Chapter 8 Intrusive igneous rocks

Tertiary sills

At some date later than the extrusion of the Tertiary lavas and prior to most of subsequent faulting and dyke intrusions the Jurassic substratum was injected by basic sills on a very large scale. These intrusive sheets do not, as Harker believed, penetrate the lava pile except rarely and then only on a small scale. Although commonly referred to in the plural, these numerous sills appear to be in almost every case the leaves of a single major sill complex within which are more or less isolated rafts of Jurassic sediments.

Prior to the late-Tertiary tilting of the whole region to the west the general level of this sill complex must have been more or less uniformly horizontal and not far above present sea-level.

Now, the sill crops out in the east almost entirely above sea-level and is magnificently exposed in the sea-cliffs extending from Loch Sligachan in the south to Staffin Bay in the north. From thence round the northern end of Trotternish much of the sill is submerged and is responsible for the formation of islands close off-shore. In the west the sill is almost entirely below sea-level except where brought up by local faulting and folding to form islands and promontories such as Isay and Mingay Islands, Ardmore Point, and Eist.

Probably the most remarkable aspect of this sill complex is that although it was intruded into Jurassic sediments which had been already folded into a pitching syncline, nevertheless it appears to have maintained a more or less constant level with regard to the peneplaned surface on which the lavas had been extruded. In order to maintain this level the leaves of the complex, which, in common with most intrusions of this type, had followed the planes of least resistance, i.e. the sedimentary bedding planes, had perforce to transgress the stratification at frequent intervals. These transgressions form one of the most common and spectacular features of the sill complex wherever it is seen, and many other such transgressions can be inferred from the recognizable displacements of the Jurassic sequence.

It is believed that at the time of the intrusion of the sill-complex the lava field had attained a more or less uniform thickness over the whole area and had not yet been dissected by erosion, and that the sill-complex was everywhere injected along a plane of equal pressures. In other words the sill-complex was injected at the level where the magma pressure was cancelled exactly by the overlying rock pressures.

The numerous transgressions of the component sills attracted the attention of Macculloch over a century ago and were somewhat fancifully illustrated in his 'Description of the Western Isles of Scotland' (Macculloch 1819, vol. 3, pl. 17).

Another striking feature of this sill-complex is its uniform thickness. The aggregate thickness of the component sheets visible in any one place appear to be always of the order of 750 ft. This may be an underestimate since it is impossible to be certain that the entire complex is exposed in any one place. Individual sheets may attain a thickness of over 300 ft as for example that which forms the sea-cliff at Meall Tuath, north of Duntulm, but there is great variation.

There is some evidence to suggest that this sill-complex is composite. In general the rock is an olivine-dolerite but to the north of the Trotternish peninsula, in particular, picritic and teschenitic variations are found and there is in one or two places evidence suggesting that the rock was not always intruded in the same direction.

All the thicker sheets display well-developed columnar jointing as is well seen at the Kilt Rock where the columns extend for over 100 ft without a break, and in the cliff section between An Corran and Rubha Garbhaig at Meall Tuath where they attain a length of at least 150 ft. Generally the columns are nearly vertical and normal to the bedding planes of the sedimentary rocks within which the intrusive sheets lie, but in a few cases they are appreciably tilted as at Creag na h-Eiginn north of Flodigarry and on the islands of Trodday and Fladdachuain where the columns lean to the west at angles of 15–20°. At Steall a'Ghreip, one mile north of Flodigarry, the columns are vertical in the lower part of the cliff but bend over toward the west in the upper part. Anomalous jointing is very well displayed in the cliffs east of Rubha Hunish, the most spectacular example being fan jointing seen in Lub a'Sgiathain which owing to its fancied resemblance to a

bird's wing has given the bay its name (Bay of the Wing).

It seems probable that these sudden changes in orientation of the columnar jointing are due to the presence of pre-existing faults or planes of weakness in the country rock which have locally disturbed the distribution of pressures.

Though the major part of the sill-complex consists of olivine-dolerite there are many local variations. Some of these have been studied by Walker (1932), who claimed that he had found evidence of gravity differentiation within certain leaves of the complex. According to Walker four distinct rock types are to be found in the sills, i.e. olivine-dolerite, picrite, dolerite-pegmatite and teschenite.

Picrite and picritic-dolerite is said to be found in all the thicker sheets along the coast from Flodigarry to the cliffs west of Camas Mor, and analyses are given of specimens from the cliffs west of Camas Mor and from Kilmaluag.

The mapping of the one-inch Rubha Hunish (90) Sheet has confirmed the occurrence of picritic-dolerite at Curidh nan Ob, Duntulm, Kilbride Point, Rubha Hunish, Druim na Slochd, Kilmaluag and Bomaskitaig. The rock Walker referred to as dolerite-pegmatite has been located in the sill at Ru Bornaskitaig, 3 miles south-west of Duntulm, at Rubh'a Chaim Leith, a mile further south, and at Druim na Slochd as well as at the Kilt Rock where it was recorded by Walker but not found by him in situ. This coarse-grained rock resembles a gabbro in appearance but differs little in mineral composition from the normal olivine-dolerite of the sill-complex.

A circle drawn on the map centred on the peak of Meall nan Suireamach and of rather less than six miles radius includes all the recorded picritic and gabbroic varieties of the sill. Other minor modifications are seen in that leaf of the sill lying in the Palagonite tuffs north of Fuirnean which is a porphyritic theoleiitic dolerite, and in a small sill seen west of Loch Fada which has crinanitic affinities.

By far the commonest variant however, is a teschenitic dolerite, a rock rich in zeolites, which has been found in many localities chiefly lying outside the area of the picritic variants.

In the extreme north, the sill forming Eileann Trodday and Sgeir nan Maol is of this type, as is the rock knob of Ben Volovaig, the Ascrib Islands, south-east of Dun Borrafiach, the island of Mingay, south-east of Port na Caigan, the northern end of Beinn Bhreac, the River Chracaig, 2 miles north of Portree, three quarters of a mile south of Loch Fada and a sill in the tuffs south of Loch Fada.

Walker (1932) claimed that gravity differentiation was a feature of these Skye sills. He stated that the only major leaf of the sill which is entirely olivine-dolerite from top to bottom is that over which the outflow of Loch Mealt falls to the sea. This example is however an unfortunate choice for the appearance of this sill is deceptive. What appears to be a sill 190 ft thick is shown by the stratigraphy of the surrounding Jurassic sediments to be in fact the riser of a transgressing sill not more than 30–40 ft thick see (Figure 7). Thus the vertical face under the Mealt Fall cannot be regarded as giving a vertical section of the sill, and the actual position of the olivine and augite concentration recorded by Walker at 20 ft above the exposed base of the sill cannot be related with certainty to any specific horizon in the sill. The question of gravity differentiation in this sill is therefore still unsettled. Another example quoted by Walker is the sill at Druim na Slochd which is a picrite in the lower part, becomes a picritic dolerite at 80 ft from the base and at 100 ft up is a normal ophitic olivine-dolerite. Unfortunately, this too is a point at which the sill is transgressing from a position near the top of the Great Estuarine Series to a higher horizon in the Corallian and it is impossible to say what are the relative positions in the sill of the samples collected from the cliff face.

In the sill at Meall Tuath, Walker's claim that the lowest visible portion is olivine-dolerite which is succeeded by picrite-dolerite and higher still by dolerite again has been substantiated (p. 126). In the Creagan Iar Sill south of Duntulm the lower two thirds is said to be picrite and the upper third olivine-dolerite. On the other hand in the sill at Bornaskitaig the reverse is said to be the case, picrite forming the upper and olivine-dolerite the lower part of the sill. Thus it appears that there is no consistency in the relationship of the picritic and doleritic portions of the sills in these various localities.

There is little evidence therefore that the picritic phases of the sill are generally due to gravity differentiation in situ, though settling may have occurred in certain places. Instead this variation in composition appears to be mainly of a

regional character. North of the Uig-Loch Mealt line the sill is generally richer in olivine and includes coarsely crystalline pegmatitic types, south of this line the modifications consist primarily of an enrichment in water and soda.

Harker noted that the sill-complex became thicker northwards and suggested a possible centre of intrusion in the extreme north of Trotternish or in the Shiant Isles. But since he included in his calculations all the hard centres of the lavas above, which he believed to be sills, this argument cannot now be seriously considered. Some grounds can in fact be found for suggesting an exactly opposite origin for the sill. The generalization made earlier in this chapter, that the lava pile was of reasonably uniform thickness, is certainly not true in detail. It seems quite certain, that if the sequence of lavas has been correctly interpreted, there was a gradual thinning of the total thickness in all directions from a centre somewhere in the Bracadale area. It follows therefore that if the sill-complex was intruded from the north the isobaric level should be higher there than in the south. Since this is not the case it appears more likely that the sill-complex originated from more or less the same axis as the lava flows either from a single fissure near the centre of the island or, what is more likely, in view of the regional differentiation of the sills, from the several more or less parallel fissures which give rise to the various groups of flows. There is moreover a grouping of intrusive rock types into areas which show a rough correspondence with those occupied by the lava groups. Thus the picritic dolerite leaves and the sill-complex are found only below the area originally covered by the lavas of the Beinn Edra Group, the rare mugearite sills are found only in the areas occupied by the alternating basalt and mugearite lavas of the Beinn Totaig Group, and the distribution of the acid sills is approximately that of the trachyte and mugearite lavas of the Bracadale Group.

Transgressions of the Sills. In no other part of Britain can the behaviour of a sill-complex be so well studied as in northern Skye both in fine detail and on a broad regional basis. Though there have been innumerable minor transgressions in the various leaves of the sill their aggregate effect is relatively simple.

The highest major sill of the complex is seen at sea-level between Loch Sligachan and Camastianavaig where it occupies a position between the Inferior Oolite and the base of the lavas, sometimes below, sometimes within the Palagonite Tuffs. It is rarely more than thirty feet in thickness. Lower leaves are hidden below sea-level, two of which appear in the sea-cliff just north of Port a'Bhata and transgress the Inferior Oolite until at Craig Ulatota they lie at and near the base of the Great Estuarine Series, only to join, and again transgressing, descend through the sequence to the Middle Lias where they disappear below sea-level except where they form the island of Holm, and further north where these combined sills crop out for a short distance along the shore in Bearreraig Bay. Discrepancies in the levels of the Jurassic sedimentary groups indicate the presence of thick intrusive sheets below the whole of this area, only visible however in the small horst east of Pein a'Chleibh.

The section of the uppermost leaf of the complex seen just north of Fuirnean shows some remarkable features. Here an offshoot from the sill has pushed through the Palagonite Tuffs as far as the basal lava flow which it failed to penetrate (Figure 3). The transgression forms a series of steps ascending from north to south which have only recently, in the geological sense, been uncovered by erosion so that the steps in the sill form topographic features and the nature of the jointing in each riser is clearly seen. The uppermost step in particular is formed of contorted columns of the type often seen on a smaller scale in the blunt tongue terminating a sill. At Holm this uppermost unit of the sill lies between the Inferior Oolite and the base of the Great Estuarine Series but at Bearreraig it transgresses 260 ft to the north so as to lie in a new position at the top of the White Sandstone of the Great Estuarine Series (Plate 3). The average thickness of the upper leaf in this area is about 300 ft.

Half a mile north of Rubha Sughar this uppermost leaf divides into a lower portion which transgresses downwards into the Inferior Oolite and appears to die out at Rigg Burn, and an upper portion which continues at more or less the same stratigraphical level as far as Upper Tote. Just north of Armishader, however, this upper leaf had divided into three and it is the lowest of these which is seen in the sea cliff from Rigg to Upper Tote. The middle limb, at a higher level is only seen in the sea cliff just north of Rigg, whilst the uppermost sheet, occupying a still higher position in the Jurassic sediments forms the great inland outcrop at Creag Langan.

At Eaglais Bhreagach the lowest of these three sheets transgress upwards to a position near the top of the 'Estheria' Shales. It is faulted down north of Dun Grianan, crosses the Lealt River, where it is responsible for the waterfall just east of the road bridge, and continues at the same stratigraphical level as far as Port Earlish, where a further upward

transgression raises the sill 100 ft up into the Concretionary Sandstones.

The middle leaf here reaches the coast again to form the cap of Dun Dearg and rejoins the lower leaf at Loch Mealt. Inland in this area the upper leaf has an outcrop of some 3 miles but this too rejoins the two lower leaves, the line of junction being marked as far north as Staffin Bay by a line of small inclusions of the Ostracod Limestones. North of the Mealt Fall the combined leaves again split leaving a lower sheet at sea-level, forming the lower part of the cliff at the Kilt Rock and the wave cut platform at Sgeir Bhan, and north of the Breun Phort Fault, Sgeir nam Faoileann and Staffin Island. Rubha Garbhaig and An Conan are composed largely of the downfaulted upper leaf.

Though north-south transgressions are clearly visible in the cliff section from Portree to Staffin, east-west changes of stratigraphical level are not so easily demonstrated. At the Mealt Fall the appearance is that of a thick sill which with the exception of a thin band of sediments at the base forms the entire cliff. Two small quarries at the cliff top, however, show that a considerable thickness of the Concretionary Sandstones, the whole of the Lower '*Ostrea*' Beds, and part of the Ostracod Limestones have been apparently replaced by igneous rock. This can only mean that at this point the sill has transgressed upwards for a distance equivalent to the thickness of the missing sediments and that the cliff face is actually formed by the riser of the sill (Figure 7). In the Maligar, Elishader and Staffin areas the sill complex lies mainly within the Great Estuarine Series. Further north in the area north of and including Duntulm and Kilmaluag and in the west at Peingown, Herbusta and in the area north of Totscore and west of the Hunglader Fault it occupies a similar stratigraphical position.

Further inland the sill transgresses upwards to a position between the Oxford Clay and the Great Estuarine Series. Another lift brings it between the Lower and Middle Corallian. This is a transgression clearly demonstrated by exposures between Flodigarry and Druim na Slochd. In the central area lying almost entirely below landslip and lavas the sill probably occupies a position between the Upper Corallian and the Kimmeridge Clay.

Though the numerous minor transgressions and irregularities of the sill have little effect on the regional distribution of the rocks nevertheless they are important in that they demonstrate the detailed behaviour of a sill-complex of this type and help to resolve certain anomalies of distribution and habit. In the Palagonite Tuffs where bedding is virtually absent the penetrating sill is highly irregular and the columnar jointing contorted as is well seen at Fiurnean (Figure 3) and Camas Ban (Portree). There are, however, in the Palagonite Tuffs bedded planty flagstones within which the intrusive sheet behaves in a regular fashion. In the closely and evenly bedded sediments of the 'Estheria' Shales the sills tend to remain at one horizon for long distances but may vary greatly in thickness from place to place without transgression. Changes of level tend to be abrupt and at right angles to the bedding. In the sea cliff north of Rigg Burn a sheet of dolerite having persisted for over a mile with a fairly uniform thickness of 20 ft, swells suddenly to 200 ft without transgression. Further north near Rubha nam Brathairean a 20-ft sill in the same position makes eight small vertical transgressions without any change in thickness in a distance of 200 yd.

In the southern face of the gorge below the lower Inver Tote waterfall are exposed three intrusive sheets in the '*Estheria*' Shales. The two lower sheets, 150 ft east of the fall, show an interesting example of mutual interference. The lowest leaf wedges out to the east within a few feet whilst the middle leaf abuts against this termination, retreats, and continues with reduced thickness at a higher level. The shale caught between the opposing sills bears witness to the temperatures and pressures involved. It has been indurated and violently contorted. An even better example of this effect is seen in the '*Estheria*' Shales which form the promontory of Eist and the nearby Mointeach nan Tarbh in the extreme west of Skye. These shales have been invaded by thick sheets of teschenitic dolerite. The lowest leaf has a highly irregular surface, one knob in particular rising 200 ft above the general level of the sill through shales which are highly contorted (Figure 14). Similar phenomena are visible above this same leaf of sill just before it merges with the overlying sheet which forms Mointeach nan Tarbh in Camas nan Sithean. By analogy with the Lealt River section it seems probable that these irregularities in the lower sill represent attempts at transgression rendered abortive by the presence of the previously emplaced middle leaf above. Also in Camas nan Sithean the Mointeach nan Tarbh sill is seen to give off several vertical risers or dyke-like bodies which in turn have fed numerous thin sills see (Figure 14). A similar phenomenon is inferred to explain the structure of the sill-complex below Lon Druiseach in the east.

In Oisgill Bay, north of Eist, the lavas are cut by three inclined sheets dipping steeply to the south. The most southerly is thickest and is multiple, the central portion being chilled on both sides against the enclosing sheet. There are a number of irregular offshoots all with chilled margins and in one case with a thin skin of tachylytic glass. In the neighbouring stream draining into Oisgill Bay, '*Estheria*' shales are exposed with leaves of sill above and below. The northern face of this upper sill has the appearance associated with a steeply plunging intrusion, resembling closely the surfaces seen in the irregular transgression near Fiurnean. It is possible that the irregular behaviour of the sills in this area north of Eist is due to the presence of pre-intrusion faults in the Jurassic sediments and perhaps also in the lavas which have determined the course taken by the intruded material.

In the well-bedded sediments comprising the Concretionary Sandstones the sill-complex tends to behave in a more orderly manner though occasionally, and particularly in the sandstones, anomalies do occur. For example in a roadside quarry 2½ miles south of Inver Tote and ¼ mile north of Rigg, two leaves of sill are exposed. The lower shows a transgression of normal type whilst the upper cuts obliquely across the bedding.

In the shales of the Oxford Clay, Corallian and Kimmeridge the sills behave in a similar manner to that described for the '*Estheria*' Shales, i.e. though the sills are in general regular they tend to give rise locally to irregular masses.

There are three features of this sill-complex which are worthy of consideration, firstly its maintenance in general of an isobaric level; secondly the fact that its variations in composition, i.e. olivine-basalt, picritic and teschenite phases are regional in distribution and thirdly the more or less uniform amount of igneous material involved in any one place. With respect to the last it can be stated that in the south the complex consists largely of numerous thin leaves spread through a considerable thickness of sedimentary rock (Figure 7). Northwards, individual leaves tend to merge or to die out whilst others thicken so that finally in the area north of Loch Mealt the complex virtually consists of two thick sills which at Rubha Hunish are only separated by a thin layer.of sediment. The first and third of these considerations suggest that the sill-complex was intruded from a single source and that probably located in the centre of the island in the neighbourhood of the Cuillin igneous masses. The second suggests multiple sources probably from the same fissures that supplied the material for the lava-flows and apparently in the same order.

No mention is made in the above account of the numerous small sills and intrusive sheets which occur as offshoots from the regional dykes. These are all later than the main sill-complex and have no bearing on the problems connected with it.

Dykes

Vertical sheet intrusions or dykes are extremely abundant throughout Skye, so much so that only a selection can be shown on the one-inch geological map. Certain features of their distribution are therefore not evident; for example, the vast majority are olivine-dolerites and it is these that are most frequently omitted from the map, whilst all the rarer rock types are shown. Again there is a marked increase in the size, number and variety of dykes as the Cuillin centre is approached and multiple and compound intrusions become more common. The great majority trend N.N.W., but on the east coast between Portree and Sligachan there are a number of N.N.E. dykes, the predominant direction of the Tertiary dykes on the mainland opposite in Applecross. In the gabbro mass of the Black Cuillins and the area to the west of it are dykes radiating from a centre near the head of Harta Corrie.

Harker (1904, p. 291) devoted an entire chapter of his book to the field relations of the basic dykes. The mapping in N. Skye has repeated many of his observations and confirmed most of his conclusions, but briefly these: i. the basic dykes are remarkably constant in direction which must therefore be primarily due to regional factors. ii. dykes tend to be grouped and are more abundant in some rocks than others. This Harker believed to be due to the degree of penetrability of the country rock, but hardness in itself is not important. Sheet intrusions, whether dykes or sills, appear to follow pre-existing planes of weakness, bedding-planes, joints and faults. Rocks such as conglomerates which do not have any regular planes of weakness offer resistance to intrusion, witness the soft Palagonite Tuffs lying at the base of the lavas in which intrusive sheets become highly irregular and lose direction. iii. many dykes show flow structure, the direction of which is not vertical but inclined at an angle. Clough (in Harker 1904, p. 392) recorded the angle of the rodding on the sides of many dykes and they were only rarely vertical. iv. the majority of dykes have a hade to the east, i.e. they lean over to the west in conformation with the general tilt of the region. v. the basic dykes belong to different groups of

different ages but there is no certain way of separating them. Their distribution in N. Skye, however, as will be shown in the sequel, could suggest that the majority of the most common group, i.e. olivine-dolerites, belong to the last or regional phase of minor intrusion, whereas those with mugearitic, crinanitic and teschenitic affinities, which are more limited in distribution, appear to be linked with the various lava groups.

In the following account the dykes of N. Skye are dealt with in three groups : 1. trachytic, mugearitic, doleritic, picritic and gabbroic dykes associated with the lava groups, 2. the big gabbro dykes of central area, 3. the regional dolerite dykes, 4. multiple intrusions.

Trachyte

Harker (1904, p. 386) referred to a group of trachyte dykes found near the head of Loch Harport as 'The Drynoch Group'. These are of medium width the largest seen crossing Bracadale Burn and being from 15–20 ft across. They vary from light to dark grey in colour and often show a rusty staining connected with the platy fracture. They are non-porphyritic, dull surfaced, fine-grained rocks of low density, consisting essentially of minute feldspar laths orientated parallel to the flow. They are probably, as in the case of the lavas, closely connected with the mugearites, from which they differ chiefly in the absence of olivine.

It is perhaps significant that these trachyte dykes lie entirely within the area occupied by the trachyte lavas. The Broadford and Sleat trachyte dykes studied by Clough (in Harker 1904, p. 388) appear not to be directly connected with the former group, They commonly have spherulitic margins and the sides frequently exhibit a "rodded" structure the inclination of which Clough carefully recorded and found that the average was in the neighbourhood of 45° from which it could be assumed that the movement of magma in the dykes was more or less at this angle. Harker thought these to be amongst the latest of the intrusions. Certainly their distribution suggest an origin from the granitic rather than from the gabbro centre whereas the Drynoch group seem to originate from the latter, and to be earlier in time. But the exact age relationship between these trachytes and other dykes has not been discovered in the field.

Mugearite

Harker (1904, p. 331) first recognized mugearite (oligoclase-dolerite) as a distinct type of basic dyke and described as the best example that at Am Bile, about 1¼ miles E.N.E. of Portree. This however, is somewhat unusual in having a high proportion of glass and is perhaps better classed with the variolites (Harker 1904, p. 347).

The mugearites differ from the normal basic dykes in having a higher silica percentage, lime, and especially magnesia lower, alkalis (including potash) higher. In the field they are dark with a bluish sheen, finer grained than most dolerites and usually exhibit a platy structure. As in the lavas the mugearite dykes appear both in non-porphyritic and feldspar-phyric form. They are not very common but some are large, for example two cross Vidigill Burn E. of Loch Harport 45 yd apart, one being 75 ft and the other 30 ft or more across. Some twenty of these dykes have been mapped, apart from those forming part of multiple intrusions, of which eight are feldspar-phyric. The most northerly seen are an 8-ft non-porphyritic in Aros Bay, Vaternish, and a 10-ft feldspar-phyric mugearite on the northern slope of Creag Madragil in Trotternish. Their distribution is virtually that of the mugearite lavas, though they are most abundant in the Drynoch area and their orientation is in the regional N.N.W. direction except for one running east-west at the south end of Tamer Island in Loch Bracadale.

The single example of a Leidleite (augite–andesite) dyke which crosses the Tungadal River is probably to be associated with the Drynoch group of mugearite dykes with which it is petrographically closely related.

Also to be associated with the mugearites are the Variolite dykes, i.e. andesitic or mugearitic basalts with interstitial glass and a variolitic texture. Of these the Bile (Beal) dyke has already been mentioned. Others have been seen as follows: in Allt Yelkie, 1 mile east of Cnoc Steud, just south of Uig, 4 ft in width; another 4 ft, cutting the Creag Langall sill about 2 miles south of the Lealt River; and one 8 ft wide, crossing Eas na Coille rather less than ½ mile before it joins the Varragill River. These all lie within the area occupied by the eastern group of mugearite lavas.

Dolerite

Olivine-dolerite. Dykes of olivine-dolerite are by far the most abundant in N. Skye. It is clear that the majority belong to the latest phase of the vulcanicity for they cut lavas and sills alike and are mostly later than the faulting. In general the trend is the normal, veering between N.W. and N.N.W. but there are deviations, particularly on the east coast in the area between Portree and Sligachan where a number of these dykes have a trend veering between N. and N.E. It cannot be concluded, however, that there is any great difference in age between these two sets since they cut each other indiscriminately as can be well seen on the coast between Holm Island and Bearreraig. A possible explanation of these deviations is that they are due to disturbances in the Tertiary fault pattern by an earlier fracture of some magnitude in the Sound of Raasay (see p. 174).

Essentially these dykes behave in a similar way to the other sheet intrusions the sills, but in the vertical plane. End terminations are rarely observed but one dyke on the W. side of Meall Tuath dies out upwards. Lateral displacement of dykes follows a similar pattern to that described by Clough (in Harker 1904, pp. 302–4, figs. 64–67). Typical examples were recorded by Messrs. John Knox and T. R. M. Lawrie during the mapping of N. Skye.

No single olivine-dolerite dyke has been recorded which exceeds in width that in Lon Airigh-uige in Glen Uig i.e. 20 ft. There is one 10 ft wide at Ard Beag in Vaternish but the majority are less than this.

Feldspar-phyric olivine-dolerite dykes are not common; there are two, one 14 ft and the other 20 ft wide 1 mile west of Sgurr a Mhalaidh, and two others one 2 ft-2 ft 6 in and the other 12 ft wide, one mile and two and a half miles south of Uig respectively, all in Trotternish. On the east side of Loch Greshornish several of the dykes of this type occur in groups of four or five. The distribution of these porphyritic dolerite dykes does not appear to have any special significance.

Anakime-dolerites. Dolerite dykes rich in analcime and with an ophitic texture resemble those first described by Flett (in Cunningham Craig and others 1911) as Crinanites. Others with more analcime and less olivine approach the teschenites. Both crinanitic and teschenitic dolerite dykes have a similar distribution; there is a small group in the Kilmaluag-Duntulm area all under 6 ft in width, a second group occupies a long narrow oval area running from Meall a Fhuarain N.N.W. to Kilbride Point in Trotternish, and a third group form a similar pattern in the area between Colbost and Dunvegan Head. The axis of these last two areas coincide more or less with the fissures responsible for the Bracadale and Osdale Lava Groups.

The widest crinanitic dyke seen was that in Coire Iomhair, measuring 18 ft, two others were 12 ft, i.e. that just south of Cnoc Steud, south of Uig Bay and that 1/6th mile west of Meanish in Loch Pooltiel, Duirinish. On the coast about ½mile south-east of Colbost Point in Loch Braca dale is a 5-ft crinanitic dyke unusual in two respects. It is vesicular and runs W.S.W. Feldspar-phyric crinanite dykes are rare. Those seen were all in the west e.g. that ½ mile north of Gob na Hoe, one 12 ft wide 1/6th mile south of Greshornish House and a 5-ft example ■ mile due west of Cnoc a'Chrochaire.

Single dolerite dykes with teschenitic affinities are all small, the largest seen being 8 ft wide and situated near the south end of the sediments in An Lethpheighinn, Hamra River.

In the Allt na Glas Bhuaile is one 6 ft wide but the remainder are 4 ft or less in width. Feldspar-phyric teschenites are rare, only four have been recorded, the largest of which is one 10 ft wide at Ru Chorachan, the southern point of Uig Bay.

Picritic dolerite

A relatively small number of the dolerite dykes are unusually rich in olivine and augite and so approach picrite in composition. They appear to be related to other dykes recorded as gabbroic dolerites and with these are apparently the latest of this series of minor intrusions, according to the evidence of the multiple dykes (see p. 137).

East of a line drawn north-south through Edinbain the picritic types predominate, west of it the gabbroic dykes are more common. All follow the usual N.N.W. or N.W. direction.

The largest picritic-dolerite dyke seen is 30 ft wide and runs one mile east of Kildonan; S.S.E. of Beinn Tuath is one 12 ft wide, and a 10-ft wide example crosses the River Ollisdal, ½ mile from the coast. One 5 ft wide crosses the River Tora ½ mile south of its junction with Allt Garbh and further north one 9–10 ft wide runs north and east of Glenuachdarach in Hinnisdal, another ½ mile S.E. of Camas Beag, Uig Bay, is 6 ft 6 in wide.

The gabbroic dykes fall into two categories i.e. those which behave as normal dykes and others treated separately, which are better described as igneous 'pods'. The first group, though some are larger than the average, occur as normal dolerite dykes and enter in association with other to form composite intrusions. They are mainly confined to the western half of N. Skye in Duirinish and Vaternish though one, 10 ft wide, crosses Lon Breac about 1 mile east of Lon Ruadh and west of Beinn a' Sga. The largest seen was 50–60 ft wide at the south end of the Ardroag peninsula on the west side of Loch Vatten. Another 20–40 ft wide is to be found 1 mile east of Loch Beag, Bracadale, and east of this, one west of an the other north-east of Meallan Gainmhich. At the head of Loch Dunvegan and ■th mile south of Kinloch is one 30 ft wide and in Duirinish is a 10-ft wide gabbro type at Gob na Hoe.

Gabbro and allivalite

The big gabbro and allivalite dykes differ in that the plagioclase of the gabbro is labradorite whilst that of allivalite is anorthite. Gabbros, by reduction of their ferric constituents, may grade into the pyroxene-free allivalites, and there is no doubt at all judging by the field relationships that these very large intrusive masses are all very closely related geographically, temporally and petrographically. They occur as a compact group between Bracadale and Beinn a'Chleirich within an oval area about three miles along the N.N.W. axis and two miles along the short axis.

The most southerly is on the west side of Beinn nan Braclaich on the same line as a long allivalite–gabbroic dyke which crosses Loch Beag at Struan. It is about 500 yd long and about 100 yd in width and appears to be a composite or multiple intrusion made up of four leaves of alternating gabbro and allivalite.

Some 400 yd to the N.N.W. along this same line another intrusion of this type crops out on either side the Broisgillmore Burn exhibiting very clearly the peculiar attributes of these 'dykes'. The gabbro-allivalite is emplaced in feldsparphyric mugearite lava and consists of two pods on the same axis but not continuous with one another though only a few yards separate them and the burn which runs between is entirely in mugearite.

The rock is fine grained at the margins and appears to be a crinanitic dolerite but the centre is vesicular and gabbroic.

The walls of the intrusion appear to diverge upwards like the sides of a boat and the ends similarly curve under in a boat-like fashion. It might have been thought that these 'dykes' represent the upper portions of a vent just before it merged into a lava-flow and that the very considerable bulk of the dykes and the nearness of the overlying flow has allowed them to cool sufficiently slowly to crystallize as coarsely as the gabbro of the Cuillin laccolite. The petrographic evidence (p. 170) however, shows that they were intruded as a mush of coarse crystals, lubricated by a small amount of alkali basalt magma.

Rather less than 1000 yd further along the same line to the N.N.W. another of these intrusions crosses Glen Ose about 1 mile north-east of Osdale. This, more than 150 ft wide, is classed as an allivalite. Continuing in the same direction for a little over a mile another, rather larger allivalite dyke is to be found on the east side of An Cleireach. This intrusion is over 1000 yd long and from 150–170 ft wide. Near its southern end a sill of the same rock follows the base of a lava-flow E.N.E. towards Allt Ruairidh, one of the very few sills known in the lava series. The 'dyke' is cut by a later olivine-dolerite dyke 6 ft wide with a N.W. trend.

This line of apparently discontinuous intrusions is almost 5½ miles in length extending from Glas Bheinn in the south to Bheinn a' Chleirich in the north.

Another possible fissure with a slightly more northerly trend lies between 1 mile and 1½ miles to the east. At the northern end on the southern slopes of Cruachan Glen Vic Askill is the largest of these 'dykes' over ¾ mile long, and 300 ft wide; it is classed as an allivalite. At its southern end and 200 yd to the west is another 'pod', this time gabbroic, about 230 yd long by 270 ft wide.

Southwards on the south side of the Ose River and 300 yd N.N.E. of Dun Arkaig is a possibly related gabbroic dyke 300 ft or so wide and about 600 ft long.

On the north side of Am Bidean is another similar gabbroic 'pod' about the same width as the last but considerably shorter. This is not in line with any other than perhaps one of the gabbroic dykes in the Voaker Burn east of Bracadale and seems to have no specific connections with the other 'big' dykes.

These very large gabbro-allivalite intrusions present a problem which would well repay closer investigation. They are not normal dykes. They are earlier than some of the olivine-dolerite, presumably regional, dykes. If they are feeders for lavas then they must be very late in the history of the extruded rocks for they cut the mugearite and basalt flows of the most recent lava series, and could only be related to still later flows no evidence for which now remains, yet their obvious alignment suggests a definite relation to a fissure.

Regional dolerite dykes

It is thought that the majority of the olivine-dolerite dykes belong to the final period of the collapse of the lava field. They are medium-sized intrusions very uniform in type and in all respects similar to the dykes described in Mull as being of the Plateau Basalt type (Bailey and others 1924, p. 368). The majority are less than 20 ft in width but often of considerable length. They appear to be later than almost all the faulting. Non-porphyritic and feldspar-phyric types are equally common Since it is rarely possible to distinguish the late dolerite dykes from others of earlier date little can be said about their distribution. It seems however, that they tend to increase in size and number towards the Cuillin area.

Multiple intrusions

Not only are simple olivine-dolerite dykes the moot common in N. Skye but they most frequently combine to form multiple intrusions either with each other or with dykes of different composition.

Twelve examples of multiple olivine-dolerite dykes have so far been recorded. Some are fairly large; one just south of Lon Chaorach on the east side of Glen Varragill is over 20 ft wide. Others of this size occur at Knockbreck in Vaternish, and on the south side of Eileen Creagach in the Ascrib Islands. A good example of a triple olivine-dolerite dyke 16 ft wide is to be seen in Geary, Vaternish, and 1/6th mile south of Rubha Glas; in Loch Snizort Beag is a quadruple dyke with leaves 1 ft, 2 ft, 8 ft and 7 ft wide.

On the west side of Rubba nan Cudaigean, also in Loch Snizort Beag, is an unusual type of intrusion consisting of six olivine-dolerite dykes, closely approximated with only thin sheets of basalt lava separating them, in all 30 ft across. Often one of the leaves of these multiple dykes is a crinanitic or teschenitic dolerite. For example, a crinanitic dolerite forms the middle leaf of a triple dyke 12 ft wide in the cliff, ¾ mile north of the southern end of Meall Greepa in Loch Bracadale; and on the east side of Loch Greshornish near Kildonan is a multiple dyke, 55 ft wide, made up of alternating olivine-dolerite and teschenitic dolerite leaves. This dyke actually consists of an 8-ft feldspar-phyric dolerite on the east separated by a 12-in sheet of basalt, from a 47-ft teschenitic dolerite on the west into which has been intruded a later feldspar-phyric dolerite dyke 2 ft thick.

Combinations of olivine-dolerite and mugearite dykes are also found in which the latter appears to be the later intrusion. An interesting example of this was recorded by Mr T. R. M. Lawrie 600 yds W.N.W. of McQueen's Loch in the lavas of Ben Tianavaig. In this 40-ft wide intrusion the central member is a feldspar-porphyric mugearite with variolitic dyke against its east face and flanked on both sides by olivine-dolerite. The order of intrusion determined from the chilling of the margins was : olivine-dolerite, variolite, mugearite. On the other hand in a 20-ft triple dyke on the east side of Port Beag, Loch Harport, olivine-dolerite is the middle member flanked by mugearite, and similarly in the Sumardale River a 3-ft olivine-dolerite dyke is emplaced between an 8-ft and a 4-ft feldspar-phyric mugearite.

In the Tungadal River, about 1 mile south of the mouth of Vidigill Burn Mr. John Knox recorded an unusual combination of dolerite and mugearite intrusions. This is a slightly sinuous dyke exposed for about 200 ft. An 11-ft feldsparphyric mugearite dyke has been emplaced in the centre of a 6-ft olivine dolerite, whilst four other mugearite sheets have been

intruded on the east side of it. Where the mugearite is in contact with itself there appears to have been mutual chilling so that the several leaves were probably not exactly contemporaneous.

Combinations of olivine-dolerite and gabbroic dykes are also found as at Rubha Dubh on the west side of the Vaternish peninsula, but only one case was discovered where the age relationships were clear. At Poll a'Bhaine, Greshornish, a 12-ft gabbroic dyke is emplaced in a coarse olivine-dolerite. A 10-ft fine-grained dolerite dyke alongside the gabbro may be a still later addition.

The crinanitic and teschenitic dolerites also occur as multiple dykes. For example a double crinanitic dyke occurs on the west side of Aird Point, Loch Snizort Beag, and a double teschenitic dyke 4 ft wide on the west side and 8 ft on the east crosses Lon nan Achadhanan, east of Glengrasco. Combinations of crinanitic and teschenitic dykes are rare but one is to be seen in the Treaslane River, north-west of Uigshader and another at Corran at the northern entry to Loch Eyre.

Multiple mugearite dykes are equally rare. A good example is a 20-ft triple intrusion in Lon Salach, ■ mile west of Balmeanach, where a non-porphyritic mugearite has been emplaced in the centre of a feldspar-phyric mugearite dyke.

The gabbroic dykes do not often occur as multiple intrusions. In two cases they are known to run alongside crinanitic dolerite dykes i.e. between Meallan Gainmhich and An Leitir, west of Glen Varragil, and again ½ mile south of Rubha Bhreidein in Loch Greshomish. Gabbroic dykes accompanied by olivine dolerite intrusions have already been mentioned but the association of gabbroic and teschenitic dykes has not been observed in N. Skye.

An interesting multiple dyke is that crossing Lon Loch Mhair on the north side of Glen Hinnisdal. It is 10 ft wide and is made up as follows : mugearite, olivine-dolerite, gabbro, mugearite.

Only one case is known of allivalite as part of a multiple dyke i.e. on the east side of Gairbh-sgeir, at the southern end of Lub Score is a 20-ft intrusion in which an allivalite sheet has been emplaced in the middle of an olivine-dolerite dyke.

Age relations of the dykes

Multiple dykes should yield valuable evidence as to the order of emplacement of the various types. Unfortunately, this is not always forthcoming and no firm conclusions can be reached on present evidence. All that has been so far established is that some of the olivine-dolerite dykes are earlier than the crinanitic dolerites, than the mugearitic, and than the gabbroic and allivalite dykes. Other olivine-dolerites are later than the teschenitic dolerites, than the mugearites and than the gabbroic dykes. A possible order of intrusion for the dyke rocks is then: 1. teschenitic dolerite, 2. olivine-dolerite, 3. crinanitic dolerite, 4. olivine-dolerite, 5. mugearite, 6. olivine-dolerite, 7. gabbro and allivalite, 8. olivine-dolerite.

Inclined sheets

Intrusive sheets in the lavas at Biod Ban, Oisgill Bay, which may be either regarded as dykes or sills have already been described (p. 131). Four similar but smaller sheets cross the Vidigill Burn just over a mile S.E. of Ben Duagrich; they are all olivine-dolerite and from the lowest upwards are 30 in, 20 in, 36 in, and 22 in thick.

Vents and agglomerates

In view of the vast outpouring of lavas in the area of N. Skye it is surprising that so few vents have been located. Mr. Knox records a lens of agglomerate 30 yd long by 4 ft thick on the west side of Lyndale Point within which are two dykes showing anomalous behaviour. The agglomerate is a breccia largely of lava but with so me bole and a few fragments of baked shale.

In Loch Bracadale a dyke-like strip of agglomerate occurs on the shore at Ullinish and again ¼ mile further north in the same small bay. Agglomerate has also been recorded 350 yd south of Osdale in Glen Ose, and again in Glen Bracadale associated with trachyte lavas, and south of Gesto House, but none of these can be confidently regarded as vents.

It would seem that for the most part explosive eruption was confined to the earliest stage of volcanic activity when the Palagonite Tuffs were being formed. This deposit in many places contains brecciated lava and resembles an agglomerate but nothing representing a true vent has been observed.

References

BAILEY, E. B., CLOUGH, C. T., WRIGHT, W. B., RICHEY, J. E. and WILSON, G. V. 1924. Tertiary and Post-Tertiary Geology of Mull, Loch Aline and Oban. Mem. Geol. Surv.

CUNNINGHAM CRAIG, E. H., WRIGHT, W. B. and BAILEY, E. B. 1911. The Geology of Colonsay and Oronsay, with part of the Ross of Mull. Mem. Geol. Surv.

HARKER, A. 1904. The Tertiary Igneous Rocks of Skye. Mem. Geol. Surv.

MACCULLOCH, J. 1819. A Description of the Western Islands of Scotland including the Isle of Man. London.

WALKER, F. 1932. Differentiation in the Sills of Northern Trotternish (Skye). Trans. Roy. Soc. Edin., 57, 241–57.

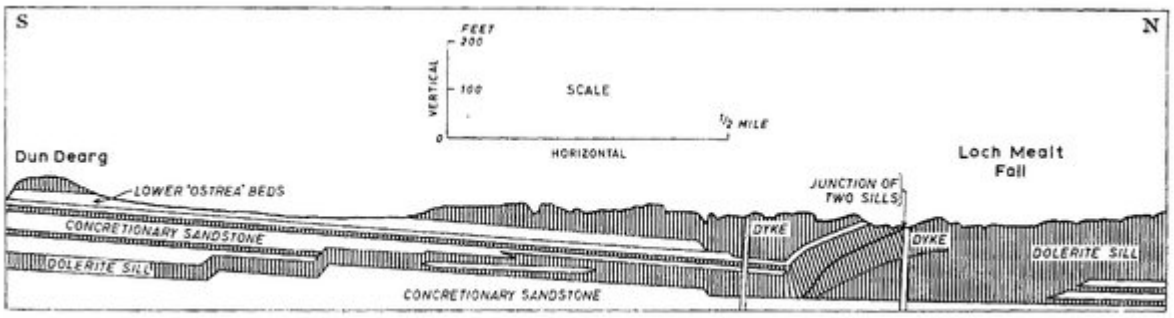

FIG. 7. *Section in sea-cliff between Drum Dearg and Loch Mealt fall*

(Figure 7) Section in sea-cliff between Drum Dearg and Loch Mealt fall.

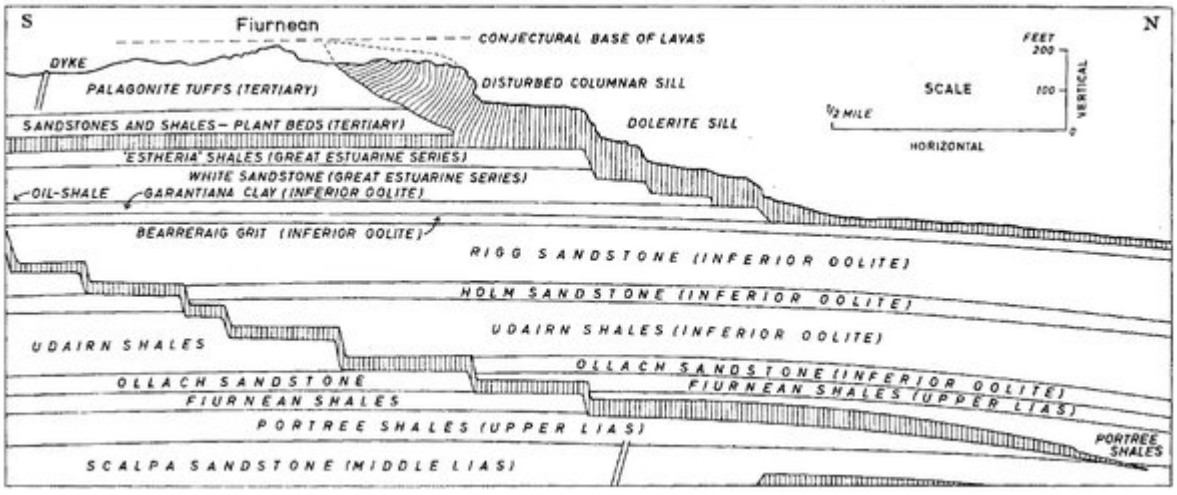

FIG. 3. *Section in sea-cliff at Fiurnean, 4 miles N.N.E. of Portree*

(Figure 3) Section in sea-cliff at Fiurnean, 4 miles N.N.E. of Portree.

(C2244)

A. BEARRERAIG BAY, 6¼ MILES NORTH-NORTH-EAST OF PORTREE
Columnar sill of dolerite overlying Inferior Oolite

(C3898)

B. COAST, SOUTH OF MEALT WATERFALL, LOOKING NORTH FROM VALTOS
Great Estuarine Series with intruded sills of dolerite

(Plate 3) A. Bearreraig Bay, 6½ miles north-north-east of Portree. Columnar sill of dolerite overlying Inferior Oolite. (C2244) B. Coast, south of Mealt Waterfall, looking north from Valtos. Great Estuarine Series with intruded sills of dolerite. (C3898).

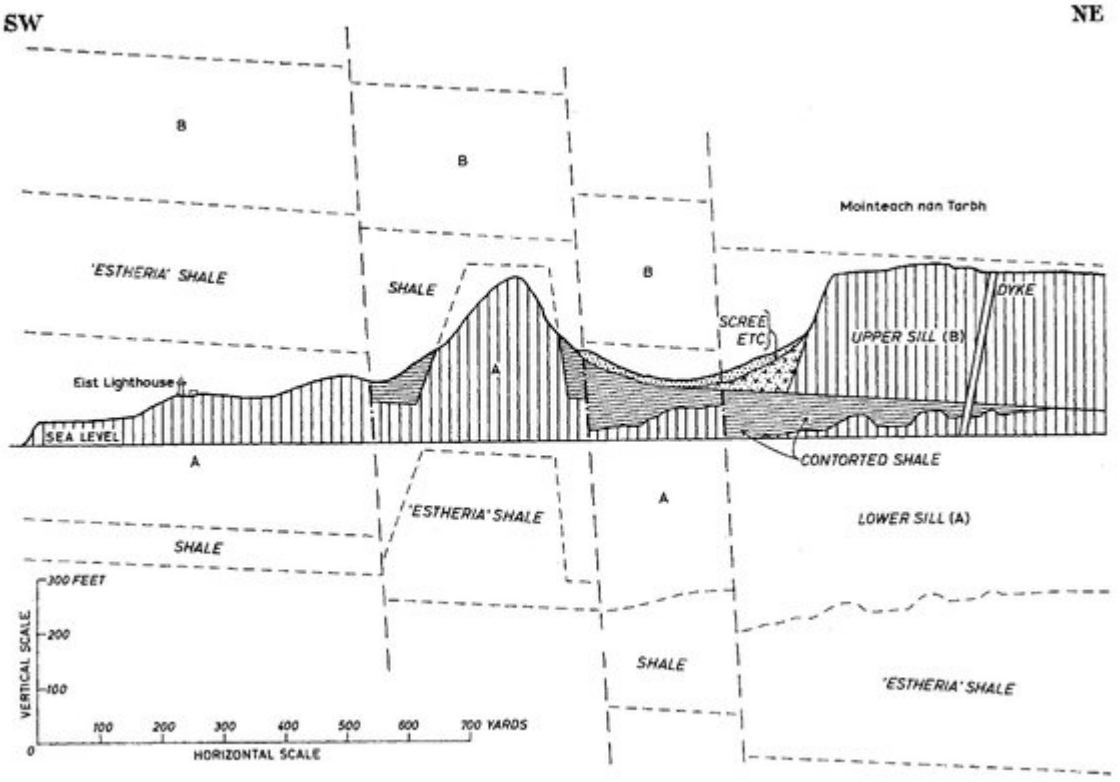

FIG. 14. *Section showing the behaviour of part of the Tertiary sill-complex at Eist*

(Figure 14) Section showing the behaviour of part of the Tertiary sill-complex at Eist.