Chapter 3 The metamorphic rocks in the Muckle Roe–Northmaven Complex

Introduction

West of the Haggrister Fault (p. 262), three large and several smaller areas of metamorphic rocks appear within the outcrop of the intrusive complex which extends from the south shore of Muckle Roe to the northern margin of the Western Shetland Geological Sheet ((Figure 5)). The largest areas lie, (i) around Skipadock, between the head of Mangaster Voe and Sullom Voe, (ii) in the Busta peninsula, and (iii) along the east coast of Muckle Roe. The smaller areas are, (i) at Djubi Dale [HU 337 743], (ii) in the island of Egilsay, (iii) around bulls Water in the Busta peninsula, and (iv) at Mill Lochs [HU 317 635] and Quhaap Knowe [HU 320 633] in the south of Muckle Roe. The metamorphic rocks form part of a banded group in which black or dark green foliated hornblendic rocks are predominant, mica-schist important, and quartzo-feldspathic schists minor components. They are collectively referred to in the following pages as 'the gneiss' when only a broad reference to the group is required.

Lithology

Djubi Dale Enclave

This mass forms a conspicuous bluff on the right bank of the Djubi Dale stream 700 yd (640 m) N by E from the north end of Glussdale Water close to the northern margin of the present Sheet. It is composed of dark foliated hornblendic rock with feldspathic bands. The strike of the foliation varies between NE–SW and NNW–SSE and is in places contorted. The dip is steep. The form of the mass is roughly oval, 150 yd (140 m) long in a NNW–SSE direction and 100 yd (90 m) broad. On the east side it is bordered by granite, though the contact is concealed, and granite crops out within 100 yd (90 m) on the north, south, and south-west of the hornblendic exposures. The mass is therefore a large enclave in the granite. No xenolith of similar rock has been noted in the surrounding granite and there appears no justification for regarding the Djubi Dale enclave as a roof pendant. Thin sections (S43766) [HU 337 741], (S44104) [HU 335 744], (S44105) [HU 335 744], (S44106) [HU 335 744]) show that it is a contact-altered epidotic andesine-hornblende-gneiss with pelitic laminae in which new biotite and pyroxene have been developed and hornblende and feldspar recrystallized. The very fine grain of the rock and the occurrence of larger grains of feldspar which are swathed in amphibole and show varying directions of streaks of included material, indicate that the original foliated rock had been sheared, and possibly milled, prior to the contact-alteration.

Skipadock area

At the south end of Northmaven the gneiss crops out over an area of about 1 km^2 between the west coast of Sullom Voe at Skipadock and the high ground of Hurda Field. On its north margin, east of the main road, the contact between gneiss and diorite as mapped is sharp and irregularly stepping southward as the ground rises, as if the diorite lay above the gneiss. On its north-eastern margin the gneiss abuts against granite with which it remains in contact southwards to the coast at Skipadock. The northern half of this eastern boundary is concealed; the southern half is well exposed and is mapped as zigzag, with longer E–W limbs, down to the coast, as if the granite alternately broke across and penetrated along the foliation of the gneiss, but had an overall vertical disposition. A small outcrop of gneiss occurs between the granite and the sea on the coast about 100 yd (90 m) E from the main contact; it is not known whether it represents an enclave or an eastward extension of the gneiss outcrop. Several dyke-like bodies of granite are intrusive in the gneiss at and to the north of Skipadock. On the south the gneiss is bounded by the sea and on the west by the Mangaster Voe Fault. Along the north margin the strike of the gneiss is consistently N–S with high westerly or vertical dip. Near the eastern border the strike is approximately E–W with the dip high in the north and inclined at 20°–30° to the north-west at the coast. In the western part of the outcrop the strike and dip are variable, due presumably to the proximity of the fault. Thus the gneiss appears to have a structure resembling the southern half of an oval bowl, the long axis of which is NNE–SSW.

The nature of the rocks is most readily observed in the coast exposures around Skipadock. They are foliated, in part thinly laminated, and locally contorted. They comprise hornblende-schist, garnetiferous pelitic schist, and banded quartzo-feldspathic granulites with pelitic laminae. All have a hornfels aspect. Petrographical examination shows that some have been sheared prior to contact-alteration (S53596) [HU 341 691], (S53601) [HU 338 732]. New pyroxene has been formed in the hornblendic rocks (S29418) [HU 341 690], (S33750) [NH 153 157] [HU 340 695], (S53596) [HU 341 691]) by contact-alteration, and late impregnation by quartz has reconstructed thermally altered pelitic schist (S44231) [HU 341 691].

Egilsay

About 1.5 miles (2.5 km) W of the Skipadock outcrop the gneiss reappears on the island of Egilsay and the islet of Black Skerry, that is on the west side of the, Mangaster Voe Fault and west of the 1-mile-(1.8-km)-broad diorite which occupies the Islesburgh peninsula. The gneiss occupies the whole of Black Skerry and the southern extremity of Egilsay where its outcrop is 200 yd (180 m) broad in an E–W direction and extends for 50 to 100 yd (45–90 m) inland to a deeply embayed contact with diorite. Along the north-west margin the gneiss is separated from diorite by a dolerite dyke, which suggests that the pre-dyke junction of gneiss and diorite was vertical here. A small outcrop of gneiss, about 100 yd (90 m) long by 50 yd (45 m) broad, completely surrounded by diorite, lies north of this dyke. The strike of the foliation is contorted but trends mainly NNW–SSE and ENE–WSW; the dip is vertical. If it is assumed that the Egilsay and Black Skerry outcrops are continuous the length of this mass of gneiss would be at least 500 yd (450 m). This considerable extent, the embayed contact with diorite, and the existence of the outlying mass suggest that the gneiss here is pendant from an eroded roof. It is cut by many granitic and pegmatitic veins and larger dykes.

The gneiss in this area appears from the specimens available to be in the main a banded pelitic and quartzo-feldspathic type (S53600) [HU 317 703] in which the layers are folded in close isoclines (S53599) [HU 317 703]. Hornblende-schist bands are also present (S55247) [HU 319 692]. The rocks are thermally altered with production of granoblastic oligoclase, unorientated idioblastic biotite, and pinite in the pelitic layers, granoblastic andesine and olive-green hornblende in the hornblende-schist. All have experienced a late permeation by quartz which gives them in hand specimen a glazed or sparkling aspect correlating with the replacement and dispersion of the hornfelsed folia by quartz as seen in thin sections. Specimens from the outlying mass in Egilsay (S44282A) [HU 317 694], (S55175) [HU 315 695]) show the contact of gneiss and diorite; microscopic aggregates of biotite in the latter may represent small partly assimilated xenoliths and there has clearly been restricted transfer of material between country and igneous rock. There is no record of xenoliths, large or small, in the vicinity of the gneiss-diorite contact.

Busta peninsula

On the Busta peninsula two main areas are occupied by the gneiss. The smaller, which lies in and east of Houlls Water, includes four small outcrops which may represent one mass intruded by granite. The rock here consists of banded siliceous granulite and pelitic and hornblendic schists (S29414) [HU 335 676], (S33741) [HU 340 676], (S53594) [HU 338 678]) which have all been hornfelsed, hydrothermally altered, and soaked by quartz. The foliation is vertical and the strike is consistently E–W except in the most south-easterly outcrop where it is N–S. The gneiss of all these outcrops is surrounded by heterogeneous granite-diorite complex and is intruded by massive granite.

The main body of gneiss covers an area of fully one third of a square mile (0.86 km^2) and is continuous from the northern end of Bays Water to the eastern end of Roe Sound. On its eastern side it is bounded by the dyke-form body of granite which extends from this position for 10 miles (16 km) northwards to Ronas Voe. Contact relations are concealed by drift, but the interposition of outcrops of gneiss and granite suggests that this contact is intricate in detail. It has, however, a persistent N–S trend on the large scale and therefore is probably vertical or steep. The foliation of the gneiss near the granite margin strikes N–S to NNW–SSE. Between Roe Sound and the Ward of Runafirth the gneiss occupies a belt about 0.25 mile (400 m) wide between granite on the east and diorite on the west and outcrops of diorite appear within this belt at 200 to 400 yd (180–360 m) NW and 200 yd (180 m) NE of Roe Bridge. The western margin runs N–S for 0.5 mile (800 m) but is deeply indented in an E–W direction corresponding with the E–W to ENE–WSW strike of foliation in the gneiss. At the Ward of Runafirth the gneiss belt changes direction to E–W, continuing for mile (800 m) towards Bays Water and thence north-westward for a further I mile (800 m) by the head of Bays Water to the Ness of Coulsetter. The gneiss ends against the rising ground of the Ness of Coulsetter along an undulating but sharp margin which appears to follow the foliation. Beyond this margin no considerable body of gneiss has been noted but inclusions of schist and basic gneiss are found in the diorite on the west coast one-third of a mile (0.5 km) S of Turvald's Head and on Lothan Skerry; these are represented in the collection by thermally altered pelitic schist (S53592) [HU 326 677] and hornblende-schist (S55168) [HU 331 676]. South of the main belt six considerable masses of gneiss, the largest 200 yd (180 m) long by 60 yd (55 m) broad, have been mapped within the diorite along a ½-mile (800-m) stretch between Bays Water and Roe Sound.

Topographically the gneiss of the main belt rises from sea level to almost 300 ft (91 m) OD south of the Ward of Runafirth, but in general its outcrops occupy rather lower ground than the eminences of diorite and gabbro, for example those of the Ward of Runafirth and the Skeo of Gossaford [HU 337 668], and its course along the hollow running west to Bays Water ends at a level between 150 and 200 ft (46 and 61 m) OD against the Ness of Coulsetter diorite which rises to 300 ft (91 m) OD. In the lower portion of this hollow outcrops of gabbro and of granite appear inside the gneiss belt, and a large body of gabbro, diorite, and granite also is enclosed south-west of the Ward of Runafirth. These relations can be interpreted in two ways : that this extensive area of gneiss forms either the lower part of an uneven roof intruded irregularly from below, or an irregular floor overlain by a sheet of gabbro-diorite. The numerous outcrops of gneiss isolated in the igneous rock between Bays Water and Roe Sound would represent, in the first case, pendants from the roof; in the second case windows in the floor of the intrusion or rafts within its mass. The outcrops of igneous rock within the gneiss area between Bays Water and Busta would represent, in the two cases respectively, plug-like projections into the gneiss roof or outliers of the intrusive sheet. No field evidence of superposition can be adduced in support of either alternative.

The rocks collected from the gneiss outcrops in the Busta peninsula represent a banded group of siliceous and quartzo-feldspathic granulites, pelitic schists, and hornblende-schist and -gneiss. Unusual types are recorded from the most westerly of the isolated masses, 200 yd (180 m) SW of the south end of Bays Water, where in hard hornblende-schist a thin irony band is found. Two speciments from this band include an amphibolite (S34995) [HU 328 673] with greenish blue hornblende and a garnet-magnetite-hornblende rock (S55166) [HU 331 669] which closely resemble the hornblendic and garnetiferous skarn round the Clothister magnetite deposit. These rocks appear to have preserved their pre-diorite character and if it may be assumed from their unusual mineralogical features that they are geologically the equivalent of the Clothister magnetite then the conclusion that the latter is of pre-granite–diorite complex date (p. 20) is supported. The presence of such rocks so far on the other side of the Haggrister Fault suggests also that the structural association of the Clothister greenschist assemblage with the banded hornblendic group of gneisses is of wide extent across the regional strike; but it remains uncertain whether the juxtaposition of the two groups is tectonic, as supposed for the Clothister area (p. 22), or successional, perhaps unconformable. The specimens of the banded group of the Busta peninsula are thermally altered in greater or lesser degree and many show later impregnation by quartz.

Muckle Roe

The gneiss on Muckle Roe occupies two main belts (Figure 5). The smaller extends from a short distance west of Roe Bridge westwards for about 0.75 mile (1.2 km). The coastal exposures of gneiss are to a large extent concealed by drift and towards the western end they are interrupted by outcrops of diorite.

The most westerly outcrop is isolated in diorite and lies directly south across Roe Sound from the most westerly of the small gneiss outcrops in the Busta peninsula. Inland from the coast the gneiss belt attains its greatest width of about mile (800 m) to the west of Kilka Water. Its boundary against diorite is irregular and deeply embayed and in the broadest part outcrops of diorite within the gneiss suggest that the surface between the intrusive mass and the gneiss is rising southwards. This east–west belt of gneiss is not seen to join with the larger belt which runs north–south along the east coast of Muckle Roe but there seems little doubt that the two belts are continuous, perhaps with interruptions of diorite, since the gneiss is exposed again in Crog Holm, in Roe Sound and on the rock which supports the bridge linking Muckle Roe to the mainland. These exposures serve also to indicate the continuity of the Busta peninsula gneiss with that of the Muckle Roe belts.

The larger belt of gneiss on Muckle Roe extends from Roe Bridge south along the east coast of the island to Scarfa Taing, a distance of 1.5 miles (2.4 km). Its outcrop is narrow except around Orwick Water where the width is nearly one third of a mile (0.5 km). It is not known whether the outcrop of gneiss 400 yd (360 m) NW of Northpund croft is continuous with the coastal exposures. A number of large gneiss enclaves crop out in granite in the Burn of Scarfataing on the coast south-west of Scarfa Taing (Figure 5).

Along the coast section relations of the country and the intrusive rocks are obscured by the effects of numerous crush-zones. These include north-easterly and north-westerly lines but the main crushes trend N–S, that is they are parallel to the line of the Walls Boundary Fault the major dislocation of which must lie close to the Muckle Roe coast. In the crush-zones the rocks are shattered, locally sheared, and locally brecciated, while the adjacent massive rock has acquired a dull, greenish black amorphous aspect so that along stretches of the more easterly length of the section field distinction of basic gneiss and basic intrusive is at best doubtful. A traverse along the coast southwards from Roe Bridge shows pinkish weathering gneiss and granulite with which numerous layers of dark hornblendic schist and granulite are interbanded; at 200 yd (185 m) NE of Northpund the basic component is a sheet, about 35 ft (11 m) thick, of massive biotite-hornblende-andesine-gneiss in a group of banded grey and green granulites. Southwards along the 300 yd (270 m) of coast between Northpund and Lubba the exposures are all of dull green massive rock showing no foliation but otherwise resembling the massive basic gneiss. Microscopically the rock is dolerite and is therefore considered to form a basic facies of the intrusive complex. Like the metamorphic rocks the dolerite is cut by dykes and veins of granite and by lines of crush. Between the southern termination of the doleritic material and Green Taing the rocks are a mixture of granite, diorite and gneiss, greatly crushed and often indeterminate, but foliated feldspathic and hornblendic gneiss is exposed in the burn from Orwick Water and along the coast north and south of the burn mouth. At and south of Green Taing the main interest of the section lies in the exposure of several parallel N–S crush-lines in rock which is mainly dioritic with granite veins but includes banded gneiss. The crush-lines are vertical but in the reefs 200 yd (182 m) S of Green Taing banded basic and acid gneiss is seen to crop out below a flat dislocation with diorite on top. The melange of igneous rock and gneiss ends at a fault where the coast bends south-westwards 250 yd (230 m) NE of Scarfa Taing. From this fault to the Burn of Scarfataing the rocks are mainly scapolitized basic gneiss with some quartz-soaked garnetiferous schist but speckled rock of dioritic aspect also occurs and in some of the specimens of scapolitized rock igneous textures as well as foliation can be seen (S45029) [HU 339 639], (S45030) [HU 339 639], (S45031) [HU 339 639]. Close association of scapolitized gneiss and basic igneous rock occurs also on the isolated outcrop of Scarfa Taing. On the coast south-west of Scarfa Taing the main rock is granite which encloses slabby or wedge-shaped masses of gneiss. This type of large inclusion can be seen also in four exposures in the Burn of Scarfataing along the 500 yd (450 m) stretch up from its mouth. These masses appear generally to be elongated along the N to NE strike and down the vertical dip, but in the exposures on the north bank 300 yd (270 m) upstream from the mouth of the burn the granite has lenticular sheet relations to the foliation of the gneiss. Interposition of granite and gneiss is found also in the outcrops on the low ridge north-east of the burn. Some of the massive unfoliated basic rock in the gneiss of the burn and ridge exposures proves to be uralitized dolerite but the relations of gneiss and basic intrusive rock are obscure along this coast owing to the extensive shattering. It is noteworthy, however, that the gneiss nearest to the major body of diorite in the north-east of Muckle Roe is texturally reconstructed (S28902) [HU 343 658], (S44621) [HU 342 657], (S45036) [HU 342 656]) and it is inferred that the thermal alteration of the gneiss was induced by the basic intrusive. The only clean contact of gneiss and diorite which has been observed in this area lies in the outcrop west of Orwick Water where the medium-grained igneous rock forming most of the outcrop has a fine-grained chilled facies along the contact with dark banded hornblendic gneiss. The contact is parallel to the general strike of the foliation; its hade is not known. Outcrops of foliated hornblendic rocks north, east and south of Orwick Water link the western outcrop with the gneiss of the coastal exposures.

The distribution of gneiss and basic intrusive rock along the strip south of Roe Sound is analogous with that in the centre of the Busta peninsula and it is here equally uncertain whether the gneiss forms a roof or a floor to the intrusion. The continuity of the gneiss from Scarfa Taing northwards for 2 miles (3.2 km) to the Ward of Runafirth and the parallelism of this long outcrop with the trend of the dyke-like body of granite in the Busta peninsula suggest that the gneiss has a generally wall-like relation to the gabbro-diorite. Exposures on the coast and in the Scarfataing Burn, described above, show that locally at least the igneous rock intrudes into this wall as sheets. The form of the gabbro-diorite is discussed more fully in Chapter 13 (p. 178).

Lithologically the gneiss of Muckle Roe is similar to that of the Busta peninsula. Foliated hornblende-rich rocks are predominant in most areas but quartzite and quartzo-feldspathic granulite occur north of Scarfa Taing and banded grey and green, pink-weathering siliceous types occur south-east of the bridge across Roe Sound. Pelitic schist appears to be rare. Thermal metamorphism of the basic rocks led mainly to textural reconstruction but pyroxene crystallized along with the new granular hornblende in one of the basic layers, though in another specimen it is uncertain whether the pyroxene is not a pre-thermal mineral. Later hydrothermal and metasomatic effects are shown in quartz permeation of garnetiferous schist and biotite-oligoclase-gneiss and replacement of granular hornblende-gneiss by microperthite. In addition to the usual foliation pre-thermal structures traceable in several specimens include a second foliation and shear or fracture planes.

Mill Lochs and Quhaap Knowe

In this area, which lies in the interior of the Muckle Roe granophyre, three outcrops of banded gneiss occur on the west and south shores of the southern of the two Mill Lochs and on Quhaap Knowe. Specimens consist of well-foliated gneiss in which folia of hornblende and andesine alternate with more biotitic and apatite-rich laminae and with quartz-oligoclase layers. The gneiss has been thermally recrystallized with development of granoblastic feldspar and hornblende and locally the amphibole is porphyroblastic. Obscure large aggregates peppered with ore granules in the biotitic laminae may represent cordierite (S44623) [HU 320 634], (S44624) [HU 320 634]. In hand specimen the rocks have a sheared aspect and in thin section relict phacoidal structure and recrystallized healed fractures are seen.

Lithologically the rocks conform with the gneiss country rock of Muckle Roe and these small masses are regarded as enclaves deeply sunk within the granophyre intrusion. In the field they have a superficial resemblance to the dark varieties of banded felsite dykes and it is possible that more enclaves of this kind remain to be recognized.

The Busta isthmus

The geology of the Busta isthmus is complicated owing to the southward convergence of faults into the line of the Walls Boundary Fault and it is difficult to assign the rocks to their uncrushed originals (p. 22). However the pelitic schists and foliated hornblendic rocks cropping out round Ell Wick and astride the main road west of the Busta road junction are very similar to those of the Skipadock area in lithology and mineral composition and like them lie on the north-east side of the southward continuation of the Mangaster Fault. On the other side of this fault gneiss appears to occur only as enclaves in the igneous rock; the only specimen available comes from the faulted mixture of granite, diorite, and gneiss on the west side of Ell Wick and is a pelitic rock which has been thermally altered, impregnated by quartz, and finally scapolitized (S53595) [HU 343 683]. East of but close to the assumed line of the Mangaster Fault and 150 yd (140 m) S of the main road an outcrop has provided two specimens, one of which is a thermally altered sheared rock (S44330) [HU 344 677], resembling the albite-schists of the Clothister area. The other is a crushed sheared rock composed largely of phacoids of quartz and of alkali-feldspar in chloritic quartzo-feldspathic rock powder. This shows no sign of thermal alteration (S55248) [HU 342 665] and may represent an early acid phase of intrusion. The outcrop from which these specimens come is shown in (Figure 5) as caught between two dislocations and as tectonically separated from the main strip of gneiss which is unshaded. Specimens from the east shore of Ell Wick include a corundum-bearing pinitized pelite (S53586) [HU 347 682] and a mylonitized and folded epidote-hornblende-plagioclase-gneiss with magnetite porphyroblasts which shows some recrystallization but no thermal reconstruction (S44278) [HU 346 683]. Thermally altered semi-pelitic schist outcrops by the roadside [HU 346 677] 150 yd (140 m) W of the Busta road junction (S28914) [HU 345 659]; the thin section gives particularly clear evidence of early folding overprinted by the thermal reconstruction. East of the fault zone which controls the coastline on the north-east of Ell Wick, the only specimen available is a banded hornblende-feldspar rock which has been sheared with folding and disruption and subsequently recrystallized (S53585) [HU 349 685]; it is uncertain whether the late re-crystallization is due to purely thermal action.

Thus in the Busta isthmus there are from west to east the following faulted strips running NNW–SSE to N–S: (1) a strip where enclaves of gneiss occur in the igneous rock; (2) a strip where granite is in contact with high grade pelitic hornfels, and which is the probable equivalent of the Skipadock gneiss; (3) a strip of gneiss which has been much sheared but little recrystallized; (4) a strip of mainly indeterminate rock (p. 19). The gneiss of strip 3 may equate structurally either with the Skipadock gneiss or with the hornblendic gneiss of South Ness (p. 15). Further field and petrographical work is required for satisfactory elucidation of the structure and geological correlations in this area.

Petrography

The schistose or gneissose rocks within or in contact with the granite–diorite complex in Muckle Roe, the Busta peninsula, and southern Northmaven include foliated basic rocks, pelitic schists, and siliceous or semipelitic granulites. Other types include a contact-altered dyke and an amphibolite interlayered with garnet-magnetite-schist. Most of the specimens examined show contact alteration and many provide evidence of later low temperature alteration by siliceous or alkaline solutions. Scapolitization is locally intense but since this affects also the igneous rocks it is described in Chapter 13.

Siliceous and semipelitic rocks

Flaggy laminated grey and pink granulite was collected from one of a number of xenoliths in granite 950 ft (290 m) WSW of Northknowe, Muckle Roe [HU 342 642]. It is the only quartz-microcline-granulite (S45032) [HU 340 641] in the collection from the area under description and is composed of granoblastic quartz between which irregular grains of microcline and bent flakes of chlorite and muscovite are moulded. The microcline shows only patchy cross-hatching and contains thin tongues of perthitic plagioclase. Drops and irregular grains of ore are abundant and zircon is common. The rock has irregular laminae of sericitic aggregate which look like pseudomorphs and locally contain tiny scales of green biotite of new development. In these sericitic laminae there are relics of oligoclase in the microcline. This feature and a tendency of late quartz to enclose smaller grains of quartz, drops of microline, and micaceous aggregate suggest slight potash-silica metasomatism. There is, however, no evidence of high temperature transformation other than the pinitic aspect of the micaceous aggregate which suggests that cordierite or andalusite may originally have been present.

Semipelitic granulite from Egilsay is composed of granoblastic quartz and oligoclase with interstitial potash-feldspar and brown biotite in laminae which alternate with dark folia of oligoclase and biotite with accessory apatite (S55175) [HU 315 695]. In these the biotite is in part coarse and raggedly terminated as in the quartzose laminae but is also commonly developed in small idioblastic laths. This rock is in contact with and is partly assimilated into a granodioritic facies of the diorite which forms the main rock of the island. Banded semipelitic rocks, from exposures in the Ell Wick area of the Busta isthmus, are greatly altered schists in which shear structures earlier than the thermal metamorphism are preserved; one of them (S28914) [HU 345 659] appears to have been mylonitized before thermal alteration. Pelitic layers are composed largely of pinite, probably after andalusite, unorientated aggregates of small flakes of brown mica, sericite, muscovite, and obscure material, and contain small round groups of unorientated biotite and chlorite which may have been formed from decomposed garnet. Another is a banded granulitic gneiss (S44330) [HU 344 677] containing green biotite in the quartzose layers, while the pelitic laminae are composed of quartz-sieved oligoclase, microcrystalline newly formed brown biotite, pinitic aggregates after cordierite swathing the plagioclase, and spinellid granules. The texture is that of a sheared rock recrystallized so much that only a folded banding is preserved. The microporphyroblastic and inclusion-filled nature of the plagioclase suggests correlation with the albite-schists of Clothister (p. 20) which are, however, not altered thermally. In this rock addition of quartz may have accompanied recrystallization of the siliceous layers with concurrent formation of chlorite along strings which may represent old shear fractures.

Pelitic schists

Pelitic members of the gneiss have been noted or collected from all areas from Skipadock to Scarfa Taing, with the exception of the Otter Ayre [HU 326 665] area, and pelitic xenoliths have been found in the far west of the Ness of Houll [HU 327 672] in the south-west of the Busta peninsula.

All the specimens in the sliced rock collection show strong thermal alteration which in most cases has been followed by low temperature change and late soaking by quartz. Those in which the minerals of contact-alteration are best preserved show the normal change of pelitic schist to homfels characterized by decussate brown biotite and lenticular or granoblastic pinitic pseudomorphs after andalusite or cordierite (S53589) [HU 338 663], (S53590) [HU 342 661]; in only one specimen are there relics of fresh andalusite and also, doubtfully, cordierite (S53591) [HU 336 666]. Fresh corundum occurs in the latter rock and also, though mostly replaced by white mica, in a specimen (S53586) [HU 347 682] from the east side of Ell Wick, and in this rock local groups of parallel prismatic grains, about 0.01 mm long, in the sericitic aggregates probably are relics of andalusite prisms. The feldspar of the pelitic schist is oligoclase (~An_{20}) but may approach andesine (~An_{30}), as in S53591. Alkali feldspar is present in the more quartzo-feldspathic layers. It is however uncertain whether this is original since there has been considerable invasion by quartz and recrystallization of the pelite (S53590) [HU 342 661]: certainly in the case of the Ell Wick pelite (S53586) [HU 347 682] the alkali-feldspar is introduced since it forms veins which enclose muscovitized and chloritized relics of the biotite-schist as well as forming a matrix to schist laminae. The feldspar is a Na–K species with β 1.525–1.526, γ 1.529–1.530. Accessory minerals include apatite, which may be very abundant, opaque or dark brown spinellid, minor zircon, and sphene which forms crystals which are small, clear and almost colourless in the homfels, but large, turbid and brown in the feldspathic veins of the Ell Wick specimen.

While none of the hornfelsed pelitic schists fails to show some later permeation by quartz this process has in some cases proceeded so far that only relict lenses or aggregates of the hornfelsed schist remain in a granoblastic mosaic of quartz with minor interstitial feldspar or chlorite (S53568) [HU 343 654], (S53594) [HU 338 678], (S53599) [HU 317 703], (S53600) [HU 317 703]. The relict schist may be well preserved. From the islet in Houlls Water [HU 340 677] a quartzose specimen shows relics of hornfelsed biotite-schist containing garnet (S29414) [HU 335 676]. But even in the best preserved hornfelsed schist the degree of sericitization and pinitization is no less than in the relics dispersed in quartz and therefore it is concluded that a low temperature hydrous change preceded the quartz invasion. It is possible that during this period a coarser recrystallization of biotite took place (S53568) [HU 343 654] and also at a later stage chloritization of biotite. The latter process is not necessarily concurrent with the influx of quartz (S53568) [HU 343 654], (S53599) [HU 317 703] since the intensity of chloritization and the proportion of quartz are not directly related.

Two quartz-impregnated pelites are very rich in garnet. In the less quartzose rock (S44231) [HU 341 691], from the north side of Skipadock, the pelitic folia consist of a multitude of small unorientated biotite flakes, elongate green and colourless pinitic aggregates, xenomorphic garnet, minor oligoclase (~An_{15}), abundant accessory apatite and magnetite and, locally, blue tourmaline. In the other, from the north side of Scarfataing Bay, most of the pelitic constituents have disappeared and their folia are represented by laminae of closely packed small garnet idioblasts, rarely over 0.05 mm across, interstitial turbid oligoclase (~An_{10}) and chloritized brown biotite, and accessory apatite (S44622) [HU 340 639]. In both rocks it appears that garnet has been the most stable of the pelitic constituents though it has been recrystallized, while feldspar, biotite, and pinite have been removed. In these rocks as in several of the others cited above the quartz is rich in inclusions, trains of which pass without interruption from grain to grain, and it is clear that the quartz-bearing solutions have contained active fluid components.

The pelitic schists have been so thoroughly transformed by thermal action and invasion of late siliceous solutions that in general no conclusion can be drawn on the possibility of an episode of shearing of the regionally metamorphosed rocks prior to the thermal recrystallization, such as is shown by the basic types of the country rock. Only in one case (S53590) [HU 342 661] does the microscopic texture suggest pre-thermal shear in the locally strong schistosity of the new biotite and the elongate structure of highly sericitized feldspar.

Basic rocks

The basic members of the gneiss vary from almost monomineralic homblende-schist through well banded hornblende-feldspar types to banded biotite-hornblende-gneiss with quartz. All show some degree of reconstruction and many clearly have been recrystallized under conditions of high or moderately high temperature and hydrostatic pressure so that the earlier foliation may be greatly obscured. Schistosity within the folia of the rocks has been extensively destroyed (S28906) [HU 342 641], (S33750) [NH 153 157] [HU 340 695] and may be preserved only as a mimetic recrystallization of hornblende, the crystals of which tend to lie with the prism axis parallel to the former schistose structure (S44280) [HU 334 677], (S44281A) [HU 338 672] [HU 338 672]. In some of the rocks, however, pre-thermal textures and structures are partly preserved. For example, the early schistosity is shown by orientation, parallel to the foliation of the rock, of pale green prisms of hornblende which is in part converted to unorientated brown hornblende (S44325) [HU 335 665]. Again, in a specimen from the Busta Voe coast 200 yd (180 m) NE of Northpund, the feldspar grains contain trains of inclusions of new recrystallized hornblende which lie parallel, transverse, or at any intermediate angle to the preserved foliation of the rock and to the mimetic schistosity in the hornblende folia (S45036) [HU 342 656]. Two periods of directed stress prior to the thermal metamorphism are thus implied. In rocks from the Skipadock area relics of shearing and cataclastic structures are clearly of pre-thermal date (S53596 (S53601) [HU 338 732] and in a rock from the Ness of Coulsetter [HU 333 676] plane-foliated laminae of very fine-grained minerals are interpreted as mylonite recrystallized in varying degree (S44280) [HU 334 677]. Sharp folding, shearing, and disruption of the foliation in a rock from one of the middle strips of the Busta isthmus are clearly earlier than the latest recrystallization but it is uncertain whether that event is here due to the plutonic intrusion (S53585) [HU 349 685]. Early fractures filled by epidote (S44621) [HU 342 657], (S53605) [HU 342 658] which cross the foliation but are interrupted by or disappear in the thermally recrystallized hornblende and feldspar, indicate pre-thermal fracture and low temperature mineral transport. These examples together provide evidence of a period of folding, shearing, and fracture of the regionally metamorphosed gneiss group prior to intrusion of the granite-diorite complex.

In thin section the basic members of the gneiss are seen to be composed essentially of hornblende and plagioclase; fully half of the sliced specimens contain pyroxene also as an essential mineral. Epidote is abundant in some but commonly absent or minor in those which are rich in pyroxene; zoisite or clinozoisite also occurs. Biotite is common in the more feldspathic members, and pelitic layers in these may contain pinite. Apatite, magnetite and sphene are accessory and each of these minerals tends to be more abundant along thin laminae.

The feldspar of those members which have been well recrystallized lies in the andesine range, An 40 to 50 per cent, and is clear and granoblastic (S53605) [HU 342 658]. It is however much more calcic, with An about 75 per cent, in a rock composed mainly of equant brown idioblastic hornblende (S44281) [HU 338 672] and (S44281A) [HU 338 672] [HU 338 672]. In this rock, which contains no pyroxene, there is transition, from place to place in the section, between pellucid plates of bytownite and microgranular aggregates of clinozoisite; an earlier schistosity is preserved by trains of tiny hornblende prisms enclosed in the new plagioclase and a vein of prehnite cuts the recrystallized rock. In many specimens the feldspar is too turbid or sericitized for determination but seems from its relief to be less calcic (S44621) [HU 342 657]. Since this feldspar is granoblastic and encloses new crystals of amphibole and sphene it is possible that the sericitization and less calcic character have been acquired after the thermal alteration. In some specimens, however. large sericitized and epidotized grains are clearly relics from the pre-thermal rock (S53601) [HU 338 732].

The usual hornblende of the contact-altered rocks forms stumpy prismatic or equant unorientated crystals with strong pleochroism X golden or straw yellow, Y deep olive-green or brown, Z olive-greenish brown; γ: c 16°–20°. Rarely it shows a tendency to late recrystallization in radiating bunches and microporphyroblasts (S53596) [HU 341 691]. The olive-brown species may pass marginally and on the prism terminations to a greenish blue species which presents idioblastic prism forms to the granoblastic feldspar (S44621) [HU 342 657]. Usually some proportion of a pre-thermal pale green to colourless amphibole is present as closely cleaved, almost fibrous prisms schistose parallel to the foliation. Transformation of this type of amphibole to the deep brown equant type can be clearly followed (S44325) [HU 335 665], (S63505). The pyroxene produced in the thermal recrystallization is colourless or faintly green and occurs as single or aggregated prismatic granules, usually less than 0.05 mm, rarely more than 0.1 mm long. These are enclosed in the granoblastic feldspar and packed among the clusters of brown hornblende with which they interfere as concurrent crystallizations and in no way as replacements (S46602) [HU 341 690], (S53596) [HU 341 691]. Pyroxene does occur also as larger (up to 0.5 mm) interfering crystals which form aggregates parallel to the foliation (S29418) [HU 341 690]. They are in part recrystallized to clear prismatic pyroxene (S53601) [HU 338 732]. The relics of large turbid epidotized feldspar grains and irregular elongate clots of pale green coarse amphibole along with the coarse pyroxene aggregates in this rock, which otherwise is composed of clear granoblastic andesine, colourless pyroxene, brown hornblende, and a little red biotite, suggest that it had been a pyroxenic epidiorite. The presence of discontinuous and in places contorted trains of ore granules through the base suggests also that the rock had been sheared prior to the thermal metamorphism.

Biotite is not a common mineral in the altered basic rocks and occurs in essential amount mainly in the more feldspathic (S45036) [HU 342 656] and quartz-bearing (S44280) [HU 334 677], (S55168) [HU 331 676] members. In the former the biotite occurs as irregular flakes, darkened by sagenite, interlocking with amphibole and plagioclase in a complex foliated base (p. 29). This rock forms a 12-yd (11-m) wide mass, perhaps a pre-foliation dyke or sheet, in banded grey and green granulites on the coast of Busta Voe, 200 yd (185 m) NE of Northpund and seems only in minor degree affected by thermal recrystallization. One of the quartz-bearing rocks, an inclusion in diorite forming the Lothan islet [HU 311 676], is a well-banded gneiss in which folia of granoblastic quartz and andesine, on which prismatic biotite is moulded, alternate with others rich in granular monoclinic colourless pyroxene (S55168) [HU 331 676]; the rock contains also sporadic grains of uralitized optically negative orthopyroxene and numerous granular pseudomorphs in chlorite and birefringent pinite. Biotite, however, is an important essential constituent of a basic schist which forms a minor outcrop in diorite on the northern slopes of Roe Sound [HU 335 664]. 200 yd (180 m) NW of Houll. The rock is composed mainly of schistose hornblende and minor granoblastic andesine (S44325) [HU 335 665]. The schistose hornblende forms pale green, closely cleaved prisms with frayed terminations and is in course of conversion to a clear yellowish-brown hornblende which appears centrally and marginally to the green variety as well as forming stout idioblastic unorientated prisms. In other layers the hornblende though idioblastically recrystallized remains green and is cemented by shapeless unorientated fox-red biotite which has a small optic axial angle (2E ~ 20°). In yet other layers this biotite is the main constituent. Since in this, and in the other rocks cited above, the biotite is an important mineral in certain bands or laminae only, its formation is due primarily to suitable chemical composition of these layers.

Potassium feldspar is present in two specimens of the basic country rock and appears to be derived from granitic material which at both localities veins the diorite in contact with the basic gneiss. One of these (S45132) [HU 340 640] is unusual in containing turbid oligoclase in irregularly sutured grains as the main mineral and in being exceptionally rich in sphene and iron ore along well-defined directions. This rock may have been a tuff. It is very variably recrystallized and the veins of potassium feldspar within it enclose fragments of the more crystallized minerals which are in optical continuity with the minerals marginal on the vein. In the other rock, which is highly contact-altered and contains pyroxene and biotite, microcline occurs in small pools among the andesine folia and in large crystals which appear to have a replacing relation to the fine-grained granoblastic plagioclase (S53601) [HU 338 732].

Outlying xenolithic bodies of basic gneiss

The small mass of basic foliated rock enclosed in the granite at Djubi Dale [HU 337 743], on the northern margin of the sheet, is similar in thin section (S43766) [HU 337 741], (S44104) [HU 335 744], (S44105) [HU 335 744], (S44106) [HU 335 744]) to the andesine-hornblende rocks containing much microgranular pyroxene and local red biotite described above. Granoblastic recrystallization of feldspar is far from complete and turbid microaugen, perhaps augiclasts, are relict.

The small masses enclosed in the granophyre at Quhaap Knowe and Mill Lochs, in the south of Muckle Roe, are foliated andesine-hornblende rocks (S44624) [HU 320 634] with folia of biotite and ore-sprinkled pinitic aggregates which may have been cordierite. The hornblende of this rock is shapeless, porphyroblastic, and sieved by plagioclase. This habit, which has not been seen in other thermally altered rocks of the area, and the sieving of plagioclase by optically continuous droplets of quartz indicate a penetrative activity of fluids during immersion of the gneiss in the consolidating granophyre.

Folia of quartz occur in the more feldspathic layers (S44623) [HU 320 634] and may represent original quartzo-feldspathic laminae. Potassium feldspar is locally abundant and its varying relation to the plagioclase, cementing, sieving, or enclosing, suggest that it is derived from the granophyre.

From a small body of country rock enclosed in diorite 200 yd (180 m) SW of Bays Water [HU 331 668] two rocks very different in character from all others from Muckle Roe and the Busta peninsula area require mention. One is an amphibolite (S34995) [HU 328 673] composed essentially of an unorientated felt of amphibole blades and fibres, pleochroism X straw yellow, Y deep green with a tinge of blue, Z deep greenish-blue and small varying optic axial angle, negative sign. The colour varies from faint in the fibrous forms through pale in the core to deep at the margins of larger prisms. Acting as a sparse cement to the amphibole are aggregates of clear overlapping grains which are demonstrably quartz when sufficiently large for determination but may include feldspar. Crystals and aggregates of magnetite are numerous and fairly evenly distributed through the rock while apatite grains, also numerous, tend to occur in short, roughly parallel chains. Epidote also is abundant forming small aggregates within the amphibole felt and occupying large spaces in which amphibole is scanty. The rock shows no indication of thermal recrystallization and is cut by thin veins of clear mineral which is probably albite. The other rock (S55166) [HU 331 669] is composed of an open sponge of magnetite crystals, the small pores of which are filled by bunches of colourless to pale bluish amphibole prisms, up to about 0.05 mm long, while the larger spaces are occupied by aggregates of interfering, straw yellow to bluish-green amphibole, which in sections showing strong Y green, Z greenish blue dichroism gives an off-centre, almost uniaxial figure in convergent light. Much less abundant than amphibole, pale pink, slightly anisotropic, garnet aggregate also occupies large spaces in the magnetite and encloses both magnetite and amphibole; it appears also as idioblastic crystals in the coarser amphibole aggregates. Apatite is a very abundant accessory constituent occurring as stout prismatic grains, up to 0.3 mm long, enclosed both in magnetite and in amphibole and tending to form chains nearly 1 cm long which are roughly parallel to one another and to thin monomineralic amphibole streaks. The only other constituents are quartz and locally associated epidote occupying small spaces between garnet and magnetite or amphibole.

In their association, their unusual mineral composition, and the species of amphibole which is their main constituent, the rocks of this outcrop compare closely with those peripheral to the Clothister magnetite deposit (p. 20); the only difference is in the abundance of apatite in the Bays Water specimen.

Before concluding this section on the petrography of the Muckle Roe–Busta country rocks attention may be drawn to the occurrence of dyke rocks which cut the gneisses but are thermally altered by the diorite, and to the scapolitization which affects some of the gneisses as well as the diorite. These phenomena are described in Chapter 13.

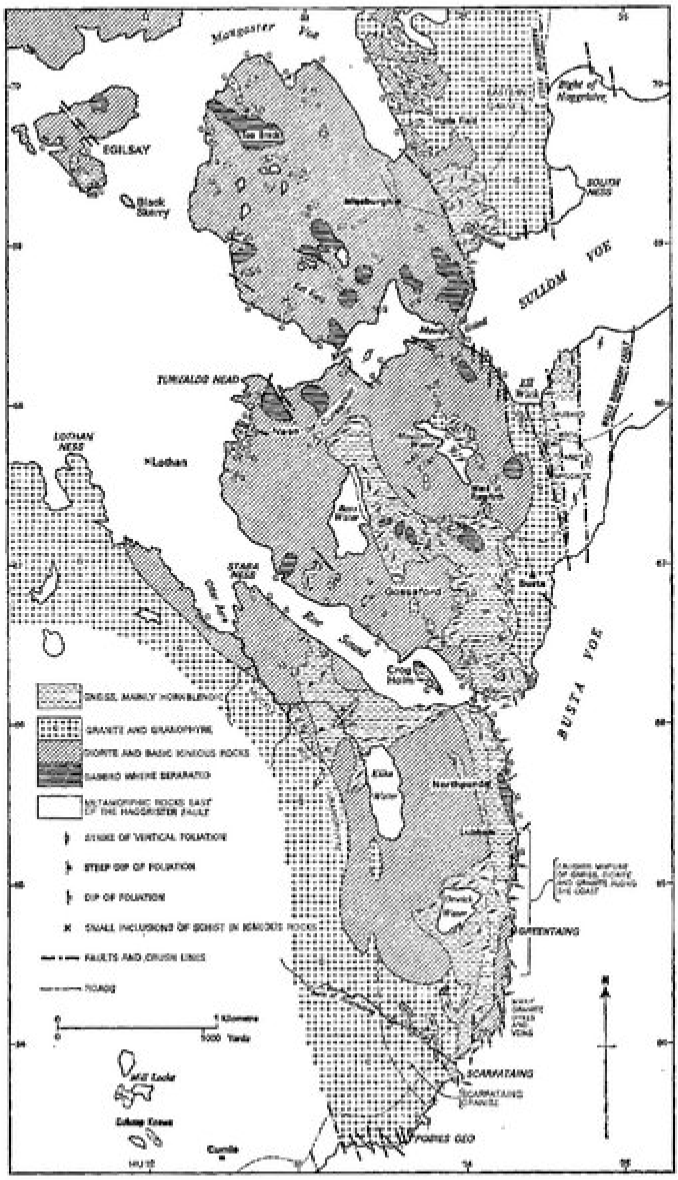
Summary

The petrography of the gneiss group shows: (i) that it is a banded series of hornblende-rich schist and hornblende-plagioclase-gneiss in which pelitic schists, locally garnetiferous, are important and quartzo-feldspathic and quartzose granulites are minor components; (ii) that this series, regionally metamorphosed in the amphibolite facies, experienced later shearing and fracturing at low temperature prior to (iii) thermal metamorphism, locally to the pyroxene-hornfels grade; (iv) that low temperature hydrothermal changes affected the thermally altered rocks with pinitization of cordierite and andalusite and metasomatism by areally active siliceous and local potassium-bearing solutions.

The combined field and petrographical data indicate that:

1. the gneiss group is the equivalent of the striped hornblende-gneiss series, the Burravoe Gneiss, which in the area of One-inch Geological Sheet Northern Shetland extends from Fethaland at the extreme north end of the Shetland mainland to Colla Firth and Eela Water;
2. the gneiss of the Skipadock area may underlie the basic igneous rock and appears to be intruded vertically, but with sheet apophyses along the foliation, by the Eastern Granite;
3. the gneiss outcrops on Egilsay and Black Skerry may represent roof pendants;
4. the gneiss of the Busta–Muckle Roe area represents either a roof or a floor to the basic igneous intrusion. There is no evidence of superposition of either on the other. Topographical distribution suggests the gneiss is the lower rock;
5. the surface between gneiss and basic intrusion is very irregular and separation takes place along generally vertical planes controlled by directions of foliation and cross-fracture in the gneiss;
6. the junction between the gneiss and Eastern Granite is near vertical with granite apophyses perhaps guided by the foliation of the gneiss;
7. no mechanical disintegration of the gneiss is associated with the intrusion;
8. chemical reaction between gneiss and igneous rock has occurred only very locally, on Egilsay;
9. thermal alteration of the gneiss is due to the basic igneous rock and was high locally but not sufficiently prolonged at high temperature to cause complete reconstruction of its more basic hornblende-feldspar components;
10. thermal alteration was followed by hydrothermal transformation and later silicification; locally potash-metasomatism was associated with granitic intrusion;
11. country and intrusive rocks were shattered by movements along the Walls Boundary Fault-zone and both were scapolitized during this period of movement;
12. the occurrence, south of Bays Water, of garnet-magnetite rock and amphibolite resembling the Clothister association (p. 20) implies that skarns of the Clothister type are, or were, more numerous than suspected. The contrast of the

abundance of apatite in the Bays Water rock and its poverty at Clothister suggests that the skarnizing fluids were of different composition in separate channels. If the two occurrences were originally related in space tectonic displacement is implied.



(Figure 5) Distribution of metamorphic rocks in the Muckle Roe–Mangaster Yoe area.