Chapter 16 Minor intrusions

Introduction

Swarms of sub-parallel north-north-west to north-north-east trending acid and basic dykes cut the diorite, granite and granophyre of Northmaven and Muckle Roe. Dykes with rather more variable trends are also abundant on Vementry Island and somewhat less abundant within a 2 to 3 mile (3–5 km) wide belt bounding the north coast of the Walls Peninsula. Sills, sheets and intrusions of irregular shape are relatively rare.

The minor intrusions fall into two main groups respectively of acid and basic composition, with a minor group of intermediate composition. The acid dykes comprise felsites, quartz-feldspar-porphyries and feldspar-phyric porphyrites. The basic dykes are principally basalts and dolerites, but many of them contain hornblende as the principal dark mineral instead of pyroxene. Some of the basic dykes have accessory quartz. The rocks shown on (Plate 28) as pyroxeneporphyrite usually contain some cryptopegmatite. Fresh olivine and orthopyroxene have not been found, but pseudomorphs after these minerals have been observed in a small number of the basic dykes. The intermediate group is represented by only a few individual dykes and includes keratophyres, spessartites and microdiorites. Keratophyric rocks occur also as thin marginal facies to some of the acid dykes.

Distribution

In Muckle Roe and Northmaven both basic and acid dykes form parallel swarms whose trend ranges from north-north-west to north-north-east, and several dykes have curving courses within that sector. The distribution of the basic dykes differs from that of the acid ones in that the former appear in roughly comparable numbers throughout the area, whereas the latter are largely restricted to the outcrop of the Muckle Roe Granophyre. The difference in distribution is readily appreciated in the east–west section along the south coast of Muckle Roe, where between Scarfataing [HU 340 637] and Picts Ness [HU 297 638] at least 60 dykes have been observed. In the central sector of this section, between Ness of Gillarona [HU 327 627] and Burki Taing [HU 317 626], all 22 observed dykes are acid. On either side of this sector of the coast basic and acid dykes crop out in alternating groups, but in the extreme east and west of the shore section basic dykes predominate. Alternate swarms of basic and acid dykes can also be traced across the central part of the island, but this alternation is less evident along the north coast where basic dykes are largely confined to the area immediately east and west of Erne Stack. The concentration of the acid and basic dykes into parallel zones suggests that tensional stress operated in two stages to provide channels along which at one stage acid magma, at the other stage basic magma was irrupted. In the central part of the island the stress effected fissuring, actual or potential, along different but parallel belts. In the west the later stage of stress operated roughly along the same belt as the earlier. This hypothesis of intrusion of acid and basic magmas respectively at different stages of active stress is consistent with the dearth of composite dykes since if both types of magma were susceptible to irruption at the same stage, the production of composite or hybrid dykes would be probable. If, however, the belt of fissures, actual or potential, caused in the first stage were healed by one type of magma, the fissuring strain caused by the second stage of stress would be produced more easily along a less well cemented zone.

The restriction of the swarm of acid dykes to the outcrop of the granophyre appears to indicate that acid magma existed in a state suitable for intrusion at only restricted places in the magmatic hearth during this late stage, whereas the basic magma remained in an intrusible condition below a much wider area.

Along the north coast of the Walls Peninsula and in the islands adjoining this coast basic and intermediate dykes have the same general trends as the dykes of similar composition in Muckle Roe and Northmaven. They are largely confined to a 2- to 3-mile (3–5-km) wide coastal strip which extends from Brough Skerries [HU 216 583] in the west to Papa Little in the east and they are most abundant in the eastern part of this section, particularly in Braga Ness [HU 315 605] where swarms consisting of up to five parallel dykes have been recorded. The acid minor intrusions of this area also have a more restricted distribution and are largely confined to a 3-mile (5-km) wide, roughly circular, zone around the Vementry Granite, though within the granite itself dykes are rare. The trend of these dykes has a roughly radial pattern centred on

the Vementry Granite, suggesting that a magma chamber underneath this granite body was the focus of irruption of the dykes.

Age of the intrusions

It is clear that both the acid and the basic dykes are younger than the main plutonic bodies which they cut. There is also abundant evidence that the basic dykes cut, and are therefore later than, the plexus of aplitic, granitic and granodioritic veins which invade the Northmaven diorite. The intrusive relations are particularly clear at Wilson's Noup [HU 300 720] and Lang Head [HU 303 706] and on Egilsay [HU 315 693]. The age of the acid dykes relative to the granitic component of the Northmaven complex is not so readily determined because of the restricted distribution of the acid dykes. An acid porphyrite has been observed to cut the granite-veined diorite on the west shore of Otter Ayre [HU 324 666]. This dyke, like the rocks into which it is intrusive, is crushed (S44321) [HU 322 667]. In the same area, on the coast west of Lee Skerries [HU 321 670] a dyke of spessartite cuts the granite-veined diorite.

There is only little evidence from the Muckle Roe–Northmaven area of the relative age of the acid and the basic dykes but what there is indicates that the acid are the earlier. A specimen collected from a dyke at the Ness of Gillarona [HU 327 628], for instance, shows a contact of acid and basic pyroxene-porphyrite types. No field observation of the occurrence is available but the microscopic evidence (S28885) [HU 327 627] of chilling of the basic rock and partial enclosure of a feldspar phenocryst of the acid rock by the basic indicates the acid as the earlier. Cutting of an acid dyke by an 8-in (20-cm) thick basaltic dyke has also been recorded on the shore [HU 304 733] 200 yd (180 m) SSW of Nibon. In the Walls Peninsula and the adjacent islands there are several exposures of basic dykes cutting acid ones. Good examples are seen on the east coast of Braga Ness [HU 318 602] and on the north-east shore of Linga [HU 285 592]. The age relationship of the intermediate dykes to the acid or basic ones is not known.

Both acid and basic dykes cut the Old Red Sandstone Sandness Formation in the Walls Peninsula and in Papa Little. W.M.

Basic and intermediate minor intrusions

Field relationships

Northmaven and Muckle Roe

Basic dykes

Few measurements have been made of the widths of individual basic dykes but in general they appear to be less broad than the acid ones (see p. 249). On the south-west shore of Muckle Roe they range in thickness from less than 1 ft (30 cm) to 40 ft (12 m). The basalts and dolerites tend to occur as groups of parallel, roughly north-south trending dykes. The pyroxene-porphyrites, which are the thickest of the basic dykes, on the other hand, have a much more localized distribution and a more variable shape. They are most common in the Busta and Islesburgh peninsulas. The pyroxene-porphyrite exposed on Kat Field [HU 330 687], 0.5 mile (0.8 km) WNW of Mavis Grind, has a persistent north-westerly trend, which is unusual in the basic dykes, and over its course of 600 yd (550 m) it exhibits an unusual thickening and thinning, which may be due, in part, to minor dislocations along north-north-west trending crush belts. The continuation of the Kat Field dyke can be traced intermittently south-eastward towards Busta, the most southerly exposure being a round boss-like mass on the Ward of Runafirth [HU 343 673], 0.25 mile (400 m) NNW of Busta. The presence of a number of small pyroxene-porphyrite dykes which appear to radiate from this boss suggests that the Ward of Runafirth intrusion may be at or near the local focus of a radiating irruption, and that the pyroxene-porphyrites represent a stage of intrusion that differed from the stage of the north-south basaltic intrusions in the character of the magma, the pattern of fissures accessible to the magma, and, consequently, in time. It is suggested that the pyroxene-porphyrite stage is the later and that it is related to the period of development of the north-west trending crush lines which fan out from the Walls Boundary Fault zone ((Figure 27), p. 262).

Only two basic dykes have been recorded in the metamorphic rocks east of the Walls Boundary Fault zone (Plate 28). One of the basalt dykes trends north-south, the other has an east-north-easterly trend. Neither basalt is foliated.

Dykes of intermediate composition

The most abundant intermediate dykes are keratophyres, three of which crop out on Mid Field [HU 313 638], Quilt Ness [HU 297 644], and Strem Ness [HU 292 658] on Muclde Roe. Other keratophyre dykes occur on the south-west corner of the Isle of Nibon [HU 296 727] and on the Mainland west-south-west of Nibon House. In the field the latter looks like a felsite and displays thin colour lamination with spherulitic and non-spherulitic banding. A number of acid dykes, composed principally of felsite and/or quartz-feldspar-porphyry, have dark keratophyric marginal facies. Good examples of these are seen in the multiple acid dyke exposed at the west end of Raavi Geo [HU 310 675] (see p. 250 and (Figure 26)), and in several other dykes exposed along the north coast of Muckle Roe between North Ham [HU 303 665] and Lothan Ness [HU 316 676]. These marginal facies are darkish grey, green or purplish in colour and have a superficial resemblance to basic dykes.

Only two lamprophyre dykes are known in the area. Both are spessartites; one trends north-north-west on the north-east coast of Muckle Roe [HU 322 670], midway between Lothan Ness and Otter Ayre and the other is exposed on Steinawall [HU 330 651], 700 yd (640 m) WSW of the south end of Kilka Water. The only microdiorite dyke known in the Muckle Roe–Northmaven area crops out at Picts Ness [HU 297 637]. J.P.

Walls Peninsula and adjacent islands

Within the southern area the basic and intermediate minor intrusions are largely confined to Vementry Island, Papa Little and a 2 to 3-mile (3–5 km) wide belt along the northern coast of the Walls Peninsula. They are here less abundant than in the area to the north. Most of the intrusions are dykes with a north-north-westerly to north-north-easterly trend and a mean trend of N5°E. Comparatively few trend parallel to the strike of the bedding or foliation of the country rock.

Basalts and dolerites and unclassed basic and sub-basic rocks

Though the one-inch geological map of Western Shetland distinguishes between basalts and dolerites on the one hand and unclassed basic and sub-basic rocks on the other, it is likely that all these intrusions belong to a single dyke-suite. The distinction between the two rock-types is largely artificial, being due to the fact that many of the unclassed basic dykes have not been examined in thin section and that the remainder are too highly altered for accurate determinations to be made. The basalts and dolerites are dark grey fine-grained and, in some instances, very sparsely microporphyritic rocks, with the feldspar phenocrysts roughly equidimensional and not exceeding 3 mm in size. The north–south trending dykes range in width from a few inches to 20 ft (6 m) and a high proportion are between 5 and 8 ft (1.5 and 2.4 m) thick. The density of dykes increases markedly towards the eastern part of the area, and in the Braga Ness peninsula they form swarms of up to five closely-spaced dykes with average thickness of 5 ft (1.5 m). The basic dykes cut the acid and sub-acid dykes but field evidence relating to the age relationship of the basalts and dolerites to the porphyrites, spessartites and quartz-dolerites is lacking. All dykes are displaced by the east-north-east trending faults.

There are a number of dykes and sheets with trend roughly parallel to the strike of the country rock. These are more variable in thickness and generally finer grained than the north–south trending dykes. One sheet of highly shattered aphanitic basalt which crops out along the junction between the metamorphic rocks and Old Red Sandstone sediments, 400 yd (360 m) ESE of Vementry House [HU 313 595], is up to 65 ft (20 m) wide. Concordant sheets exposed on the shores of West Burra Firth [HU 251 570] and the Voe of Snarraness [HU 237 567] (Plate 24) are respectively 10 and 4 ft (3 and 1.2 m) thick.

Quartz-dolerite

Only one dyke of quartz-dolerite has been recorded in the Walls Peninsula (Plate 28). This is up to 60 ft (18 m) thick and has a sinuous north-east trending outcrop which passes the north-west shore of Mousavord Loch [HU 223 554] and can be traced for 1300 yd (1200 m). It consists of pale grey medium-grained, non-porphyritic dolerite, with pale greenish grey subhedral feldspars up to 1 mm in size. The sediments adjoining this dyke are markedly indurated.

Pyroxene-porphyrite

In the Walls Peninsula pyroxene-porphyrite forms a very small number of wide north to north-north-west trending dykes. The most westerly of these dykes can be followed along a slightly sinuous course from the shore [HU 219 583] between Brough Skerries and the Skerry of Stools southwards for 1000 yd (910 m) to the west slope of the Hill of Bousta [HU 220 572]. The trend of this dyke is continued south-south-eastward by three dykes which are arranged *en échelon* to each other and can be traced for nearly 2 miles (3 km) almost to the latitude of Burga Water. These three dykes are 20 to 30 ft (6–9 m) thick throughout the greater part of their outcrop. The northern two consist of pale grey highly porphyritic rock, with abundant fresh, almost glassy euhedral to subhedral plagioclase phenocrysts, up to 10 mm in size, set in a somewhat darker grey aphanitic groundmass. In the south-eastern parts of the dyke-complex the volume-percentage of glassy feldspar phenocrysts gets gradually less and the matrix becomes somewhat finer-grained and contains small patches of pyrite and veinlets of calcite. Irregular pale greenish epidotic patches and small areas in which the feldspar phenocrysts are pink or pale red-stained are present throughout the dyke-complex.

The only other porphyrite dyke recorded in the Walls Peninsula crops out on the south shore of West Firth Burra [HU 250 569]. Because of indifferent exposures it has not been possible to determine the exact thickness and trend of this dyke, which cannot be traced inland. Two porphyrite dykes, both less than 10 ft (3 m) thick, crop out on the north-west shore of the island of Papa Little. Of these, one trends north–south and the other east–west. Both contain very platy phenocrysts of fresh, almost glassy feldspar, up to 10 mm long, set in a very fine-grained dark grey matrix.

Microdiorites and spessartites

Three spessartite dykes crop out along the north and east shores of the Neeans peninsula. The most westerly of these, exposed on the east shore of the Geo of Djubabery [HU 263 589] is 12 ft (3.6 m) wide and has a N15°E trend. It is pale reddish grey, holocrystalline and is composed of randomly orientated needles of pink feldspar up to 4 mm in size, set in a greenish grey very fine-grained matrix. The two dykes exposed on the east shore of the Neeans peninsula are less than 5 ft (1.5 m) thick and are considerably finer-grained than the Geo of Djubabery dyke.

A dyke of quartz-microdiorite crosses Swarbacks Skerry [HU 290 622] off the north-west coast of Vementry. This trends W20°N and is closely associated with a parallel dyke of spherulitic felsite. W.M.

PETROGRAPHY

Basic Minor Intrusions

The basic dykes are described under two headings: (1) basalts and dolerites, and (2) pyroxene-porphyrites. The former are further divided into quartz-bearing types and quartz-free types including a few which carry pseudomorphs after olivine.

Quartz-bearing dolerites and basalts

A small number of the basalt and dolerite dykes contain primary quartz. There are two types. In one the plagioclase and augite are both idiomorphic forming, respectively, tabular and stout prismatic crystals which range up to 4 mm in length and are seriate to groundmass dimensions, 0.2 to 0.4 mm. The plagioclase, broadly zoned from central labradorite with about 65 per cent An, is extensively sericitized and is the dominant constituent. The interstitial material is mainly chlorite in which brown flakes of biotite and anhedral grains of quartz are present in accessory proportions (S30877) [HU 221 553], and in which potassium feldspar can be locally identified as small stout prisms in quartz (S30881) [HU 224 557]. Magnetite is abundant as a minor constituent, apatite is accessory as thin prisms, and calcite occurs interstitially. A rock, which is referred to this type because of the similarity of texture, contains quartz mainly as a secondary mineral in association with chlorite and iron ore in an aggregate which might have arisen by destruction of olivine (S29976) [HU 220 553]. The other type consists essentially of plagioclase and ophitic or subophitic augite or hornblendic replacement of augite. The feldspar (labradorite) occurs as diversely orientated lathy prisms, rarely exceeding 1 mm in length, but augite, usually of comparable grain-size, may build shapeless grains, up to 4 mm across, enclosing many plagioclase laths (S30747) [HU 284 592]. Some examples contain scattered phenocrysts of plagioclase which rarely exceed 2 mm in

length (S43776) [HU 320 713], (S43780) [HU 300 724]. All the feldspar is zoned and though in some rocks it is completely albitized to oligoclase or indeterminable because of turbidity, its composition in fresher rocks is centrally labradorite in the range An 55 to 65 per cent. Except in the coarsely ophitic rock referred to above, the pyroxene is partially (S43780) [HU 300 724] or wholly (S43779) [HU 300 724] transformed into semi-opaque brown hornblende and into later clearer green and scarcer bluish green uralitic hornblende. The brown hornblende retains the subophitic shape and dimensions of the original pyroxene, which locally remains as small ill-defined relics (S43776) [HU 320 713]. The green uralitic amphibole merges into the interstitial material. The latter consists of chlorite and fibrous brown amphibole, granular quartz and feldspar, probably oligoclase, and biotite. In the rocks with fresh augite, chlorite is the important mineral of the mesostasis (S30877) [HU 221 553], (S47793) [HU 318 600] and is accompanied by flaky ragged biotite. In the uralitized rocks chlorite is scanty and fibrous hornblende with which is associated biotite in aggregates of minute clear brown or brownish green scales is the dominant component. These differences suggest that in the uralitization process a reconstitution of interstitial chloritic material to biotite which is akin to thermal metamorphism takes place (S43776) [HU 320 713], (S43778) [HU 300 724] (see also p. 204). Analogously in the fresher rocks the abundant iron ore remains black and opaque, whereas in the uralitized rocks it is thoroughly leucoxenized. Quartz is an abundant accessory or a minor constituent in these rocks and usually has a primary aspect but in the altered rocks (S30920) [HU 254 562], (S30996) [HU 277 579] much of the quartz may be secondary. Because of the reconstitution of the plagioclase to oligoclase and the pyroxene to amphibole some of the dykes mentioned could be classed as microdiorites, but they all seem to have been originally essentially basic mesocratic rocks. Albitization and epidotization have proceeded so far in one example that it is practically an oligoclase-epidote rock with some quartz and uralite (S43758) [HU 298 729]. In this rock epidote has largely replaced the pyroxene.

Quartz-free basalts and dolerites

Basalts composed essentially of plagioclase, augite or derived hornblende, and green mafic mesostasis form the largest group of the basic dykes. They include porphyritic, microporphyritic, and non-porphyritic varieties with groundmass in which the plagioclase rarely exceeds 0.5 mm in length. Only one dyke is coarse enough to be classed as dolerite. It is composed of shapeless crystals of augite, up to 3 mm across, partly or completely transformed to pale green, monocrystalline hornblende, which enclose zoned plagioclase prisms 02 to 1.5 mm long (S43774) [HU 321 725]. The latter consists of labradorite-bytownite (An_{70}) in the centre and oligoclase on the margin. Pale green cryptocrystalline aggregate, with tufts of acicular, very pale green amphibole and locally grains and prisms of epidote is interstitial to the plagioclase of the groundmass, and large (0.5 mm) crystals of leucoxenized ore which enclose plagioclase ophitically are accessory. The usual basaltic dykes when little altered show zoned plagioclase, centrally as calcic as An_{65}, enclosed ophitically by colourless or very pale brown augite which is mantled by turbid brown hornblende fringed in its turn by acicular green hornblende which merges into the mesostasis (S53570) [HU 335 648]. Some dykes are porphyritic with plagioclase more calcic than the groundmass laths (S43754) [HU 301 743], (S43772) [HU 320 726].
Feldspar-phenocrysts so greatly altered in comparison with the rest of the rock that they are probably xenolithic are also present (S43773) [HU 317 724]. Iron ore in idiomorphic and shapeless grains is abundant. The mesostasis is entirely mafic being composed of chlorite (S30742) [HU 321 595] or, more usually, chlorite and green fibrous hornblende and is commonly sufficiently abundant to isolate the plagioclase in single crystals or groups of only a few prisms. Rocks in which augite is still an important mineral though subordinate tohornblende (S43754) [HU 301 743] are transitional to those in which hornblende is the essential ferromagnesian mineral. In these rocks the subophitic texture is maintained by the amphibole enclosing lengths of the feldspar prisms; usually some relics of augite are to be found in the hornblende (S43756) [HU 302 731], (S43771) [HU 318 728], (S44326) [HU 328 671]. The plagioclase maintains its zoned, centrally calcic character. In none of the basaltic dykes has fresh olivine been observed but some contain small round or oval pseudomorphs on which the adjacent feldspar is moulded. The pseudomorphs are composed of different minerals—clear green hornblende aggregate with (S55176) [HU 315 695] or without (S30021) [HU 304 704] ore granules, carbonate aggregate (S44319) [HU 310 675], pale green serpentine (S45028) [HU 303 666]—but all may represent olivine. Most are small, the largest being 0.5 mm long, and they do not form a major constituent of the rocks. More common and larger than this type of pseudomorph are aggregates of cryptocrystalline material and of microcrystalline to moderately coarse (0.2 mm) equant anhedral masses of clear green hornblende which have no definite shape or margin against the other constituents. They may in some cases be of a vesicular nature (S43754) [HU 301 743], (S43756) [HU 302 731], (S43771) [HU 318 728], but it is probable that in others (S43767) [HU 321 735], (S43769) [HU 317 733], (S43769) [HU

317 733] they represent olivine or othopyroxene crystals or crystal groups from an early precipitation or from xenoliths. Many of the dykes are greatly altered by post-magmatic processes, such as sericitization (S49335) [HU 310 585], epidotization (S44626) [HU 297 643], (S50130) [HU 250 579], chloritization and albitization. Recrystallization of sericite has led to almost complete muscovitization of some porphyritic plagioclase crystals (S31025) [HU 239 566] and in this rock the pyroxene has been calcitized. Chloritization and albitization have converted some dykes into chloriteoligoclase rocks which could be classed as basic keratophyres (S30706) [HU 308 606], (S30708) [HU 306 605]. Two albitized basalts from South Voe, Vementry Island [HU 306 605] and West Ness, Muckle Roe [HU 298 658] (S49323) [HU 307 606], (S53578) [HU 303 667] in which the augite has remained quite fresh contain a mesostasis of chlorite with which abundant granular epidote and garnet are associated. The garnet forms round or oval grains 0.02 to 0.05 mm but exceptionally 0.2 mm long, entirely enclosed in chlorite or associated with epidote in aggregates in which chlorite may be only minor. In one of the rocks the garnet always has a semi-opaque peripheral zone which seems anisotropic (S53578) [HU 303 667]. Some grains of the garnet show alteration to cryptocrystalline matter of high birefringence which is thought to be sphene since sphene occurs enclosed in chlorite as grains of the size and shape of the garnet. X-ray examination by R. J. Merriman has confirmed the mineral as garnet, the d-spacings of which indicate a composition in the range almandine-spessartine. Scarce thin zeolitic veins, 0–5 mm wide, seen in a hornblende-basalt exposed just north of Kilka Water [HU 333 659], Muckle Roe, cut the rock irregularly and enclose small sinuous fragments of hornblende as if they occupy slight shear fractures. The zeolites are analcime and thomsonite, identified optically and confirmed by X-ray examination by Merriman who also identified leonhardite in a second vein (S53570) [HU 335 648], (S53570A) [HU 335 648].

Two of the quartz-free basalts are exceptional in containing brown biotite in the groundmass along with chlorite and microgranular oligoclase. Both contain fresh microporphyritic calcic labradorite and stout prismatic augite, interfering with the plagioclase but locally subophitic. In one of these rocks the larger crystals as well as the groundmass grains of pyroxene are almost completely carbonated and the brown biotite, which occurs as idiomorphic flakes in an obscure interstitial base of micro-crystalline calcite, idiomorphic and skeletal ore, and indistinctly interleaved chlorite and green biotite, has the appearance of neoformation (S30998) [HU 275 584]. In the other rock the augite is unaltered and the brown biotite, partly moulded on plagioclase and ore and grading into the interstitial chlorite, appears to be a late primary mineral (S47782) [HU 251 570].

Two dykes of basalt or fine-grained dolerite call for special mention because they are the only basic dykes found in the Lunnister–Haggrister area of metamorphic rocks (Plate 28). Both are composed of zoned labradorite prisms and ophitic, colourless or faintly wine-coloured augite, fringed by green or brown hornblende with abundant accessory magnetite or leucoxene and green interstitial cement which is composed largely of microcrystalline green amphibole and minor chlorite and biotite. Minor differences exist. One of the dykes contains larger crystals of bytownite, rarely over 1 mm long (S54280) [HU 343 728], the other is non-porphyritic (S34942) [HU 342 732]; in the former biotite is crystallized in small idiomorphic flakes, while in the other rock it is intermixed with fibrous amphibole. Like the dyke of quartz-porphyry from the Bight of Haggrister (p. 256) these dykes petrographically belong to the dyke-suite of the intrusive complex west of the Busta–Haggrister Fault but unlike the acid dykes they are not deformed.

Pyroxene-porphyrite

The pyroxene-porphyrites carry conspicuous tabular phenocrysts of plagioclase up to 1 cm long in a dark grey, fine-grained matrix which in the fresher examples is composed of lathy plagioclase prisms, subophitic augite, idiomorphic iron ore leucoxenized in parts, and interstitial chlorite, quartz, alkali-feldspar, biotite and local epidote. The grain-size of the main minerals in the base is usually about 0.4 mm but augite may form ophitic grains up to 1 mm across. Seriate grading of plagioclase from phenocryst to groundmass prism occurs but is rare (S56503) [HU 330 671]. The porphyritic plagioclase commonly ranges from basic andesine to labradorite (An_{48} to An_{55}), but some crystals appear to be more calcic (up to An_{55} in (S30598) [HU 219 581]. Compositional zoning in the crystals is limited to a narrow peripheral zone. The plagioclase of the groundmass is usually turbid and altered centrally and shows zoning from labradorite (An_{55}) outwards to oligoclase. Augite usually forms equant hypidiomorphic prisms or shapeless subophitic grains but occurs also in stellate groups (S28911) [HU 311 673]; it varies in colour from rock to rock, being rose (S28911) [HU 311 673], brownish yellow (S29417) [HU 332 689], (S30598) [HU 219 581], or colourless (S56503) [HU 330 671]. An early ferromagnesian mineral is represented by green pseudomorphs which may be too shapeless to provide an indication of

their original species (S44625) [HU 293 653] but may show definite olivine (S28911) [HU 311 673] or orthopyroxene (S56504) [HU 334 683] sections. The mineral of the pseudomorphs is usually chlorite but in some cases, where the original is indicated as orthopyroxene by its habit, the replacement is by clear pale green, cryptocrystalline or microcrystalline acicular actinolitic aggregate. Pseudo-morphs in granular quartz cemented by oxidized ore and of section suggesting original olivine occur in rocks which also carry pseudomorphs after orthopyroxene (S30598) [HU 219 581], S67503). The feature of the dykes of this group which distinguishes them from the basalts is the nature of the mesostasis. This is usually abundant and in the coarse-grained rocks is seen to consist of chlorite, quartz, alkali-feldspar, biotite, and locally epidote. In the finer-grained rock the constituents are not readily distinguishable but together have the appearance of the hypocrystalline cement of andesites (S28911) [HU 311 673], (S29417) [HU 332 689]. The alkali-feldspar is marginal to the plagioclase of the groundmass where the laths abut against quartz (S30598) [HU 219 581] and is present also in a feathery cryptocrystalline micropegmatite (S44625) [HU 293 653], (S56504) [HU 334 683]. Chlorite, usually interstitial in shapeless aggregate, also forms microcrystalline intergrowths with quartz and, though in rare cases derived from biotite, is predominantly a late primary product. The character of the mesostasis thus clearly allies these basic porphyrites to quartz-dolerite. Several dyke-rocks which are much altered are included in this group. In some the alteration is peritectic resulting in the conversion of augite to turbid green hornblende (S56503) [HU 330 671], (S56504) [HU 334 683] as in the augitebearing diorites. Deuteric alteration is widespread in partial to almost complete replacement of plagioclase by muscovite aggregate (S30599) [HU 219 581], (S30883) [HU 233 556], in extensive but irregular albitization to oligoclase (S52077) [HU 231 569], and in replacement of augite by cryptocrystalline material along a riddle of cracks (S47780) [HU 250 568] or by epidote and chlorite (S30599) [HU 219 581], (S52077) [HU 231 569]. In rare cases the rocks show evidence of slight deformation in twisted chlorite along shear lines (S47780) [HU 250 568]. The existence of shear stress during intrusion is indicated by curved twinning and microscopic faulting of twin lamellae in plagioclase (S56503) [HU 330 671], (S56504) [HU 334 683].

The Ward of Runafirth porphyrite (p. 241), represented by a single specimen from the centre of the outcrop (S44329) [HU 344 673], is in most respects similar to the pyroxene-porphyrites described above, but in its mesostasis contains abundant microcrystalline biotite in aggregates which peripherally disperse into both the sodic mantle of the plagioclase prisms and the interstitial quartz and alkali-feldspar. Locally the biotite aggregate is densely packed round grains of epidote and occasionally forms a monocrystalline pseudomorph. These relations suggest that the rock has undergone some degree of thermal recrystallization and it is possible that this boss-like outcrop of porphyrite is relic from a pre-diorite intrusion. It is, however, so similar to the basic porphyrite dykes that it is accepted here as a late-stage intrusion; the peculiar crystallization of its mesostasis remains unexplained.

Dykes of Intermediate Composition

This group includes the keratophyres, microdiorites and spessartites.

Keratophyre

The keratophyres are in general brownish or greenish grey, structureless, almost aphanitic rocks which are composed essentially of diversely arranged laths of turbid sodaclase feldspar, of composition about 8 to 15 per cent An, in an abundant cement of chlorite which may be only interstitial (S44332) [HU 309 675], (S53575) [HU 293 656] or may form a continuous infilling (S53571) [HU 313 638], or may be disseminated uniformly or patchily through a cryptocrystalline base (S53573) [HU 295 643], (S56716) [HU 328 657]. The feldspar laths are usually 0.2 mm or less in length: rarely they show a stellate or radiate arrangement (S44332) [HU 309 675]. Microphenocrysts of the same composition and idiomorphic stout prismatic habit, about 0.4 to 1 mm long, are usually present in small numbers and may be replaced by calcite, chlorite and quartz. The chlorite of the cement is usually in shapeless flakes and aggregates but occurs also as thin fibres or plates (S53571) [HU 313 638]; it does not possess a pseudomorphous habit. Grains of ore or leucoxene, limonitic aggregates, and grains of epidote and calcite are common accessory minerals, and apatite is sparse. Quartz is present in some members of the group as a primary mineral (S53573) [HU 295 643], (S56716) [HU 328 657]; in others it is secondary, at least in part (S53571) [HU 313 638]. Interstitial potassium feldspar has not been identified with certainty but is thought to be present in some specimens (S44332) [HU 309 675], (S53575) [HU 293 656]. Varieties with a chloritic base but also containing chlorite as pseudomorphs after a ferromagnesian mineral (S43759) [HU 298 729], (S56739) [HU 297 638] are transitional to the feldspar-porphyries or acid porphyrites and the first-cited contains quartz micrographic

with feldspar which, extinguishing with the adjacent laths, is probably sodaclase. It is noteworthy that several of the specimens referred to in these descriptions (S44332) [HU 309 675], (S56716) [HU 328 657], (S56739) [HU 297 638] occur as the dark marginal facies of quartz-feldspar-porphyries (p. 250). Keratophyres of this kind thus are petrogenetically very different from those of a spilite-keratophyre association.

An anomalous type, difficult to classify, crops out as a dyke on the coast 150 to 200 yd (135–180 m) south by west of Nibon House [HU 304 730]. The rock resembles a felsite and is colour-banded in pale and purplish grey, some bands containing tiny spherulites. Microscopically it is composed essentially of sodic plagioclase and quartz which form a cryptocrystalline to microcrystalline base through which the mafic constituents, green biotite, green hornblende, epidote, and minor chlorite, magnetite, leucoxene, and decomposed trichites tend to be severally concentrated in bands 1 mm to 1 cm broad (S30007) [HU 304 729], (S33747) [HU 304 729], (S33748) [HU 304 729]). The plagioclase is albite (An 5–8); no potassium feldspar was positively identified. The texture of the rock is controlled by a mesh or a banded variation in the degree of crystallinity. The coarsest bands contain subprismatic albite of about 0.5 mm length. The banding though probably original is accentuated by recrystallization accompanying redistribution or accession of silica so that some bands are composed mainly of dusty and granular quartz and grains and prisms, locally radiating, of epidote. In these bands relics of plagioclase persist and some contain biotite recrystallized in tiny, clear, equant grains. The original composition of the rock is uncertain but it is probable that the bands had differing mineral compositions during intrusion. The rock can be classified as quartz-albitite or as a quartz-keratophyre.

Spessartite

The few lamprophyric rocks of this group are composed essentially of idiomorphic plagioclase, hornblende and biotite with minor ore and interstitial chlorite, feldspar and quartz (S56643) [HU 328 652]. Augite is abundant in some specimens as stout prisms, up to 0.3 mm long, and as clusters of granules (S47744) [HU 278 592], but rare and relict as thin prisms enclosed in plagioclase in others (S44323) [HU 321 670]. In general the plagioclase is zoned and greatly sericitized or chloritized but has been determined as of intermediate labradorite-andesine composition in the core (S15107) [HU 334 620] while the margins range to alkalic feldspar. The crystals are idiomorphic prisms less than 0.4 mm long and microporphyritic stout prisms up to 1 mm long are common. Hornblende and biotite also are idiomorphic in thin brown prisms which are usually chloritized. Hornblende occurs also as microporphyritic crystals up to 0.5 mm across. Secondary minerals include epidote, which is usually abundant, and calcite. Xenocrystic quartz is rare (S56643) [HU 328 652]. A micro-ocellar structure formed by a crude tangential orientation or concentration of small hornblende prisms round spaces filled by more coarsely crystallized minerals is apparent in one member of the group (S44323) [HU 321 670]. The coarser mineral may be plagioclase which forms hypidiomorphic prisms with a tendency to fan arrangements, or xenomorphic chlorite which encloses pale green fibrous amphibole. In both types granular epidote is abundant. The structure is perhaps due to reconstitution of feldspar or pyroxene xenocrysts, or crystals precipitated from the magma at a deeper level, during the ascent of the dyke.

Microdiorite

The few rocks representing this group are composed essentially of plagioclase and hornblende which, however, do not show the sharply idiomorphic habit characteristic of the spessartites. Varieties transitional to spessartite have turbid idiomorphic plagioclase diversely arranged in lathy prisms, averaging 0.5 mm long, against which prismatic green hornblende is moulded and in places subophitic (S47757) [HU 265 589]. Obscure small aggregates which are probably altered pyroxene are present and quartz is interstitial.

The more usual microdiorites resemble the plutonic diorites in texture but are of finer grain and the plagioclase constitutes by far the greater volume of the rock. It is consistently dusky with a brownish impregnation and from poorly determinable optical properties appears to be an acid oligoclase. Its hypidiomorphic prisms interfere with one another and with equant grains of colourless augite (S30880) [HU 225 556] or prismatic to subophitic green hornblende (S28610) [HU 296 639], (S50136) [HU 264 590]. Titaniferous magnetite, partly leucoxenized, is a minor essential mineral forming crystals which are generally idiomorphic but form also shapeless growths of black ore which enclose augite and prismatic plagioclase. Interstitial material, abundant in patches, consists of chlorite, epidote, colourless feldspathic or zeolitic mineral, and granules of sphene and ore. Apatite in long slender prisms which locally form bundles, is an abundant

accessory. The colourless mineral is greatly obscured by small plates of chlorite which in places are disposed in a pattern so regular as to suggest micrographic intergrowth (S50136A) [HU 264 590]. It has low birefringence, is optically negative with moderate or low optic axial angle, and has refractive indices distinctly lower than the balsam cement; no cleavage was observed in its allotriomorphic grains. The mineral is provisionally assigned as scolecite. If this is correct the occurrence is similar to that of thomsonite in the altered gabbros (p. 186). J.P.

Acid minor intrusions

Field relationships

Northmaven and Muckle Roe

The acid dykes within the northern part of the present area form parallel swarms which have a general north-north-west to north-north-easterly trend. Unlike the dykes of Vementry (p. 251) they show no definite radial pattern in their distribution which would imply a central focus of irruption. Except for a small number of dykes around Nibon [HU 305 731] and at the mouth of Gunnister Voe [HU 308 738], the acid dykes are restricted to the outcrop of Muckle Roe Granophyre and within that outcrop they form swarms of roughly north–south trending dykes which alternate, in an irregular fashion, with swarms of basic dykes of a similar trend (see p. 241). Around Lothan Ness [HU 316 676] on the north-eastern margin of the granophyre outcrop there is a change in the trend of the dykes to the north-east, which may indicate a greater ease of fissuring in a radial direction at the margin of the granophyre.

The acid dykes are generally from 1 ft (30 cm) to about 60 ft (18 m) wide, widths between 4 ft (1.2 in) and 20 ft (6 m) being most common along the Muckle Roe coast. Inland they weather more quickly than the granophyre and here many of the fine-grained acid rocks appear to have short lenticular outcrops up to 60 yd (55 m) wide. Though these outcrops could be interpreted as small bosses it seems more probable that they represent local thickenings of dykes. This view is supported by the observed changes in width along the course of a dyke traced from Raavi Geo [HU 310 676], where it is 15 ft (4.5 m) wide, southwards for 250 yd (230 m) to a small loch where it has increased to 90 ft (27 m) in width; while a still broader dyke, lying 200 yd (180 m) to the west, splits at the mouth of Raavi Geo into two members of less total width. The length of the dykes is probably comparatively great but where so many occur in proximity, connection of isolated outcrops is uncertain. A quartz-feldspar-porphyry exposed at Grusterwick Geo [HU 296 649] is traceable for 800 yd (780 m), and several in the north-west part of the island for 600 yd (550 m).

The acid group of dykes includes porphyritic and non-porphyritic, spherulitic and non-spherulitic felsites, porphyries containing conspicuous quartz and feldspar phenocrysts, and acid porphyritic rocks without visible quartz. In colour they range from grey through flesh-coloured to brick red. There is no apparent spatial distribution of types and several types occur in one dyke. A multiple acid intrusion exposed at the west end of Raavi Geo, has six members and a section across this intrusion is shown in (Figure 26). The members, from east to west, have the following thickness and petrographical characteristics:

A	5 ft (1.5 m)	Purplish biotite-feldspar-porphyry; coarse-grained felsitic groundmass with some decomposed mafic minerals (S46409) [HU 474 613].
B	12 ft (3.6 m)	Red and yellow felsite banded by the presence and absence of microporphyritic feldspar and mafic crystallites and by varying degrees of devitrification (S56410) [HU 310 674].
C	15 ft (4.5 m)	Pale red unbanded microcrystalline felsite with microphyric feldspars and sparse decomposed mafic minerals set in a cryptopegmatitic base (S56411) [HU 310 674].

D	10 ft (3 m)	Aphanitic, dull red felsite; non-spherulitic, cryptopegmatitic groundmass banded by varying proportions of decomposed mafic material (S56412) [HU 310 674]; one band is feldspar-phyric.
E	6 ft (1.8 m)	Brick-red biotite-feldspar-porphyry; spherulitic, quartz-rich, with a patchily chloritic groundmass (S56413) [HU 310 674].
F	2 ft (0.6 m)	Purplish grey, feldspar-microphyric acid porphyrite or quartz-keratophyre (S44332) [HU 309 675] (see p. 251).

The banding illustrated by members B and D is a common feature of the acid dykes. It is conspicuous in many dykes because of the colour change induced by the decomposition of the mafic minerals which exist in varying proportion in the bands. In others it is made evident by variation in the proportion and size of spherulites or of quartz and feldspar crystals. In general it is parallel to the course of the dykes; around Lothan Ness, however, banding oblique to some dyke margins has been recorded. The nature of this structure, which is recorded as a vertical foliation, is not certain; it may result from the NW–SE crushing which affects the rocks of this locality. The general small-scale banding of the dykes probably represents fluxional structure due to differential movement of unequally crystallized portions of the upwelling magma. In some cases in which it is of only millimetre to centimetre scale and related to small variations in mafic content it must indicate a degree of heterogeneity in the intrusive material. It is probable, however, as in the case of the multiple dyke described above that some kinds of banded structure are caused by pulsatory intrusion of magma of slightly differing composition from pulse to pulse.

Columnar structure transverse to the course of a dyke has been recorded in only one case, a thick dyke of feldspar-porphyry exposed in the scars [HU 303 670] between Erne Stack and Limpet Geo. This has columnar joints at right angles to the walls and meeting along a median surface.

The narrow dark member (F) of the dyke figured in (Figure 26) exemplifies a common characteristic of the acid dykes which can be readily observed in the exposures along the north coast of Muckle Roe between North Ham and Lothan Ness. These marginal facies have the composition of keratophyre and are described in p. 248. J.P.

North shore of Walls Peninsula and adjacent islands

The acid dykes cutting the metamorphic rocks adjoining the Vementry Granite can be divided into two major groups: (1) quartz-feldspar-porphyries and (2) spherulitic or fluxion-banded felsites. The former give rise to extensive north-north-east trending dyke swarms, small rounded bosses and irregular sills; the latter form west-south-west and east-west trending dykes and dyke swarms. The quartz-feldspar-porphyry and felsite dykes together have a roughly radial pattern with a focal point within the Vementry Granite ((Plate 24), p. 207).

Quartz-feldspar-porphyries and feldspar porphyries

Irregular bosses, dykes and sills

Quartz-feldspar-porphyry with a medium- to fine-grained holocrystalline matrix forms three small circular outcrops, 30 to 50 yd (27–45 m) in diameter, close to the north and south shores of Maa Loch, where they are closely associated with a swarm of thick quartz-feldspar-porphyry dykes. T. Robertson (manuscript notes) has tentatively suggested that these are bosses projecting from the roof of the Vementry Granite and it seems possible that they are on the line of a southward underground projection of the granite, like that exposed at the head of Suthra Voe and just west of Cow Head (p. 207).

The composition and texture of the rock forming these bosses is, however, more closely related to that of the adjoining quartz-porphyry dykes and it is thought by the author that they may be roughly cylindrical feeders to the dyke swarms. A

number of highly irregular boss- and dyke-like intrusions of quartz-feldspar-porphyry crop out on Braga Ness just east of Vementry Island. These include at least one intrusion with a circular outcrop and none have a consistent trend. It seems likely that these may also have formed irregular feeders to an overlying dyke swarm.

A group of feldspar-porphyry intrusions, mainly in the form of west-southwest trending sills up to 15 ft (4.5 m) thick, crops out on the islands between south-western Vementry and Neeans. These are usually devoid of quartz phenocrysts, and their matrix, instead of being felsitic, is composed largely of small randomly orientated plagioclase laths (p. 256).

North-north-east trending dykes and dyke swarms

North-north-east trending dyke-swarms of quartz-feldspar-porphyry are abundant in a 1-mile (1.64-km) wide zone south-west and south of the Vementry Granite. Isolated dykes thought to belong to this group have been recorded as far west as the skerries north of the Neeans peninsula, 1.5 miles (2.4 km) SW of the granite margin.

A dyke-swarm, ranging in width from 0.25 to 0.33 mile (0.4–0.5 km) and containing a large number of closely spaced dykes, extends from the south-western corner of the granite outcrop at the head of Suthra Voe south-south-westwards across the Brindister Hill peninsula. The dykes within the swarm have a trend which varies from N25°E to N36°E, but individual dykes cannot usually be followed for long distances. Many are irregular in outline, but others have straight margins for distances of up to 200 yd (180 m). In certain areas within the swarm, as, for instance, at the head of Suthra Voe, porphyry dykes make up over 50 per cent of the total exposed rock and along the coast on either side of Trea Wick, where the dykes dip steeply to west-north-west, adjacent intrusions are separated only by thin screens of metamorphic rock. The thickness of individual dykes within the swarm varies from a few inches to 30 yd (27 m). Members of the swarm cut the nose of the Vementry Granite exposed on the headland projecting into Suthra Voe, but very few appear to extend far into the main body of the granite farther north.

Porphyry dykes up to 15 ft (4.5 m) thick are common in the southern part of the western peninsula of Vementry, between the western granite margin and Heill Head. Their trend changes gradually from N30°E close to the granite to E30°N on the coast north of Heill Head. In the latter locality dykes of both quartz-feldspar-porphyry and spherulitic felsite (pp. 254–5) are present, the two together forming an intricate network.

Concentrations of quartz-feldspar-porphyry dykes also occur on Vementry Island, between the granite and Maa Loch, and along the south shore of Uyea Sound just north and north-east of Vementry House. In the former area there are several very thick NNW to NNE trending dykes of a very coarse-grained variety of porphyry, which locally grades into porphyritic microgranite. In the latter area dykes of variable trend, many of them trending roughly east-west, locally form nearly 50 per cent of the total rock outcrop.

Within the Vementry Granite quartz-feldspar-porphyry dykes are much less common than in the surrounding country rock. On the shore of South Voe (Plate 24) there is a vertical composite dyke which, from west to east, has the following members:

	feet	metres
Fine-grained basic rock (olivine-basalt)	4–6	1.2–1.8
Quartz-feldspar-porphyry	15	4.5
Basic rock, locally sheared	2	0.6

All junctions are vertical and there is marked chilling of the basalt against the porphyry. There is also a close association of acid and basic dykes on the cliffs forming the south-west shore of Lamba Wick [HU 303 607]. No other composite acid-basic dykes have been recorded.

Felsite

Dykes of sparsely porphyritic or non-porphyritic felsite, some of which are spherulitic and/or banded, have been recorded on Vementry Island, both within the granite and in the adjoining metamorphic rocks. They are particularly abundant in the north-western peninsula between Heill Head and Swarbacks Head, where they have a trend which varies from

south-west (exceptionally south-south-west) in the south to roughly east-west in the north. There is a swarm of east-west trending dykes in the vicinity of Corbie Geo, in which individual dykes vary greatly in width, averaging 6 ft (1.8 m) and locally reaching 25 ft (7.5 m). Another swarm of spherulitic felsite dykes, steeply inclined to the south-east, cuts Heill Head, where some quartz-feldsparporphyries are also present. Felsite dykes also cut The Heag [HU 279 602], the island just west of Gruna. Within the Vementry Granite only two dykes of spherulitic felsite have been recorded.

Felsite intrusions, many trending north-east, parallel to the strike of the country rock, cut the basal sediments of the Sandness Formation, which forms the high ground south of Vementry House between the Stead of Aithness and North Voe of Clousta, as well as the Ness of Nounsbrough. They are also present in the basal sediments of the Sandness Formation farther west and in the strongly folded strata of the Walls Formation between the Voe of Clousta and the head of Bixter Voe. The geographical distribution, trend and petrographical character of the intrusions within the Sandness Formation suggest that they may be unrelated to the felsite dykes described above, and that they are probably associated with the phase of extrusive volcanism which gave rise to the Clousta Volcanic Rocks (p. 83). The north-north-west trending intrusions in the Walls Formation between Clousta and Bixter Voe cut strata which are thought to be younger than the Clousta Volcanic Rocks and must thus have been intruded at a later date. These dykes may have their source in a granite which underlies the sedimentary rocks and links the Vementry and Sandsting granites at depth. Finlay (1930, p. 685) has suggested that the Vementry and Walls granites are part of one intrusive complex whose top is depressed by the Walls Syncline, and that this belt of felsite dykes marks the zone in which the granite is nearest to the surface. W M.

Petrography

This large group of minor intrusions is subdivided into felsites, quartz-porphyries and feldspar-porphyries including acid porphyrites.

Felsites

The term 'felsite can be usefully applied by both the field geologist and the petrographer to a range of rocks which are macroscopically non-porphyritic, aphanitic, poor in mafic minerals, and which are composed essentially of quartz and alkali-feldspar. Other terms, such as microgranite or aplite, are inappropriate to these rocks.

They may be macroscopically structureless or show banded, nodular, or spherulitic structure. Microscopically the rocks which show macroscopic structure range from hypocrystalline, through microcrystalline to cryptocrystalline, the degree of crystallinity varying in banded (S28593) , cellular (S29503) [HU 317 628], honeycomb (S29409) [HU 312 671], (S53588) [HU 313 676], or nodular (S28609) [HU 312 651], (S28613) [HU 311 674] fashion. The banding is commonly combined with one of the other structures, for example as banded-nodular (S30709) [HU 281 601]. The nodules are formed of single or clustered, isotropic, cryptocrystalline, or spherulitic bodies, the latter being composed mainly of alkali-feldspar. Though usually these bodies represent early plastic, less or more deformed autolithic globules of glass moulded on feldspar crystals, they appear in some cases to be xenolithic since they contain or are coated by chloritic and opaque material which is not present in the matrix (S28907) [HU 322 630]. One specimen is specially noteworthy because of the presence of very thin lines of dark inclusions and silicified cracks which run generally parallel through the nodules but are not seen in the matrix. These lines are deviated locally through about 30 degrees in nodules elongated along the macroscopic flow structure, indicating a period between peneconsolidation and renewal of intrusive stress (S28609) [HU 312 651]. Devitrified glass may be present also as orientated fragments which show both angular and plastic outlines (S30731) [HU 284 604]. All the rocks show extensive sericitization, and in some cases calcitization, which affects the more poorly and the better crystallized parts unequally but not preferentially.

About half of the felsites from the area under description consist of a uniformly cryptocrystalline, microgranular, or microlitic aggregate of quartz and feldspar identical with the more crystalline parts of the matrix of the banded and nodular rocks. In this structureless ground microporphyritic turbid feldspar is sporadic and quartz rare (S30583) [HU 187 554], (S30709) [HU 281 601], (S30732) [HU 282 603]. The feldspar phenocrysts are not so numerous as in the nodular varieties mentioned above and, as in them, they are mainly orthoclase, soda-orthoclase and microperthite but include also acid plagioclase, with An probably about 10 per cent. They may be single idiomorphic, glomeroporphyritic, or

cumulophyric (S28612) [HU 312 673], (S30732) [HU 282 603], (S30743) [HU 321 595], (S31000) [HU 275 583], (S53580) [HU 303 665]. Generally autolithic the feldspar phenocrysts include also xenolithic crystals (S53588) [HU 313 676], and in one specimen fragmented crystals with attached devitrified glass indicate flow-brecciation (S30887) [HU 229 540]. Crystals forming the nucleus of nodules tend to extend skeletal processes into the devitrifying envelope. The micro-crystalline portions of the quartz-feldspar groundmass show a variety of textures from rock to rock and in the one rock. The two minerals may be mixed in allotriomorphic ffelsitic' aggregate; feldspar microlites may be enclosed singly or micropoikilitically in quartz; they may be intergrown as micrographic grains, as small as 0.05 mm, or as spherulites, radiating cones, or feathery growths of micropegmatite in which quartz and feldspar are not individually observable. In some rocks the proportion of determinable quartz is low (S28612) [HU 312 673], (S30723) [HU 285 613], in others, perhaps because of late magmatic or post-consolidation growth or redistribution, it is high (S29503) [HU 317 628], (S30710) [HU 281 601], (S31028) [HU 261 589]. The relative proportions of potassium feldspar and plagioclase are not normally determinable microscopically owing to fineness of grain and close dissemination of alteration products. Either may appear, on criteria of shape or aggregate refractive index, to be dominant ((in S3023) potassium-feldspar, in (S30724) [HU 286 613] plagioclase) or both equally present (S30585) [HU 196 535]. Mafic minerals, present only in accessory proportions in most felsites, are represented by shreds and ragged or mossy patches of chlorite or limonite, or by trichites and microlites replaced by chlorite, epidote and ore dust which in some cases (S28907) [HU 322 630], (S30710) [HU 281 601] resembles the riebeckite needles and acmite grains of the granophyric blue felsites of the North Roe–Ronas Hill area (Phemister and others 1950). In a few examples in which the dark minerals are present in minor essential proportion, biotite and green hornblende can be recognized among the microlites (S33742) [HU 302 734] but in others replacement by chlorite, epidote and oxidized ore is complete (S43755) [HU 303 732], (S53580) [HU 303 665], (S53588) [HU 313 676]. Chlorite and ore may be so abundant and universally distributed in the groundmass that the rock is transitional to the quartz-keratophyres (S30585) [HU 196 535]. Allanite occurs as a scarce accessory mineral (S30709) [HU 281 601].

Quartz-porphyries

In this group, quartz, potassium feldspar and plagioclase are always present as phenocrysts though in relatively varying amount. Biotite and hornblende occur in most examples as idiomorphic microphenocrysts occasionally exceeding 2 mm in length but are always pseudomorphed, biotite by chlorite, ore and sphene, hornblende by chlorite, sphene, ore, and calcite or epidote (S30711) [HU 302 604]. In a few, more leucocratic, specimens the mafic material is represented only by trichites and ore granules in a groundmass which is patchily cryptocrystalline, microspherulitic, minutely micropegmatitic, and micropoikilitic (S30860) [HU 227 488], (S54282) [HU 350 700]; they are in effect quartz-feldspar-phyric felsites. Transitional to the more numerous biotite-hornblende-bearing porphyries are rocks which contain small microphenocrysts of chloritized biotite and chlorite longulites (S53576) [HU 289 658] or chlorite dispersed through the base (S29420) [HU 326 659]. All the leucocratic members show patchy quartzification which is perhaps no more than recrystallization of the silica of the base. In the porphyries containing mafic minerals as minor essential constituents (S28611) [HU 291 654], (S30735) [HU 299 613], (S30736) [HU 300 612], (S53577) [HU 295 689] biotite and hornblende occur as idiomorphic pseudomorphs senate from 2 to about 0.05 mm in length. The accessory minerals include iron ore, and chlorite, the former in small equant crystals, up to 0.3 mm, normally black magnetite but also leucoxenized (S30763) [HU 295 594], and in granules and short rods; chlorite occurs mainly in aggregates of flakes replacing biotite and hornblende, and rarely in spherulitic form (S50140) [HU 303 607]. Apatite is scarce as is sphene except as an alteration product of biotite and hornblende. Allanite is sporadic in small crystals (S30711) [HU 302 604], (S30763) [HU 295 594] but is conspicuous as a zoned microphenocryst, 1 mm in length, with one end of the prism embedded in a quartz phenocryst, the other end in a hornblende crystal ((Plate 29), fig. 8). The quartz-feldspar groundmass of these rocks varies in texture as described under the felsites, that is it may be felsitic, microlitic, micropoikilitic, minutely micrographic, or microspherulitic.

The quartz phenocrysts of the porphyries are idiomorphic and practically always corroded, with deep embayments filled by material identical with the groundmass.

Most have turbid microcrystalline to cryptocrystalline coronas in which the quartz is in optical continuity with the quartz of the phenocrysts. The same optical continuity does not appear in the quartzo-feldspathic aggregate enclosed in the phenocryst (S30763) [HU 295 594], (S47328) [HU 311 915]. In one specimen (S28910) [HU 300 637] the coronas are cryptopegmatitic whereas the groundmass is microlitic; the resulting structure giving the corona and phenocryst a

xenolithic aspect. In this case the coronas may represent magma locally enriched in silica by the process of corrosion but prevented by consolidation from incorporation into the bulk. Similar cryptopegmatite coronas are observed around feldspar phenocrysts but in that case spherulitic micropegmatite is abundant in the groundmass (S28885) [HU 327 627].

The porphyritic feldspar of the porphyries always includes both potassium feldspar and plagioclase. The former is represented by both orthoclase and microperthite as idiomorphic crystals, patchily or completely argillized, or hypidiomorphic groups which with associated plagioclase can reach 1 cm in diameter. The proportion of plagioclase varies from approximately 1:1 downwards and when low the potassium-feldspar is entirely microperthite (S53577) [HU 295 689]. Orthoclase phenocrysts with no discernible perthite admixture may enclose small perfectly idiomorphic crystals of plagioclase, partly chloritized biotite and rarely (?)pyroxene (S30763) [HU 295 594]. The porphyritic plagioclase is greatly sericitized and when determinable is consistently of oligoclase composition (about An 10–12 per cent). Unlike the potassium feldspars it shows seriate diminution from several millimetres in prism length down to groundmass dimensions. Both feldspars are in general autolithic but some glomeroporphyritic groups contain flakes of biotite, only partially chloritized (S28910) [HU 300 637], which indicate crystallization from a more deep-seated stage. Patches of turbid orthophyric (S29420) [HU 326 659] and microgranular quartz-plagioclase-cryptopegmatite aggregates (S53577) [HU 295 689] similarly are early crystallizations.

Some phenocrysts however show peculiarities which prove them xenolithic though cognate. For example, plagioclase sieved or cavernous with chloride aggregate carry, contrary to the usual relations, idiomorphs of orthoclase (S53574) [HU 296 645]; cryptopegmatite replaces the feldspar, as a crystal or a coarse granular group, marginally or completely (S28908) [HU 300 633]; corrosion cavities in oligoclase are filled with material of coarser grain than the surrounding matrix (S30711) [HU 302 604]; fragmental plagioclase, spotted with quartz inclusions and showing a very close twinning which contrasts with the usual habit, is mantled by microperthite (S53576) [HU 289 658].

A dyke of porphyry from the Ness of Haggrister, east of the Walls Boundary Fault, is of the same type as those described above. It carries whole and fragmental crystals of quartz and perthite and a xenolith of coarsely granophyric rock in a turbid, cryptocrystalline, partly silicified base which contains limonitized pseudomorphs of an acicular mineral (S54282) [HU 350 700]. Curved threads of ore granules suggest original perlitic structure and cryptocrystalline shells round the phenocrysts and xenolith may represent chilled envelopes of glass.

Feldspar-porphyries and acid porphyrites

The rocks of this group repeat the characteristics of mineral composition and texture shown by the quartz-porphyries but contain no porphyritic quartz. As in the quartz-porphyries two subgroups are distinguished.

In one, which is referred to here as feldspar-porphyry, the members are highly leucocratic and contain phenocrysts of potassium feldspar and acid plagioclase which are conspicuous in hand specimens but do not usually exceed 2 mm in size. The other subgroup, the acid porphyrites, contains an essential proportion of ferromagnesian minerals, usually sedate from 2 mm downwards, in addition to the porphyritic feldspar which is predominantly acid plagioclase (An about 8 per cent) and forms single crystals up to 3 mm long and glomeroporphyritic groups up to 6 mm across.

In the feldspar-porphyries phenocrysts of microperthite or orthoclase containing small patches of plagioclase are as numerous as those of acid plagioclase. Both feldspars occur as single crystals and in glomeroporphyritic groups and also interfere in cumulophyric clusters with which may be associated ore grains and chloritized ferromagnesian minerals (S30748) [HU 287 595] of larger size than any in the groundmass. The latter consists essentially of quartz and alkali-feldspar the nature of which is uncertain owing to fineness of grain, cryptocrystalline spherulitic structure, and decomposition. In two specimens, however, skeletal prisms of fresh orthoclase, only 0.05 mm at most across, pierce the turbid spherulitic material and enclose it where the prisms are hollow (S30745) [HU 282 589], (S53581) [HU 302 666]. It is of interest to note that in one member of the group (S31161) [HU 310 545] evidence of stress during crystallization is afforded by bent twinning and the strain extinction pattern of plagioclase.

In the acid porphyrites, which are more abundant than the feldspar-porphyries, potassium feldspar is sparse and may not be present at all (S53572) [HU 296 637], (S53579) [HU 303 667] among the phenocrysts; it may be only microporphyritic

and mantled by plagioclase or in one and the same rock appear as a microphenocryst within plagioclase or as a phenocryst moulded on plagioclase. Sedate down from about 3 mm to groundmass dimensions, plagioclase is always idiomorphic in single crystals and in the free faces of glomeroporphyritic groups. Large spongy shapeless crystals which are apparently xenolithic also occur but are rare (S30740) [HU 319 601]. Owing to the universal turbidity and common sericitization the composition of the porphyritic plagioclase is difficult to ascertain.

The ferromagnesian minerals are always altered but their outline in section and the style of replacement by the secondary chlorite and ore, epidote and sphene show that both hornblende and biotite have been primary minerals. Iron ore is abundant as octahedra and large grains in the groundmass which contains also much interstitial chlorite and ore granules and grains of epidote scattered through the turbid base of microcrystalline, in some rocks partly cryptopegmatitic, alkali-feldspar and quartz. Apatite in thin prisms is a common accessory mineral and zircon is rare; trichites of chlorite are numerous in members containing cryptopegmatite (S29504) [HU 300 662].

Some features of the space relations of the potassic and sodic feldspars call for attention. The non-seriate character of the potassium feldspar contrasts with the seriate crystallization of the sodaclase. Large phenocrysts of potassium feldspar are moulded on plagioclase (S56413) [HU 310 674] and in this rock and others (S44318) [HU 303 664], (S56409) [HU 310 674] microporphyritic potassium feldspars are enclosed within idiomorphic plagioclase usually with a separating zone of groundmass material. These features considered together seem to imply the existence, in a dominantly sodic feldspathic magma, of potassium-rich gouts which in some cases are trapped by the growing plagioclase. J.P.

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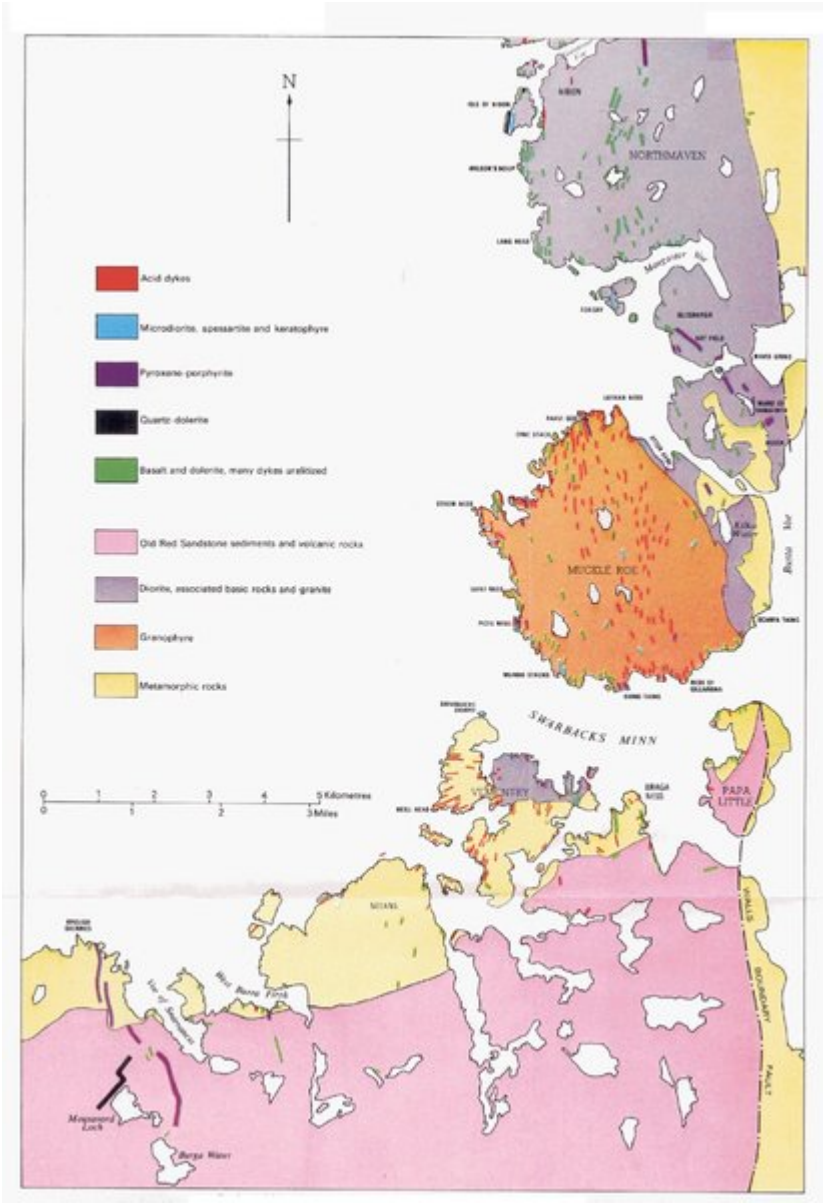
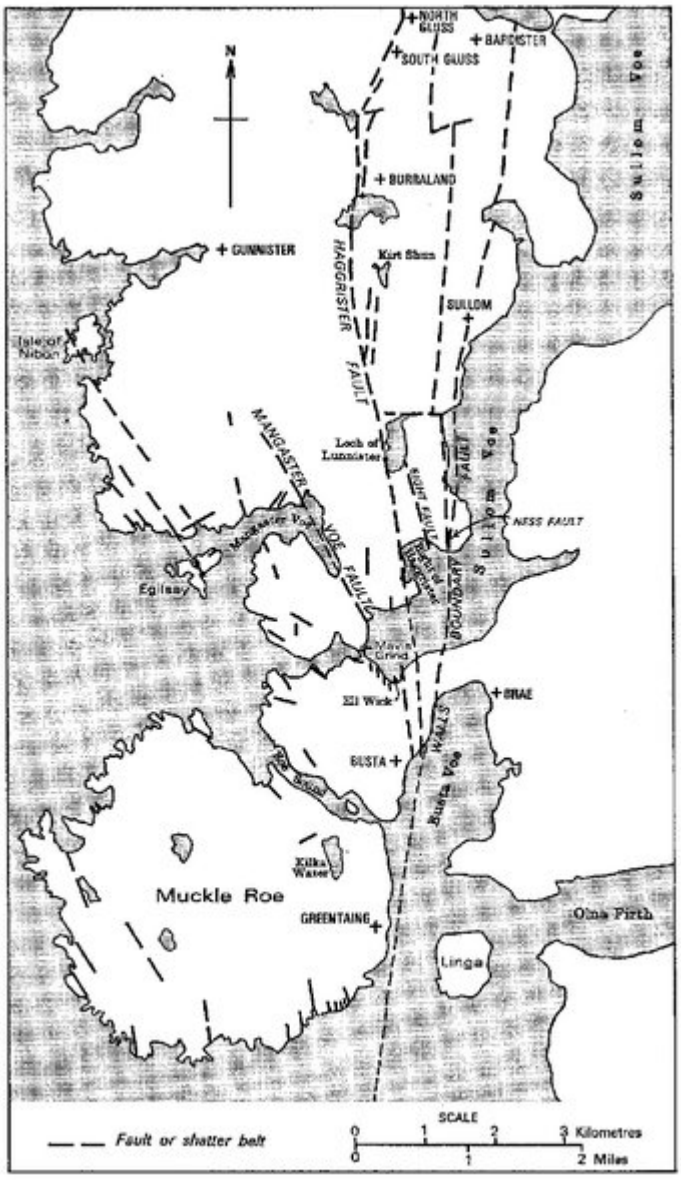
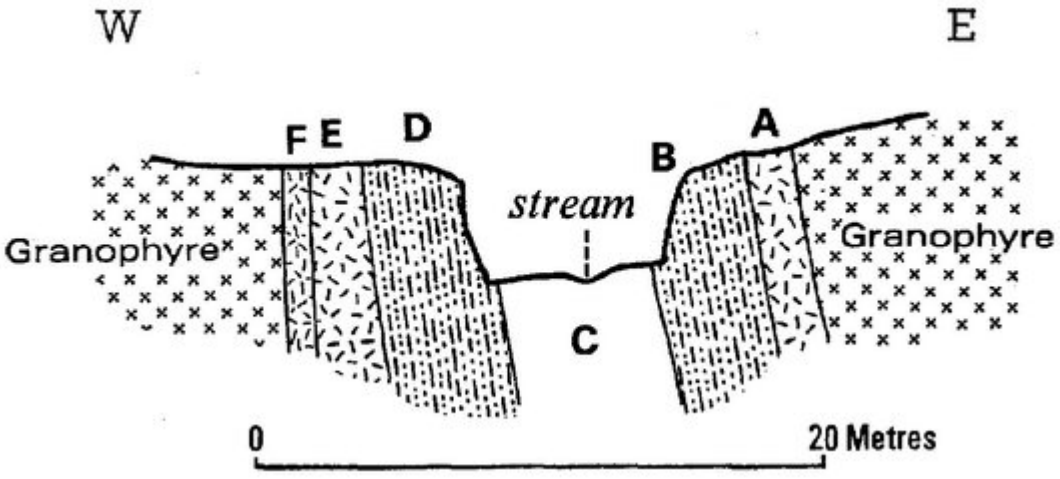


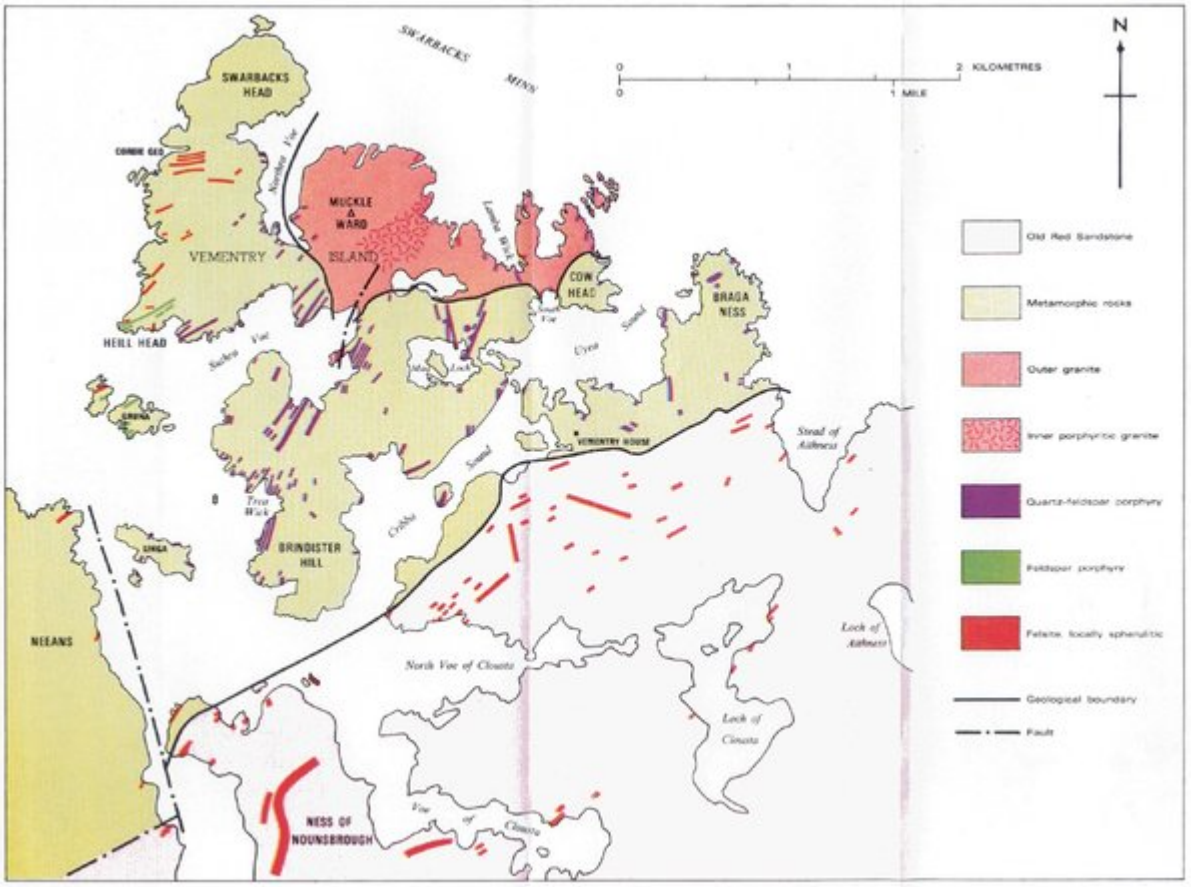
(Plate 28) Basic, acid and intermediate minor intrusions in Western Shetland.



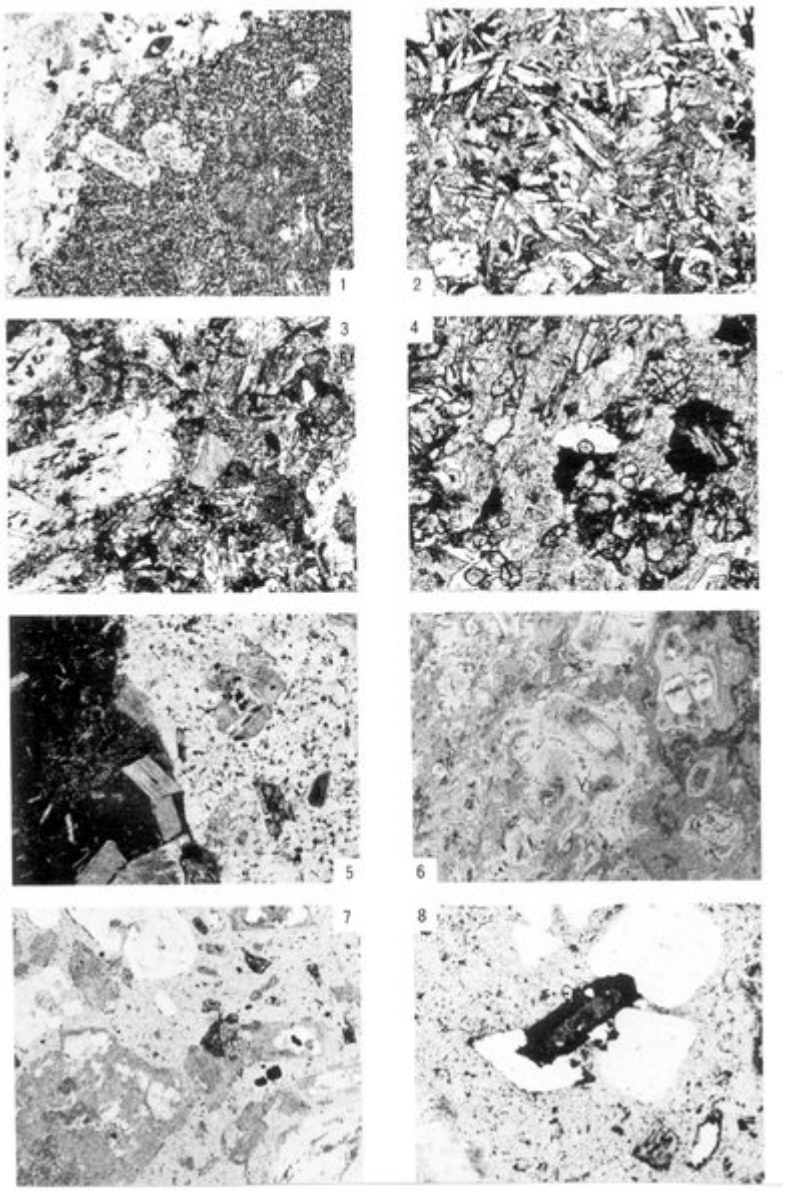
(Figure 27) Major faults in the area north of Busta Yoe.



(Figure 26) Multiple dyke, west end of Raavi Geo, Muckle Roe.



(Plate 24) Vementry Granite and related acid minor intrusions.



(Plate 29) Photomicrographs of the basalt-granite breccia and minor intrusions Fig. 1. Slice No. (S55676) [HU 302 706]. Magnification × 14. Plane polarized light. Breccia-form basalt cemented by granodiorite. The basaltic rock has a microgranoblastic base of andesine, hornblende and biotite in which lie small phenocrysts of zoned calcic plagioclase, marginally recrystallized, and recrystallized groups of amphibole and biotite prisms pseudomorphous after ferromagnesian phenocrysts. The rock resembles the thermally altered dyke of (Plate 22), fig. 1. Lang Head, 49 yd (45 m) inland from Geo of Drengi [HU 303 704]. Fig. 2. Slice No. (S43772) [HU 320 726]. Magnification × 14. Plane polarized light. Hornblende-basalt. Tablets and stout prisms of zoned plagioclase (centrally An 70+) are subophitically related to xenomorphic green hornblende and cemted by pale green fibrous amphibole; minor augite (NW of centre) is ophitie to plagioclase. South-east shore of Soolmisvird Water [HU 320 726]. Fig. 3. Slice No. (S30598) [HU 219 581]. Magnification × 11. Plane polarized light. Basic pyroxene-porphyrite. Phenocrysts of labradorite ($An_{65–70}$) and of yellow augite lie in a base of strongly zoned plagioclase laths, subophitic to purplish augite, and minor magnetite which are cemented by a turbid mixture of chlorite, biotite, alkali-feldspar and some quartz. Near Skerry of Stools, 710 yd (650 m) NW of Bousta [HU 219 582]. Fig. 4. Slice No. (S49323) [HU 307 606]. Magnification × 65. Plane polarized light. Garnet in basalt. Small garnets, about 0.02 mm across, are enclosed in clear chlorite (centre) and turbid plagioclase (SE of centre). Grains in chlorite (SW corner) include one garnet and two epidotes. North shore of South Voe, Vementry Island [HU 305 605]. Fig. 5. Slice No. (S28885) [HU 327 627]. Magnification × 16. Plane polarized light. Feldspar-porphyry and basalt. The basalt is chilled; its margin partly enwraps an alkali-feldspar phenocryst of the porphyry. Ness of Gillarona, Muckle Roe [HU 327 627]. Fig. 6. Slice No. (S30732) [HU 282 603]. Magnification × 14. Plane polarized light. Nodular felsite. The nodules consist of feldspar-phyric glass, variably devitrified. The base is microcrystalline to cryptocrystalline quartz-feldspar aggregate, variably sericitized, with frayed slivers of glass. Heill Head, Vementry Island [HU 282 605]. Fig. 7. Slice No. (S30711) [HU 302 604]. Magnification × 13. Plane polarized light. Quartz-feldspar-porphyry with microporphyritic

hornblende, biotite and ore. The feldspar phenocrysts include orthoclase (usually mottled) and more abundant albite (usually turbid). Hornblende is replaced by chlorite-calcite aggregate; biotite is pseudomorphed by chlorite. Egga Field, 83 yd (75 m) N of Maa Loch, Vementry Island [HU 301 604]. Fig. 8. Slice No. (S28908) [HU 300 633]. Magnification × 22. Plane polarized light. Allanite. One end of the zoned crystal is embedded in an idiomorphic crystal of hornblende (SE of centre; almost completely destroyed in grinding the section); the other end is held in a rounded crystal of quartz. Such a cumulophyric group, though cognate, is xenocrystic, possibly derived from an early drusy stage of crystallization. The rock is a hornblende-quartz-porphyry. North of Murbie Stack, south-west shore of Muckle Roe [HU 303 630].