Chapter 25 General review of Tertiary igneous activity in Skye

In the previous chapters we have given in detail the results of our study of the Tertiary igneous rocks of Skye, both in the field and in the laboratory. We have endeavoured to range them in natural groups, each belonging to a defined epoch, and these have in general been treated in chronological sequence. The departures from such order have ina few instances been dictated by convenience, to avoid repetition: more often they have been necessitated by the imperfection of the record or by our failure to decipher it. We have now to summarise the principal events during the prevalence of igneous activity in Skye in the earlier half of Tertiary time; at the same time touching upon certain considerations with respect to the origin and mutual relations ofthe rocks, which arise naturally from such a general review of observations already recorded. That the assemblage of igneous rocks described in the foregoing pages may be treated as a connected whole will be generally conceded without formal discussion, and has been implicitly assumed in the course of our account of the rocks. Our investigation therefore, though deficient in certain particulars, affords the requisite data for tracing to some extent the progress of igneous activity in its various manifestations from the earliest to the latest stage. The area studied, though but a small part of a vast region throughout which similar conditions prevailed contemporaneously, is wide enough to have furnished us with a large body of facts ; it is in some respects anatural district complete in itself, especially as containing one of the principal centres of plutonic intrusions ; and authorities, who differ widely in their interpretation of what is seen there, have agreed in regarding it as a pattern of the whole region.

One aspect of the subject upon which we have not yet touched is the relation subsisting between igneous activity and differential movements of the earth’s crust, regarded as the expression of the forces by which they were brought about. The starting-point of any consideration of this kind is the general principle that important outbursts of igneous activity have always been closely bound up with great crust-movements in the same region and, in a broad sense, of the same age. As applied to the European area, this principle has been admirably worked out by M. Marcel Bertrand.<ref>Sur la distribution géographique des roches éruptives en Europe. Bull. Soc. Geol. Fra. (3), vol. xvi., pp. 573–617: 1888.</ref> He points out that the Tertiary and post-Tertiary igneous rocks of Centraland Southern Europe stand in intimate relation with the folding which has given rise to the Alpine system of mountains. At the same time he recognises in addition an extra-Alpine suite of Tertiary eruptions, including those of the British Isles, which form part of a more or less continuous belt along the western border of the Old World. Bertrand associates these also with crust-movements, but with movements of a larger order than those which originated the Alps: he connects them with the depression of the Atlantic basin.

While this commends itself as a general conclusion to provisional acceptance, it must he remembered that the Alpine system of movements was felt at least in some degree in England, and we cannot assume that the Inner Hebrides lay wholly beyond the possible scope of minor disturbances of a like kind. The effect will be recognised there, if at all, only asa subordinate factor modifying the operation of the larger one, or, it may be, rising locally to the first importance. The significance of this point lies in the fact that the two systems of movements belong to different types, characterised by different manifestations of igneous activity. The Atlantic system is of the plateau-building type, consisting in differential movements in the vertical sense, which express themselves in monoclinal folding or (as in our case) faulting: the Alpine system is of the mountain-building type, involving more or less of the element of lateral thrust, and resulting in anticlinal folding or (if proceeding to an advanced stage) isoclinal folding and reversed faulting. In the Inner Hebrides we seem to recognise not only the former but, in an early stage of its development, the latter also; the one affecting the region as a whole, the other making itself apparent in certain limited districts. To the former belong the voluminous fissure-eruptions, the numerous and extensive sill intrusions, and the great system of parallel dykes: to the latter belong the central volcanic outbursts, the plutonic intrusions forming bosses and great laccolites, the radial and other special groups of dykes, etc. In brief, recalling the distinction enforced in former chapters between regional and local groups of intrusions in our area, we connect these with the regional and local systems of crust-movements respectively.

We may conceive the crust of the earth in the British area as being during the earlier half of Tertiary time, or at frequent epochs during that time, in a state of strain; and both crust-movements and igneous activity may be regarded as attempts to relieve that strain and restore internal equilibrium. The crustal strain was made up of two elements: firstly one of uniform type over the extensive region, and related doubtless to events of a large order, such as the Atlantic depression as suggested by Bertrand; and secondly, superposed upon the first in certain places and there becoming paramount at certain epochs, systems of strain related to particular centres of disturbance.

Apart from possible vertical movements affecting the whole area in common and not to be detected by the survey of a small tract, the regional strain found expression in faulting and monoclinal tilting of the faulted blocks. But these were not the first nor the last events falling under this category. The normal result of the condition of strain, recurring many times, was the formation of sub-parallel (N.W. or N.N.W.) fissures, in which molten rock-magma, rose forming dykes ; and in the earlier part of the time these uprisings of magma reached the surface as volcanic eruptions. If at any later epoch the magma again found exit at the surface, no evidence of this is preserved in Skye. The dyke-fissures, of all ages, were apparently not lines of differential vertical movement : the earlier ones at least are never connected with faults. The faulting and tilting of the tract clearly belong, in the main if not wholly, to a subsequent epoch, 1ater than the plutonic phase, and later too than the intrusion of the great group of sills;<ref>This is to be understood as applying to the regional, not to the local disturbances</ref> for the sills are broken by the faults and tilted in common with the bedded rocks. The strain then was relieved first by the uprise of molten magma through fissures communicating with the surface, then by the uprise of magma which did not find exit but was injected along bedding-planes; only after this did bodily displacement of solid rock-masses come into play in the form of faulting and tilting.

One point which is perhaps of sufficient interest to warrant a short digression is the relation of the Tertiary crust-movements to earlier movements in the same region. Although the older rocks are concealed over the greater part of Skye, there are not wanting indications of pre-Tertiary movements of the plateau-building type, expressing themselves in considerable dislocations with the monoclinal arrangement. The effect has been to produce a general westerly dip with normal faults throwing down to the east. The most important of these pre-Tertiary faults actually exposed is that which our colleague Mr Wedd has laid down along the Abhuinn nan Leac valley and east of the Blaven range. In the system of movements thus brought to light we seem to find a foreshadowing of the like movements which have subsequently affected the Tertiary rocks themselves.

This point comes out more clearly when we turn from regional crust-muvements to those which belong to the local category. Between the time of the great post-Silurian disturbances, when the Torridonian strata were thrust over the Cambrian, and the Tertiary volcanic period, with which our more immediate subject begins, there were at least two epochs of local differential elevation in Skye; one anterior, and the other posterior, to the deposition of the Triassic and Jurassic strata. In both cases the result wasa relative upheaval of what are now the mountain districts.

As regards the pre-Triassic elevation, we note first the distribution of the Paleeozoic rocks. The base of the Mesozoic in Skye rests usually upon the Torridonian. This is still true in part of the belt surrounding the gabbro and granite intrusions, when the relations can be examined.<ref>North and west of the Cuillins the base of the Mesozoic is nowhere exposed.</ref> When we come to the eastern Red Hills, however, we find indications that at some places the upper portion of the Torridonian had been removed prior to the deposition of the Mesozoic rocks, and at other places clear evidence that the whole of the Torridonian had been so removed. The Mesozoic rocks rest on the Cambrian on both sides of the Beinn an Dubhaich anticline, showing that that feature is in part of pre-Mesozoic date. The arrangement of the Mesozoic rocks themselves affords similar evidence, for the lower members of the succession in places overlap one another in the direction of the mountains. This again is most evident in theeastern part of the district. The Triassic conglomerate at the base is well developed on Raasay, at the N.W. corner of Scalpay, and in the country east and south of Broadford. Passing westward from this last locality, however, we find that between Beinn an Dubhaich and Glen Boreraig the conglomerate is overlapped by the Lower Lias, so that the limestones of this group, and finally the succeeding shales, come to rest on the Cambrian limestones. Farther north the evidence is very fragmentary, the boundaries being mostly faulted; but the conglomerate is not seen in the Beinn na Caillich district, and evidently dies out too towards Sligachan. Around the Cuillins the relations are almost everywhere concealed below the basalts, and in places below sea-level. The Trias conglomerate appears as a very small patch on the shore of the Sound of Soay, but is immediately overlapped by the Lias. Summarily, we see that there was a certain amount of elevation in pre-Triassic times, which may have affected in some degree the whole of the mountain district of Skye, but was at least most marked in the eastern part of the district, where at a later epoch occurred the boss-formed Tertiary intrusions, themselves attended by local uplifts.

By like evidence we can prove local elevation of the same general character at some epoch post-Jurassic but pre-Tertiary, or at least anterior to the oldest Tertiary rocks of Skye. The fact that the volcanic group rests on different formations in different places is of course attributable mainly to the regional system of disturbances (with concurrent erosion), but local elevations in what is now the mountain tract are also clearly indicated. As we travel towards the mountains, e.g. southward from Portree or northward and westward from Strathaird, we find that the Tertiary volcanic rocks rest first on the Oolites, then on the Lias. Still nearer to the mountains, e.g. on the shores of the Sound of Soay, they pass from the Lias to the Torridonian. To the north of Beinn na Caillich the basaltic lavas rest on the lower part of the Torridon Sandstone. On the site of Beinn na Caillich itself we find that even the Torridonian had been stripped away prior to the volcanic epoch, for in the enclosed patches within the granite the lavas are seen lying upon the Cambrian limestones; first upon the upper and then upon the lower of the zones of limestone present in the district. We infer that in this case too the elevation was most marked in that part of the area where subsequently occurred the boss-formed intrusions with their attendant uplift. Whether such post-Jurassic but pre-Volcanic elevation belongs to a single epoch or to two distinct epochs, one Mesozoic and the other post-Mesozoic, we are not able to decide. Cretaceous strata have been detected at two places near the border of the plutonic intrusions, viz. by Mr Clough on the Sound of Soay and by Mr Wedd in the southern part of Scalpay, and they rest unconformably on different members of the Jurassic; but these relics are of too fragmentary a nature to decide the question.

The correspondence between crust-movements of different dates becomes very apparent where the disturbance of the strata has taken the form of definite folds, as is partly the case in the eastern portion of central Skye. The clearest instance is seen in the curved anticline of Ben Suardal and Beinn an Dubhaich. Here the Cambrian and the overlying Torridonian, with the surface of overthrust dividing them, are thrown into a sharp anticlinal fold. This, as we have seen, is partly of pre-Triassic age. The Mesozoic strata, however, on the two flanks of the ridge also dip away from the axis, though at lower angles, proving a later folding on the same line. Possibly some part of this later folding was accomplished at the time when the granite was intruded as an elongated boss in the core of the anticline, but it seems in the main to have antedated the volcanic outbursts.<ref>The bedded volcanic rocks have been removed by erosion from this neighbourhood. The nearest lavas rest on the grits of the Lower Lias.</ref> We see then that at this place there has been anticlinal folding on the same axis at two (or more probably three) widely separated epochs. The tendency of later folding to follow the same lines as earlier folding in a given district seems, according to Bertrand<ref>See especially M. Bertrand, Sur Ja continuité du phénomene de plissement dans le bassin de Paris, Bull. Soc. Géol. Fra. (3), vol. xx., pp. 118–165 ; 1892.</ref> and others, to be a law of considerable generality.

In Tertiary times there were repeated disturbances of the earth’s crust at the old centres which seem to have been more or less clearly marked out before the close of the Paleozoic era; but these disturbances were now closely bound up with successive episodes in the igneous activity of the Skye focus. The nature of this relation, involving the question of how far the disturbances were the cause, how far the consequence of the igneous eruptions, is a subject not to be discussed here. In the most general view we may, as suggested, regard the two classes of events as alike the effects of a common set of causes.

We turn now from tectonic to petrographical considerations. Assuming all the Tertiary igneous rocks of Skye to belong to one connected suite, we must suppose them to have had in some sense a common origin; and the simplest form of this hypothesis is that which regards the various rocks as products of " differentiation " from one common stock, viz. a large body of fluid rock-magma initially of uniform composition and occupying an intercrustal reservoir at some unknown but probably very considerable distance beneath the surface. Such a hypothesis is not susceptible of deductive proof, but it is in harmony with conceptions now very prevalent among petrologists, and it will be provisionally adopted here as the starting-point for what follows.

SiO_2	49.36	49.49	58.98
TiO_2	1.86	1.60	0.52
Al_2O_3	16.45	15.87	15.41
Fe_2O_3	4.17	4.43	4.78
FeO	6.46	6.27	2.70
MnO	0.18	0.32	0.41
MgO	6.40	6.10	3.71

CaO	8.89	9.02	4.83
Na_2O	2.57	2.78	3.18
K_2O	1.25	1.50	2.77
H_2O	2.44	2.27	2.17
P_2O_5	0.11	0.11	0.21

I. Mean composition of Tertiary igneous rocks of Skye, calculated from 8 parts basic lavas, 3 parts basic sills, 1 part gabbro, and 1 part granite.

II. The same from the mean of 23 analyses taken without selection.

III. Mean composition of British igneous rocks of all ages, for comparison, being the average of 536 analyses taken without selection. The Fe_2O_3 is too high, and the FeO too low, the total iron having in many of the analyses been estimated as ferric oxide.

The first and most obvious point concerning this initial homogeneous magma is that it must have been of thoroughly basic composition, at least if it is fairly represented by the rocks brought to light by erosion. Those which play the most important part as regards bulk are the basalt lavas and associated dolerite sills. If for the purpose of a very rough estimate we suppose these to make up three-fourths of the whole, and to be in equal amount, and if we divide the remaining quarter equally between gabbro and granite, then, on the basis of analyses already given, we find the mean composition of the whole to be that given below in column I. It is clear that by altering in any reasonable manner the estimated proportions of the several rocks, by allowing for the peridotites and the dykes, etc., no very material difference would be made in the result, Or if we simply calculate the mean of such analyses as we possess of the rocks, without selection,<ref>One only has been omitted, viz. that of a thin ultrabasic "schliere" in the banded gabbros, analysed on account of its peculiar composition, but not representing any important rock-mass.</ref> we get practically the same result (II.). For comparison we give in column III. what may be taken as the mean composition of British igneous rocks in general, calculated from a large number of analyses.<ref>See Harker, On the Average Composition of British Igneous Rocks, Geol. Mag., 1899, pp. 220–222. The figures here given are calculated in the same way, but include additional analyses. </ref> The great preponderance of basic types among the Tertiary igneous rocks is true not only of Skye, but of the other Western Isles, with Antrim, and of the much larger region of which the British area is only a fragment.

Another point in the general petrography of the suite of rocks is that they belong entirely to one of the two great branches of igneous rocks, viz. to what Iddings styles the "Sub-alkali" as distinguished from the "Alkali" Group. This appears in the analyses and equally in the mineral composition of the rocks. Types rich in alkali-felspars, without free silica, are of very exceptional occurrence; the "felspathoid" minerals, viz. leucite, nepheline, sodalite, and primary analcime, are almost, if not quite, unrepresented<ref>Nepheline is stated to be present in a thick sill in the Shiant Isles (Heddle, Mineralogy of Scotland, vol. ii, p. 46; 1901), and analcime occurs in a sill in the south of Arran (Corstorphine, Tsch. Min. Petr. Mitth. (N.S.), vol. xiv., p. 464; 1895). This latter mineral was regarded by the author named as secondary after nepheline, but to the present writer it seems more probably a primary constituent of the rock : see Geol. N. Arran, Mem. Geol. Sur. Scot., pp. 112–114; 1903.</ref>; and an alkali-bearing amphibole is known from but one place in Skye and one other occurrence among British Tertiary rocks.

If the entire suite of rocks has originated from a common stock-magma, once homogeneous, we have to recognise that here typical acid rocks, such as granites, have been derived by processes of differentiation from a basic magma. Further the differentiation which gave these acid rocks was completed, as regards some portion at least of the magma, at a very early stage; indeed at an epoch antedating any known intrusion or extrusion in the area. This is proved by the oldest of all the igneous rocks dealt with above, viz. those which supplied fragments to the volcanic agglomerates of the earliest outbursts. We have already seen that the material of the agglomerates in certain parts of the island indicates the prior existence of both gabbros and granites which have not anywhere been brought to light as rock-masses. These rocks must have been consolidated either in some part of the primitive reservoir itself or as intrusions from that reservoir at lower horizons than those of any rocks exposed in the district. The acid rock, or part of it, must have been in some sense intrusive, for some of the gabbro fragments are traversed by granite veins; but this might conceivably happen within the original reservoir itself.

Acid rocks more or less closely resembling in composition the granite fragments in the agglomerates have been extruded or intruded within our area at several distinct epochs during the succeeding events. In proof of this we may adduce the local rhyolitic eruptions, the granite and granophyre intrusions of the Red Hills, and the later granophyric and felsitic dykes, etc.; to which may be added the xenoliths and xenocrysts of acid material enclosed in certain groups of basic dykes, such as those of the Suardal district. This recurrence of similar rock-types within a given area points to one of two explanations as a priori possible. Hither differentiation has operated along identical lines, at the same centre, at wide intervals of time; or a considerable body of acid magma, separated at a very early stage, has remained throughout the whole time as an available source, which has been drawn upon at several distinct epochs. We may conceive this body of acid magma, or rather the unexhausted portion of it at any time, as contained within the primitive magma-basin or reservoir, and may further suppose a part or the whole of it to have been consolidated and re-fused more than once in that situation. Of the two alternatives, the latter, as thus qualified, has the advantage of simplicity, and is more in accordance with some of the special phenomena observed. It is probable, however, that we must further modify our conception by supposing that the processes which gave birth to the acid magma, though completed within a certain limited portion of the deep-seated reservoir at a very early epoch, enlarged those limits progressively during later stages. The granite fragments in the volcanic agglomerates, the granite and granophyre intrusions of the Red Hills, the later acid dykes, and the acid xenoliths in the later basic dykes indicate a gradual extension of the area involved from stage to stage.

Although we have appealed primarily to the distribution in time and space of the acid rocks, we might draw confirmatory testimony from other rock-types. Especially is this seen when we consider together the gabbro and the granite, rocks which in any view must be regarded as of closely cognate origin. We have already pointed out that the fragments of these rocks in the basal agglomerates show a certain defined areal distribution, which is in remarkable agreement with that of the later and somewhat more extended plutonic intrusions of like rocks. This seems to indicate a certain differentiation and separation in a lateral or horizontal sense, as between the gabbro and the granite, outlined at a very early time but persisting later. It is clearly traceable throughout the succeeding phase of minor intrusions.

We have then good reasons for supposing that differentiation to an advanced degree was effected in a part of the parent-magma of our rocks at a very early time in the Tertiary history of the region, and that rocks or rock-magmas of basic and acid composition coexisted throughout a very long period in different parts of a deep-seated reservoir underlying the area; these being at certain times solid rocks, at other times fluid simultaneously or almost simultaneously, or perhaps solid in parts of the reservoir and fluid in other parts. Such a hypothesis, suggested by the simpler and more obvious relations of the rocks, is greatly strengthened by a consideration of some of the more peculiar phenomena, such as the occurrence of composite intrusive masses and mixed rocks, and the great profusion of xenoliths in several groups of intrusions. These special features must undoubtedly be regarded as highly characteristic of the great suite of igneous rocks under discussion, and we are in this view able to correlate them with general features, equally characteristic, which indicate that the principal differentiation was in great part effected at a very early stage. Further differentiation doubtless went on, both in the parent magma and in "partial" magmas drafted from it, at later stages; but on the whole the progressive march of differentiation is much less marked here than in many other connected suites of igneous rocks which might be cited.

The successive episodes which make up the history of Tertiary igneous activity in Britain will not fall into their places as parts of a connected whole unless we take into account the areal distribution, as well as the sequence in time, of the several groups of rocks. Certain groups are not connected with any special centre, but have a very wide distribution, coextensive perhaps in some cases with the limits of the "Brito-Icelandic province" itself. Other groups are more narrowly restricted in space, and stand related to defined foci of activity, one of which was situated in the central part of Skye. This Skye focus, which may doubtless be taken as a type of others in the province, was initiated at a very early epoch, prior to the outbreak of vulcanism. Once established, it became the seat of renewed activity at numerous epochs during the succeeding time. These local manifestations culminated in the plutonic phase of activity, when outbursts of the regional kind seem to have been in abeyance: the succeeding minor intrusions connected with the focus give evidence of waning energy.

We have already emphasised this distinction between regional and local groups of igneous rocks in our area in connecting them respectively with the two different types of crust-movements. The distinction is no less significant from the petrographical point of view, for the rocks belonging to the local groups collectively present a much greater range of variety than those which have a regional extension. The relation between localisation and specialisation is much too striking to be regarded as accidental, and it clearly proves that the distinct foci at which activity was from time to time localised were also the principal centres of magmatic differentiation. While the rocks of the regional series are all of basic composition, with a range of less than 2 in the silica percentages of specimens analysed, those of the local series vary in different groups from ultrabasic to highly acid. Some diffferentiation there doubtless was in the former series; but the analyses already given show a much closer resemblance in composition among the basic lavas, sills, and dykes of regional distribution than among the local groups of basic rocks, such as the gabbros, the dykes of the Beinn Dearg type, and the inclined sheets of the Cuillins.

This fundamental distinction must be borne in mind in the general review of the sequence of events to which we now proceed. As regards certain of these events, the great region or "province" may be treated as a unit; as regards others, it must be viewed as an assemblage of distinct foci, at each of which development followed the same general lines. Episodes affecting the whole region alternated, and sometimes partly synchronised, with others related to the special foci; and the discrimination of these two parallel series is essential to a proper understanding of the sequence,

Here, as in numerous other areas and at various geological periods, igneous activity has manifested itself successively under three different phases, the Volcanic, the Plutonic, and the "Dyke Phase", or as we prefer to call it (in view of the important part played by sills) the Phase of Minor Intrusions. The epithet "minor" must be understood as applying to the individual intrusions, for the sills of the great group collectively surpass in volume all the plutonic masses. The three phases indicated embrace the actual manifestations of igneous activity in the form of extrusions and intrusions: as preface or prologue to the whole we may reckon those preparatory deep-seated operations, which are matters of speculation. only, and have in part been briefly glanced at.

The earliest overt act, ushering in the volcanic phase, was of the local category, and consisted in the opening of several large volcanic vents within a limited area in the central part of .the island. The eruptions were of a violently explosive kind, and the vents, enlarged by successive outbursts, attained in some cases diameters of a mile or two miles. Only in one instance is the actual funnel now exhibited, cutting through the older stratified rocks; and here the structure is that of a sharp anticline, with the vent breaking through the arch. The material which fills the vents and extends for some little distance beyond them is, as regards its volcanic element, of basic composition; but there are abundant fragments of the disrupted country rocks and, in the heart of the district, débris of plutonic rocks, probably consolidated within the deep-seated magma-basin. At this earliest epoch then our area could boast great volcanoes, a feature repeated only in a single instance in the ensuing time. There can be little doubt that the eruptions were subaérial, the land standing higher above sea-level than at present, and this state continued, probably not without considerable oscillations of level, throughout nearly the whole of Tertiary time.

The much more important eruptions which followed had a regional extension, and illustrated a totally different type in the mechanics of vulcanicity. They took the form of tranquil outpouring of lava in innumerable small flows emanating from a system of parallel fissures; and by prolonged extravasation of this kind a thick pile was built up over a vast extent of country, of which the plateaux of Skye are but a fragment. In many other regions of volcanic activity, of various geological periods, a regular succession is to be traced among the various types of lavas erupted, connecting itself with the hypothesis of progressive differentiation in a subterranean magma-basin. Thus, as Iddings has pointed out, a common sequence is one beginning with intermediate lavas and continuing with types on the one hand more basic and on the other hand more acid; *i.e.* showing an increasing divergence in opposite directions from the initial type. In our area the initial magma was not an intermediate but a basic one, and no wide departure from it on systematic lines is found. The pyroxene-andesites intercalated among the prevalent basalts do not indicate any ordered sequence. It is interesting to note that with this great outpouring of lava there were during the earlier part of the time a few small outbursts of the explosive type, and that these were more frequent and continued later in the immediate neighbourhood of the focus of central Skye.

At one place on the border of the central district there was, as we have seen, an outburst of the local series, and a central volcano was formed (Chapter 5). With this there was a resumption in part of the paroxysmal type of eruption. The products of this volcano were petrographically in strong contrast with the contemporaneous lavas of the regional series, exhibiting very considerable variety with progressive change. They were first trachytic (and andesitic) and afterwards rhyolitic. Taking into account the earlier local outbursts of basaltic nature, we have here an order of increasing acidity.

If any special circumstances attended the extinction of regional volcanic activity, the record is in this respect imperfect, for the summit of the basalt group has everywhere been removed by erosion. The volcanic phase was sharply marked off from that which succeeded, but the phenomena of metamorphism in the basalts suggest that the interval was not one of long duration.

In the *plutonic phase* regional activity was wholly in abeyance. Skye now became more clearly defined as a natural district, containing as it did one of the foci at which igneous energy was exclusively concentrated. This was included in the central part of the island, which had already experienced the local outbursts of the volcanic phase. Other centres were comprised in the neighbouring parts of Britain, the nearest being some fifteen miles distant, in what is now the Isle of Rum ((Figure 1), p. 3). The events of the plutonic phase fall into three well marked stages, characterised by ultra-basic, basic, and acid intrusions respectively. The law of succession indicated, that of decreasing basicity or increasing acidity, is one very general among associated plutonic rocks of all ages throughout the world.

The ultrabasic magma was intruded in the south-western part of the central area. It rose through fissures, and formed a number of laccolitic masses, the largest of which was at least 2½ miles in diameter and 1500 feet in thickness. The most striking feature is extreme complexity of structure. The rock-types represented range from troctolite, through picrite, to dunite, and even to seams of pure picotite; and these have been intruded in part simultaneously, so that they alternate in bands, in part successively, so that a later rock veins an earlier or is crowded with debris of it. The intimate association of these rocks proves that they come from a common stock, viz. the general peridotite magma of the district. This being itself a product of differentiation, the rock-types met with must result from differentiation of a subsidiary order, and the great range of variety compassed *in* this way seems to be characteristic of ultrabasic magmas.

The peridotites were succeeded, apparently with little or no interval, by intrusions of gabbro, which were of much greater volume and affected a much larger area of central Skye. They assumed partly the laccolitic, partly the boss-form. The mechanical conditions which determined one or the other habit were probably complex. We have already given reasons for believing that the form of the boundary of a large intrusive body depends in part upon the nature of the country rock; but the distribution of crustal strain must also have been an important factor, and perhaps the prime one. It is very noticeable, in both gabbro and granite, that the laccolitic habit prevails to the west and the boss-like to the east, the latter being the quarter in which, as we have shown, the strain was most narrowly localised and most strongly accentuated. We have shown that the plutonic intrusions cannot be considered as in any sense representing the cores of volcanoes. The gabbro has no connection with the basaltic lavas other than the remote one of an ultimate common origin from the same great magma-reservoir. Nor does it extend indefinitely downward with plug-like habit or with a spreading form, although one intrusion has for a certain vertical distance assumed the shape of a boss with perpendicular walls.

The most important body of gabbro is that from which the Cuillins and the Blaven range have been carved out. Here the magma has risen through fissures and spread in laccolitic fashion in, or in places a little below, the basalt lavas. The horizon is not very different from that affected by the chief ultrabasic intrusions, and most of the peridotites, as well as numerous lenticles of the volcanic rocks, have been enveloped by the gabbro. The great laccolite had a diameter perhaps not less than 10 miles and a thickness of over 3000 feet. The shape of its base, as displayed diagrammatically on the sketch-map ((Figure 15), p. 36), shows (i.) a general inclination towards the centre; (ii.), modifying the preceding, a general inclination to S. or S.S.E.; (iii.), exaggerating this, a sharp rise at the N.N.W. border, about Bruach na Frithe; and (iv.) another sharp rise on the N.E. side, where part of the laccolite is missing. This last, being apparently connected with the granite intrusion of Alarm), etc., must be considered the result of subsequent deformation: the other features seem to belong mainly to the epoch of the gabbro itself, and to be connected with the circumstances of its intrusion. The inward inclination of the base may be interpreted as indicating a settling down of the floor, at the time of the intrusion, to close the space which would otherwise have been left at some depth below by the abstraction of the magma from its reservoir. If this be so, the intrusion need not have occasioned any important uplift of the basaltic lavas which formed its roof. The general inclination, to S. or S.S.E., which modifies the general inward slope of the base and throws the area where the gabbro is below sea-level towards that direction, is also an original feature, not due to subsequent tilting. The base of the basalts, which is very near sea-level at Loch Sligachan and Loch Ilarport, and presumably so between those places, comes to the sea-level also at Loch Scavaig; but, while the thickness of basalt below the gabbro is great on the north and north-west sides of the Cuillins, it is very small on the south side, and disappears altogether at places near Blath-bheinn. The laccolite then has for some reason made its way in a direction related, not to the horizontal plane, but to a plane inclined towards S. or S.S.E. The high altitude of the base of the gabbro on Bruach na Frithe, though partly connected with this general inclination, is due in part to the dying out of the lower component sheets of the laccolite towards the boundary. It may, however, be more than an accident that the rise coincides very closely with the site of the old trachytic and rhyolitic volcano.

The laccolite was built up by a multitude of distinct injections, which differed somewhat in composition, though not in this respect rivalling the peridotites. It is clear that in many instances a single intrusion has included various kinds of magma, which did not mingle, but have often been drawn out into a banded or ribboned arrangement. From a chemical point of view the subsidiary differentiation thus indicated did not always follow the same lines. In particular the extreme basic modifications show a special enrichment or "concentration" in some cases of magnesia, in others of iron-oxides and titanic acid. Both differ again from the special chrome-iron-alumina concentrations of the peridotite magma. All this differentiation seems to have been effected prior to intrusion: of differentiation in place there is little clear indication except in the "segregation veins". The comparatively uniform character of the gabbro of the Broadford boss is in accord with this, and we may note a contrast with some occurrences of gabbro in other regions, *e.g.* that of Carrock Fell in Cumberland. If again there was any progressive change in the average composition of successive injections of gabbro-magma in the Cuillin laccolite, such change must have been confined within much narrower limits than the variation set up in individual injections by the subsidiary differentiation, and it is thus difficult to verify. It comes out clearly only in the latest incident of the gabbro stage, which was the injection of various aplitic and felspathic veins of relatively acid composition, carrying out the general law of increasing acidity among our plutonic intrusions.

That in some parts of our area no interval of quiescence divided the gabbro-stage from the succeeding granite-stage is sufficiently proved by the phenomena described on Marsco. We may consider the dividing-epoch to be accurately marked by the intrusions of marscoite, representing a gabbro-magma modified before (and in places after) intrusion by granite material.

The granite, like the gabbro and presumably for the same reasons, assumed the laccolitic habit in the west and the boss-form in the east. In the former case it was intruded partly beneath and into the gabbro, which it lifted and partially invaded; but apart from this overlapping, the granite is found to the northeast of the gabbro, *i.e.* on the side away from the peridotite, indicating a displacement of the seat of activity in a northeastward direction from stage to stage in the plutonic phase. Regarding all the plutonic rocks as derivatives from a common stock-magma, we may perhaps see in this distribution a sign of differentiation in the horizontal sense, and connect it with the fact that the granite itself seems to grow somewhat more acid. towards the north-east and east. We may recall too that in the gabbro laccolite the relatively acid aplitic and felspathic veins are found chiefly in the eastern and north-eastern part.

The actual form of the large body of granite and granophyre cannot be made out with any precision. In the neighbourhood of Marsco and Meall Dearg, where it was doubtless thick, it has occasioned a very considerable uplift of the gabbro; while in the Blaven range, where it was thinning away, it has assumed the same synclinal form as the gabbro above. The granite does not maintain the laccolitic or sheet-like habit with the same regularity as the gabbro, but often shows a frankly transgressive junction, especially in its eastern part. Again, though it has undoubtedly been built up by distinct injections, these are less numerous than in the case of the gabbro, and show much more uniformity of composition. These differences, tectonic and petrographic, must be considered characteristic of an acid as contrasted with a basic magma.

The boss-formed masses of granite and granophyre in the eastern part of central Skye exemplify more than one fashion of intrusion. The Beinn an Dubhaich granite has risen through the core of an old anticline, and presents very remarkable relations to the dolomitic limestones which it intersects (pp. 132–135). The Kilchrist granophyre has found its way up the sides of the old volcanic funnel at that place. The larger mass, of generally elliptic outline, which forms Beinn na Caillich and its neighbours has also broken through on the edge of the old vent, but eccentrically, and it has partly invaded the earlier boss of gabbro. That igneous activity has thus been localised here at three distinct epochs is not surprising, for we have seen that this spot had been a special centre of strain (in the sense generally of upward pressure) since Palaeozoic times. It is further interesting to notice that the strain was renewed after the intrusion of the granite boss, and was only relieved by a considerable relative upheaval at a later time. Owing to the narrow localisation of this upheaval, and perhaps in part to the nature of the surrounding rocks, the displacement in this case took the form of faulting. The north-western boundary is now a straight fault which cuts off the granite itself; and, as has been pointed out, this fault has its maximum throw in the middle part of its course and dies out both ways at or near the boundary of the granite, thus marking its connection with a vertical elevation of the granite boss. In its semicircular southern half the boundary of the granite is marked by a plexus of more or less tangential faults, the fracture here having occurred nearly along the junction of the relatively unyielding boss with the adjacent Liassic and volcanic rocks. On the eastern and north-eastern sides the granite was in intimate contact with a more stubborn mass, viz. the boss of gabbro, and the line of faulting here sweeps round at a wider radius (Figure 28), p. 131, its curiously curved line from Strath Suardal to the Sound of Scalpay emphasising its relation to the granite boss with which it is concentric. The faults, and others connected with them, cut the composite sills and some minor acid intrusions; and the elevation of the Beinn na Caillich boss is thus referred to a somewhat late epoch. It was not accompanied by any igneous intrusions.

The plutonic phase does not seem to have been divided by any prolonged interval of time from that of the minor intrusions, and one remarkable group may be regarded as in a certain sense marking the transition from the one to the other. In various regions where the record of events during one complete suite of igneous eruptions can be followed it is seen that, while in the plutonic phase the succession of rock-types follows an order of decreasing basicity, in the "dyke phase" this order is reversed. This generalisation is applicable to Skye, provided that we confine our attention to those groups of intrusions which are related to the special focus of activity; the regional groups, which show little variation of any sort, being excluded. If, with this limitation, we may regard the reversal of order in the "dyke phase" as a general law, whatever be its significance and explanation, we may expect that between the plutonic phase and that which follows there will be a certain *critical epoch,* when, if intrusions occur, basic and acid magmas may be intruded almost simultaneously. It is precisely to this epoch that we refer those composite intrusions, consisting of basic and acid rocks in intimate association, which we have described under the name of the Cnoc Càrnach group (Chapters 12, 13). In this view they belong to a point of time accurately separating the plutonic phase from that of the minor intrusions, and evince a nicely balanced state which marked a turning-point in the mutual behaviour of basic and acid magmas at the Skye focus. The rarity of such remarkable composite intrusions in other regions we should then ascribe to the fact that the plutonic phase of activity and that which succeeds it are in general divided by a period of quiescence. As regards the areal distribution of the peculiar composite intrusions of this epoch in Skye, it is to be noticed that they occupy a semicircular belt of country, partly surrounding the granite tract of the Red Hills, but lying beyond it to the N.E. They are thus on the side remote from the gabbro of the Cuillins, and carry on a step farther that displacement northeastward of the centre of activity which we have noticed in the successive episodes of the plutonic phase. (*See* (Figure 58), p. 273.)

The *phase of minor intrusions* opened with a great revival of regional activity. There was an invasion of basic magma in the form of sills, collectively of enormous volume, intruded among the basaltic lavas and the underlying strata. This was apparently not a regional episode in the strictest sense of affecting the entire region alike; but it certainly had no connection with the Skye focus. If the sills of the great group in Skye are related to any centre, it must be to one lying towards the N. or N.W., in which directions the sills become thicker and more important, while they die out towards the S.E.

The intrusion of the great group of sills was followed by a long succession of episodes, which, as we have already insisted, fall into two parallel series, the local and the regional. The former was restricted to a limited area, including and surrounding the mountain tract of central Skye, and consisted of several distinct groups of intrusions, both dykes and sheets, with *a* wide range of petrographical variety. The latter comprised a vast number of basic intrusions, in the form of dykes with a predominant N.W. or N.N.W. direction, and is less easily divided into distinct groups. For this reason it will be convenient to consider the two series separately.

In the *local series of minor intrusions* we distinguish three principal stages, corresponding with those of the plutonic phase of activity but with an important difference. The sequence in the earlier phase was — ultrabasic, basic, acid: in the minor intrusions it is — acid, basic, ultrabasic; *i.e.* an order of decreasing acidity or increasing basicity. This reversal of order in the "dyke phase" has been recognised in other regions, and attempts have been made to explain it on general principles,*<ref>E.g., see Barrow, *Quart. Journ. Geol. Soc*., vol. xlviii., p. 121; 1892</ref> but a discussion of these would lead us too far from our main subject.

The minor acid intrusions constituting the first of the three stages took the form of dykes and sheets, not often maintaining the regular disposition of typical sills. Their epoch is well marked with reference to the regional as well as to the local sequence; for, while they were later than the great group of sills, they were earlier than the generality of the basic dykes which followed the sills over the whole region. The distribution of the acid intrusions in space is rather wide, but still clearly defined, including the Red Hills but extending for a considerable distance beyond (*see* sketch-map,(Figure 58), p. 273). The later acid intrusions are thus clearly related to the same focus as the granite, and indicate a resumption of activity at that focus, on a feebler scale but over a more extended area, after a lapse of time at least as long as that required for the intrusion of the great group of dolerite sills. It appears, however, that the crustal strain which provoked the new outburst was compounded of both local and regional elements, of which the latter exercised a powerful influence on the behaviour of the minor acid intrusions. The area affected by these intrusions, though centring in the granite focus, has an elongated outline with its long axis in the direction of the regional dykes, and the acid dykes themselves have in general the same direction.

In the absence of chemical analyses, the nature of these later acid rocks can only be inferred from their mineralogical composition. They appear to be somewhat poorer in ferro-magnesian constituents than the rocks of the granite group. If we suppose them to be derived from the granite-magma, or one of like composition, by further differentiation, we may look for a "complementary" group of basic rocks rich in iron and magnesia. The rocks to which we may most probably assign this role are the dykes of the Beinn Dearg group (pp. 324–326); which have the required petrographical characters, and present the peculiarity — otherwise anomalous — of a group of basic rocks whose distribution is closely bound up with that of the granite. We have included as aberrant members of the minor acid intrusions certain highly felspathic types with little or no free silica. These find their counterparts at earlier epochs in a rare syenitic modification of the granite, described as occurring below Creagan Dubha, and in the felsitic member of the composite sill of Rudh' an Eireannaich.

The minor basic intrusions of the local series followed the acid ones after an interval which must have been of long duration, for during this time were intruded a large proportion — perhaps the majority — of the regional basic dykes. This long pause, contrasted with the rapid succession of events during the plutonic phase, we must interpret as a sign of waning energy at the Skye focus.

Just as the minor acid intrusions showed a distribution about the Red Hills, so the minor basic intrusions (of the local series) are manifestly related to the Cuillin district. Here, however, the relation is of a stricter kind, for the rocks in question are scarcely found beyond the limits of the gabbro laccolite itself. Further, the directions of the intrusions have clearly been determined by some forces centring in or beneath the interior of the gabbro tract; the forms assumed being (successively or in part simultaneously) tangential dykes, radial dykes, and inclined sheets dipping towards the interior. The striking contrast between this disposition and that found in the minor acid intrusions is in some measure capable of explanation. During the interval between the two outbursts the regional crustal strain had been relieved by faulting on a very extensive scale, and the whole country broken up into separate strips or blocks. One block which thus became in some degree isolated included the gabbro laccolite and the immediately adjacent country, and it was of sufficient extent to allow of the development of a local system of strain in its interior. The precise nature of this strain, which provoked, and was relieved by, the minor basic intrusions of the Cuillin group, offers a mechanical problem of considerable difficulty, but we should picture it as a tendency to upheaval at the centre of the area. It is perhaps significant that the system is slightly eccentric, the point towards which the sheets incline being situated a little to the north-east of the centre of the laccolite (*see* (Figure 72), p. 367). If the magma of these intrusions was derived from the old gabbro-magma, or one originally of like composition, there must have been some further differentiation of this.

We cannot estimate precisely the interval which severed the intrusions just dismissed from the next well marked group, that of the minor ultrabasic intrusions. A considerable number of dykes of the regional series cut the former but are cut by the latter. Certain rocks in Skye which are petrographically on the borderline between basic and ultrabasic perhaps belong to this interval. This seems to be the case at least with a few rocks answering to this description which are found in the Cuillins, but as regards others (such as those of the Ben Aslak type) we are in doubt as to whether they belong to the local series or the regional.

The minor ultrabasic intrusions are collectively much inferior in importance to the basic group. The principal representatives are the later peridotite dykes of the Cuillins. In their radiate arrangement they recall the preceding group, and exceptionally at places in the heart of the district they assume the "inclined sheet" habit. Their distribution in space is interesting, the crescentic area which includes them covering the western and south-western parts of the gabbro laccolite, with some extension towards the south-east (sketch-map, (Figure 75), p. 375). This embraces only half a circle, viz. the south-western half, within which the much earlier plutonic peridotites were intruded. The three principal local groups of minor intrusions in Skye show thus an evident relation to the corresponding plutonic intrusions respectively, and the reversal of the order of succession in the final phase implies therefore a reversal of the direction of shifting of the centre of activity. If we take account of the shifting indicated in the old trachytic and rhyolitic volcano of Fionn Choire, the displacement throughout the three successive phases of igneous activity seems to have been of an oscillatory kind, as follows:

Volcanic — from N.E. to S.W.

Plutonic — from S.W. to N.E.

Minor intrusions — from N.E. to S.W.

Before proceeding to the minor intrusions of the regional series, we may briefly mention certain *subsidiary groups,* the precise relations of which to other members of the great suite we have not in all cases deciphered. They all belong to late epochs; but whether they are older or younger than the peridotites just considered, we have no means of ascertaining.<ref>In Rum we have found the later peridotite dykes to cut the augite-andesites</ref> The trachyte and trachy-andesite dykes have been described in Chapter 23. Most of them, occurring near Broadford and in the Sleat district, have no close connection with the Skye focus, but belong to a group which has its chief area of distribution farther south-east, on the Scottish mainland. Like the great group of basic sills, it enters Skye from without, but from the opposite direction (Figure 76), p. 387. The Drynoch group of trachytes seems to be of distinct origin, though still of late date; and to the same epoch we may conjecturally refer the mugearites and allied types (oligoclase- and orthoclase-basalts, etc.) noticed in Chapters 15 and 18. The dykes of augite-andesite and of acid pitchstone are scarcely numerous enough to afford a basis for any generalisation. We have seen indications (*see* p. 402) of an interesting relationship between the two types, but this does not come out so clearly in Skye as in Arran. The pitch-stones seem in our area to have a very restricted occurrence, which might, however, be somewhat extended by including devitrified rocks perhaps referable to this group. The typical examples discovered have a distribution compatible with a relation to the granite centre. If this connection with the local series can be assumed, it is interesting, for it shows the oval area of distribution of the minor acid intrusions contracted during this final and feeble recrudescence of activity to little more than a line, following the usual direction of the regional dykes (Figure 76), p. 387.

The sequence of the *regional series of minor intrusions* subsequent to the epoch of the great group of sills we have not succeeded in tracing out systematically from stage to stage. The difficulty of dividing the rocks into distinct groups and arranging these in order of chronological succession arises chiefly from three circumstances. (i.) The intrusions have almost exclusively the form of dykes. (ii.) A general community of petrographical characters runs through the whole series. (iii.) All the dykes have in general a common direction of strike; so that intersections, which might serve to determine the relative ages of different dykes, are not often found. A few remarks may be made on each of these three points.

The form and habit assumed by igneous intrusions at any epoch were directly dependent on the nature of the crustal strain at that epoch. During the earliest part of the phase of minor intrusions the regional strain had been such that the invading magma was injected in the form of very regular sills. This was also the case in varying degree with the local groups, viz. the peculiar composite intrusions of the Cnoc Càrnach group and the minor acid intrusions of the area surrounding the Red Hills. Shortly after the epoch of these last, however, occurred an event of the first importance in the geological history of Skye, viz. the principal faulting (of Tertiary age) in our area. To this is due the characteristic structure — that of a succession of gently tilted plateaux divided by lines of fault — which is the most striking tectonic feature over the greater part of the island. Its effect was no less important as altering the conditions under which igneous magmas were intruded. In the country thus shattered a new distribution of strains was set up, and the continuity of the strata (including the lava-flows and the dolerite-sills) was broken. Henceforth when molten magma again rose in fissures throughout the region — sometimes in the old fissures reopened — it was neither to spread laterally among the country rocks nor (so far as we know) to be poured out at the surface. The later dykes are in this sense self-sufficing intrusive bodies, neither the feeders nor the offshoots of other igneous masses. Such dykes differed functionally from those belonging to earlier epochs.

We have already insisted upon one conspicuous difference between the local and the regional series of rocks, a difference of a petrographical kind running through the entire suite in all phases of activity: the groups with regional distribution show nothing of the wide differentiation which we have had to notice in the local groups. This comes out strikingly in the chemical analyses here reproduced for comparison, though doubtless a more extended examination would discover greater variety than is apparent in these few examples. The basic dykes certainly present a remarkable monotony of petrographical characters when viewed as a whole, and we have found among them but few specific features which can be tentatively regarded as marking distinct natural groups or pertaining to defined epochs in the succession. Prophyritic dykes seem to belong in general to a rather late time, and the later dykes are also perhaps richer on the whole in xenoliths and xenocrysts. These points may possibly be significant (Chapter 20). It is true there are certain subsidiary groups of which we have made mention, the trachy-andesites of Sleat and other types containing oligoclase and orthoclase, besides rocks on the other hand rich in olivine and carrying picotite; and some among these may possibly claim to be included in the regional series. We might rather say perhaps that there are certain subsidiary centres of activity in the region in addition to the chief foci, and these were also in a minor degree centres of differentiation. In any case the fact that all these special rocks, including also the pitchstones, etc., made their appearance at quite late epochs seems to show that, outside the principal local foci, any very important differentiation was arrived at only in the final stages of igneous activity in the region.

The general law of direction of the dykes has been sufficiently discussed in Chapter 17. We recur to the subject here only to point out how the varying direction, as well as the varying frequency, of the regional basic dykes illustrates the mutual interaction of the regional and local elements of the crustal strain. The intervention of the regional influence in the behaviour of the

SiO_2	I.	II.	III.
SiO_2	46.61	45.69	47.49
TiO_2	1.81	2.93	not det.
Al_2O_3	15.22	16.35	19.48
Fe_2O_3	3.49	6.09	5.02
FeO	7.71	7.70	9.05
MnO	0.13	0.26	not det.
MgO	8.66	6.10	5.29
CaO	10.08	8.27	10.05
Na_2O	2.43	2.80}	2.39
K_2O	0.67	0.96}	
H_2O	3.17	2.81	1.20
P_2O_5	0.10	0.15	not det.

I. Basaltic lavas (one analysis only).

II. Sills of the "great group" (mean of two).

III. Dykes of "regional series" (mean of two).

intrusions of the local series is apparent at more than one stage, Ind is most marked in the distribution and orientation of the acid Sykes, intruded not long anterior to the faulting of the region. But a reciprocal influence is also to be observed. The energy displayed in the intrusion of the regional series of dykes seems to have attained its maximum in the neighbourhood of the gabbro Focus. This appears in the extraordinary profusion of dykes in a broad belt of country surrounding the Cuillins, and especially in the distribution of multiple dykes, as already noticed (Figure 52), p. 238.

Further, there is (Figure 63), p. 301 a decided tendency in the regional dykes to a radiate disposition about the chief centres of plutonic intrusions, a tendency discernible as a secondary influence modifying the primary principle of parallelism. This of course must be attributed not to the plutonic intrusions themselves, but to the local crustal strains with which these are intimately bound up; and accordingly the granite centres are attended by the same effects as the gabbro.

Despite the exception here implied, and generally away from centres of local disturbance, the dykes hold their normal course with a want of regard for geological structure and tectonic accidents which is very remarkable. Especially noteworthy is it that they have rarely taken advantage of the presumable lines of weakness offered by faults. The dykes are, it would seem, the expression of a larger law than that which is'realised in the ordinary dislocations of strata. This independent behaviour characterises the Tertiary dykes of Britain as a whole.<ref>*Cf.* Sir A. Geikie, *Trans. Roy. Soc. Edin.,* vol. xxxv., pp. 63–68; 1888: *Ancient Volcanoes of Great Britain,* vol. ii., pp. 116–171; 1897.</ref>

In conclusion we venture to suggest a question which may have more than a local application. One of the most remarkable circumstances brought out by a study of the basic dykes in the field, and one discussed at length in its proper place, is the mannerin which the intrusions have been controlled by the nature of the country-rock. The dykes, traversing some formations in vast numbers, show a singular reluctance to enter certain other formations. Whatever be the explanation of this behaviour, the fact has bearings which are possibly of some importance. On a *priori* grounds dykes which freely intersect one formation, but do not penetrate another overlying one, might with considerable show of probability be referred to an age intermediate between those of the two formations concerned; but the results of our survey forbid us, in the area mapped, to attach any weight to negative evidence of this kind. Now in the northern, midland, and western counties of England and in parts of Wales there are numerous dykes and other intrusions of basic rocks, which intersect the Carboniferous and older strata, but not the New Red rocks; and these intrusions have therefore generally been held to be of pre-Permian age. The facts which we have recorded suggest that an inference based on such grounds should be open to reconsideration. There is the more force in this suggestion since one dyke at Swinnerton Park in Staffordshire<ref>Kirkby, *Trans. N. Staffs. Nat. Field Club,* vol. xxviii., p. 129; 1894.</ref> does actually cut the New Red rocks; while Mr Greenly<ref>*Geol. Mag.,* 1900, pp. 160–164.</ref> has found a similar case in Anglesey, and has put forward the opinion that a large number of dykes in that island, hitherto referred to the interval between Carboniferous and Permian, are in reality a part of the great Tertiary system of intrusions. If geological and petrographical evidence should be found to confirm and extend this conclusion, we may have to enlarge considerably the area admittedly affected by the latest suite of igneous intrusions in Britain.<ref>On this subject see also Watts in Sketch of the Geology of the Birmingham district, *Proc. Geol. Ass.,* vol. ay., pp. 399,400; 1898.</ref>

To exhibit in one view some of the more important results summarised in this chapter, we append a table (Unnumbered table) showing the sequence and in some degree the mutual relations of the chief groups of igneous rocks of the regional and the local series in Skye. The local episodes are indicated by separate tablets inserted in the table, their vertical spacing being intended to represent diagrammatically the time-intervals between the successive groups.

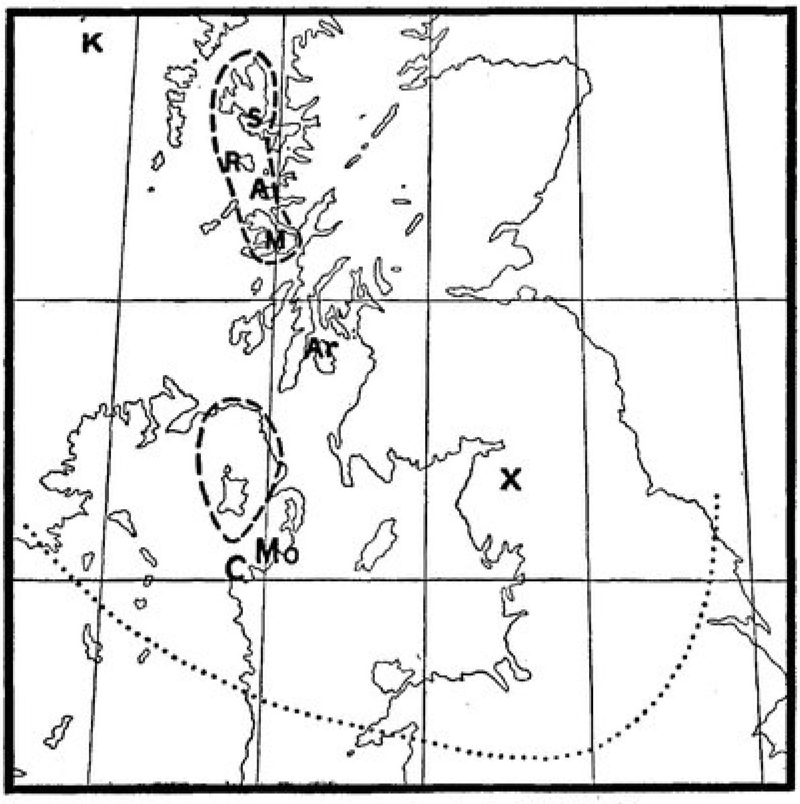


Fig. 1.—Sketch-map to show the distribution* of Tertiary igneous rocks in the British Isles.

The broken lines enclose the areas in the west of Scotland and the north-east of Ireland where Tertiary volcanic rocks are preserved.
The dotted line marks the southern limit in England, Wales, and Ireland of basic dykes believed to be of Tertiary age.
The situations of the principal plutonic intrusions of Tertiary age are indicated by letters, as follows: K, St. Kilda; S, Skye; R, Rum; A, Ardnamurchan; M, Mull; Ar, Arran; Mo and C, Mourne Mts and Carlingford. The letter X marks the situation of the gabbro and granophyre intrusions of Carrock Fell, possibly of Tertiary age, but only proved to be post-Silurian.

* 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).

(Figure 1) Sketch-map to show the distribution of Tertiary igneous rocks in the British Isles. The broken lines enclose the areas in the west of Scotland and the north-east of Ireland where Tertiary volcanic rocks are preserved. The dotted line marks the southern limit in England, Wales, and Ireland of basic dykes believed to be of Tertiary age. The situations of the principal plutonic intrusions of Tertiary age are indicated by letters, as follows: K, St. Kilda; S, Skye; R, Rum; A, Ardnamurchan; M, Mull; Ar, Arran; Mo and C, Mourne Ma and Carlingford. The letter X marks the situation of the gabbro and granophyre intrusions of Carrock Fell, possibly of Tertiary age, but only proved to be post-Silurian.

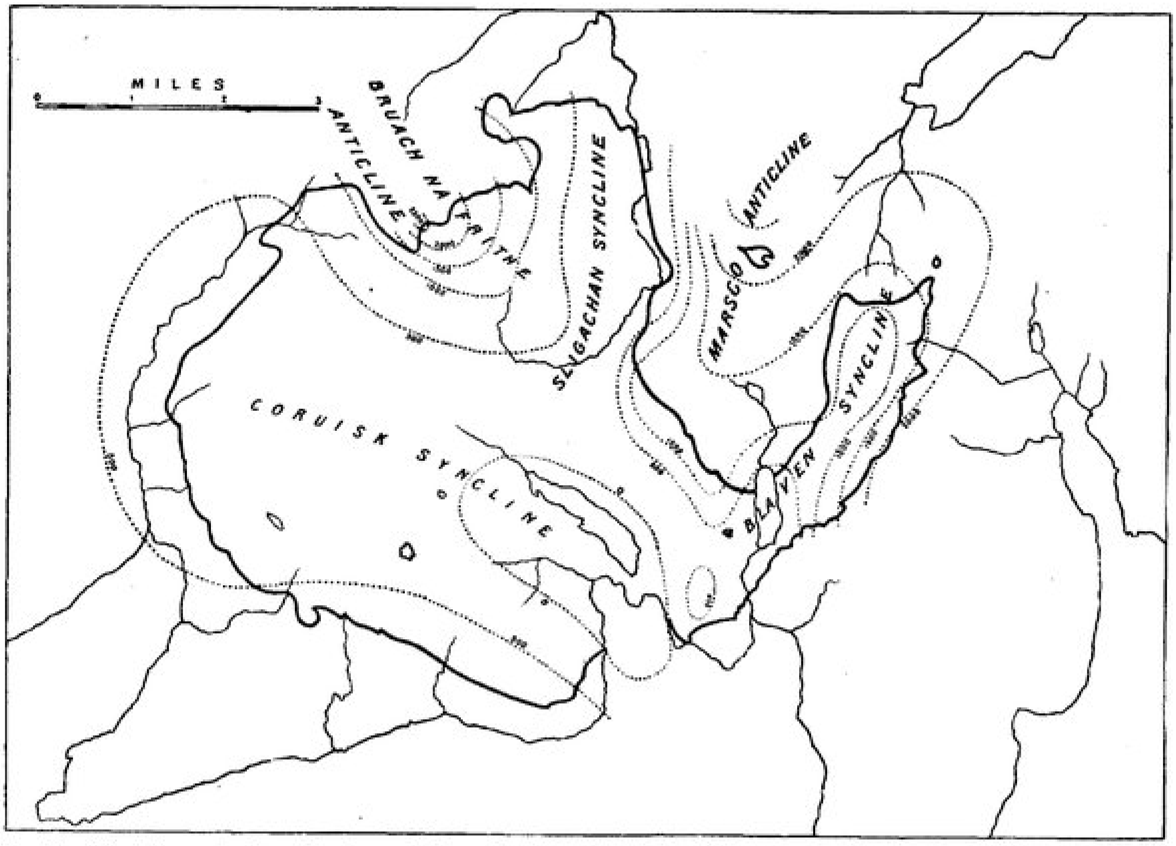


FIG. 15.—Sketch-map to show the shape of the gabbro laccolite of the Cuillins: scale, ½ inch to a mile. The boundary of the laccolite (omitting minor irregularities) is shown by the heavy line; the chief streams and lakes and the coast to the south by lighter lines. The dotted lines are intended to represent approximately the shape of the lower surface of the laccolite, being contour-lines of that surface at intervals of 500 feet, reckoned from sea-level.

(Figure 15) Sketch-map to show the shape of the gabbro laccolite of the Cuillins: scale, ½ inch to a mile. The boundary of the laccolite (omitting minor irregularities) is shown by the heavy line; the chief streams and lakes and the coast to the south by lighter lines. The dotted lines are intended to represent approximately the shape of the lower surface of the laccolite, being contour-lines of that surface at intervals of 500 feet, reckoned from sea-level.

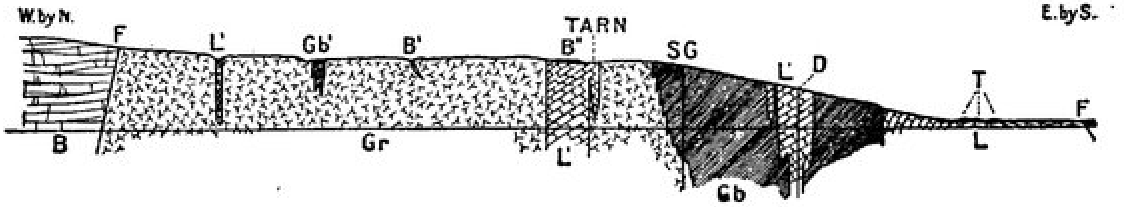


FIG. 28.—Section through Lochain Beinn na Caillich and towards Broadford, crossing the northern part of the granite boss of Beinn na Caillich and the southern part of the gabbro boss; scale, 2 inches to a mile.

F, F are faults, the easterly one bringing on the Lias (Pabbay Shales). L, Cambrian Limestone (Balnakiel group); B, basaltic lavas; Gb, gabbro; Gr, granite.

L′, B′, Gb′ are enclosed patches of limestone, basalt, and gabbro; B″, an outlier of the basalt resting on an enclosed patch of limestone; T, small outliers of Torridonian upon the limestone, with a thin sheet of granophyre intruded along the dividing "thrust-plane."

SG, dyke of spherulitic granophyre; D, dyke of basalt.

(Figure 28) Section through Lochain Beinn na Caillich and towards Broadford, crossing the northern part of the granite boss of Beinn na Caillich and the southern part of the gabbro boss; scale, 2 inches to a mile. F, F are faults, the easterly one bringing on the Lias (Pabbay Shales). L, Cambrian Limestone (Balnakiel group); B, basaltic lavas; Gb, gabbro; Gr, granite. L′, B′, Gb′ are enclosed patches of limestone, basalt, and gabbro; B″, an outlier of the basalt resting on an enclosed patch of limestone; T, small outliers of Torridonian upon the limestone, with a thin sheet of granophyre intruded

along the dividing "thrust-plane". S G, dyke of spherulitic granophyre; D, dyke of basalt.

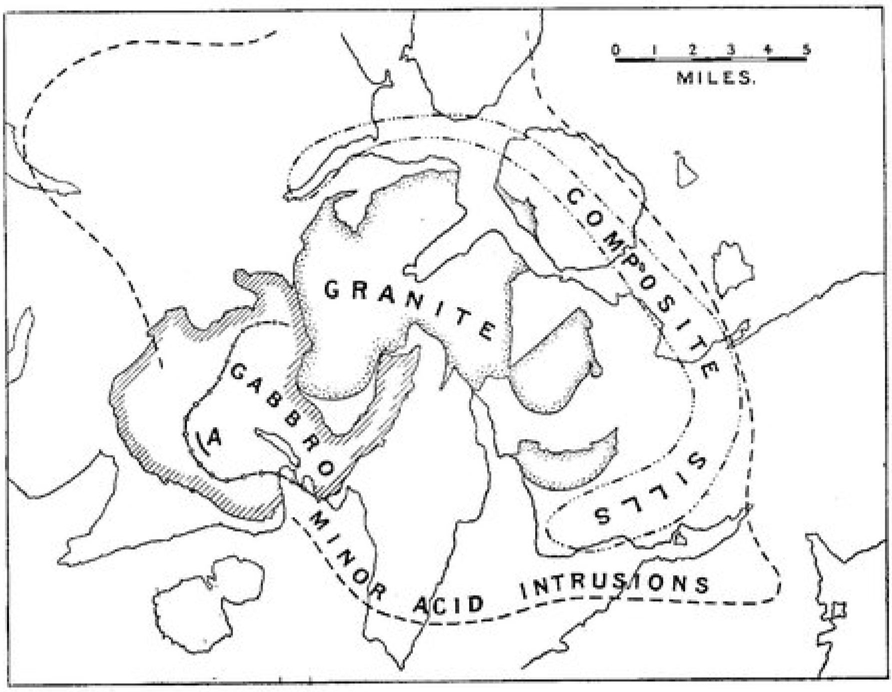


FIG. 58.—Sketch-map illustrating the distribution of certain groups of acid intrusions in relation to the granite of the Red Hills. Scale, ¼ inch to a mile.

(*a*.) The line (of small circles connected by dashes) in the gabbro area indicates the western limit of granite and granophyre veins, in so far at least as they are locally abundant and noticeable, in the gabbro of the Cuillins. It may probably be taken as showing, with rough approximation, the concealed extension of the granite beneath the gabbro laccolite.

(*b*.) The roughly semicircular belt, enclosed by a line of dots and dashes, marks the distribution of the peculiar composite (basic and acid) intrusions of the symmetrical kind, which we have distinguished as the Cnoc Càrnach type.

(*c*.) The heavy broken line indicates the area of distribution of the minor acid intrusions in general. It is an irregular oval, about 24 miles long, centring in the granite of the Red Hills, and having its long axis in a direction nearly agreeing with that of the dykes.

(*d*.) The short heavy line at A marks the position of the peculiar felsite of the Alaisdair Stone-shoot.

(Figure 58) Sketch-map illustrating the distribution of certain groups of acid intrusions in relation to the granite of the Red Hills. Scale, ¼ inch to a mile. (a.) The line (of small circles connected by dashes) in the gabbro area indicates the western limit of granite and granophyre veins, in so far at least as they are locally abundant and noticeable, in the gabbro of the Cuillins. It may probably be taken as showing, with rough approximation, the concealed extension of the granite beneath the gabbro laccolite. (b.) The roughly semicircular belt, enclosed by a line of dots and dashes, marks the distribution of the peculiar composite (basic and acid) intrusions of the symmetrical kind, which we have distinguished as the Cnoc Càrnach type. (c.) The heavy broken line indicates the area of distribution of the minor acid intrusions in general. It is an irregular oval, about 24 miles long, centring in the granite of the Red Hills, and having its long axis in a direction nearly agreeing with that of the dykes. (d.) The short heavy line at A marks the position of the peculiar felsite of the Alaisdair Stone-shoot.

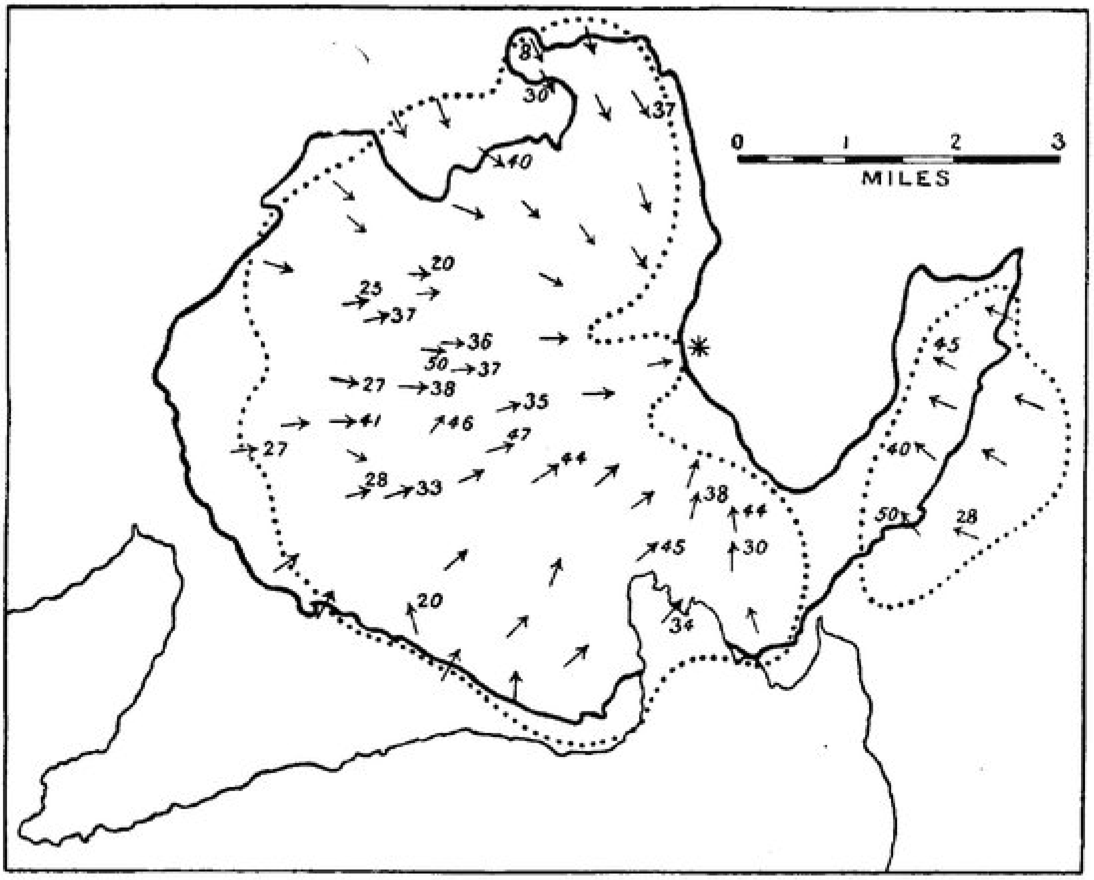


FIG. 72.—Sketch-map to illustrate the distribution and inclination of the inclined basic sheets of the Cuillins. The strong line marks the outline of the gabbro area: the dotted lines enclose the areas within which the inclined sheets are found, and the arrows (with figures) indicate the dips of the sheets.

(Figure 72) Sketch-map to illustrate the distribution and inclination of the inclined basic sheets of the Cuillins. The strong line marks the outline of the gabbro area: the dotted lines enclose the areas within which the inclined sheets are found, and the arrows (with figures) indicate the dips of the sheets.

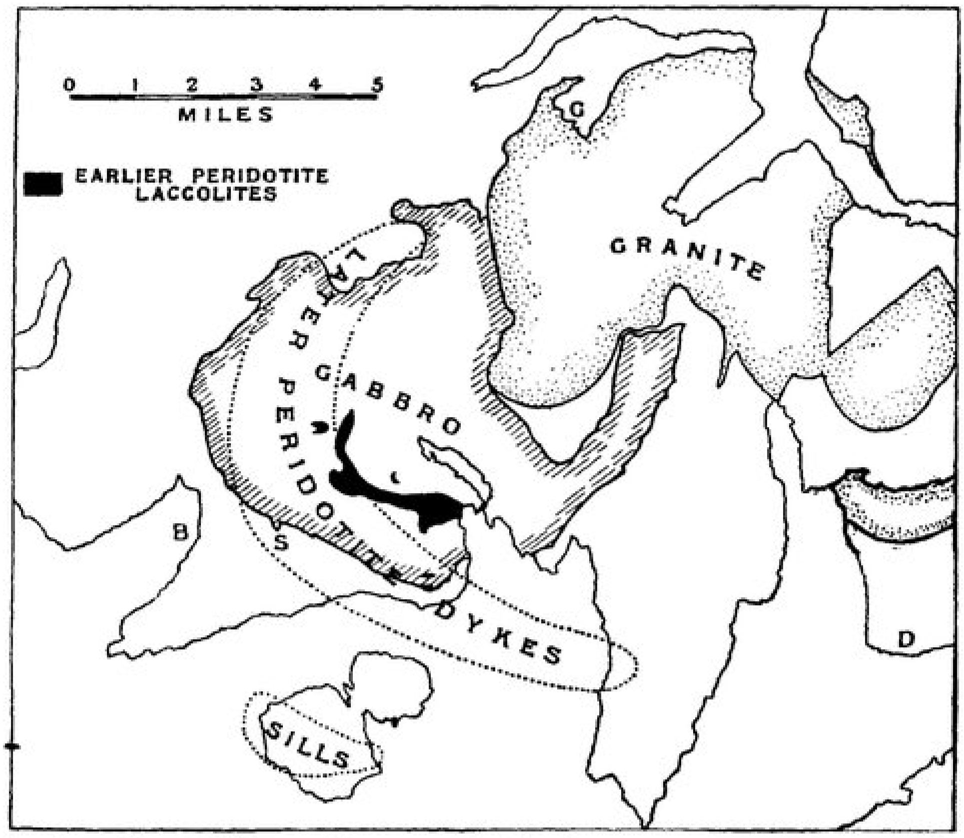


FIG. 75.—Sketch-Map to illustrate the distribution of the peridotites, older and younger. Scale, ¼ inch to a mile.

The older plutonic laccolites of the south-western Cuillins (with one in the Isle of Soay) are marked in black.

The large crescentic area enclosed by a dotted boundary embraces the younger peridotite dykes of the Cuillins and the Strathaird peninsula. The only peridotite dykes outside this area are a group on the coast of Loch Brittle at B, but peridotite sills occur in Soay as indicated. The boss of An Sgùman is situated at the point marked S, and the intrusions of Glamaig and Carn Dearg at G and D, on the prolongations of the two horns of the crescent.

(Figure 75) Sketch-Map to illustrate the distribution of the peridotites, older and younger. Scale, ¼ inch to a mile. The older plutonic laccolites of the south-western Cuillins (with one in the Isle of Soay) are marked in black. The large crescentic area enclosed by a dotted boundary embraces the younger peridotite dykes of the Cuillins and the Strathaird peninsula. The only peridotite dykes outside this area are a group on the coast of Loch Brittle at B, but peridotite sills occur in Soay as indicated. The boss of An Sgùman is situated at the point marked S, and the intrusions of Glamaig and Carn Dearg at G and D, on the prolongations of the two horns of the crescent.

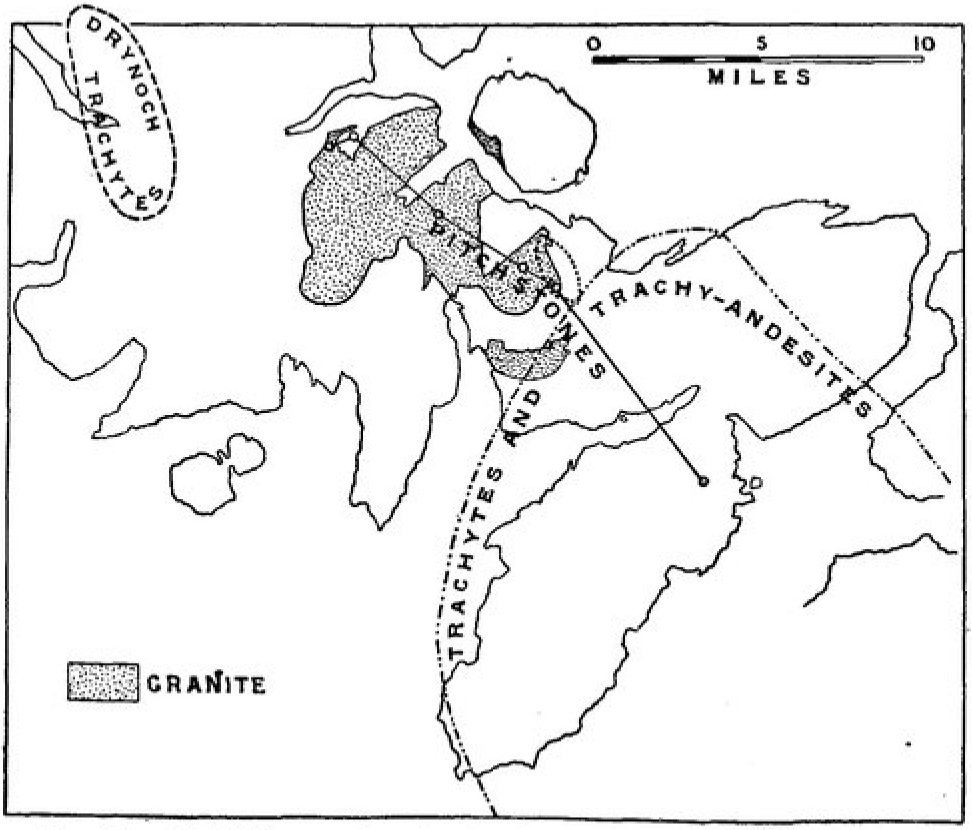


FIG. 76.—Sketch-Map to show the distribution of some trachytic and other dykes.

(*a.*) The broken line encloses the oval area of distribution of the Drynoch group of trachytes.

(*b.*) The line made up of dots and dashes marks the limits of distribution in Skye of the trachytic and allied dykes of Sleat and the Broadford district.

(*c.*) The small circles connected by straight lines indicate the known localities of acid pitchstone dykes.

(*d*) The small oval enclosed by the dotted line shows the area affected by the Coirechatachan type of dykes, probably altered pitchstones. It falls in the middle of the narrow strip of country including the occurrences under (*c*).

(Figure 76) Sketch-Map to show the distribution of some trachytic and other dykes. (CL) The broken line encloses the oval area of distribution of the Drynoch group of trachytes. (b.) The line made up of dots and dashes marks the limits of distribution in Skye of the trachytic and allied dykes of Sleat and the Broadford district. (c.) The small circles connected by straight lines indicate the known localities of acid pitchstone dykes. (d) The small oval enclosed by the dotted line shows the area affected by the Coirechatachan type of dykes, probably altered pitchstones. It falls in the middle of the narrow strip of country including the occurrences under (c).

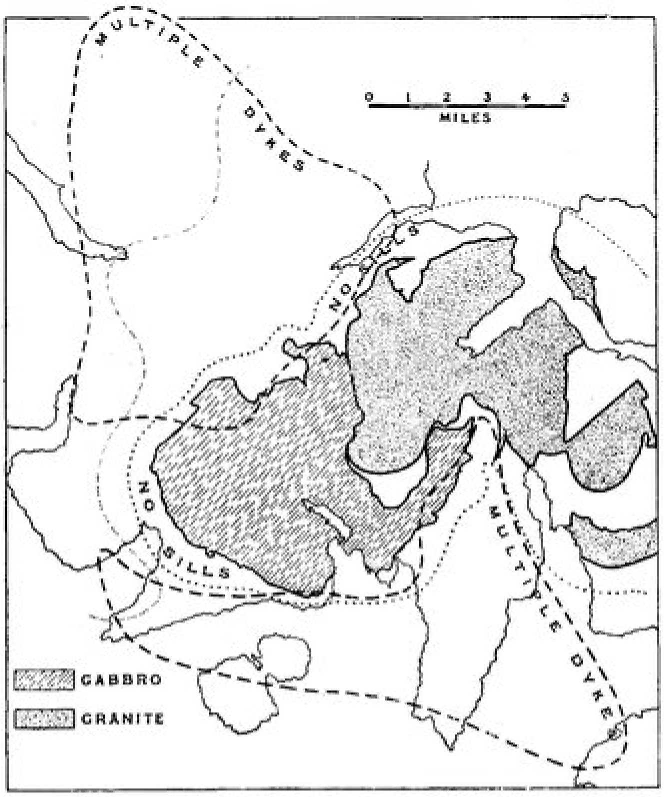


FIG. 52.—Sketch-map illustrating the distribution of the basic sills, and also of the multiple basic dykes, in relation to the large plutonic intrusions. Scale, ¼ inch to a mile.

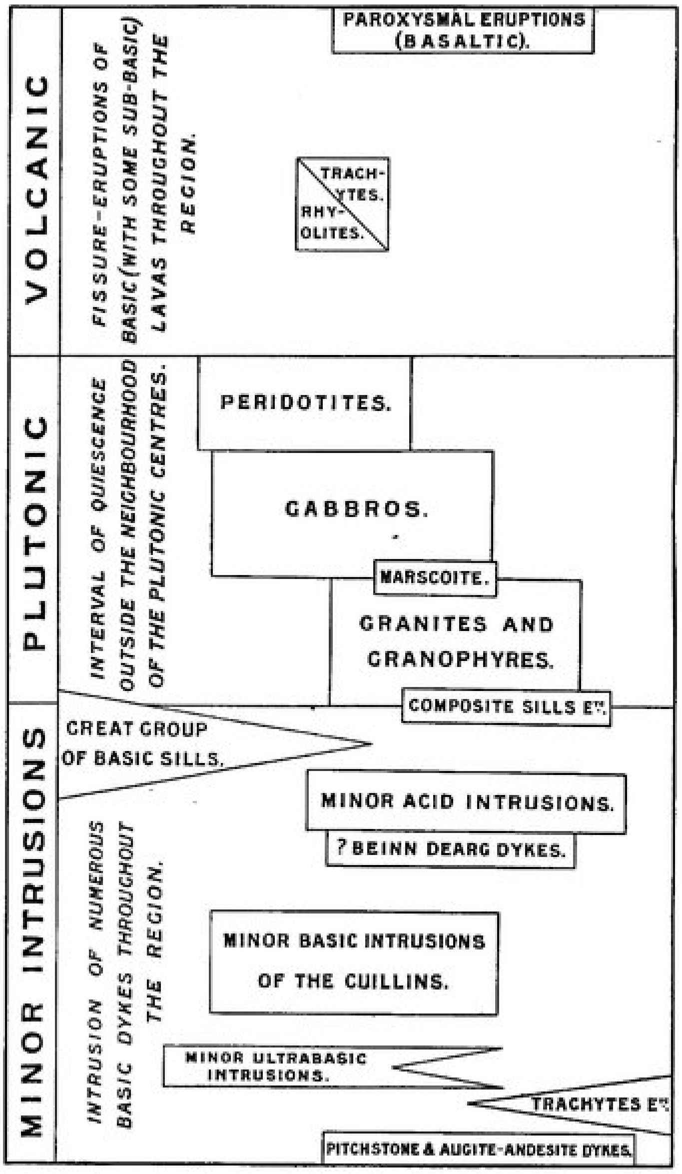
(a) The heavy dotted line indicates the area (embracing the plutonic intrusions with a narrow surrounding belt) which is free from sills belonging to the great group. The lighter dotted line marks the limit (in this part the eastern limit) of multiple sills. This depends partly upon the general attenuation of the group in this direction, but partly also upon the progress of erosion, since the multiple sills are developed chiefly in the upper portion of the lava group.

(b) The heavy broken line indicates the distribution of the principal multiple basic dykes. They are found within an elongated oval tract, about eleven miles long, centring in the great gabbro laccolite and having its long axis in the general direction of the dykes themselves. This oval tract, however, is divided into two detached areas by the plutonic masses. It is not improbable that better exposures might enable us to join these two areas on the west side of the Cuillins, but on the east side the granite has offered an impenetrable resistance (see Chap. XVII.).

(Figure 52) Sketch-map illustrating the distribution of the basic sills, and also of the multiple basic dykes, in relation to the large plutonic intrusions. Scale, ¼ inch to a mile. (a) The heavy dotted line indicates the area (embracing the plutonic intrusions with a narrow surrounding belt) which is free from sills belonging to the great group. The lighter dotted line marks the limit (in this part the eastern limit) of multiple sills. This depends partly upon the general attenuation of the group in this direction, but partly also upon the progress of erosion, since the multiple sills are developed chiefly in the upper portion of the lava group. (b) The heavy broken line indicates the distribution of the principal multiple basic dykes. They are found within an elongated oval tract, about eleven miles long, centring in the great gabbro laccolite and having its long axis in the general direction of the dykes themselves. This oval tract, however, is divided into two detached areas by the plutonic masses. It is not improbable that better exposures might enable us to join these two areas on the west side of the Cuillins, but on the east side the granite has offered an impenetrable resistance (see Chapter 17).

Fig. 63.—Sketch-map illustrating the bearings of the basic dykes in different parts of Skye. The letters C and R mark the situations of the Cuillins and the Red Hills respectively.

(Figure 63) Sketch-map illustrating the bearings of the basic dykes in different parts of Skye. The letters C and R mark the situations of the Cuillins and the Red Hills respectively.



(Unnumbered table) Sequence and in some degree the mutual relations of the chief groups of igneous rocks of the regional and local series in Skye.