lava-group, their presence is not easily explained.

The *thickness and extent of the individual flows* is a question of importance with reference to the hypothesis of fissure-eruptions. The evidence on this point' is chiefly of an indirect kind, for it is not always possible to determine by inspection the actual line of junction of two flows, and, as has been said, exposures showing any considerable total thickness of the lavas are rare. A criterion often applicable in other regions, viz. the vesicular or scoriaceous character of the upper and lower surfaces of a flow, fails us here, because the lavas are as a rule vesicular throughout. This fact is perhaps sufficient in itself to suggest that the flows are thin and numerous, and more positive testimony to the same effect is not wanting. We shall describe later the important group of dolerite sills which are intruded with remarkable regularity along the bedding of the lavas. In some places these sills are of small thickness, and are intruded at short intervals in the vertical succession. If we assume that the lava between two such sills represents in each case a single flow, we find that the average thickness of the flows may be about 20 feet or somewhat less. This is probably an over-estimate, for we are scarcely warranted in assuming that every divisional surface between the lava-flows has been injected with the sill-magma.

In one place, as will be shown later, we get a more definite insight into the manner in which the great mass of basalts is built up by many small overlapping flows. This is in An Fhionn-choire, on the northern border of the Cuillins, where we have intercalated among the basic lavas a group of rhyolitic and other rocks which are very different from them. Here it is seen that these acid rocks dovetail into the basalts in a fashion which proves that the latter, as well as the former, are of very complex constitution, consisting of many comparatively thin sheets which rapidly thin out in a lateral direction (*see* (Figure 9), below).

In other places, and especially in the Talisker district, the individual flows may be picked out by the effects of contemporaneous atmospheric weathering, which has produced advanced decomposition in the upper surface of one flow before it was covered by another. Here again we find ample confirmation of the statement that the great thickness and extent of the basalt group results only from the superposition and overlapping of a vast number of separate flows, each of which is of very insignificant dimensions.

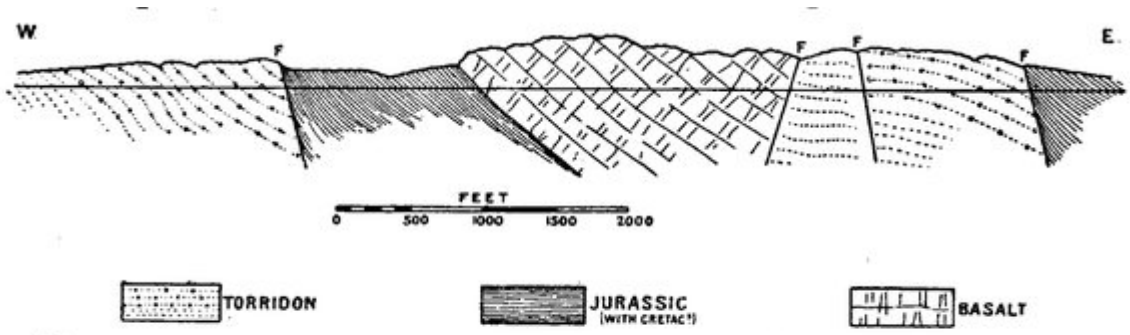

FIG. 2.—Section in the southern part of the Isle of Scalpay, showing a faulted area of the basaltic lavas, resting on Jurassic and Cretaceous strata and thrown against the Torridonian. Scale, 3 inches to a mile.

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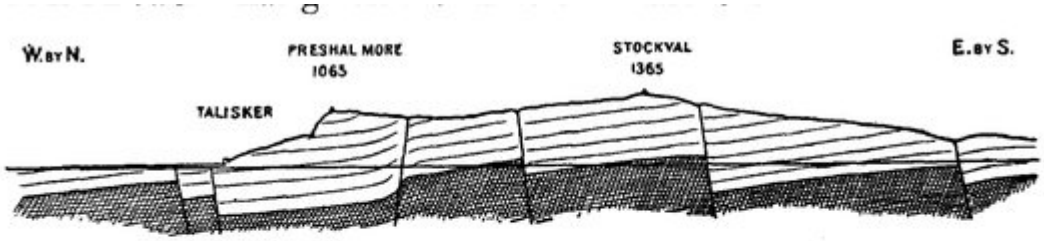

FIG. 3.—Section from Talisker Bay through Preshal More and Stockval to the Eynort River, to illustrate the structure of the basalt plateaux. The general dip is westerly, while the important faults usually throw down to the east. It is probable that the base of the volcanic series is in no place very far below sea-level. Scale, 1 inch to a mile.

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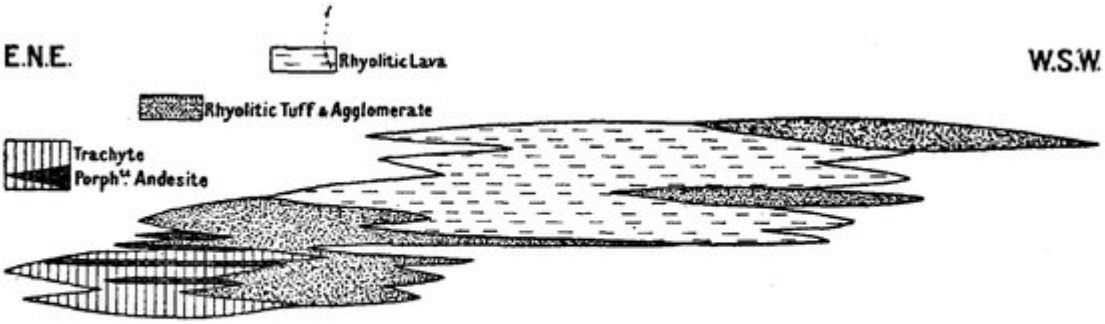

FIG. 9.—Diagrammatic representation of the relations of the trachytic and rhyolitic rocks to one another and to the basalts. The figure is an ideal general section of the group, not drawn to true scale.

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