Chapter 15 The Sandsting Granite–Diorite Complex

Introduction

The Sandsting granite-diorite complex forms the south-eastern part of the Walls Peninsula (Plate 25) and extends over a land area of approximately 12 sq. miles (31 km^2). It is intruded into the sediments of the Walls Formation and in the western part of the outcrop the junction between the granite and overlying sediments trends roughly east–west and is inclined at 40°–70° to the north. The north-eastern part of the complex, however, appears to form a series of near-vertical sill-like intrusions with a north-north-westerly trend, which thin and finger out in a northerly direction.

The complex consists of the following rock types arranged in probable order of intrusion :

1. Diorite, including melamicrodiorite, biotite- and hornblende-diorite, quartz-diorite and syenodiorite; gabbro which forms at least two small dyke-like masses within the diorite; and an ultrabasic rock, which has been located by the presence of blocks.
2. Granodiorite.
3. Coarse-grained biotite-granite grading locally into graphic granite.
4. Porphyritic microadamellite and fine-grained porphyritic granite.
5. Felsite and porphyritic microgranite forming dykes which cut both the intrusive complex and the adjoining sediments.

The members of the diorite group are very variable in grain size and colour index and are veined by leucocratic diorite and pegmatite. The veins are most abundant in the west. The more westerly diorite outcrops contain a number of enclaves of indurated sediment, which range from blocks a few feet (tens of centimetres) in diameter to large masses like that between Loch of Sotersta and Sand Water, which is over 0.5 mile (800 m) long. Melamicrodiorite forms relatively small near-vertical dyke-like masses within the diorite as well as in the granite and adjoining sediment. In a number of cases the melamicrodiorite is clearly earlier than the diorite as it is brecciated and veined by the latter, but there are also dykes cutting diorite and granite, indicating that intrusions of this type are among the earliest and the latest members of the complex.

The granitic rocks are almost everywhere demonstrably later than the diorites, which are commonly brecciated and veined by granite. The evidence regarding the relative ages of the various 'granitic' members of the complex is rather inconclusive, and it is possible that a single intrusive body may consist of several rock types. It is, however, considered that the coarse-grained granodiorite which crops out in a narrow strip extending from Keolki Field to Culswick is earlier than the other types (p. 221).

A feature of the coarse-grained biotite-granite forming the Wester Wick and Skelda Ness areas is the presence within the granite of near-vertical roughly north-north-west trending belts of intensely sheared and locally mylonitized rock. Sodic scapolite occurs as both a replacement mineral and as a vein mineral in these crush belts and as a vein mineral in the basic minor intrusions and in the sediment adjoining the granite. The scapolite appears to have been introduced by hydrothermal solutions along active shear belts, joints and other lines of weakness, shortly after the emplacement of the Sandsting Complex (Mykura and Young 1969).

Miller and Flinn (1966, pp. 107–9) produced a radiometric age date of 334 + 13 m.y. for the Sandsting Granite. Potassium-argon age determinations by N. J. Snelling of granite and diorite from the complex are as follows: Biotite from granite, roadside 0.5 mile (800 m) NE of Culswick [HU 279 457] % K 6.72, radiogenic ^{40}Ar 0.191 p.p.m., Age 360 ± 11 m.y.; hornblende from diorite, Hestinsetter Hill [HU 291 457] % K 2.40, radiogenic ^{40}Ar 0.023 p.p.m., Age 369 + 10 m.y. The Sandsting Complex may thus have been emplaced in late-Middle or early-Upper Devonian times.

The sediment overlying the granite-complex in the western part of the area is hornfelsed or highly indurated within a zone extending up to 1 mile (1.6 km) from the junction (Plate 12). Within this zone there is no evidence of the minor folds and lineations which are a feature of the less altered sediments to the north (p. 131). Instead, the baked sediments adjoining the folded rocks outside the aureole are merely shattered, suggesting that when the folding took place they were already hornfelsed by the granite intrusion. The sediment is in places cut by an anastomosing complex of granite sills and elsewhere by dyke swarms and isolated dykes of granite and felsite and by veins of scapolite. Several of these dykes and veins extend beyond the zone of induration into the intensely folded sediment where they are themselves deformed and have in some cases acquired the small-scale folding and regional lineation.

Diorites and associated rocks

Field relationships

Diorite forms four large and several smaller outcrops within the complex (Plate 25). The four main diorite masses are termed (from west to east) the (1) Culswick, (2) Hestinsetter, (3) Scarvister–Loch of Arg–Skelda Voe and (4) Garderhouse diorites. The first three of these may be part of an originally continuous sheet intruded into the Walls Sandstone. This sheet forms the first major intrusion of the complex (pp. 237–8) and contains numerous inclusions of sediment. It is now steeply inclined to the north in the Culswick and Hestinsetter areas, possibly arched into a north–south trending elongate dome in the Scarvister–Easter Skeld district, and steeply inclined to the east along the eastern shore of Skelda Voe. The thickness of the sheet cannot be estimated but it can be assumed that it is at least 1200 ft (360 m) thick in the west, and thins irregularly eastward and south-eastward to less than 600 ft (180 m) in the Easter Skeld and Scarvister areas. The sheet is intensely veined by granite close to its southern, presumably lower, margin along the shores of the Stead of Culswick, and throughout its width along the shores of Skelda Voe and at Scarvister.

Diorite

Culswick

In the western and southern parts of the outcrop, there is no evidence of flow-foliation or regular layering within the diorite. On the shores of the Stead of Culswick, the fine-grained dark diorites are commonly cut by coarser more leucocratic diorite, with junctions ranging from sharp and angular to undulating. In some cases a gradual transition from fine- to coarse-grained diorite takes place within a few inches, but there are also some instances on this shore of two adjacent masses of virtually identical diorite separated from each other by a chilled margin in one of the diorites.

On the western shore of Keolki Field [HU 253 454], between 500 and 700 yd (460 and 640 m) N of Culswick Broch, the oldest intrusive rock is medium-grained diorite which ranges in composition from quartz-biotite-diorite to dark hornblende-rich diorite, and in places contains blocks and fragments of indurated sediment. The diorite contains several near-vertical north-west trending bands of coarse-grained leucocratic diorite, with acicular hornblendes up to 1 in (2.6 cm) long, now largely replaced by biotite, set in a pale matrix of plagioclase.

Hestinsetter

The diorite forming Hestinsetter Hill and the ground extending southwards towards Lunga Water displays a marked differentiation into near-vertical layers with distinctive textural and mineral compositions. In the roadside quarries on the west slope of Hestinsetter Hill this banding trends E30°N and reflects a vertical alignment, not only of the constituent minerals of the diorite but also of the acid and granitic veins. Several thick vertical layers traversing the south slope of Hestinsetter Hill are composed of fine-grained diorite full of pale buff ovoids ranging in diameter up to 10 mm. These ovoids are composed of pyroxene-monzonite with a nucleus of sphene which may reach a length of 3 mm. Less clearly defined bands of diorite with pale ovoid patches containing large sphenes are exposed on the north slopes of the Knowes of Westerskeld, 200 to 400 yd (180–360 m) east of Lunga Water. Other members of the diorite suite exposed between Hestinsetter Hill and Housa Water are granodiorite, syenodiorite, quartz-diorite, and dark fine-grained diorite rich in hornblende and biotite. The relationships between these rock types are not clear and some may grade into each other.

Scarvister–Loch of Arg–Skelda Voe

The diorite forming the arcuate outcrop between Scarvister and Easter Skeld contains some of the most basic members of the complex and the rocks exposed 150 to 200 yd (135–180 m) NE of Loch of Arg are composed mainly of fine to medium-grained diorite (p. 216) the chemical composition of which borders on that of hornblende-gabbro (Guppy and Sabine 1956, pp. 14, 24). Finlay (1930, p. 689) has also recorded gabbro on the eastern shore of Skelda Voe, and augite-diorite at Tarasta, 550 yd (500 m) SSE of Loch of Arg. These records have, however, not been confirmed. The headland west of the Ayre of Swartagill, which forms the most southerly exposure of diorite on the east shore of Skelda Voe, consists of fine-grained meladiorite. The latter is sheared and contains a number of irregular veins or lenticles of very coarse-grained strongly ophitic gabbro, which has been amphibolitized and saussuritized. These veins trend west-north-west and range from 4 in (10 cm) to several feet (over 1 m) in thickness. Along the south shore of this peninsula the fine-grained meladiorite is veined by a pink hornblende-rich rock. Hybrid or metasomatized rocks are common among boulders on the Ayre of Swartagill, just east of the peninsula, the most widespread being a coarse-grained quartz-diorite with large porphyroblasts of potash feldspar.

Garderhouse

The 'diorite' cropping out on the west shore of Seli Voe south of Garderhouse is intensely shattered because of its close proximity to the Walls Boundary Fault. It is predominantly fine-grained and ranges in composition from quartz-diorite to ophitic gabbro with completely amphibolitized pyroxenes.

The impression gained from the field exposures is that this diorite forms the base of an irregular sheet inclined to the east. The outcrop is split into a number of discrete masses by thick granite veins.

Melamicrodiorite dykes

The range in grain size and composition of the diorite in the outcrops described above is considerable and its fine-grained basic members grade into

hornblende-rich microdiorite. There are, in addition, a number of dyke-like bodies of very fine-grained almost basaltic-looking melamicrodiorite, the age of intrusion of which appears to range from pre-diorite to post-granite.

a. Pre-diorite intrusions

The most accessible of these is a vertical sheet of melamicrodiorite exposed on the northern slope of Hestinsetter Hill [HU 290 458] close to the northern margin of the Hestinsetter diorite (p. 212). It is approximately 180 ft (55 m) wide and has a trend and inclination parallel to the banding in the diorite. Along its southern margin there is an 18 ft (5.5 m) wide brecciated zone composed of angular blocks and fragments of melamicrodiorite embedded in a net-vein complex of diorite and quartz-diorite. These veins are, in turn, cut by veins of granitic material. It is not certain if the diorite of the vein-complex is derived directly from the flow-banded diorite bounding it to the south, but the presence of small fragments of melamicrodiorite in the latter suggests that the melamicrodiorite is older than the diorite.

A large mass of melamicrodiorite crops out a short distance above the east shore of the Stead of Culswick, 300 yd (275 m) S of the head of the bay (Plate 25). Its shape and the character of its junction with the adjoining diorite are not easily determinable, as both are intensely net-veined by granite. The microdiorite is largely broken into angular blocks within a net-vein complex of granite, whereas the junctions between diorite and granite in this area are highly undulating, suggesting contact of two fluid magmas, and thus implying that the intrusion of melamicrodiorite preceded that of diorite.

b. Post-diorite dykes

Two dyke-like bodies of melamicrodiorite, which appear to be younger than the surrounding diorite, crop out on the north-west shore of the Stead of Culswick (Plate 25). Both are irregular in shape, with maximum widths of 25 and 7 ft (8 and 2 m) respectively. They have chilled margins against diorite and both contain belts of sheared rock lined with irregular anastomosing veinlets of sodic scapolite (Mykura and Young 1969, p. 3). The more westerly of the two dykes ((Figure 24)(4)) is bounded by granite. It appears to have chilled margins against the granite, but is also cut by a number of granite veins.

The diorite cropping out on the shore west of Keolki Field, 570 yd (520 m) N10°W of Culswick Broch, is cut by a 14 in (35 cm) dyke of dark microdiorite which trends N10°W and is steeply inclined to the east. It has slightly undulating, strongly chilled margins and contains a number of irregular veinlets of a black almost completely hornblendic rock. Though clearly later than the diorite, the age-relation of this dyke to the granite is not known.

c. Post-granite dykes

Dykes of hornblende-rich melamicrodiorite cut the shattered granite cropping out along the shore of Seli Voe north of Rea Wick, the granite sills interdigitated with sediment just south of Bixter Voe, and the indurated sediment around Bixter Voe. The dykes range in thickness up to 5 ft (1.5 m) and some are cut by thin irregular veinlets of sodic scapolite. Though these dykes are petrographically closely allied to the melamicrodiorites described above (p. 214), they are clearly the last igneous intrusions associated with the complex.

Acid veins

The diorite of the western part of the Culswick area is cut by a network of generally leucocratic quartz-diorite veins, characterized in field exposures by the presence of small euhedral plagioclase phenocrysts. The quartz-diorite contains local concentrations of biotite. The veins are branching, irregular in outline, and do not normally exceed 1 ft (30 cm) in thickness.

The quartz-diorite veins are themselves cut by veins of pegmatite composed largely of crystals of pinkish white microperthite up to 2 in (5 cm) in size. The pegmatite veins contain small elongate cavities along their middle, which are filled or lined with radiating aggregates of acicular crystals, up to 1 in (2.5 cm) long of pale-green epidote. The veins vary greatly in thickness, with a recorded maximum of 18 in (45 cm). They are usually near-vertical and branching, but have no consistent trend. In some instances pegmatites are, for a short distance, intruded along the middle of a quartz-diorite vein ((Figure 24)(3)).

Granite-diorite net-vein complexes

The areas of diorite intensely veined by granite are shown in (Plate 25). In some outcrops, as on the shores of the Stead of Culswick, granite forms up to 40 per cent of the total volume of rock, with individual veins ranging in thickness from a few inches to over 30 ft (9 m). Most commonly the diorite blocks enclosed in granite are angular and straight-sided ((Figure 24)(1)) suggesting that the diorite had consolidated before the granite was intruded. In some instances, however, the contacts between diorite and granite are lobate or crenulate (Figure 24)(2), which suggests that both granite and diorite magma were fluid at the point of contact. Diorite is not normally chilled at these junctions. At the Stead of Culswick there are several exposures of granite chilled to porphyritic micro-granite within a 2 in to 1 ft (5–30 cm) wide zone along the more lobate margins. There are a number of instances at Shalders Taing [HU 272 437] on the east shore of the Stead of Culswick of complete gradation from fine-grained granite to coarse-grained quartz-diorite which itself veins the finer-grained diorite.

Metasomatism at contacts between granite and diorite is uncommon in the Sandsting Complex, but good examples are seen on the shore south-west of Tarasta Ayre [HU 304 436] 600 yd (550 m) SSE of Loch of Arg. Here the width of the zone of alteration at the junction of diorite and coarse-grained granite averages 1 ft (30 cm). It is characterized by the presence within the diorite of porphyroblasts of potash feldspar up to 1 in (2.4 cm) in size which increase in abundance as the contact is approached. Included masses of diorite within the granite are thoroughly altered to porphyritic granodiorite, and similar material forms veins within unaltered diorite, suggesting that the altered rock was locally mobilized.

The association of granite and basic rock in igneous complexes has been widely studied, and a number of observers (Bailey and McCallien 1956; Elwell 1958; Blake and others 1965) have shown that adjoining basic and acid magmas are commonly coeval.

Ultrabasic rock

The only evidence for the presence of ultrabasic rock within the Sandsting Complex is found close to Stump Farm, 250 yd (230 m) E of Gossa Water, where there is a concentration of boulders of an olivine-rich rock (p. 220). There is little doubt that this represents a small outcrop which may be the surface expression of either an isolated pipe of ultrabasic rock that has penetrated through the diorite, or, less likely, a large block engulfed by the diorite magma. Small masses of similar ultrabasic rock, usually found only as detached surface blocks, occur in the Northmaven Complex near the northern margin of the present Sheet (pp. 183 and 193).

Petrography

Diorite

The members of the diorite suite show a wide range in both composition and grain size, which does not appear to be related to either geographical distribution or order of emplacement. The rock types in the main dioritic masses appear to form a continuous series which ranges from granodiorite and syenodiorite through quartz-diorite ((Plate 26), fig. 2) to biotite- and hornblende-diorite ((Plate 26), fig. 4), the more basic varieties of which approach the composition of gabbro (p. 218; Guppy and Sabine 1956, p. 24). The finer-grained varieties are locally porphyritic. The granodiorites and syenodiorites are generally slightly coarser than the diorites.

Plagioclase

Plagioclase occurs in euhedral to subhedral crystals which range in length from 3.5 to 0.7 mm in the coarsest varieties, and from 0.8 to 0.12 mm in the finest. The crystals are almost invariably zoned, usually with a fairly large homogeneous central area and narrow outer rims. The composition of the core in the majority of specimens is sodic andesine but in some it is mid-oligoclase. Labradorite and andesine-labradorite have been recorded in two basic coarse-grained members of this suite (S51543) [HU 332 471], (S30035) [HU 304 447]. The outer rims in most plagioclase crystals are sodic-oligoclase, though in one case (S30035) [HU 304 447] Guppy and Sabine (1956, p. 24) have recorded an outer rim of albite.

In many specimens the plagioclase is fresh throughout but the core of larger crystals is often altered to a cloudy aggregate which contains epidote and biotite.

Potash feldspar

Microcline occurs as an interstitial constituent in virtually all specimens. In the normal diorite it usually forms less than 5 per cent of total volume. In the syenodiorites potash feldspar forms between 15 and 20 per cent of total feldspar and in granodiorites up to 40 per cent. In the last two rock types the percentage of interstitial microcline is not much greater than in diorite, the additional potash feldspar taking the form of large, highly poikilitic phenocrysts of microperthite or microcline-microperthite enclosing plagioclase. Individual crystals reach 3 mm in diameter and in one case (S51547) [HU 332 469] crystal clusters up to 5 mm have been recorded.

Quartz

Quartz is a minor interstitial constituent in the diorites. In the syenodiorites and granodiorites, the division between which is here drawn at 5 per cent quartz, quartz content ranges from 0 to 15 per cent by volume of total rock. In addition to interstitial quartz the granodiorite contains anhedral quartz crystals up to 0.5 x 0.3 mm in size, and in one case patches (possibly juvenile) up to 3 mm in diameter have been recorded.

Within the 'diorites' with less than 5 per cent potash feldspar, quartz is invariably interstitial. Quartz-diorite with up to 20 per cent of quartz (S31141) [HU 252 451] is locally present.

Mafic minerals

The total content of mafic minerals within the diorite suite ranges from less than 20 to 45 per cent in the varieties approaching gabbro in composition, but in the melamicrodiorites it may exceed 50 per cent. Biotite and hornblende are usually moulded on to euhedral and subhedral feldspar crystals, but they are also found in fairly large clusters, which locally also contain apatite and epidote. The ratio of biotite to hornblende is very variable. In one mafic syenodiorite large hornblendes with small inclusions of biotite make up to 50 per cent of the total volume. The size of these hornblendes ranges up to 1.5 mm. The largest hornblendes are usually partially altered to biotite and an olive-green amphibole which is structureless or, less commonly, fibrous.

Pyroxenes are only rarely found in the diorites. Medium-grained diorite from the shore 0.25 mile (400 m) NNW of Culswick Broch (S31141) [HU 252 451] contains a number of subhedral or, more rarely, ophitic crystals, of pyroxene (?augite) which are partially altered to amphibole.

Epidote

Epidote is present in small quantities in many of the diorites. It occurs both in altered patches within and along the margins of plagioclase and as individual subhedral crystals, associated with the clusters of biotite and hornblende. It is abundant in certain restricted pockets, particularly in the vicinity of Culswick Broch, and appears to be a late hydrothermal replacement mineral, as it is abundant in the pegmatites cutting the diorites of this area. Epidote is also found as grains in melamicrodiorite.

Accessory minerals

Apatite and large sphenes are common. Allanite is a rare accessory in the granodiorites (S51537) [HU 306 438] and syenodiorites (S31143) [HU 260 442]. Rutile inclusions are common in biotite and quartz.

Diorite with sphene-bearing ovoids

The pale spheres or ovoids with a large central sphene which are abundant in the banded diorite at and near Hestinsetter Hill (p. 212), are composed of coarse-grained pyroxene-monzonite. They normally range in diameter from 2 to 5 mm but may reach 20 mm (S51528) [HU 293 454], (Plate 26), fig. 8). The monzonite is composed of roughly equidimensional euhedral crystals of oligoclase set in large (up to 3 mm) poikilitic crystals of microcline. It contains numerous stumpy near-euhedral crystals of augite which are commonly about 0.2 mm in diameter, but may attain 0.5 mm. The augite is only locally altered to amphibole. Green hornblendes, some euhedral, are present only near the margins of the ovoids. Sphene is abundant, commonly forming euhedral crystals up to 3 mm long in the centre of the ovoid, but also occurring in smaller euhedral crystals throughout. Interstitial quartz forms approximately 5 per cent of the total volume of the rock. It is of interest that the rock forming these ovoids is the only member of the diorite suite which contains abundant unaltered pyroxenes, and completely fresh feldspars. This would suggest that they are cognate xenoliths which crystallized from a 'dry' magma, whereas the bulk of the diorite was formed from a magma rich in H_2O and other volatiles, probably due to saturation by volatiles released from the neighbouring acid magma (see Bailey 1958).

Gabbro

Gabbro is a very minor constituent of the Sandsting diorite, being confined to narrow dyke-like bands in the eastern part of the complex. The gabbro (S51533) [HU 312 433] is coarse-grained and contains subhedral plates of sodic labradorite which are, in some instances, albitized to an irregular blotchy aggregate of chlorite, sodic plagioclase and muscovite. Deep green amphibole occurs along cracks and twin-planes, and there are small aggregates of epidote along some crystal margins. Individual feldspar plates are up to 10 mm long. They are enclosed in large ophitic crystals of largely amphibolitized pyroxene, which forms 30 per cent of the total volume. The pyroxene, a pale non-pleochroic augite, is commonly stained yellowish orange and peripherally altered to amphibole, which is deep green along the margins.

In the gabbro of the Garderhouse area (S51543) [HU 332 471] the ophitic pyroxene is completely uralitized. Primary hornblende, some showing polysynthetic twinning, is abundant. The feldspars are locally saussuritized. Epidote associated with calcite and chlorite is also present in veinlets.

(Table 5) Analyses of specimens from Sandsting Complex

	1	2	3	4	5	6
SiO_2	69.49	70.96	57.60	55.35	51.94	51.98
Al_2O_3	16.12	15.18	16.66	17.82	18.65	18.70
Fe_2O_3	0.83	1.69	2.60	2.28	1.49	1.62
FeO	1.63	—	4.34	3.86	4.04	3.95
MgO	0.90	0.70	2.99	3.58	5.86	5.94
CaO	1.94	1.52	5.27	6.60	8.96	8.88
Na_2O	4.14	4.32	3.97	4.28	3.18	3.20
K_2O	3.98	4.68	3.01	2.88	2.24	2.27
$H_2O > 105°$	0.65	0.66	1.05	0.76	1.20	0.86
$H_2O < 105°$	0.10	0.18	0.27	0.18	0.16	0.18
TiO_2	Trace	Nil	1.73	1.74	1.34	1.36
P_2O_5	0.09	Trace	0.59	0.66	0.68	0.66
MnO	Trace	—	0.11	0.13	0.10	0.07
CO_2	—	—	Trace	Trace	n.d.	—
SO_3	n.d.	n.d.	—	—	Trace	—
Cl	n.d.	n.d.	0.04	0.02	Trace	n.d.
S	n.d.	n.d.	0.05	0.03	—	n.d.
FeS_2	—	—	—	—	0.13	0.24
Cr_2O_3	n.d.	n.d.	—	—	n.d.	0.03
BaO	—	—	0.12	0.11	0.09	—
SrO	n.d.	n.d.	—	—	—	—
Rb_2O	n.d.	n.d.	0.01(s)	0.01(s)	—	—
Li_2O	n.d.	n.d.	—	—	—	—
Total	99.87	100.00	100.41	100.29	100.06	99.94
Less O for Cl	—	—	0.01	n.d.	n.d.	—
	99.87	100.00	100.40	100.29	100.06	99.94
Sp. gr.	n.d.	n.d.	2.79	2.78	n.d.	n.d.

s = Spectrographic determination
n.d. = not determined

	1	2	3	4	5	6
Q	23.88	23.62	8.61	2.46	0.00	0.00
C	1.68	0.24	0.00	0.00	0.00	0.00
or	23.52	27.66	17.79	17.02	13.24	13.42
ab	35.03	36.56	33.00	35.92	26.91	27.08
an	9.04	7.54	19.06	21.06	30.00	29.96
hl	0.00	0.00	0.11	0.05	0.00	0.00
di	0.00	0.00	2.61	5.89	8.00	7.80
by	4.55	1.74	9.26	8.61	11.82	11.52
ol	0.00	0.00	0.00	0.00	2.23	2.38
mt	1.20	0.00	3.77	3.31	2.16	2.35
cm	0.00	0.00	0.00	0.00	0.00	0.04
hm	0.00	1.69	0.00	0.00	0.00	0.00
ilm	0.00	0.00	3.29	3.30	2.54	2.58
ap	0.21	0.00	1.37	1.53	1.58	1.53
pr	0.00	0.00	0.11	0.06	0.13	024

bao	0.00	0.00	0.12	0.11	0.09	0.00
Others	0.75	0.84	1.33	0.95	1.36	1.04
Total	99.87	99.89	100.41	100.29	100.06	99.94
Q	28.97	26.89	14.49	4.45	0.00	0.00
Or	28.53	31.49	29.95	30.72	32.97	33.13
ab	42.50	41.62	55.56	64.83	67.03	66.87
Total	100.00	100.00	100.00	100.00	100.00	100.00
or	34.80	38.54	25.46	23.00	18.87	19.04
ab	51.83	50.95	47.25	48.54	38.36	38.44
an	13.37	10.51	27.29	28.46	42.77	42.52
Total	100.00	100.00	100.00	100.00	100.00	100.00
ab	79.49	82.90	63.39	63.04	47.28	47.48
an	20.51	17.10	36.61	36.94	52.72	52.52
Total	100.00	10000	100.00	100.00	100.00	100.00

- Granite, Skelda Ness, (Exact locality not known). Anal: W. H. Herdman (Finlay 1930, p. 693).
- Granite, Gruting Voe, (Exact locality not known). Anal : R. R. Tatlock (Finlay 1930, p. 693).
- Diorite, 400 yd (380 m) ESE of Wester Skeld. [HU 299 438]. (S33678). Lab. No. 1066. Anal: G. A. Sergeant; spect. det. H. K. Whalley. (Guppy and Sabine 1956, pp. 14–15).
- Diorite, 0.25 mile (390 m) ENE of Lunga Water. [HU 293 452]. (S33676). Lab. No. 1067. Anal: G. A. Sergeant, spect. det. H. K. Whalley. (Guppy and Sabine 1956, pp. 14–15).
- Gabbro-diorite hybrid, 150 yd (140 m) NE of Loch of Arg, Sandsting. [HU 304 446]. (S33677). Lab. No. 1068. Anal: G. A. Sergeant. (Guppy and Sabine 1956, pp. 14–15).
- 6. 'Hornblende-gabbro', 150 yd (140 m) NE of Loch of Arg, Sandsting. [HU 304 446]. (S30035). Lab. No. 970. Anal: B. E. Dixon. (Guppy and Sabine 1956, p. 24).

Melamicrodiorite and other mafic intrusions

The petrographical characters of the larger intrusions of melamicrodiorite ((Plate 26), fig. 5) grade into those of the fine-grained meladiorite but the thin dykes cutting granite and sediment have the textural features of dolerite and porphyritic basalt altered to epidiorite. The former (S51518) [HU 270 443] contain sporadic phenocrysts of mid-andesine up to 0.7 mm long and groundmass feldspars of oligoclase-andesine which average 0.3 mm. Potash feldspar is generally absent, but up to 5 per cent of interstitial microcline has been recorded in some sections. Hornblende and deep green biotite make up between 30 and 50 per cent by volume of the rock, and form irregular crystals moulded against feldspar or, occasionally, small clusters. Sphene and apatite are common accessory minerals.

The melamicrodiorite dykes close to the Walls Boundary Fault are sheared and chloritized and individual minerals are broken up or streaked out.

Pegmatite veins

The composition and texture of the pegmatite varies greatly within a single vein (S51514) [HU 252 452], (S51514A) [HU 252 452] in which distinct zones can usually be recognized. The inner zone which adjoins an epidote-lined cavity consists of large crystals mainly of microcline and relatively rare plagioclase cut by a network of veinlets of epidote. The epidote is locally coarsely crystalline and may form as much as 50 per cent of the total volume of the rock. Some of the epidote veinlets are parallel to the twin planes of the microcline. The feldspar is also cut by irregular vein-like patches of quartz which are themselves cut by epidote. The outer zone of the pegmatite veins consists largely of crystals of micropegmatite up to 8 mm in diameter. These are composed of graphically intergrown quartz and micro-cline, with a few irregular inclusions of epidote ((Plate 26), fig. 7)

Ultrabasic rocks

The blocks of ultrabasic rock 180 yd (165 m) WNW of Stump Farm [HU 310 456] (S31157) [HU 308 457], (S51535) [HU 309 457], (Plate 26), fig. 6) contain up to 50 per cent of olivine which forms subhedral to anhedral crystals ranging in size from 4 to 0.5 mm. These are commonly surrounded by a sheath of serpentine, which, together with iron ore, also fills cracks within the crystals. Some olivine crystals are largely altered to serpentine. The olivine is set in a matrix of large subhedral plates of bytownite ($An_{70–80}$) and large isolated crystals of pyroxene which range up to 3 mm in size. Pyroxene occurs in areas where the concentration of olivines is relatively low. Both enstatite and augite are present. Pyroxene forms nearly 20 per cent by volume of the total rock, bytownite up to 30 per cent. In addition poikilitic crystals of strongly pleochroic reddish brown biotite are a characteristic feature of the rock.

It is not easy to give this rock an appropriate name. It compares fairly closely with the ultrabasic rocks from the east shore of Moora Waters (p. 193–4), which range from harrisite to lherzolite.

Granodiorite

Field relationships

A sheet of coarse-grained granodiorite which is texturally similar to the granite and averages 200 to 300 ft (60–90 m) in thickness, overlies the Culswick diorite, the junction between the two being irregular and steeply inclined to the north. This sheet can be traced from the west shore of Keolki Field, between 650 and 800 yd (595 and 730 m) N of Culswick Broch, eastward as far as Culswick village. At several localities inclusions of baked sediment occur along the diorite-granodiorite boundary, and a number of blocks of sediment, including sandstone with convolute bedding, are entirely in the granodiorite. The junction between diorite and granodiorite is well seen on the west shore of Keolki Field, where the latter contains numerous large xenoliths of diorite. Most diorite xenoliths are straight-sided and angular. Some are horizontally elongated and up to 20 ft (6 m) long. There can thus be little doubt that the intrusion of granodiorite was later than that of diorite.

The granodiorite is cut by a number of felsite dykes, up to 1 ft (30 cm) thick, which trend roughly north–south.

Petrography

The granodiorite is coarsely crystalline and composed of broad tabular crystals of calcic oligoclase, usually with a narrow rim of more sodic plagioclase. These range in length from 5 to 0.4 mm and are set in large anhedral poikilitic masses of microcline-microperthite and blotchy microperthite. Plagioclase is only slightly in excess of potash feldspar. Quartz, commonly with small liquid inclusions, which forms about 10 per cent of the total volume of the rock, usually occurs interstitially but in rare cases forms irregular intergrowths with potash feldspar. Dark minerals form 15 per cent of the total volume with thick greenish plates of biotite slightly more abundant than pale greenish hornblende, which is commonly intergrown with the biotite. Sphene occurs in large skeletal crystals, and small euhedral needles of apatite are abundant. The most common ore mineral is pyrite which is present in very small euhedral crystals.

Porphyritic microadamellite and associated rocks

Field relationships

The porphyritic microadamellite is a rock with distinctive field characteristics. In hand specimen it is generally fine-grained with no readily visible quartz, with abundant small plates of black mica and prominent phenocrysts of pink or white feldspar, which may be up to 1 cm in diameter.

Its main outcrop, as shown on (Plate 25), extends from Green Head on the Whites Ness peninsula eastward via the Ward of Culswick to the head of the Culswick Valley, where it is displaced southwards by the Culswick Fault. It can be intermittently traced eastward from the east slope of the Culswick Valley to the hillside north-west of Housa Water. Fine-grained granite, texturally similar to the porphyritic microadamellite, forms a sheet-like intercalation in the Culswick diorite, extending from the head of the Stead of Culswick, westward for nearly 1 mile (1600 m) to The Nev. Microadamellite also forms a number of small outcrops on the headland north-west of Culswick Broch. Microgranite, locally porphyritic, forms a high proportion of the veins and major crosscutting intrusions within the diorite, not only in areas where microgranite adjoins diorite, but also within the diorites of the Hestinsetter and Scarvister–Loch of Arg–Skelda Voe areas (p. 212).

Age relationships

Microgranite and microadamellite everywhere cut the diorite and, with a few exceptions (p. 215, (Figure 24)(1, 2)), the diorite xenoliths in these rocks are angular. Their relationships with the coarse-grained granodiorite and coarse-grained granite are, however, less clear, as junctions are either poorly exposed or faulted.

The junction between granodiorite and microadamellite appears to be sharp, but as there are no good exposures of the contact the age relationship is uncertain. Contacts between microadamellite and coarse-grained granite are well seen in shore sections 1300 yd (1190 m) WNW of the Ward of Culswick and 150 yd (135 m) W of the Broch of Culswick. In the former exposure the junction is vertical and, where undisturbed, it is fairly sharp. There is here a zone, about 4 in (10 cm) wide, in which large feldspars, similar to those in the coarse-grained granite, form abundant porphyroblasts within the microadamellite. The latter is sheared for a distance of 3 to 5 ft (90–150 cm) from the contact, but the granite is unaffected. This shearing may not be connected with the emplacement of magma. The junction is also partially obscured by a 3-ft (90-cm) dyke of felsite. A number of small irregular masses of microadamellite, in one case associated with baked sediment, are present in the granite some distance north of the junction. The junction exposed just west of Culswick Broch is sharply defined, near-vertical, but in detail wavy and irregular, suggesting that the adjoining magmas co-existed in an incompletely consolidated state. Evidence as to age relationships from the contacts is thus inconclusive, but the fact that in most areas the coarse-grained granite is in contact with the overlying sediment (Plate 25) and that there is nowhere a screen of baked sediment between the inner fine-grained and outer coarse-grained 'granite' would suggest that along the northern (upper) margin of the complex, at least, the coarse granite was emplaced first, but was not fully consolidated when the microadamellite magma was intruded.

Veins

In areas where both microadamellite and granite vein the diorite very few junctions between the two granitic types have been recorded. At the south end of Shalders Taing, 700 yd (640 m) S of the head of the Stead of Culswick, the two types appear to grade into each other, with a complete transition within a distance of 1 ft (30 cm) though the disappearance of the large quartz crystals of the granite is abrupt. There is no evidence of one kind of granite vein truncating the other. Veins of porphyritic microadamellite have been recorded in all diorite outcrops except that of Garderhouse. In some cases the veins have a dark marginal zone up to 1 ft (30 cm) wide in which euhedral feldspar phenocrysts are enclosed in a mafic matrix.

Variation of texture

Though the microadamellite is characteristically porphyritic with subhedral to euhedral potash feldspar phenocrysts, the abundance of phenocrysts varies very considerably. The grain size of the matrix is also very variable, ranging from aphanitic in certain minor intrusions cutting the diorite (as seen in large blocks on the east shore of Keolki Field, 420 yd (384 m) NNW of Culswick Broth), to medium-grained in the main outcrop.

Petrography

The salient feature of the microadamellite is the presence of euhedral, generally poikilitic phenocrysts of potash feldspar, which reach a length of 10 mm, but are commonly about 3.5 mm long. They are composed of orthoclase full of small irregularly shaped inclusions of plagioclase, which are in optical continuity throughout the crystal. Phenocrysts of various types of perthite, microperthite, microcline-microperthite and microcline are also present in various sections ((Plate 26), fig. 3). The groundmass contains subhedral laths of oligoclase-andesine, generally with a thin rim of sodic oligoclase. Within the main outcrop these range in length from 1.5 to 0.15 mm and are stumpy in some sections but markedly elongated in others. Interstitial microcline and quartz occur in large irregular highly poikilitic areas up to 2 mm in diameter. Quartz forms between 15 and 25 per cent by volume of the rock. The ratio of plagioclase to potash feldspar varies in different specimens from 40:60 to 80:20, the rock type thus ranging from adamellite to granodiorite. In most sections, the ratio approximates to 50:50. Hornblende and biotite form up to 10 per cent of the total. Hornblende exceeds biotite and commonly forms euhedral crystals up to 0.5 mm long. Biotite is partially altered to chlorite. Epidote occurs in rare irregular grains, either associated with biotite-feldspar aggregates or in the centres of altered feldspars. Allanite is relatively common, either associated with epidote (S51505) [HU 276 457] or as patches enclosed in potash feldspar phenocrysts. Small needles of apatite are abundant, but sphene is rare.

It will be noted that the grain sizes of the feldspars forming the matrix are in some cases larger than the accepted maximum (0.5 x 0.5 mm) for micro-granites. As, however, the average grain size of the whole group is smaller than this, and as it has not been found advisable to divide the group according to an arbitrary grain-size boundary, all members have been shown on the map as porphyritic microadamellite.

The rock which cuts the diorite cropping out on the north-west shore of the Stead of Culswick (S28736) [HU 271 435], (S29882) [HU 262 443], (S51519) [HU 264 441], is a fine-grained sparsely porphyritic, granophyric microgranite, composed of up to 30 per cent quartz and up to 70 per cent feldspar, mainly in the form of blotchy, rather cloudy, perthite or microcline-microperthite which occurs both interstitially and as phenocrysts. The latter are generally poikilitic with small irregular inclusions of plagioclase. The plagioclase is albite-oligoclase with a narrow rim of albite. It never makes up more than 20 per cent of the total feldspar. Biotite and hornblende are present in equal proportions but together do not exceed 5 per cent of the total. The biotite occurs as thick plates and the hornblende as isolated anhedral crystals up to 0.6 mm long.

Granite

Field relationships

Coarse-grained quartz-rich biotite-granite forms over half of the outcrop of the Sandsting Complex (Plate 25). Its grain size is fairly consistent throughout the greater part of the outcrop, but there is a slight eastward decrease in the amount of mafic minerals present. This is coupled with an eastward increase in the proportion of quartz and a decrease in plagioclase. North-north-west of the latitude of Garderhouse the granite forms a series of near vertical sheets in the steeply inclined sediments of the Walls Formation. These thin out northwards and on the shores of Bixter Voe and Effirth Voe they form a number of sill swarms, consisting of a large number of individual sills, which are steeply inclined to the east-north-east and range in thickness from 2 ft (60 cm) to possibly 400 ft (120 m). These sills show a gradual, though uneven northward reduction in grain size, becoming increasingly more granophyric in texture towards Bixter Voe. The thinner dykes are in places felsitic in texture, and in Laxa Burn, a tributary of Bixter Voe, two fine-grained basic dykes respectively 6 ft (1.8 m) and > 2 ft (> 60 cm) thick cut the granite.

The granite and graphic microgranite sills of Bixter Voe are in some respects similar to the sheets of granite and felsite which cut the Walls Formation on the shores of Seli Voe, Gruting Voe and Vaila Sound. On the shores of the Holm of Gruting and Hoga Ness a sill swarm about 800 yd (730 m) wide contains at least 15 sills, of which some consist of very coarse-grained microperthite-granite and others of fine-grained almost aphanitic felsite.

Junctions with sediment

Except at Green Head in the Whites Ness peninsula and for a short distance in the area north-west of the Ward of Culswick the Walls Sandstone is directly underlain by the coarse-grained granite. Good sections of the contact are exposed on the east shore of Gruting Voe, 1850 yd (1618 m) N of Culswick Broch and at Coukie Geo and Vine Geo on the south shore of the Island of Vaila.

On the east shore of Gruting Voe indurated sandstone overlying the granite dips at 28° to 35° to the north-north-east. The granite-sediment junction is sharp, with no marked chilling within the granite and with a 5 mm thick layer of crystalline quartz along the contact. Near sea level the junction is stepped alternately parallel and normal to the bedding, thus producing a steep overall dip to north-north-east. There are a small number of irregular inclusions of sediment within the granite and a number of tongues of granite extend up to 6 ft (1.8 m) into the sediment. The granite in these tongues is in places very fine-grained, almost felsitic in texture. The upper half of the exposed contact is concordant with the dip of the sediment, though minor transgressions of horizon are common.

The junction between sediment and granite at Coukie Geo, Vaila (Plate 25) is inclined at 65° to NNW, being locally roughly concordant with the dip of the overlying sediment. A number of irregular tongues and veins of granite extend into the sediment. The southern and eastern margin of the Vaila Granite is exposed at several localities in the vicinity of Vine Geo. It is near-vertical, but extremely irregular with many granite veins passing into the adjoining sediment. The indurated and somewhat shattered sandstone adjoining this granite on either side of Vine Geo has a strike which is almost normal to the regional strike of the sediment and contains an intricate network of granite veins. In one locality it contains diorite veins which are in turn veined by granite. It is thought that the intensely veined sediment of this area forms part of a fault-bounded screen of veined and shattered sediment which extends from the south-east corner of Vaila, south-eastward via Muckle Flaes and the Taing of Keolkifield to Burri Geo (p. 228).

Petrography

Granite of main intrusion

The granite forming the main intrusive mass is a typically coarse-grained quartz-rich biotite-granite with 30 to 40 per cent of quartz and with anhedral plates of potash feldspar usually up to 3.5 mm in diameter but in some cases reaching a maximum of 10 mm. Plagioclase forms up to 15 per cent of the total feldspar and normally occurs as euhedral to subhedral plates of oligoclase up to 1.7 mm long, though usually considerably smaller and frequently grouped in clusters. The predominant ferromagnesian mineral is partially chloritized biotite which forms small irregular plates. Hornblende is generally present only along the granite-diorite margins, but is found in certain areas (S51536) [HU 307 436] within the main granite, where it forms euhedral crystals up to 3.5 mm long. Sphene and allanite occur as small isolated crystals; apatite is fairly abundant.

Potash feldspar

Potash feldspar occurs in the form of large plates of microperthite or microcline-microperthite and small interstitial patches of microcline. Several forms of microperthite and perthite have been recorded. The most common variety is rod-microperthite (Deer, Howie and Zussman 1963, p. 68), with parallel rods of exsolved sodic plagioclase ranging in width from 0.01 to 0.03 mm, orientated normal to the length of the crystal and cutting the twin planes of microcline and the two main cleavages of the feldspar at 45°. Rods, though most commonly parallel to each other, are branching and generally form a network with the two main sets of rods crossing each other at a very acute angle. String-microperthite with straight parallel fairly widely spaced strings approximately 0.05 mm thick is less common. The strings and rods do not always extend along the whole length of the crystal, in some cases (S51550) [HU 328 514] the rods are widest at the edges of the crystal and taper inward, leaving the centre of the crystal relatively free of exsolved sodic plagioclase. Many rods extend for a third to half the length of the crystal.

Of less common occurrence is microperthite with branching vermicular or curved rods up to 0.02 mm thick, which in some cases are roughly parallel to each other and are connected by thin fibrous branches. The plagioclase in microperthite of this type commonly follows the cleavages and at intersections it widens out to form beads up to 0.75 mm wide. The sodic plagioclase forming these beads is commonly cloudy.

Another fairly common form of perthite is the type termed replacement perthite by Ailing (1938, fig. 2). The plagioclase consists of a number of roughly equidimensional patches of irregular outline which are in places connected with each other and are all in optical continuity throughout the crystal (S28875) [HU 293 419], (S51521) [HU 255 445]. The patches are usually concentrated near the centre of the crystal, range in diameter from 0.05 mm to 0.1 mm and may form as much as 60 per cent of its total volume.

Antiperthite has not been recorded in the granite of the main Sandsting area, but occurs in the graphic granite forming the sills of Laxa Burn and Bixter Voe. Texturally this is very similar to the replacement perthite described above. All inclusions of potash feldspar within the sodic plagioclase are in optical continuity and the average diameter of these inclusions is 0.075 mm.

Quartz

Quartz occurs in large anhedral crystals which are usually highly poikilitic. Its margins with adjacent potash feldspar are usually serrate and in a few cases areas of graphic intergrowth are developed. In some cases the marginal area of intergrowth is so irregular that it resembles myrmekite. Graphic intergrowth is less common in the main granite than in the granite of the Bixter Voe sills. The quartz of many specimens from the main granite is characterized by the extreme abundance of liquid inclusions. These are of irregular shape, average 0.005 to 0.01 mm in diameter with a maximum of 0.02 mm and have a slight brownish tinge and a much lower refractive index than the quartz (S29526) [HU 308 445], (S29518) [HU 276 474], (S28736) [HU 271 435]. In most cases these inclusions are evenly distributed throughout the quartz crystal, but in some thin sections (S31164) [HU 238 454], (S28875) [HU 293 419] inclusions are confined to thin narrow roughly parallel lines traversing the crystal. Minerals enclosed in quartz include apatite and rarely rutile. In many cases the quartz has undulose extinction, due to slight strain.

Sphene

Sphene is present as small crystals in the more calcic phases of the granite and close to contacts with diorite.

Alteration products

The plagioclase is in places patchily saussuritized into aggregates of chlorite and epidote in the centres of crystals (S28875) [HU 293 419]. Small grains of epidote are also associated with altered biotite. Potash feldspars are in places patchily altered to sericite.

Graphic granite of the northern sills

The granite sills extending from the eastern end of the granite outcrop near Garderhouse towards Bixter Voe contain coarse-grained granite with microperthite and antiperthite as described above, but only small amounts of ferromagnesian minerals. This granite grades into graphic granite which becomes progressively finer-grained and has more extensive zones of graphic intergrowth as it is traced northwards. The coarse-grained granite of the sills (S31132) [HU 327 494], (S31133) [HU 329 510], (S51548) [HU 327 505] differs from the granite of the main mass in that it contains a higher proportion of quartz (up to 40%). This has serrate margins with rudimentary graphic intergrowth. Oligoclase is fairly abundant, forming clusters of euhedral crystals (S31133) [HU 329 510]. Hornblende is absent and biotite is present as small interstitial scraps.

Graphic intergrowth of quartz and microperthite or microcline ranges from coarse, with the width of adjacent quartz and feldspar phases averaging 1 mm and with an irregular intergrowth pattern (S31133) [HU 329 510], to very fine with a regular pattern in which adjacent units are 0.08 mm thick (S51550) [HU 328 514], (Plate 26), fig. 1). The quartz-feldspar ratio in the latter is about 50:50.

Granite veining in shattered sediment within Sandsting Complex

A thin north-west trending fault-trough of shattered sediment intensely veined by granite separates the coarse-grained granite forming the cliffs southeast of Culswick Broch from the outcrop of diorite south-east of Keolki Field. The fault-trough extends from Burri Geo, where it is approximately 30 yd (27 m) wide, north-westward via the Loch of the Brough to the coast south of the Taing of Keolkifield, where it has widened to over 150 yd (137 m). The north-westward continuation of the fault-trough is uncertain. The islands of Muckle Flaes, 500 to 700 yd (460–640 m) NW of Culswick Broch, and the peninsulas on either side of Vine Geo at the south-east corner of Vaila, are also formed of shattered sediment intricately veined with granite. These areas may be within the north-westward continuation of the above-mentioned fault-trough, whose outcrop has further widened.

At the Taing of Keolkifield and in part of the Green Head peninsula of Vaila, the shattered sediment is veined by diorite, which is, in turn, intensely veined by fine-grained granite. The vein granite throughout this area strongly resembles the porphyritic microgranite exposed on the north-east shore of the Stead of Culswick. The fault crossing the Taing of

Keolkifield separates the veined sediment and diorite from diorite without veins and can clearly be seen to truncate the granite Veins. The fault clay within the zone of shear is, however, affected by thermal alteration, suggesting that this part of the complex was still hot when the faulting took place.

At Burri Geo the screen of sheared and veined sediment is very steeply inclined to the north-east but on the shore north of Culswick Broch its bounding faults are approximately vertical. It is difficult to obtain a satisfactory picture of the structure of this part of the complex as nothing is known of the seaward extension of the various rock types. It is, however, likely that the coarse granite south-east of Culswick Broch and the coarse granite of Vaila form part of the granite sheet overlying the diorite and that the diorite of Keolki Field has been pushed upward relative to the granite south of the fault belt, possibly during the period of emplacement of the Stead of Culswick microgranite. The screen of sediment between the two masses of igneous rock was shattered and veined by fine-grained granite during an early phase of the movement, but movement along the fault continued after vein emplacement had ceased.

Late fine-grained acid and basic intrusions

Intrusions cutting sedimentary rocks in the Gruting Voe–Walls district

Field relationships

Fine-grained acid intrusions which appear to be derived from the Sandsting igneous centre have been recorded in sediments up to 2 miles (3 km) from the granite margin, the most distant being the felsite dykes cutting intensely folded sediments forming the Mara Ness peninsula [HU 269 496] on the west shore of Gruting Voe. Most of these dykes have a trend ranging from W20°N to N25°W. Two felsite dykes have been recorded even further from the Sandsting Granite, on the north shore of Loch of Vadill [HU 227 488], 1 mile (1610 m) WSW of Walls Pier and 530 yd (480 m) E of Bruntskerry [HU 227 502], 1 miles (1810 m) NW of Walls Pier. Both dykes are composed of spherulitic felsite with corroded phenocrysts of quartz, orthoclase and plagioclase.

On the south shore of Gruting Voe, between the northern margin of the Sand-sting Complex and the Hoga Ness sill swarm (p. 226), dykes ranging in thickness up to 36 ft (11 m) cut the highly indurated sediments of the Walls Formation. Their trend in this area ranges from N25°W to N50°W, cutting obliquely across the strike of the sedimentary rocks. All these dykes are felsitic in texture, but at least one has a central porphyritic zone. Some contain fragments of sediment. One dyke exposed on the south shore of Gruting Voe is composite with a central zone of felsite and narrow outer zones of fine-grained basic rock. This is the only recorded composite dyke in the complex.

Petrography

The felsite of these dykes (S51492) [HU 246 480], (S51505) [HU 276 457] ranges from aphyric to strongly porphyritic with euhedral phenocrysts of quartz, microperthite and calcic oligoclase set in a groundmass, just over half of which is made up of spherulites composed of radiating fibres of quartz-feldspar aggregate. The remainder of the groundmass consists of small interlocking grains of quartz and feldspar locally showing micrographic intergrowth around corroded quartz crystals. Phenocrysts range in diameter from 2 to 0.3 mm and may form up to 50 per cent of the rock. The ratio of feldspar to quartz phenocrysts is approximately 60:40. Adjacent quartz phenocrysts are commonly in contact and some are in optical continuity. The potash feldspar is usually poorly developed microperthite which may have slightly wavy margins. Plagioclase phenocrysts are relatively rare and composed of calcic oligoclase. The basic outer portions of the composite dyke exposed on the south shore of Gruting Voe (p. 229) are microdiorite composed of hornblende and cloudy plagioclase laths in roughly equal proportion. There are rare plagioclase phenocrysts which are partly enclosed in hornblende. The microdiorite is cut by a number of veinlets, up to 0.4 mm thick, composed almost entirely of fine-grained hornblende. These veinlets also penetrate into the adjacent brecciated sediment.

Intrusions cutting sedimentary rocks at Skelda Voe, Rea Wick and Roe Ness

Dykes and veins of felsite, many highly irregular and very thin, are present in the trough-faulted wedge of Walls Sandstone, which reaches the sea at the head of Skelda Voe, and in the folded and shattered sediment exposed on the east coast between Rea Wick and Roe Ness. In the latter area the felsite intrusions are branching and irregular and locally shattered by later earth movements associated with the Walls Boundary Fault.

Intrusions cutting the Sandsting Complex

A few thin felsite dykes have been recorded in the granite and diorite of the Sandsting Complex, both on the east shore of Gruting Voe between the granite–sediment junction and the Taing of Keolkifield and on the shore between the head of Seli Voe and Rea Wick. The dykes cut both the diorite and the coarse-grained granite, but have not been recorded within the porphyritic microadamellite. They are similar to the felsite intrusions cutting the sediment overlying the Sandsting Complex, and it is thought that all these felsites belong to the same period of intrusion.

The metamorphic aureole

The thermal aureole within the sediment adjoining the Sandsting Complex is up to 1 mile (1.6 km) wide in the Gruting Voe area, but is considerably narrower and less well defined along the eastern margin of the granite outcrop, where narrow wedge-shaped granite sheets penetrate the sediment (Plate 12). The zone in which the sediment is completely hornfelsed and the original texture is entirely obliterated is very much narrower, probably nowhere greatly exceeding 550 yd (500 m). All sedimentary enclaves within the Complex (pp. 114–5) are hornfelsed.

Sandstone, siltstones and shales

The alteration of the sedimentary rocks is most intense within the enclaves and xenoliths in both granite and diorite (S28884) [HU 255 454], (S31156) [HU 273 439], (S51515) [HU 255 452], (S52552) [HU 253 453] and at the granite contact (S51507) [HU 255 465], 53694) [HU 240 455]. In these the sandstone ((Plate 27), fig. 1) is reconstituted into a mosaic of quartz and feldspar grains with polygonal outlines and with adjoining quartz grains fused to produce irregular masses up to 1 mm long with re-entrant angles. The quartz is in most cases clear and devoid of shadowy extinction and inclusions. In two specimens (S28882) [HU 254 453], (S28883) [HU 314 454] however, the quartz grains contain abundant brownish liquid inclusions, like those in the quartz of the Sandsting Granite (p. 227), and in one specimen (S31156) [HU 273 439] the quartz contains numerous small cracks intersecting each other at right angles. The feldspars are completely clear in the most intensely hornfelsed sections 53694) [HU 240 455] but more commonly they are slightly turbid, and the decomposition products are in some cases concentrated in the centres of grains. The original chlorite-carbonate matrix (pp. 117–121) is altered to a crystalline aggregate composed of varying proportions of the following minerals:

1. Green hornblende, which forms crystals ranging in outline from ragged to almost euhedral, or poikiloblasts up to 2 mm in diameter, which may be subhedral or euhedral.
2. Biotite, which forms thick flakes in part poikiloblastic, is commonly arranged in a decussate pattern. Close to the granite contact and within the sedimentary enclaves the biotite is commonly strongly pleochroic from straw-coloured to reddish brown. There is, however, considerable variation in the colour, and even in the same thin section it varies from reddish brown to brownish black. In a number of thin sections cut across the granite-sediment contact reddish brown micas are also present within the granite. Biotite and hornblende can occur together throughout the rock or singly along separate bedding planes.
3. Epidote and clinozoisite, usually forming anhedral grains partly mantling other minerals, occur in highly variable amounts, probably disposed along original calcareous laminae.
4. Clinopyroxene, probably entirely diopside, forms small anhedral grains in some xenoliths and along the granite contact, where it is developed to the complete 53694) [HU 240 455] or partial (S51515) [HU 255 452] exclusion of amphibole.

Mudstone and siltstone close to the contact (S51782) [HU 255 466], (Plate 27), fig. 2) is altered to a black splintery hornfels composed of angular quartz grains up to 0.03 mm in diameter, set in a decussate network of stumpy strongly-pleochroic reddish brown biotite flakes commonly about 0.03 mm long. The hornfels contains numerous poikiloblasts of green hornblende, which are irregular in shape, in some cases slightly elongated parallel to the bedding and average 0.5 mm in length. Hornblende forms approximately 60 per cent of the volume within these poikiloblasts. In certain bands adjacent poikiloblasts have coalesced into large composite aggregates. Pyroxene has not been recognized in the hornfelsed mudstones.

Away from the granite the mosaic texture of the quartz and feldspar grains disappears fairly rapidly, and the polygonal outlines of the grains give place to more irregular serrate outlines. In thin sections from more than 550 yd (500 m) away from the contact the newly formed coloured minerals have not obliterated the original texture of the sediment but are confined to the interstices, originally occupied by the chlorite-carbonate matrix. Quartz grains are, however, partially fused together throughout the aureole. Biotite, amphibole, epidote and clinozoisite are present throughout the aureole and there is no evidence that amphibole gradually disappears and that its place is taken by biotite, as was suggested by Finlay (1930, pp. 675–6). The changes in the mafic minerals away from the granite contact are as follows:

1. The biotite changes colour from reddish brown to brown approximately 200 yd (180 m) from the contact, and to greenish brown or khaki near the outer margin of the aureole. The change from brown to greenish biotite appears to take place closer to the granite in the fine sediment (S53693) [HU 255 462] than in the sandstone. Biotite near the contact forms aggregates or isolated flakes with decussate orientation and, in some cases, irregular poikiloblastic masses, but as the outer margin of the aureole is approached it forms a fine-grained interstitial aggregate grading into the metamorphic biotite of the tectonite belt (p. 122).

Mineral composition of specimens: (S52541) [HU 241 464] finely granular diopside, zoisite-clinozoisite, poikiloblasts of calcic scapolite, acicular amphibole associated with zoisite; (S52542) [HU 241 464] finely granular diopside, veins and patches of zoisite-clinozoisite; (S52534) [HU 241 464] cordierite poikiloblasts, calcic scapolite, veins of clinozoisite, calcite and actinolite; (S52535) [HU 241 464] calcite, calcic scapolite diopside; (S52536) [HU 241 464] poikilitic grossularite and idocrase, finely granular diopside, veins and patches of zoisite; (S52540) [HU 241 464] calcite, calcic scapolite, idocrase, amphibole, veins of calcite and zoisite; (S52539) [HU 241 464] calcite, poikiloblasts of grossularite with diopside grains, calcic scapolite, veins of calcite; (S52538) [HU 241 464] shale; amphibole laths and poikiloblasts biotite, clinozoisite; silt-stone: diopside amphibole, zoisite, calcic scapolite; (S52537) [HU 241 464] poikiloblasts of calcic scapolite with finely granular diopside, veinlets of clinozoisite.

2. Amphibole is present both in the sandstones and the fine-grained sediments throughout the aureole, but individual crystals become progressively smaller and more acicular near its limit. The amphibole from the outermost specimens is pleochroic from straw-coloured to yellowish green.

3. Epidote and clinozoisite are common in the bands which were originally carbonate-rich and are in many cases associated with fine-grained amphiboles.

No calc-silicates of secondary origin have been recorded in the outer half-mile (800 m) wide belt of the aureole.

Limestone and calcareous mudstone

The thick bed of mudstone and calcareous mudstone with two limestone bands respectively 1 ft 8 in (50 cm) and 3 ft (91 cm) thick (Figure 25) exposed on the east coast of Vaila, 230 yd (210 m) N of the granite-sediment contact (Plate 25), is the only sediment containing appreciable quantities of calcite within the aureole. The mineral content of the hornfelsed limestone and calcareous mud-stone, in addition to calcite, quartz, mica and clay minerals, is as follows:

Limestone

Grossular, calcic scapolite, idocrase, diopside, epidote and clinozoisite. Grossular occurs as large highly poikiloblastic crystals forming 50 per cent of the total volume of one section (S52536) [HU 241 464], (Plate 27), fig. 4). Scapolite and idocrase form both subhedral to anhedral crystals and poikiloblasts. The diopside is generally finely granular and enclosed by the other minerals.

Calcareous mudstone and shale

Cordierite, usually poikilitic, amphibole, diopside, calcic scapolite and rare idocrase. Cordierite ((Plate 27), fig. 3) is only present in the mudstone immediately adjoining the limestones, and has not been recorded in hornfelsed mudstones elsewhere in the aureole.

The hornfelsed sediments are cut by veins of calcite containing clinozoisite and tremolite.

Metamorphic grade

The paragenesis of the sediments within the inner part of the contact aureole and the sedimentary enclaves within the complex suggests that pressure-temperature conditions during the granite and diorite emplacement were those of the hornblende-hornfels facies (Turner 1968, pp. 193–225), grading outwards into the albite-epidote-hornfels facies near the limit of the aureole. There is no evidence of mineral assemblages suggesting pressure-temperature conditions characteristic of the pyroxene-hornfels facies, even in xenoliths enclosed in diorite. Though these contain diopside, they also have ophitic plates of reddish brown biotite, and in most cases, subordinate hornblende, which in some sections mantles the pyroxene. A diagnostic feature of the pyroxene-hornfels facies is the absence of hornblende.

Scapolitized crush zones within Sandsting Complex

Linear north-north-west trending crush belts

Field relationships

Zones of crushed and partially mylonitized rock, which were recorded by Finlay (1930, p. 686), but first recognized as crush zones by Wilson (*in* Summ. Prog. 1933, p. 76), are present in the southern part of the complex. In the Skelda Ness, Silwick and Wester Wick areas they take the form of near-vertical lenticular crush belts, commonly trending west-north-west to north, and ranging in thickness from less than 1 ft (30 cm) to 50 yd (46 m). They consist of sheared granite and locally diorite, and show a gradual transition from relatively uncrushed granite on the outside to a central pale or dark grey zone of variable thickness, which resembles flinty crush and is composed in part of mylonite (p. 235). The crushed rock of the central zone, and, to a lesser extent, the outer zone, is in places metasomatically replaced by sodic scapolite which is itself sheared. The period of scapolite emplacement more or less coincided with the duration of shearing (Mykura and Young 1969).

The following are descriptions of the better-developed crush belts :

1. Hillside between Wester Wick and Loch of Wester Wick

The crush belt in this area trends N30°W, and has a maximum width of 35 yd (32 m) of which only the central 5 yd (4.6 m) is intensely sheared. In the wide outer zones individual crystals of feldspar, still more or less intact, are set in a dark greyish groundmass. Locally patches of almost unaltered pink granite are preserved within this zone.

2. Cliff top, north-west corner of Wester Wick

The belt of mylonitized rock, which is well seen in the cliffs exposed at the north-west corner of Wester Wick, trends N20°W, is steeply inclined to the west-south-west and attains a thickness of 15 ft (4.6 m). It consists entirely of silicified flinty crush rock and has virtually no marginal zone of less crushed granite.

3. East shore of Wester Wick 700 yd (640 m) SSE of Wester Wick village

The granite exposed on the cliffs forming the eastern shore of Wester Wick, 400 yd (366 m) SSE of the head of the bay, is not cut by a single well-defined crush belt, as in the other areas described. It is cut by two intersecting sets of joints along which the granite is locally slightly crushed. In the northern part of the cliff section the granite contains irregular enclaves of shattered diorite and micro-diorite. The granite is traversed by a 40 yd (36 m) wide zone containing belts of scapolitization and numerous scapolite and calcite veins. Many of the scapolite veins are emplaced along the two intersecting sets of joints.

4. Pundswell, near Scarvister, Skelda Ness peninsula

This crush belt, which trends N15°W and dips steeply to the east, is well exposed 40 yd (36 m) north of the ruin of Pundswell [HU 305 421], where it is nearly 50 yd (46 m) wide. The central strongly sheared zone is 6 yd (5.5 m) wide and is composed of a banded flinty-looking rock, with a slightly wavy schistosity parallel to the trend and inclination of the crush belt. It contains several lenses of white scapolite up to 6 in (15 cm) wide and 2 ft (60 cm) long, as well as an intricate network of minute scapolite veinlets. On either side of the central belt the granite is streaked out, and is generally of cherty aspect, with individual shattered feldspar crystals still visible on weathered surfaces. The effects of shearing are strongly marked within 12 yd (11 m) wide zones bounding the central belt but decrease rapidly away from these zones.

5. Crush belts in Skelda Ness peninsula

The southern part of the Skelda Ness peninsula contains a number of parallel, near-vertical crush belts, trending N10°W. The most easterly of these, exposed in Blo Geo, 900 yd (823 m) NE of the southern end of the peninsula is up to 40 yd (36 m) wide and is composed of roughly alternating bands of sheared-out granite and almost normal granite. In this crush belt there is no evidence of extensive scapolitization, but in the one 200 yd (183 m) farther west, which can be traced for 400 yd (366 m) along its strike, and is up to 5 yd (4.6 m) in width, the mylonitized rock is intensely scapolitized and veins of virtually pure scapolite are present. One of these veins reaches a thickness of 8 ft (2.4 m) at the coast.

Petrography

Sheared granite of the outer zones

The first indication of shearing in the outer zones of the shear belts is the distortion of the fabric of the quartz crystals producing undulose extinction and the breaking up of coarse-grained biotite (S51524) [HU 284 430]. Slightly further in (S29873) [HU 303 404], (S31121) [HU 304 421] quartz grains become streaked out with an elongation ratio of up to 10:1 and a highly undulose extinction. In some cases the quartz is finely granulated with grains separated by sutured margins. More commonly the quartz is converted into a very fine mosaic. The plagioclase crystals are usually bent with open cleavages and other cracks. A further effect of strain is the development of twin-planes normal to the original albite twinning of the crystal, producing an intimate intergrowth of two sets of twin lamellae. The potash feldspar shows less evidence of strain, but undulose extinction is seen in some crystals. The cracks within crystals and between adjacent crystals are filled with a very fine-grained aggregate of green mica, which commonly forms up to 30 per cent of the total volume of rock. Fine-grained scapolite forms thin (< 1.8 mm) discontinuous veinlets within the micaceous aggregate; and some of the veinlets are cut and displaced by small shear planes.

Inner mylonitized zones

In the less intensely mylonitized crush belts and in the zones bounding the central belt of others, sheared granite of the type described above is further broken up into clasts elongated parallel to the schistosity (S29872) [HU 300 408]. These fragments are enclosed in a matrix of finely comminuted biotite with some larger plates of biotite and rare sphene. There are also thin parallel belts of fine-grained mylonitized quartz which in some cases flows round porphyroclasts of sheared quartz.

The most intensely sheared rock in the crush belts is a dark grey chertylooking rock with pale patches (S31126) [HU 301 410]. It consists of roughly oval porphyroclasts of quartz elongated parallel to the schistosity which range in length from about 1.5 to less than 0.1 mm. The quartz clasts have undulose extinction and a number of irregular cracks and are enclosed in an extremely fine-grained, laminated quartzose matrix. The planes of movement within this mylonite are roughly parallel to the trend and inclination of the shear belt but show evidence of minor folding, with axial plane cleavage locally developed. In places the mylonite is broken up into small irregular blocks by shear planes, with individual blocks rotated relative to each other (S31126) [HU 301 410]. Individual fragments do not exceed 1 mm in diameter and the rock therefore does not strictly correspond to kakyrite (Christie 1960, p. 83) in which individual fragments are megascopically recognizable. Veins of scapolite cutting this ultramylonite are also slightly folded and stepped by later faults.

Associated mineralization

Mylonite from the shear belt exposed on the north-west side of Wester Wick (S51783) [HU 282 426] is cut by a network of small irregular patches and linked cross-cutting veinlets of a very fine-grained aggregate of a green unidentified mineral with high refractive index which locally forms up to 40 per cent of the total volume of the rock. This mineral is in turn cut by thin branching veinlets of potash feldspar and carbonate and a few veinlets containing carbonate and sphene, both of which are affected by late small-scale faulting ((Plate 27), fig. 8).

The mode of occurrence of scapolite ((Plate 27), figs. 5, 6) and calcite within the shear belts, and that of the scapolite veins in melamicrodiorite dykes within the complex and in the sediment adjoining it, have been described by Mykura and Young (1969), who have suggested that the sodic scapolite was formed both by the metasomatic replacement of feldspars and by the direct deposition in veins from hydrothermal solutions. Scapolitization was more or less contemporaneous with the movement along the crush belts but vein emplacement may have continued for some time after the movement had ceased.

Origin of crush belts

The texture and composition of the crush rock within the crush belts indicates that shearing took place at a fairly low crustal level in an environment of fairly high temperature and hydrostatic pressure, possibly before the granite had cooled completely. In the most highly mylonitized and scapolitized areas there is evidence of several phases of movement. There is, however, little evidence of either great vertical or horizontal displacement along these crush belts, as they do not displace any of the junctions between the different rock types within the complex. The lenticular shape and limited length of their outcrop suggests that they may have been formed within 'islands' of consolidated granite which were surrounded by areas of still viscous magma which was able to absorb the movements by flowing rather than by shearing.

Irregular areas of crushed rock

In addition to the near-vertical linear crush belts there are three outcrops of crushed granitic and dioritic rock of irregular shape. Two of these are situated just west of Culswick village and a smaller mass crops out on the Knowes of Westerskeld between Wester Skeld and Housa Water. The rock forming these masses is crushed throughout but the grey aphanitic mylonite of the vertical belts is never developed. As these areas are located either close to a junction between diorite and granite or diorite and sediment, it is possible that they were formed during differential movement of two adjacent almost consolidated masses. The irregular shape of the outcrop of these crush zones suggests that they may be lenticular masses whose inclination is almost horizontal.

Shearing in area adjoining walls boundary fault

The granite and other members of the Sandsting Complex are intensely shattered within a 1-mile (1200-m) wide zone adjoining the Walls Boundary Fault (Summ. Prog. 1933, p. 80). The Old Red Sandstone sediments within this zone are both strongly folded and intensely shattered (p. 134). The shearing within the granite is best seen along the south shore between Skelda Voe and the Ayre of Deepdale, where the granite is cut by a large number of closely spaced sub-parallel faults and joints, whose trend varies from N25°E to N10°W and whose inclination is consistently 60 to 80 degrees to the east. Rather less well developed cross-joints, with trends ranging from east–west to E30°S, are locally present. At Aaskberry Taing, 1 mile (1600 m) WNW of Ayre of Deepdale, where the north-north-east trending faults are closely spaced, the granite fabric is distorted within a zone extending from 2 to 4 ft (61–122 cm) from the fault planes, and within a 6-in (15-cm) belt along some fault planes it becomes black and flinty-looking with local pink patches. The sheared rock is, however, shattered and friable, and chlorite is developed along shear planes, suggesting that shearing here took place at a much higher crustal level than in the Skelda Ness–Wester Wick crush belts.

The granite exposed on the west shore of Seli Voe north of Rea Wick is intensely shattered throughout, but there is little consistency in the trend of the fault planes. It contains a number of north-north-west trending near-vertical belts of crush rock, which is very fine-grained, black, cherty in texture and in some places partly replaced and intensely veined by scapolite and calcite (Mykura and Young 1969, p. 5). These crush belts are in some respects comparable with the crush belts of the Skelda Ness–Wester Wick area and as they are themselves affected by the later shearing, they may, like the Skelda Ness crush belts, have originated at a fairly low crustal level and may not be directly connected with the Walls

Boundary Fault.

A small wedge-shaped mass of intensely sheared granite, separated from outcrops of Walls Sandstone by two sub-parallel near-vertical, south-southwest trending faults, crops out on the south shore of Rea Wick. The granite is cut by many fault planes and contains a number of faulted slices, up to 15 yd (14 m) long, of intensely shattered sandstone and sandy siltstone. Many of the shear planes in this zone trend roughly parallel to the bounding fault and have an inclination ranging from 25 to 45 degrees to the east.

Structure and mode of emplacement of the complex

As only part of the probable outcrop of the Sandsting Complex may be exposed above sea level (McQuillin and Brooks 1967, p. 14) any speculation as to its structure and mode of emplacement must be tentative. Though the field evidence as a whole is inconclusive, the structure of the north-eastern part of the complex suggests that, rather than being a stock with steeply inclined margins, the complex is a compound sheet which is intruded into the sedimentary rocks of the Walls Formation.

The sheet appears to dip northward at an angle of 40 to 70 degrees in the west, is possibly almost horizontal in the central area between Culswick and Scarvister and dips steeply to the east in the vicinity of Easter Skeld. Its upper junction is sub-parallel to the bedding of the sediment, but steps down slightly to the north-west. The portion of the complex east of Skelda Voe forms a sheet dipping steeply to the east and fingering out northward. In the north the fingers of the sheet are concordant with the bedding of the enclosing sediment.

The first major intrusion of the complex was the diorite which formed a sheet that was roughly concordant with the bedding of the enclosing sediment. This sheet appears to have decreased in thickness from west to east. It contained several large and many small enclaves of sediment. Before the diorite had consolidated completely, two complex sheets of granodiorite, granite and microadamellite were intruded along the lower and upper contacts of the diorite. The lower sheet may have been considerably thicker than the upper, and there appear to have been connecting branches which cut across the diorite in the area between Culswick and Housa Water and in the ground north of the Ward of Reawick. In some instances (e.g. 0.25 mile (400 m) N of Viville Loch) small masses of diorite intervene between the upper margin of the granite and the overlying sediment, while elsewhere (e.g. east of Housa Water) enclaves of sediment occur between the diorite and granite, suggesting that the upper sheet was not everywhere intruded precisely along the diorite-sediment junction.

Nothing is known of the total thickness of this hypothetical compound sheet, as its lower junction is nowhere exposed. The faulted-in portions of net-veined sediment near the Broch of Culswick and at Vine Geo, Vaila (pp. 228–9) could be parts of the floor of the sheet, but they could equally well be parts of sedimentary enclaves or even stoped portions of the roof of the complex.

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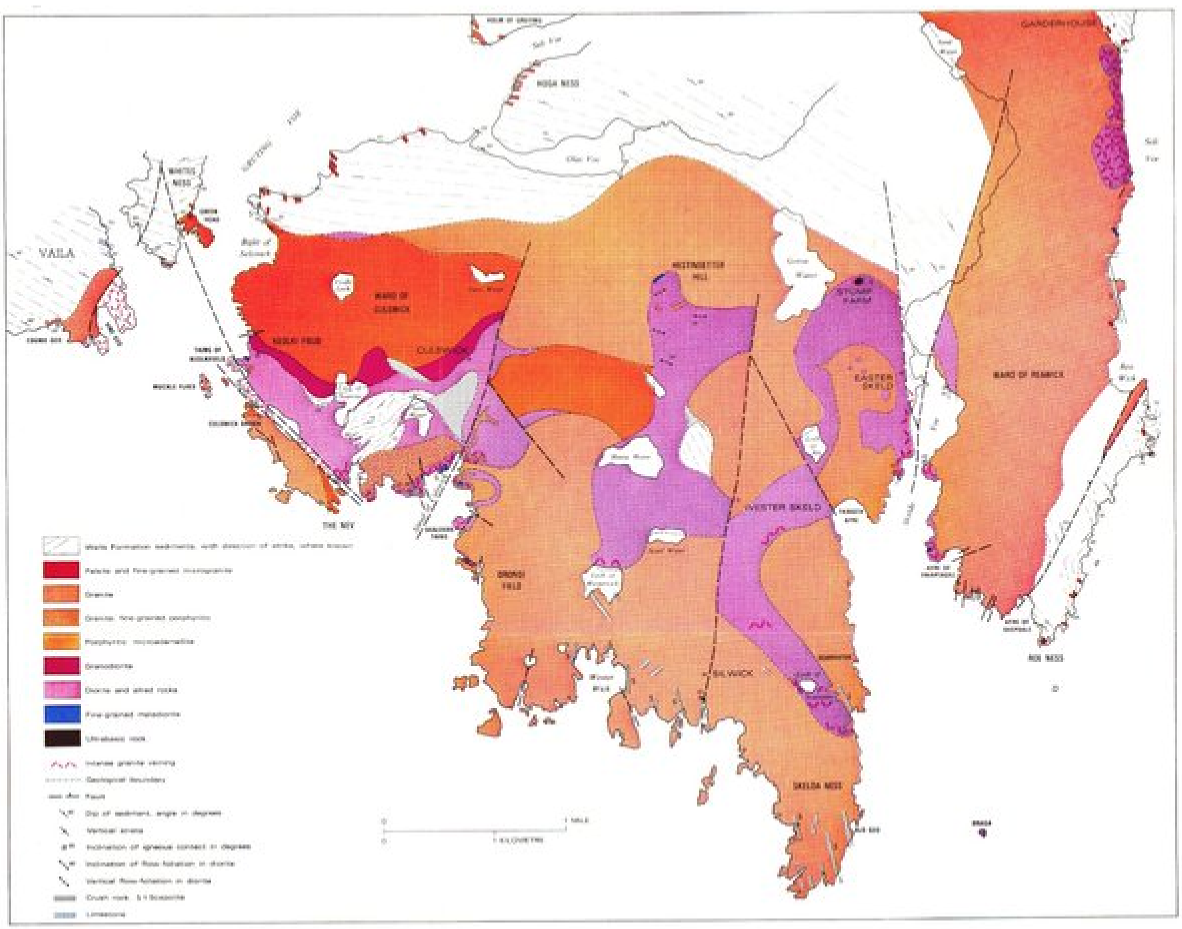
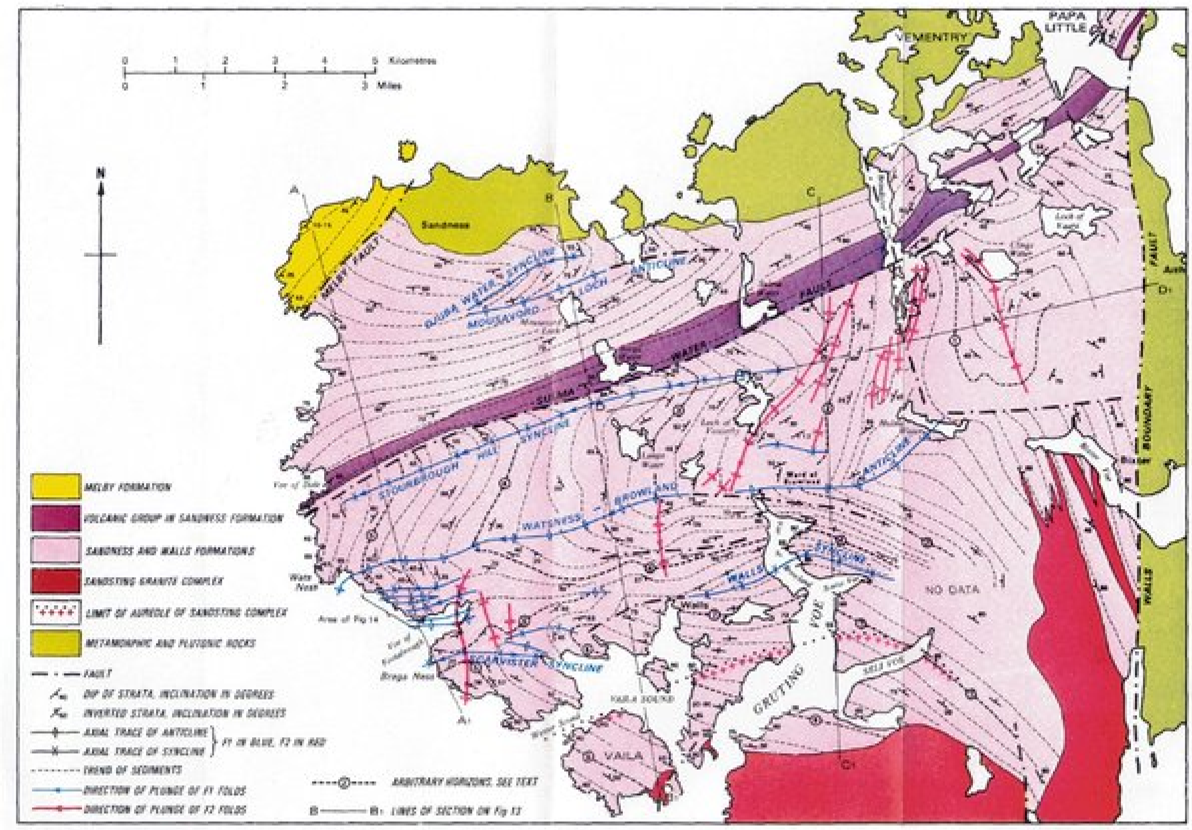
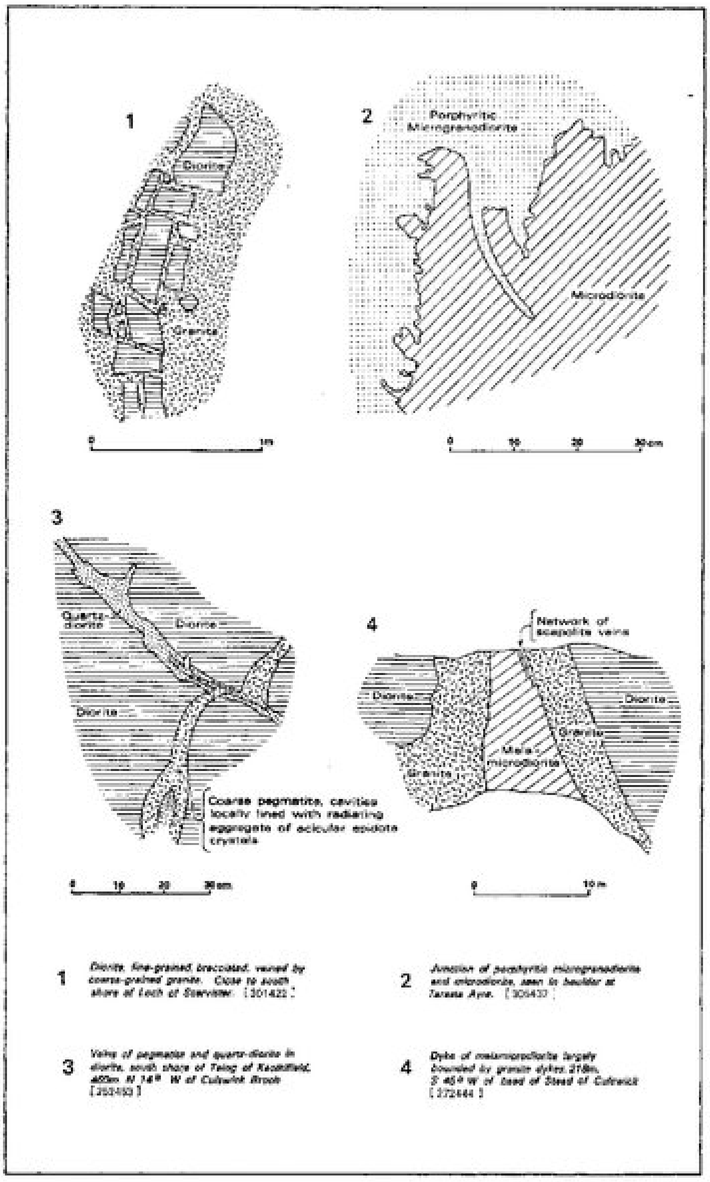


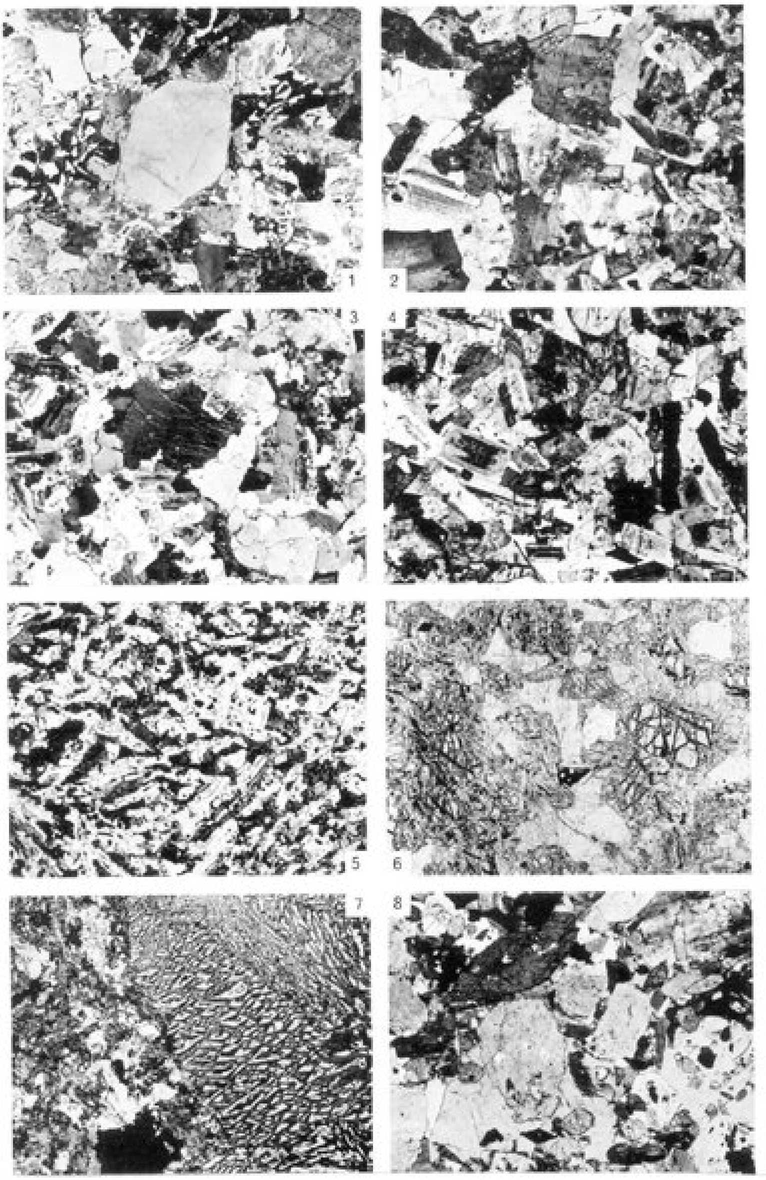
(Plate 25) Geological Sketch map of the Sandsting Granite–Diorite Complex.



(Plate 12) Major stratigraphic and structural features of the Old Red Sandstone sediments and volcanic rocks of the Walls Peninsula.



(Figure 24) Diagrams of igneous contacts, dykes and pegmatite veins in the Sandsting.



(Plate 26) Photomicrographs of the Sandsting Granite–Diorite Complex Fig. 1. Slice No. (S51550) [HU 328 514]. Magnification × 16. Crossed polarisers. Granophyre sill in Walls Sandstone, composed of graphic intergrowth of quartz and potash feldspar and scattered subrounded crystals of microcline and albite-oligoclase. West shore of Bixter Voe, 240 yd (225 m) SSE of Mosshouse [HU 328 514]. Fig. 2. Slice No. 33678) [HU 299 438]. (Analysed specimen No. 1066, Guppy and Sabine 1956, p. 14, No. 653.) Magnification × 16. Crossed polarisers. Diorite, with plates of andesine rimmed with oligoclase, subordinate hornblende, biotite and rare sphene. Interstitial microcline, microperthite and quartz. 1400 yd (1280 m) ESE of Wester Skeld, near Loch of Arg [HU 299 438]. Fig. 3. Slice No. (S51509) [HU 253 461]. Magnification × 16. Crossed polarisers. Microadamellite. Clusters of near-euhedral plates of zoned plagioclase (andesine rimmed by oligoclase) form 40 per cent of the total feldspar. Large irregular plates of microperthite and interstitial microcline form the remaining 60 per cent. Quartz forms 10 per cent of the total volume. The mafic minerals hornblende and biotite are present in equal proportion. Apatite is an abundant accessory. Coast of Scurdie, 470 yd (425 m) SE of Green Head [HU 253 459]. Fig. 4. Slice No. (S28878) [HU 296 427]. Magnification × 17–6. Crossed polarisers. Fine-grained hornblende-diorite. Near-euhedral plates of calcic andesine rimmed with calcic oligoclase. Interstitial microcline and quartz. Hornblende and greenish brown mica are present in equal volume. Sphene and small needles of apatite are abundant accessories. Brunt Hamar, 830 yd (760 m) NE of Silwick [HU 299 426]. Fig. 5. Slice No. (S51523) [HU 271 441]. Magnification × 42. Plane polarized light. Melanocratic microdiorite. Irregular decussate laths of sodic andesine set in interstitial base of ragged plates of deep green biotite forming 30 per cent of total volume. Clusters of small crystals of hornblende. Abundant accessories are sphene and small specks of iron ore. South-east side of Stead of Culswick, 550 yd (500 m) S32°E of south end of Sand Water [HU 272 442]. Fig. 6. Slice No. (S51535) [HU 309 457]. Magnification × 16. Plane polarized light. Ultrabasic rock resembling harrisite. Olivine is sheathed in serpentine. Pyroxene (augite and enstatite) forms large in part poikilitic plates. Also subhedral plates of labradorite-bytownite and plates of reddish brown *mica (?lepidomelane) enclosing skeletal iron ore. 190 yd (175 m) W20°N of Stump Farm [HU 307 457]. Fig. 7. Slice No. (S51514) [HU 252 452]. Magnification × 16. Crossed polarisers. Pegmatite vein in diorite. Large crystal of micropegmatite (quartz-microcline intergrowth) set in matrix of irregular plates of microcline and quartz with grains and veinlets of epidote. South shore of Taing of Koelkifield, 530 yd (480 m) N18°W of Culswick Broch [HU 252 452]. FIG . 8. Slice No. (S51528) [HU 293 454]. Magnification × 16. Crossed polarisers. Part of ovoid of pyroxene-monzonite in microdiorite. Characterized by large euhedral sphenes, and smaller euhedral crystals of colourless pyroxene set in base of near-euhedral crystals of clear orthoclase, plagioclase and microcline. West slope of Hestinsetter Hill, just east of road, 340 yd (310 m) S18°E of Giant's Grave [HU 293 455].*

	1	2	3	4	5	6
SiO_2	69·49	70·96	57·60	55·35	51·94	51·98
Al_2O_3	16·12	15·18	16·66	17·82	18·65	18·70
Fe_2O_3	0·83	1·69	2·60	2·28	1·49	1·62
FeO	1·63	—	4·34	3·86	4·04	3·95
MgO	0·90	0·70	2·99	3·58	5·86	5·94
CaO	1·94	1·52	5·27	6·60	8·96	8·88
Na_2O	4·14	4·32	3·97	4·28	3·18	3·20
K_2O	3·98	4·68	3·01	2·88	2·24	2·27
$H_2O > 105°$	0·65	0·66	1·05	0·76	1·20	0·86
$H_2O < 105°$	0·10	0·18	0·27	0·18	0·16	0·18
TiO_2	Trace	Nil	1·73	1·74	1·34	1·36
P_2O_5	0·09	Trace	0·59	0·66	0·68	0·66
MnO	Trace	—	0·11	0·13	0·10	0·07
CO_2	—	—	Trace	Trace	n.d.	—
SO_3	n.d.	n.d.	—	—	Trace	—
Cl	n.d.	n.d.	0·04	0·02	Trace	n.d.
S	n.d.	n.d.	0·05	0·03	—	n.d.
FeS_2	—	—	—	—	0·13	0·24
Cr_2O_3	n.d.	n.d.	—	—	n.d.	0·03
BaO	—	—	0·12	0·11	0·09	—
SrO	n.d.	n.d.	—	—	—	—
Rb_2O	n.d.	n.d.	0·01(s)	0·01(s)	—	—
Li_2O	n.d.	n.d.	—	—	—	—
TOTAL	99·87	100·00	100·41	100·29	100·06	99·94
Less O for Cl	—	—	0·01	—	—	—
	99·87	100·00	100·40	100·29	100·06	99·94
Sp. gr.	n.d.	n.d.	2·79	2·78	—	—

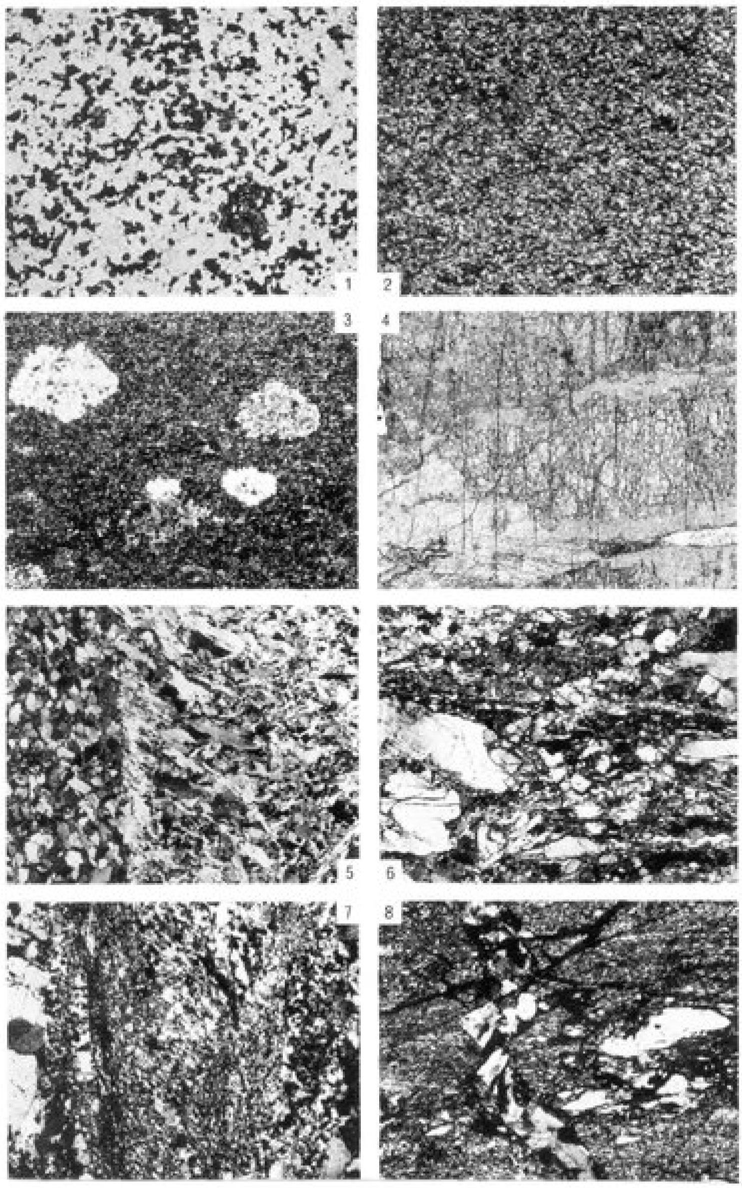
1. Granite, Skelda Ness, (Exact locality not known). Anal: W. H. Herdman (Finlay 1930, p. 693).
2. Granite, Gruting Voe, (Exact locality not known). Anal: R. R. Tatlock (Finlay 1930, p. 693).
3. Diorite, 400 yd (380 m) ESE of Wester Skeld. [299 438]. S 33678. Lab. No. 1066. Anal: G. A. Sergeant; spect. det. H. K. Whalley. (Guppy and Sabine 1956, pp. 14–15).
4. Diorite, ¼ mile (390 m) ENE of Lunga Water. [293 452]. S 33676. Lab. No. 1067. Anal: G. A. Sergeant, spect. det. H. K. Whalley. (Guppy and Sabine 1956, pp. 14–15).
5. Gabbro-diorite hybrid, 150 yd (140 m) NE of Loch of Arg, Sandsting. [304446]. S 33677. Lab. No. 1068. Anal: G. A. Sergeant. (Guppy and Sabine 1956, pp. 14–15).
6. 'Hornblende-gabbro', 150 yd (140 m) NE of Loch of Arg, Sandsting. [304446]. S 30035. Lab. No. 970. Anal: B. E. Dixon. (Guppy and Sabine 1956, p. 24).

NORMS

	1	2	3	4	5	6
Q	23·88	23·62	8·61	2·46	0·00	0·00
C	1·68	0·24	0·00	0·00	0·00	0·00
or	23·52	27·66	17·79	17·02	13·24	13·42
ab	35·03	36·56	33·00	35·92	26·91	27·08
an	9·04	7·54	19·06	21·06	30·00	29·96
hl	0·00	0·00	0·11	0·03	0·00	0·00
di	0·00	0·00	2·61	5·89	8·00	7·80
hy	4·55	1·74	9·26	8·61	11·82	11·52
ol	0·00	0·00	0·00	0·00	2·23	2·38
mt	1·20	0·00	3·77	3·31	2·16	2·35
cm	0·00	0·00	0·00	0·00	0·00	0·04
hm	0·00	1·69	0·00	0·00	0·00	0·00
ilm	0·00	0·00	3·29	3·30	2·54	2·58
ap	0·21	0·00	1·37	1·53	1·58	1·53
pr	0·00	0·00	0·11	0·06	0·13	0·24
bao	0·00	0·00	0·12	0·11	0·09	0·00
Others	0·75	0·84	1·33	0·95	1·36	1·04
Total	99·87	99·89	100·41	100·29	100·06	99·94
Q	28·97	26·89	14·49	4·45	0·00	0·00
or	28·53	31·49	29·95	30·72	32·97	33·13
ab	42·50	41·62	55·56	64·83	67·03	66·87
Total	100·00	100·00	100·00	100·00	100·00	100·00
or	34·80	38·54	25·46	23·00	18·87	19·04
ab	51·83	50·95	47·25	48·54	38·36	38·44
an	13·37	10·51	27·29	28·46	42·77	42·52
Total	100·00	100·00	100·00	100·00	100·00	100·00
ab	79·49	82·90	63·39	63·04	47·28	47·48
an	20·51	17·10	36·61	36·94	52·72	52·52
Total	100·00	100·00	100·00	100·00	100·00	100·00

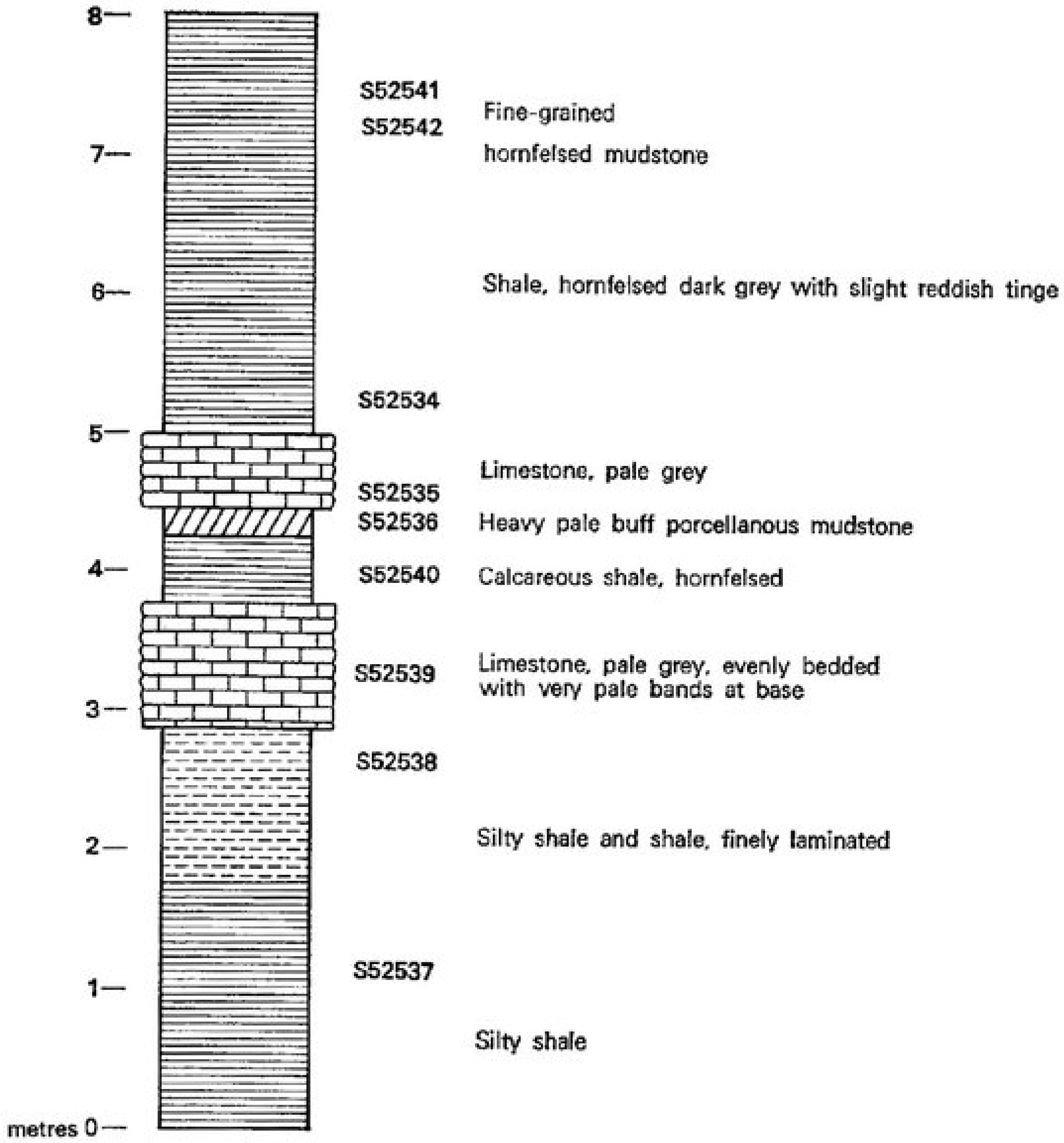
s = Spectrographic determination n.d. = not determined

(Table 5) Analyses of specimens from Sandsting Complex.



(Plate 27) Photomicrographs of the thermal aureole and hydrothermal mineralization in the Sandsting Granite–Diorite Complex. Fig. 1. Slice No. (S51515) [HU 255 452]. Magnification × 42. Plane polarized light. Hornfelsed sandstone in sedimentary enclave within diorite. Quartz and feldspar grains are welded together. The interstitial matrix is recrystallized into granular epidote, brown biotite and subordinate hornblende. The larger dark patches consist partly of ophitic hornblende. Koelkifield, 500 yd (450 m) N8°E of Culswick Broch [HU 254 452]. Fig. 2. Slice No. (S51782) [HU 255 466]. Magnification × 42. Plane polarized light. Dark grey homfelsed silty mudstone close to junction with Sandsting Granite. Serrate quartz grains set in matrix of stumpy brown biotite. The darker areas are spongy, highly ophitic crystal aggregates of green hornblende which are up to 0.5 mm in diameter. North-east shore of Bight of Selistack, 650 yd (590 m) E37°N of south point of Green Head [HU 256 466]. Fig. 3. Slice No. (S52534) [HU 241 464]. Magnification × 42. Crossed polarisers. Indurated mud-stone overlying limestone, within thermal aureole of Sandsting Complex. Fine-grained hornfelsed calcite-mudstone with oval poikiloblasts (white) of cordierite. The mudstone contains small patches of clinozoisite. Island of Vaila, west shore of Easter Sound, 650 yd (590 m) WNW of Ram's Head Lighthouse [HU 242 463]. Fig. 4. Slice No. (S52536) [HU 241 464]. Magnification × 22. Plane polarized light. Hornfelsed impure limestone within thermal aureole of Sandsting Complex. Composed largely of intensely sieved grossularite enclosing minute grains of diopside. The opaque bands consist almost entirely of finely granular diopside. The white lens in the bottom right of the picture consists of feldspar with diopside grains. Elongate crystals of clinozoisite near bottom left. Island of Vaila, west shore of Easter Sound, 650 yd (590 m) WNW of Ram's Head Lighthouse [HU 242 463]. Fig. 5. Slice No. (S51502) [HU 265 472]. Magnification × 16–8. Crossed polarisers. Junction of scapolite vein with Walls Sandstone. The scapolite forms irregular laths which intersect the vein-margin at an angle of 45°. South shore of Gruting Voe, 820 yd (750 m) E19°N of Hogan [HU 272 473]. Fig. 6. Slice No. (S31121) [HU 304 421]. Magnification × 16. Crossed polarisers. Sheared and partly mylonitized granite with small discontinuous, partly sheared veinlets of scapolite laths. Skelda Ness peninsula.

Pundswell, 200 yd (180 m) NNW of summit of Longa Berg [HU 304 422]. Fig. 7. Slice No. (S28732) [HU 287 425]. Magnification × 31. Crossed polarisers. Sheared-out and partly mylonitized scapolite adjoining granite. Hillside, 200 yd (180 m) E of Wester Wick [HU 287 424]. Fig. 8. Slice No. (S31126) [HU 301 410]. Magnification × 31. Crossed polarisers. Intensely scapolitised sheared granite cut by faulted veinlet of potash feldspar. Skelda Ness peninsula, 1000 yd (910 m) SSW of summit of Longa Berg [HU 302 411].



(Figure 25) Hornfelsed limestones and associated calcareous shales, east coast of Voila [HU 242 464]. Mineral composition of specimens: (S52541) [HU 241 464] finely granular diopside, zoisite-clinozoisite, poikiloblasts of calcic scapolite, acicular amphibole associated with zoisite; (S52542) [HU 241 464] finely poikiloblasts of calcic scapolite, acicular amphibole associated with zoisite; (S52542) [HU 241 464] finely granular dlopside, veins and patches of zoisite-clinozoisite; (S52534) [HU 241 464] cordierite poikiloblasts, calcic scapolite, veins of clinozoisite, calcite and actinolite; (S52535) [HU 241 464] calcite, calcic scapolite diopside; (S52536) [HU 241 464] poikilitic grossularite and idocrase, finely granular diopside, veins and patches of zoisite; (S52540) [HU 241 464] calcite, calcic scapolite, idocrase, amphibole, veins of calcite and zoisite; (S52539) [HU 241 464] calcite, poikiloblasts of grossularite with diopside grains, calcic scapolite, veins of calcite; (S52538) [HU 241 464] shale; amphibole laths and poikiloblasts. biotite, clinozoisite; siltstone: diopside amphibole, zoisite, calcic scapolite; (S52537) [HU 241 464] poikiloblasts of calcic scapolite with finely granular diopside, veinlets of clinozoisite.