Fig.44a. Group of small pillows separated from each other by often very thin layers of granophyre and hybrid acid rock, at an exposure on the west side of Hvalnes. From left to right the individual pillow gradually merge into one large basic mass. The scale is given by the rule, which is 24cms. in length.

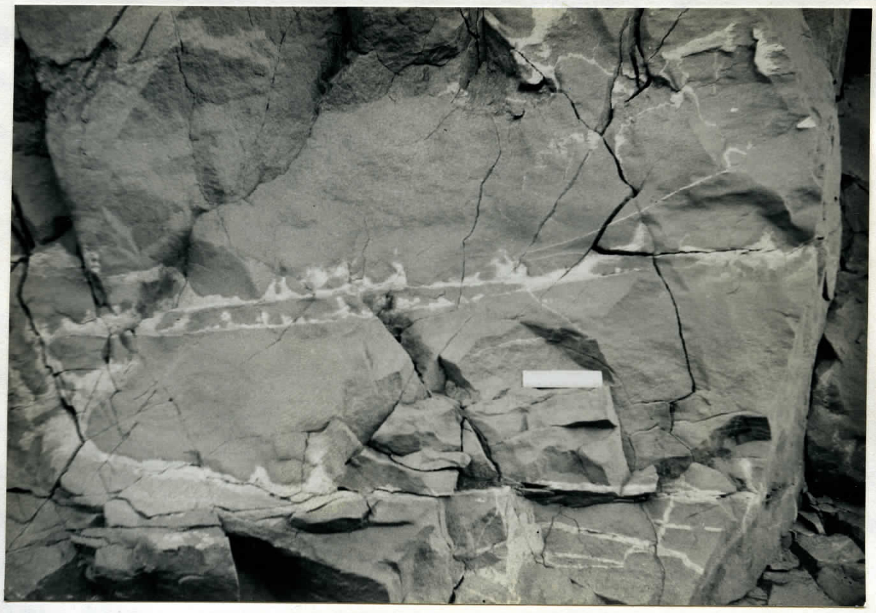

Fig.44b. Nearly horizontal "sheet layers" of granophyre between closely spaced tabular pillows at an exposure on the raised beach below Hvasshjalli.

Further examples are found on the northern side of the Austurhorn where pillows are rare and most of the basic rock occurs as large masses of dolerite and gabbro. Unfortunately the cliff is inaccessible and the relationships between the acid and basic rocks could not be determined, but it is likely that the dolerite masses, and possibly also those of gabbro, represent large basic pillows. Large dolerite masses also occur on Hvalnes, below Hvasshjalli and at the southern end of Krossanes, all of which are surrounded by undoubted pillows of similar rock type: these masses are again probably large pillows (or groups of pillows), each more than 25m. in diameter. The dolerite of the masses below Hvasshjalli differs from the other dolerites in possessing a nodular weathered surface, due to slightly upraised and often coalescing knobs, from 3cm. to 10cm. in diameter: these knobs are formed of ophitic ferro-magnesian aggregates.

Hybrid Rocks

These include the acidified basic rocks and basified acid rocks which are found throughout the net-veined complex. The acidifcation of basic inclusions varies from the development of pale spots within normal basalt and dolerite to the almost complete alteration of the basic rocks, with only nebulous patches of greyish rock to indicate their former existence (fig. 41a). The granophyre surrounding such inclusions may also show a certain amount of contamination.

Hybridised basic pillows are often more acidified in their centres, where feldspathic patches are commonly developed. On the east side of Hvalnes extreme examples of this type have been found. Many pillows have here become almost completely acidified, and only the original dense marginal zones of the pillows are faintly discernible, with their apparently sharp crenulate external contacts still visible; this marginal zone usually grades into normal drusy granophyre within the pillow interior. All stages of acidification are seen here between these nebulous pillows and more normal basic pillows.

Some nebulous pillows may also be represented by the many grey granodioritic masses which have crenulate contacts with the surrounding more acid granophyre, as at Hvalnes and Krossanes. These masses usually show no textural zoning and appear homogeneous throughout.

Many other basic inclusions (those that are not obviously pillow-like) are more altered at their margins, with normal basic rock at the centre of the inclusion passing outwards, through a greyish contaminated (hybrid) zone, into acid granophyre. The contamination zones vary considerably in thickness and are often spotted or streaky.

Normal Xenoliths (fig.45)

Small angular inclusions of basic rocks, generally less than 10cm. in diameter, occur throughout the net-veined complex. These inclusions, which are often cut by acid veins, generally have sharp boundaries and, unlike the basic pillows, they are not texturally zoned. Inclusions of gabbro, identical with the gabbro of Hvalnesfjall, are invariably of this type, and are widespread though never very abundant. Angular fragments of dolerite and basalt are more numerous that those of gabbro, and many of these are derived from fragmented basic pillows (fig.45a). Fragments of basified granophyre are not uncommon, and may themselves contain basic inclusions; fragments of porphyritic felsite similar to that associated with the granophyre on Vikurfjall have also been found. All these inclusions appear to be normal xenoliths in that they were solid rock when incorporated within the acid magma, now granophyre, which surrounds them.

Acid Rocks

The relative amount of acid rock within the net-veined complex varies locally from more than 95%, where the rock is either a pure or xenolithic granophyre, to less than 5%, where the acid rock occurs as thin cross-cutting veins or as thin layers between closely spaced

Fig.45a. Xenolithic granophyre containing angular basic inclusions, many of which are derived from fragmented pillows. Shore exposure on the west side of Hvalnes.

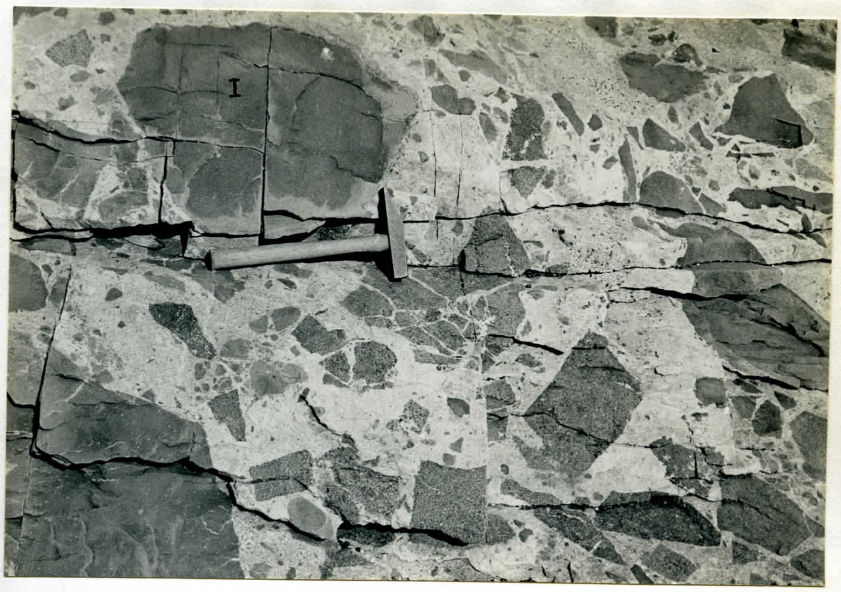

Fig.45b. Xenolithic granophyre at Krossanes containing angular fragments of basalt and dolerite and also a "multiple" inclusion (I) made up of a pillow-like basic inclusion surrounded by an irregular layer of grey basic granophyre.

pillows and other inclusions. The acid rock never becomes finer-grained at its contact with the basic inclusions.

The acid rock is similar to that outside the net-veined complex and includes granophyric and granitic varieties. The contacts between the different acid rocks are sometimes sharp, sometimes diffuse, and often one type is veined by another. Usually the granophyre is heterogeneous, with a spotted appearance caused by innumerable partly digested inclusions of varying sizes. In the immediate vicinity of basic inclusions the granophyre is often enriched with dark minerals, and there may be a patchy or streaky "hybridised" zone around the margins of partly acidified basic inclusions.

The granophyre, particularly the leucocratic pink variety, is commonly drusy. The druses tend to be larger than those in the similar granophyre outside the net-veined complex and are often more than 10cm. in length, especially where there are nearby basic inclusions. The druses are commonly lined with euhedral crystals of feldspar, quartz (often as parallel overgrowths on feldspar crystals), magnetite and green epidote; hair-like aggregates of green and brown amphibole are also sometimes present. Epidote is locally very abundant in the granophyre, especially in the pale non-pink varieties, where it occurs within the granophyre matrix and on joint-surfaces as well as in druses.

Petrography

(a) Basic pillows.

The interiors of most of the larger basic pillows are composed of a coarse doleritic rock (fig. 46a) made up of plagioclase, augite and ore, with interstitial quartz and alkali feldspar: apatite is an abundant accessory, while pseudomorphs after olivine are rare; secondary minerals include hornblende, chlorite, serpentine (after olivine) and occasional calcite. The margins, which are markedly finer-grained, are made up of the same minerals, with the addition of biotite (fig. 46b).

The plagioclase of the pillow interiors occurs as subhedral and commonly elongate crystals zoned from basic labradorite (An 60-70) in the cores to andesine or oligclase at the margins, and the crystals are usually traversed by irregular veins of albite and chlorite. Augite, the only pyroxene, forms very pale pinkish subhedral crystals which are often sub-ophitic; they show marginal and sometimes also internal alteration to brown uralitic hornblende and commonly contain inclusions of granular ore. Opaque ore occurs as equant and acicular crystals and also as irregular patches associated with serpentine in rare pseudomorphs after olivine. Chlorite is widespread, as isolated mica-like crystals and as irregular crystal aggregates; some is also an alteration product of plagioclase and augite. Quartz and alkali feldspar are invariably present as interstitial minerals, quartz often occurring in irregular pools into which grow euhedral plagioclase crystals and around which alkali feldspar forms a vermiform granophyric intergrowth with the quartz; both minerals also occur together in small discrete finely granophyric grains. Biotite is found only in the pillow interiors associated with cross-cutting acid veins.

The grain-size of the pillows progressively decreases towards the margins (fig 46) and at a short distance from the pillow contacts (usualy a few centimetres) the augite crystals begin to break down into small, almost colourless granules. A little closer to the contact the twinning of the plagioclase laths, which are now also much smaller, usually becomes indistinct and the zoning less marked

Within the fine-grained dense pillow margins themselves (figs 46-48) the general texture typically becomes sub-variolitic. Plagioclase phenocrysts often lose their clear cut outlines and the groundmass feldspar no longer forms distinct laths but instead constitutes a matrix made up of elongate crystals arranged in a radial or sheaf-like pattern (similar to that described by Chapman, 1962, p.548, from similar pillow margins) within which the other minerals are situated. Larger elongate plagioclase laths, commonly skeletal (fig.47a) may also occur. The groundmass augite is entirely granular, and is partly or completely replaced by rather larger crystals of green hornblende, though small augite phenocrysts, pale pink with dusky margins, may still be preserved right to the pillow contact. Opaque ore appears to be more abundant in the dense pillow margins than in the interiors, and occurs as skeletal crystals (fig.48a) made up of small groups of parallel rods: larger granular ore crystals frequently line the pillow granophyre contact. Minute highly elongate apatite needles are very common, the needles often being arranged in parallel groups similar to those of ore. Large, poikilitic and often euhedral crystals of brown hornblende and biotite are characteristic of the pillow margins, those of biotite frequently being surrounded by a thin feldspar rich zone (fig.46b). These biotite and hornblende crystals may grow across the pillow - granophyre contact and may also occur in the granophyre immediately adjacent to the pillow. Only rarely can quartz and alkali feldspar be distinguished in the fine-grained groundmass of the pillow margins.

Two chemical analyses, one of the centre, the other of the margin of the pillow, are shown in table 10 . These two analyses show that there is little variation in composition within this pillow except for a higher soda and lower potash content in the pillow margin.

Many of the petrographic features of the pillow margins are comparable to those of similar pillows at Sleive Gullion (Bailey and McCallien 1956) and on Mount Desert Island, Maine (Chapman, 1962) and also to other fine-grained edges of basic rock against acid

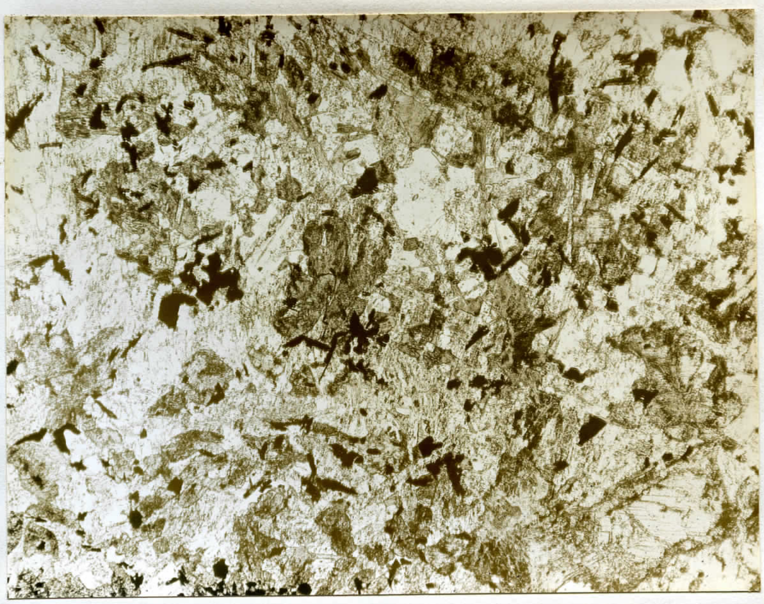

Fig.46a. Photomicrograph of the interior of a large doleritic pillow made up of augite (dark grey), feldspar (slightly turbid), opaque ore and quartz (clear). X15. Ordinary Light. (H668)

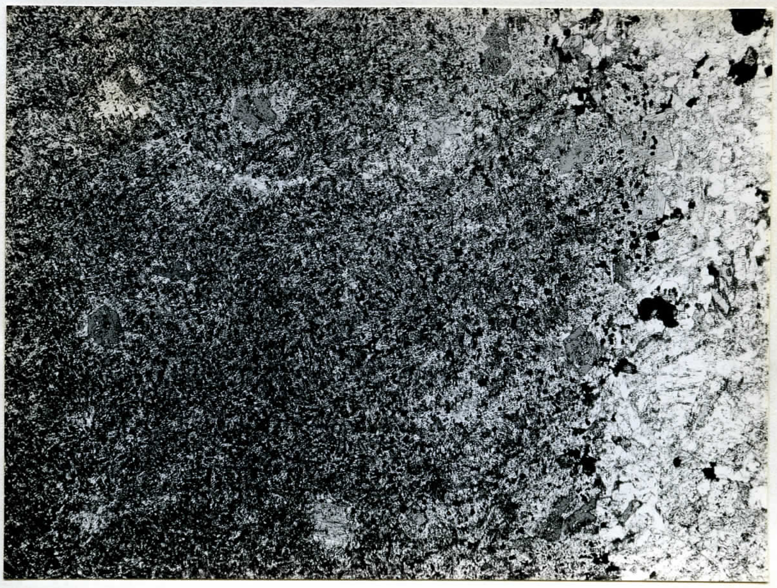

Fig.46b. Photomicrograph of the contact of a basic pillow and granitic acid rock, showing the fine-grained margin of the pillow (the same pillow as above) containing large crystals of biotite surrounded by pale feldspathic fringes. X15. P.P.L. (H667)

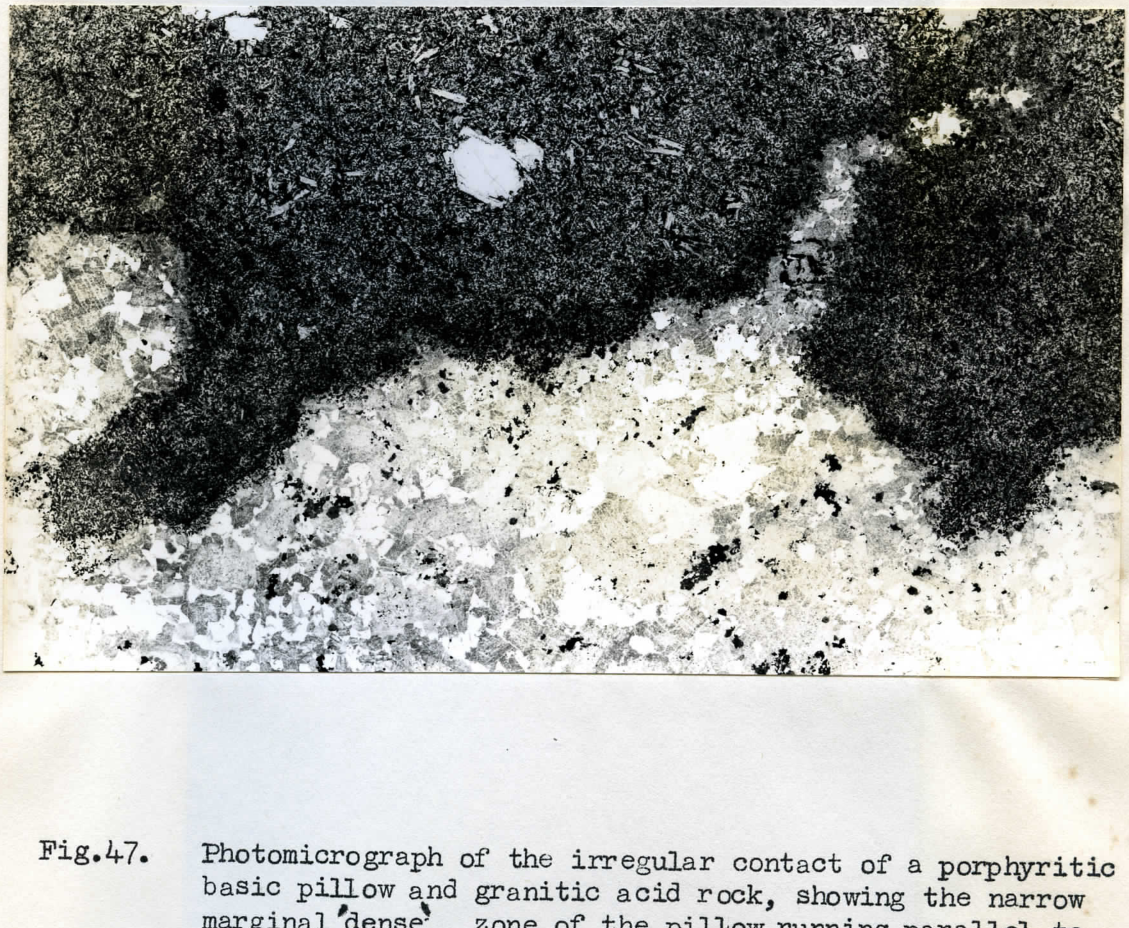

Fig.47. Photomicrograph of the irregular contact of a porphyritic basic pillow and granitic acid rock, showing the narrow marginal 'dense' zone of the pillow running parallel to the contact. The pillow basalt contains euhedral plagioclase phenocrysts and also skeletal plagioclase laths. The acid rock, composed chiefly of quartz and turbid alkali feldspar, contains inclusions of fine-grained basalt similar to that of the pillow margin. X6. Ordinary light. (H420)

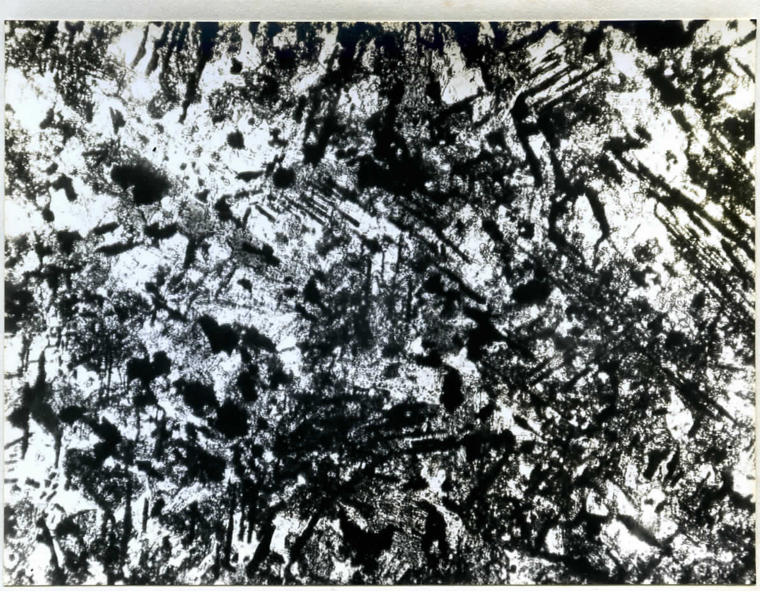

Fig.48a.Photomicrograph of the marginal basalt of a basic pillow (the same pillow as in fig. 47) showing skeletal magnetite crystals. X100. Ordinary light (H420)

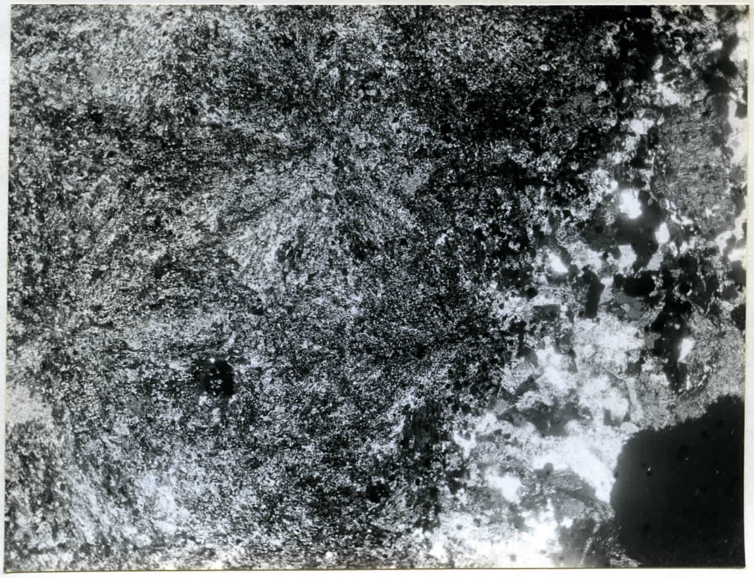

Fig.48b.Photomicrographs of the contact of a basic pillow and granitic acid rock, with micols crossed, showing the sheaf-like structure of the groundmass plagioclase within the pillow basalt There is a concentration of euhedral iron ore crystals at the edge of the pillow. X15. (H120).

as again at Slieve Gullion (Reynolds, 1937, 1951; Elwell, 1958) and also on Guernsey (Elwell et al, 1962). Particularly characteristic are the sub-variolitic texture, the sheaf-like plagioclase aggregates; the skeletal plagioclase crystals which occasionally occur; the granular habit of the augite and its partial or complete replacement by hornblende, the larger crystals of biotite and hornblende and the concentration of ore along the pillow contact.

The rather rare olivine-basalt pillows do not show the marked textural zoning of the other pillows, although they are much more friable and more readily eroded in their interiors than at their margins, and this may reflect a coarser grain-size in the interior. The olivine-basalt is coarsely ophitic, with plagioclase laths, up to 2mm. long, enclosed in pale brown augite which shows partial alteration to brown hornblende and biotite: olivine, pseudomorphed by talc and chlorite; hypersthene (an unusual mineral in olivine-basalts), usually pseudomorphed by pale green amphibole; and iron ore are the other essential minerals. The calcic cores of the plagioclase crystals (average An70, zoned to margins of andesine, An40) are cloudy, suggestive of thermal metamorphism. Similar clouded feldspars have been recorded from doleritic pillows at Slieve Gullion (Bailey and McCallien, 1956, p.498).

(b) Other basic inclusions

The gabbro, dolerite and basalt xenoliths can be matched petrographically with specimens of Hvalnesfjall gabbro and of doleritic pillows. The large doleritic masses are of quartz-dolerite of similar type to that in the centres of the larger pillows.

The diorite outcropping on the west side of Hvalnes has been chemically analysed (table 10). It is a medium-grained rock (average grain-size 1.5 mm) consisting of plagioclase (54%), augite (6%), hornblende (19%), iron ore (6%) and micrographic alkali feldspar and quartz (14%), with accessory apatite and sphene (1%) and secondary biotite and chlorite. The plagioclase crystals are generally sub-hedral with an elongate tendency: they are strongly zoned from labradorite cores (average An55) to oligoclase outer margins and are mantled by turbid alkali feldspar. Sometimes the plagioclase appears to be partly replaced by micrographic quartz and alkali feldspar. Augite is usually subhedral with a very faint brownish tinge, the crystals showing internal alteration to biotite and marginal alteration to hornblende. Hornblende also occurs as separate crystals and irregular crystal aggregates: it varies in colour from green to greenish brown. Ore occurs as granular crystals, often closely associated with augite and hornblende. The diorite shows no marginal textural or mineralogical variations.

(c) Acid rocks

The petrograophy of the acid rocks within the net-veined complex is generally similar to that of the other acid rocks within the Austurhorn intrusion, although differences are seen in the immediate vicinity of many basic pillows and other inclusions, where granitic textures are more common than micrographic (fig.47a). Phenocrysts are sometimes absent in acid layers between closely spaced pillows and are never found in the thinner acid veins or in granophyre-filled vesicles within basic inclusions. In the acid rock within a centimetre of many pillow contacts there are concentrations of greenish-brown hornblende and iron ore, often with associated zircon, sphene, brown biotite (usually marginally altered to chlorite) and, less commonly, very pale green augite: hornblende sometimes has rhythmically banded overgrowths of colourless to green amphibole (probably tremolite and actinolite). Similar concentrations of hornblende and ore adjacent to fine-grained basic rock have been noted by Bailey and McCallien (1956, p.496) and Elwell (1958, p.96) at Slieve Gullion. Xenocrysts, usually cracked or corroded, of calcic plagioclase and augite are quite common in the acid rock, as also are small crystals of iron ore and hornblende obviously derived from a nearby basaltic inclusion.

Flow-banding is sometimes apparent in the acid layers between closely spaced pillows, as when elongate plagioclase phenocrysts are aligned parallel to the adjacent pillow contacts. This flow-banding is similar to that described by Elwell et al (1962, p.217) in acid rock adjacent to basic in the Guernsey net-veined complex. Thin and discontinuous bands of magnetite and hornblende crystals also occur within the acid rock parallel to the adjacent pillows, again indicating possible flow-banding.

(d) Hybrid Rocks

These are intermediate in composition between normal granophyre and the normal basic rock of the net-veined complex. They commonly contain much apatite, as minute acicular crystals. Apatite is also a characteristic mineral of many other hybrid rocks (Nockolds, 1933), such as those at Ardnamurchan (Richey and Thomas, 1930), Glen Tilt (Deer, 1938) and Jersey (Wells and Wooldridge 1931). Xenocrysts of calcic plagioclase and basaltic augite are common in acid hybrids, the augite usually being partly replaced by uralitic green hornblende. Quartz, alkali feldspar, hornblende and often biotite occur in the basic hybrids..

The grey granodioritic pillow-like masses within the net-veined complex have an average grain-size of about 1mm. The chief minerals are hornblende, as small elongate crystals; plagioclase, as small euhedral to subhedral laths; opaque ore granules; quartz; and alkali feldspar; with accessory apatite; the texture is generally microgranitic, with local micrographic patches. These masses show no textural zoning, and their contacts with the surrounding acid rock are diffuse.

The nebulous pillows south of Olneshofn have a generally similar texture to the granodioritic pillows, with usually small subhedral plagioclases lying in a rather fine-grained granitic and patchily granophyric groundmass of quartz and alkali feldspar: dark minerals - green hornblende, and opaque iron ore - make up about 5%

of the rock. Remnants of calcic plagioclase and pale brownish augite phenocrysts also occur, the augite showing alteration to hornblende, chlorite and calcite. In the groundmass quartz sometimes forms irregular pools poikilitically enclosing the other minerals. The general texture is similar in the darker margins of these pillows and the higher colour index here is due to numerous thin needles of greyish green hornblende which cut across all the other minerals. The hornblende needles are up to 2mm. long and contain inclusions of granular ore: they show no apparent preferred orientation and they indicate that the more basic margins of the pillows have been recrystallised. The cumulose contacts of the nebulous pillows with the surrounding acid rock are seen to be quite diffuse in thin-section.

In the many small angular basaltic inclusions which have become acidified the original basaltic texture is still preserved, but the plagioclase has been replaced by alkali feldspar and the pyroxene by either hornblende or chlorite and calcite: the ore remains unaltered. Remnants of plagioclase and augite are still sometimes preserved in partly altered phenocrysts.

The streaky "hybrid" zones around some of the basic fragments have a cataclastic texture, with fragmentary crystals of augite, feldspar, etc.

The acid hybrids include homogeneous and patchy varieties. The homogeneous hybrids are similar to the granodioritic granophyres (e.g. H187) found outside the net-veined complex and consist of strongly zoned plagioclase, hornblende and iron ore, sometimes with augite, in an often sparse matrix of micrographic quartz and alkali feldspar. The patchy acid hybrids are streaky or mottled, due to irregular concentrations of biotite, hornblende, chlorite and iron ore crystals in a general groundmass of quartz, alkali feldspar and sometimes plagioclase. The texture of the groundmass is itself patchy, varying from microgranitic to micrographic.

Many of the hybrid rocks are similar to those described by Thomas and Smith (1932) from the Trégastel-Ploumanach granite, and by Nockolds (1935) from Barnavave, Carlingford. Some are also similar to the skialiths described by Chapman (1962) from Mount Desert Island, Maine.

Table 10 Chemical analyses of basic rocks within the net-veined complex

	H407	H667	H668
SiO_2	53.6	54.3	54.1
Al_2O_3	14.2	14.7	14.8
Fe_2O_3	3.6	2.6	2.7
FeO	9.6	7.8	7.9
MgO	2.2	3.8	3.8
CaO	6.0	7.2	7.2
Na_2O	5.1	5.2	4.1
K_2O	1.3	1.0	1.4
H_2O^+	0.5	1.2	1.2
H_2O^-	0.1	0.1	0.1
TiO_2	1.64	2.10	2.19
P_2O_5	1.42	0.53	0.48
MnO	0.30	0.21	0.15
	99.5	100.7	100.1

H407 Diorite from Hvalnes.

H667 Margin of basic pillow, Krossanes.

H668 Centre of the same basic pillow, Krossanes.

Analyst: D.H. Blake.