Chapter 2 The Lunnister Metamorphic Rocks

Introduction

The Lunnister Metamorphic Rocks crop out in the north-eastern corner of the present area (Figure 3). They form a triangular outcrop which has its apex at the head of Busta Voe and widens northwards to 1.25 miles (2 km) at the northern margin of the map. This area is bounded by two converging faults. On the west the metamorphic rocks are brought against unfoliated granite of the Muckle Roe–Northmaven Complex by the Haggrister Fault ((Figure 27)b) which is seen at the west end of the Bight of Haggrister to be a reversed fault dipping W at 70° and which causes severe shattering of the schists and some shattering of the granite. On the east the Walls Boundary Fault separates the Lunnister rocks from the foliated granite-with-schist of the Delting Injection Complex (see Flinn 1954). The two faults converge southwards into the Walls Boundary Fault-zone which passes under Busta Voe close to its western coast. As the Lunnister Metamorphic Rocks have been described in detail elsewhere (Phemister in press), only a short summary of their lithology and structure is given in the present chapter.

The Lunnister Metamorphic Rocks are believed to include several geological formations. They comprise banded gneisses, siliceous, sericitic and graphitic schists, greenschists and calcareous schists with limestone bands. All of these are greatly deformed, sheared and, in places, mylonitized and phyllonitized. They also contain the magnetite deposits and skarn rocks of Clothister. Towards the southern end of their outcrop the Lunnister rocks occupy only a narrow strip of ground which is about 400 yd (365 m) wide on the north side, 200 yd (180 m) wide on the south side, of the Sullom Voe–Busta Voe isthmus. Within this strip the rocks are so greatly crushed and mylonitized that only exceptionally can an outcrop be referred to a specific unit of the Lunnister group. The eastern and western limits of the strip are ill-defined owing to the severity of the crushing which has occurred along the two lines of fault. Close to the northern margin of the map the Lunnister Metamorphic Rocks consist of four groups (Figure 3), which have been named from west to east (1) the Western Unclassed Group, (2) the Green Beds Assemblage, (3) the Calcareous Group and (4) the Banded Gneiss Group. It has proved possible to correlate these groups with geological units recognized in the Ollaberry–Gluss district of Northmaven, as shown in (Figure 4) and the table on p. 15.

This table summarizes, on the left, the groups and the lithology of the rocks which enter, or may enter the Lunnister area from the north; and, on the right, the groups of the Lunnister Metamorphic Rocks as subdivided for description in the following pages and their lithology.

Banded Gneiss Group

The rocks of the Banded Gneiss Group are best exposed along the west shore of Sullom Voe south of the Houb of Lunnister (Figure 3). They are mainly striped hornblendic and epidotic gneisses with which more micaceous and albitic components are interbanded. The foliation is vertical and the strike varies from north-east to north-west. The rocks are everywhere shattered, crushed or flasered and, in places, they are converted to banded mylonite. On the south coast of the Ness of Haggrister the group is cut out, since limestone, unknown in the Banded Gneiss Group, adjoins the Walls Boundary Fault. Green chloritic epidotic blastomylonite, which is exposed 70 yd (65 m) west of the fault, might possibly represent a faulted or thrust intercalation of the banded gneiss within the Calcareous Group.

Ollaberry–Gluss area
Foliated granite-with-schist of the Delting and Yell Sound Injection Complex
Walls Boundary fault
Bardister Gneiss (homblende-gneiss, hornblende-schist banded with mica-schist)
Calcareous Group (quartzose calc-schists with limestone and muscovite-schist bands)
Greenschist Group (laminated green and white schists, greenschist with 'pebbly' albites, intercalations of muscovite-schist and quartzite)
Siliceous Group (quartzites, fissile muscovite-schists, intercalations of green-schist and calcite-epidote-chlorite-schist)
sheared junctions

Hornblendic Group (hornblende-schist, banded hornblendic and feldspathic gneiss pyroxenic in part)
Intrusive contact in the north, faulted junction in the south
Unfoliated granite of the Western Plutonic Complex
Lunnister area
Foliated granite-with-schist of the Delting and Yell Sound Injection Complex
Walls Boundary fault
Banded Gneiss Group (epidotic, hornblendic and albitic gneisses, granulitized and mylonitized)
(calc-schists, limestone bands, quartz-schist and quartzite)
Green Beds Assemblage (chloritic, sericitic albite-schists with some fibrous amphibole and pyroxene, local amphibolite and felted amphibole-schist, quartzose schist graphitic in part, local conglomeratic greenschist, magnetite ore and skarn rocks at Clothister)
Western Unclassed Group (mainly mylonitic and crushed rocks, hornblendic gneiss at south end of South Ness)
Haggrister Fault
Unfoliated granite of the Western Plutonic Complex

Calcareous Group

The Calcareous Group is composed of a series of micaceous calcareous schists, together with some more quartzose and micaceous schists, and thin bands of dull grey microcrystalline limestone. The rocks are well exposed in the Ness of Haggrister and discontinuously farther north. Both the outcrop of the group and the strike of the foliation have a general N–S trend, but there are many local deviations in strike. The softer schists are greatly contorted and often flasered. The harder are shattered, disjointed and noded, while the limestones are deformed into small, complex folds. Near the mouth of the Lunnister Burn the rocks of this group are interflasered with gneiss of the Banded Gneiss Group.

On the low hill [HU 347 721] about 250 yd (230 m) N of the Loch of Lunnister, limestone and quartzitic rock are associated in a contorted mass resembling conglomerate. The quartzitic material occurs as spheroidal and oval bodies, up to 1 ft (30 cm) long, in contorted, thinly banded, micaceous, more and less calcareous schist alternating with hard, more siliceous ribs. The boulder-like bodies show healed shear fractures at low angles to their largest principal plane and the enveloping beds are milled to fine grain. Though many of the bodies are isolated like boulders, in other places they are connected in a noded structure. No conglomerate has been observed in the Calcareous Group farther north and it is believed that this rock is a pseudo-conglomerate produced by local intense disruption or boudinage of hard bands and reshaping of the pieces under continued shear stress.

Along the south coast of the Ness of Haggrister grey phyllitic micaceous schists, calcareous schists, and bands of limestone are involved with green-schists in complex folding. In general the folds are tight with vertical axial planes, but there are narrow zones of corrugated beds in which the overall dip is almost horizontal. In the cliffs immediately east of the beach the folds are seen to plunge north. Midway between the beach and the Walls Boundary Fault (Figure 3) a crush-zone is exposed. Calcareous members are abundant east of this zone, micaceous and green schists are predominant to the west. The close interleaving of calcareous beds with rocks ascribed to the Green Beds Assemblage and the prevalence of shearing and mylonitization in the Ness of Haggrister section, combined with the westward reappearance of the Calcareous Beds inland north of the beach (Figure 3), imply that their association at the Ness is essentially tectonic. All specimens from the Ness coast section in the Institute's collection are of mylonitized rocks. The area appears to be dominated by a series of closely spaced planes of movement which are now vertical and which diverge in a narrow fan northwards. Along these planes mylonitization without obvious rupture and, more rarely, crushing have taken place. Between the planes the beds are alternately close folded with shearing and open folded. The impression gained is of a series of beds of varying but generally low competence which have been compressed between two more competent groups converging towards the south.

South of the Ness of Haggrister the Calcareous Group is found only on the western shore near the head of Busta Voe (Figure 5). The rocks in the dislocation zone are here shattered and crushed and are largely indeterminate but a calcareous zone with limestone has been traced for 250 yd (230 m) along the coast. Granite with schist inclusions of the Delting Complex crops out on the northeasterly turn of the coast and the limestone outcrop must lie very close, within 25

yd (23 m), to the Walls Boundary Fault.

Green Beds Assemblage

The rocks of this assemblage include siliceous, feldspathic, sericitic and chloritic schists. Feldspathic schist composed of comparatively large grains, 0.5 to 1.00 mm, of albite-oligoclase in a sericite-chlorite base, forms an important component of the assemblage. In many of the feldspathic schists aggregates of fibrous colourless or pale green amphibole are present. More basic rocks composed of green hornblende and plagioclase with some saussurite or epidote are minor components. The group has therefore been distinguished as the Green Beds Assemblage though it is not so typical of Green Beds as the series of laminated green schists and metabasaltic rocks which lies west of the Calcareous Group in the Ollaberry area of North Mainland. Graphitic schists are present in the Lunnister Green Beds Assemblage of this area, and as these have not been recorded in association with either the Green Beds or the Calcareous and Siliceous groups around Ollaberry, the correlation of the groups in the two areas is imperfect. The assemblage includes also an important component of quartzose schists which may represent the quartzites of the banded quartz- and muscovite-schists of the Ollaberry section. It has not been found possible to make any satisfactory separation in (Figure 4) between the siliceous, graphitic and greenschist components of the assemblage.

Busta isthmus and South Ness

No rock in the narrow part of the dislocation zone between the Haggrister and Walls Boundary faults in the Busta–Sullom isthmus [HU 348 680] is sufficiently recognizable for positive assignment to the Green Beds Assemblage. On South Ness, however, sericitic and chloritic albite-quartz-schists exposed along the eastern coast are appropriately included in the group. They are polymetamorphic schists which show an earlier foliation on which has been superimposed a schistosity which is related to the prominent folding of the rocks. This schistosity is traversed by mylonitic schlieren.

Haggrister–Lunnister area

Along the central part of the south coast of the Ness of Haggrister tightly folded and sheared chloritic and micaceous schists are interlayered with calcareous schists and limestones of the Calcareous Group. The latter are not seen west of the crush-zone [HU 360 700] which crops out near the most southerly point of the Ness, and the crush zone is taken as a convenient position for a mapping line between the Calcareous Group and the Green Beds Assemblage. At the western end of the coastal cliffs, close to the Bight Fault (Figure 3), the rocks are deformed into tight northward plunging folds and, in places, severely crushed.

Rocks referable to the Green Beds Assemblage are exposed near the east and north-east shores of the Loch of Lunnister where they include epidotic hornblende-albite-phyllonite, albite-hornblende-schist, epidote-hornblende-pyroxene-mylonite and a crushed rock which appears originally to have been a phyllonitized albite-schist. All these rocks contain varying amounts of finely divided graphitic matter, and a black pyritous schist has been recorded near the south-west and west banks of the loch. The group also includes a granulitized schistose grit which is exposed in a knoll 500 ft (150 m) S of the loch.

Deformed conglomerate has been recorded by Dr. F. May in the area [HU 344 722] between the Loch of Lunnister and the Burn of Vestavirdin. This contains a variety of pebbles, including quartzite and granulitized tonalite, set in a dark greenish schistose matrix composed of green hornblende, brown biotite, chlorite, epidote, optically positive sodic plagioclase and local quartz. The pebbles have been deformed into elongate ovoids, the collected quartzites ranging up to 8 in (20 cm) in length and up to 2 x 1.25 in (5 x 3 cm) in cross section. Though none of the pebbles appear to be volcanic ejectamenta, the matrix of the conglomerate can only have been derived from basaltic material. Both in the nature and shape of the pebbles and in the basic composition of the matrix, this conglomerate is comparable with the Funzie Conglomerate of Fetlar (Summ. Prog. 1930, p. 83; Flinn 1956). No similar conglomerate has been found elsewhere on the Mainland of Shetland.

Vesta Virdin–Clothister area

In the Burn of Vestavirdin, just south of Clothister Hill, pyritous graphitic schists and a massive dark green epidotic amphibolite are exposed. North of the burn a large quarry [HU 342 728] exposes green schists faulted against graphitic schists. The green schists contain a band up to 2 ft (60 cm) thick of garnet-magnetite rocks within a zone of calcsilicate rock, an association which is the same as that of the ore and skarn of Clothister Hill (p. 20). The rocks in the quarry also contain thin white bands composed of mylonitic calcite and rock fragments, which may have been ribs of limestone.

The country rocks of Clothister Hill were seen in trenches dug during the exploration of the magnetite deposit (pp. 285 and 287). They consist of banded or foliated quartz-, quartz-albite- and albite-schists in which sericitic, chloritic and tremolitic laminae are common and biotite is rare. Graphitic phyllonite was recorded in one locality close to the ore margin. Practically all the specimens show either mylonitization or phyllonitization, followed by recrystallization. Many have a second schistosity superimposed on an earlier schistosity or foliation. The inclined bores sunk to investigate the orebody at depth ((Figure 30), pp. 285–7) encountered chloritic and graphitic schists, the foliation of which is inclined at 35° to 60° to the west. Nine borings put down on positions of high magnetic anomaly 388 to 450 yd (350–400 m) N of the orebody proved mainly sericitic, chloritic and graphitic quartz- and albite-schists which have been subject to two foliations and are in places smashed or mylonitized. The most westerly bore and the upper 169 ft (51.5 m) of the most easterly bore traversed calcareous quartz-schists, suggesting that tectonic slices of rocks belonging to the Calcareous Group are present in this area. In some of the bores a rock described as 'granite injection schist' has been recorded. Though no specimen is available this material is unlikely to be injection gneiss in the usually accepted sense of the term.

Clothister Hill magnetite and skarn

The Clothister Hill orebody, the exploration, shape, size and quality of which are described on pp. 285–7, lies in schists of the Green Beds Assemblage. Neither the ore nor the skarn show evidence of the severe deformations which affected the country rocks, but they are affected by minor slipping and faulting. It is believed that the magnetite ore was introduced and the skarnization of the country rocks induced along a narrow pre-existing dislocation belt. The skarn sheath enclosing the magnetite body consists essentially of garnet, hornblende, pyroxene and epidote and its chemical analysis shows that it is rich in lime (Phemister in press, table 3). This suggests either that the ore has replaced a lens of limestone or that there has been an accession of lime and iron from an unknown source. The petrographical evidence tends to favour the latter hypothesis, as in one specimen the magnetite has replaced hornblende-albiteschist and as the calcite associated with the skarn is a late introduction. The source of the iron is uncertain; it may be derived from the pyrite which is abundant in some of the rocks of the Green Beds Assemblage, and which in some schists adjacent to the ore deposit is replaced by magnetite.

The ore and skarn, though close to the margin of the Northmaven Plutonic Complex, are not in contact with the plutonic rock. Both Groves (1952, pp. 294–5) and Phemister consider that the emplacement of the ore was not related to the intrusion of the granite part of the complex. No scapolite has been found in the skarn, nor have any boron or fluorine minerals.

Summary

From the petrography of the complex group of rocks forming the Green Beds Assemblage and the skarn and magnetite ore of the Clothister–Lunnister area the following conclusions can be drawn:

1. The metasediments comprised carbonaceous silts and basic tuffs with which thin basic igneous sheets were associated. The metasediments are characterized by abundance of a plagioclase with about 10 per cent of the anorthite molecule.
2. This group of rocks was already metamorphosed to greenschist and associated types before a metamorphism of an essentially dynamic type produced a second foliation and mylonitization.
3. The magnetite ore and skarn sheath are only locally affected by shear.
4. There is direct evidence that the ore is replacive in greenschist, but no similarly direct microscopic evidence that it has replaced mylonitized schists. There is some evidence of early oxidizing conditions prior to the ore mineralization.

Western unclassed rocks

The rocks occupying the strip along the margin of the Northmaven Granite are probably mainly referable to the Green Beds Assemblage. Where seen near the Haggrister Fault which bounds the granite, they are greatly shattered. The shattered rock includes a blastomylonite which has tight folds with horizontal axial planes and in which there is vague evidence of an earlier foliation. Other exposures show mylonitic and phyllonitic rock ranging in type from schistose grit to graphitic schist. One foliated crush-rock contains grains of blastomylonite. At South Ness (Figure 3) and at Clothister there are some banded hornblende-feldspar rocks which can be referred with considerable assurance to the banded hornblendic gneiss of the Fethaland Series (Figure 4). These rocks show intricate folding, plastic disruption and differential mylonitization superimposed on an earlier foliation. Mylonitized feldspathic rocks from the upper part of the most westerly boring on Clothister Hill are thought to represent feldspathic members of this group, while basic rock from a lower level in the same bore could be either a basic member of this group or a metabasalt from the Green Beds Assemblage which has been mechanically intercalated.

All the rocks show some form of post-deformation recrystallization tending towards an unstrained or unorientated condition, but without any mineralogical change indicative of further metamorphic transformation. There is no evidence of thermal alteration by the granite except in one anomalous case. Late veining by potassium-feldspar has been noted. There is also evidence of post-deformation veining by calcite and analcime and post-fault veining by calcite and calcic zeolite.

Structural interpretation

The dislocations affecting the rocks in the Busta–Haggrister fault-zone are of two types. Of the more obvious type are the faults which produce sharp breaks and have only minor shatter and shear belts. Examples are the Haggrister Fault and the Walls Boundary Fault, which are shown in (Figure 3) by the usual fault ornament. Of the second type are the dislocations which affect the rocks between these faults. They are of a type involving shearing, refoliation, mylonitization and phyllonitization. Petrographical evidence (see Phemister in press) shows that in the central area mylonitic and phyllonitic deformation affected a schistose 'green beds' assemblage and a probably older formation of banded hornblendic gneisses and that a later deformation caused a second folding which induced a new cleavage or schistosity and varying degrees of flasering and shearing.

The general distribution of the rocks in the Lunnister area and its northward continuation (Figure 4) suggests that they occupy a tight northward plunging synform with a near-vertical axial plane. The core of this synform contains variably competent sediments which are bounded by massive banded gneiss on both flanks. In the area which falls within the Western Shetland map the gneisses on the eastern flank are mylonitized and marginally interleaved with the rocks of the core. On the western flank the structural relations of the gneiss with the metasediments are almost completely obliterated by the granite intrusion, but the vestiges of greatly deformed gneiss and of mylonites which are considered to represent gneiss indicate that this flank also formed a zone of essentially mechanical dislocation. The structure is now that of a vertical wedge thinning towards the south into the position of the Aith Voe–Busta Voe Fault. At the south end of the wedge the rocks are entirely mylonite and only rarely, as in the case of the limestone on the coast north of Busta, has even the rock group been determined. As the wedge broadens northwards the rocks of the core become identifiable at Haggrister as representing the Calcareous, Green Beds and, possibly, the Siliceous groups of North Mainland. They are, however, so contorted, interfolded, and locally mylonitized that separation of them into these groups is uncertain and even distinction of the core rocks from the gneiss of the eastern flank is conjectural. From Lunnister northwards separation into the groups becomes possible. The rocks of the core continue to be highly contorted and flasered, and mylonitization appears to be more frequent and increasingly more severe towards the western flank.

The structure and polymetamorphic condition of the rocks in the Lunnister area may have been produced by a sequence of events as adumbrated by one of the following hypotheses.

1. Rock formations already regionally metamorphosed were further deformed by folding in a tight northward-plunging syncline, the axial plane of which was vertical and along the sides of which smaller scale tight folding and shearing

took place. Dislocation involving flasering and mylonitization of beds and mechanical interpolation of groups occurred along the smaller folds on the flanks and probably also along more central planes.

2. The metamorphic formations were involved in a local recumbent fold along the upper and lower limbs of which low-angled thrusting and imbrication, with concomitant mechanical metamorphism, took place. The folded rocks were later rotated into verticality on the north-eastern limb of a great fold on a NW–SE axis which affected the existing N–S strike of the Northmaven metamorphic formations and the E–W strike of their counterpart along the northern coast of the Walls Peninsula.
3. Formations already regionally metamorphosed to higher grade gneisses and lower grade schists were re-orientated in a fold of great amplitude with steep NW–SE axial plane as outlined in (2) above. On the north-eastern limb of this fold a succession of subsidiary complex folds and dislocations, accompanied by much mechanical reconstruction, was induced by constriction of the limb towards the culmination of the fold at a position immediately south of the Lunnister–Busta area.

Phemister's detailed account has demonstrated a succession of periods of deformation affecting the already metamorphosed Lunnister rocks and offers some support thereby to the second hypothesis. This hypothesis is supported also by the evidence in the Eela Water area (see the Geological Sheet of Northern Shetland, 1968) of a major displacement of hornblendic paragneisses which appears to have been caused by sharp folding and lateral movement on NNE–SSW lines. On the other hand the evolution of a NW–SE fold of such magnitude as the broad structure of the metamorphic rocks of the Northmaven–Walls region indicates must have been prolonged in time and involved subsidiary, locally intense tangential adjustments at intervals. The third hypothesis may therefore be considered preferable.

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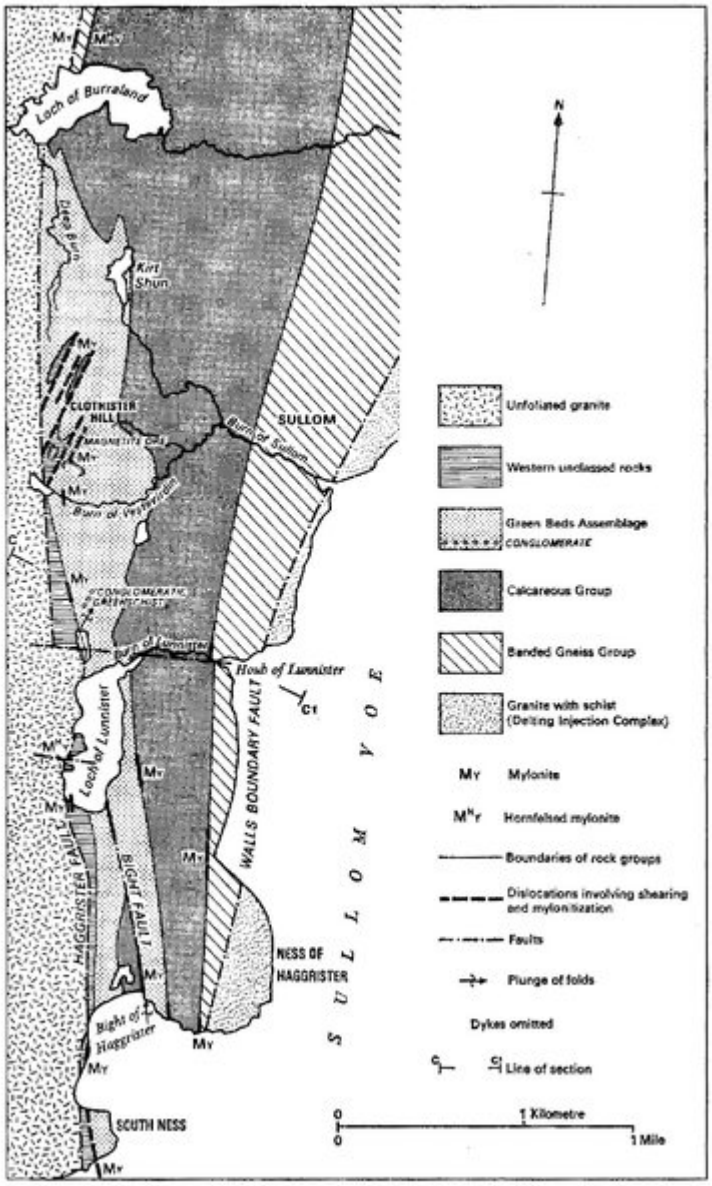
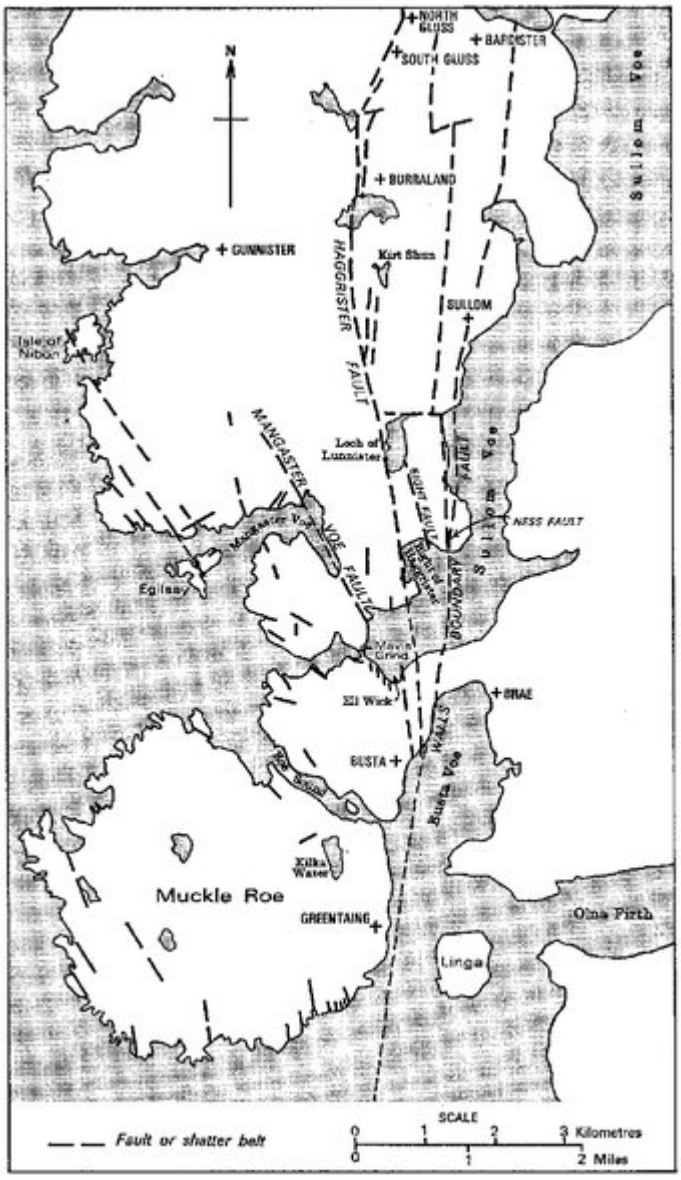
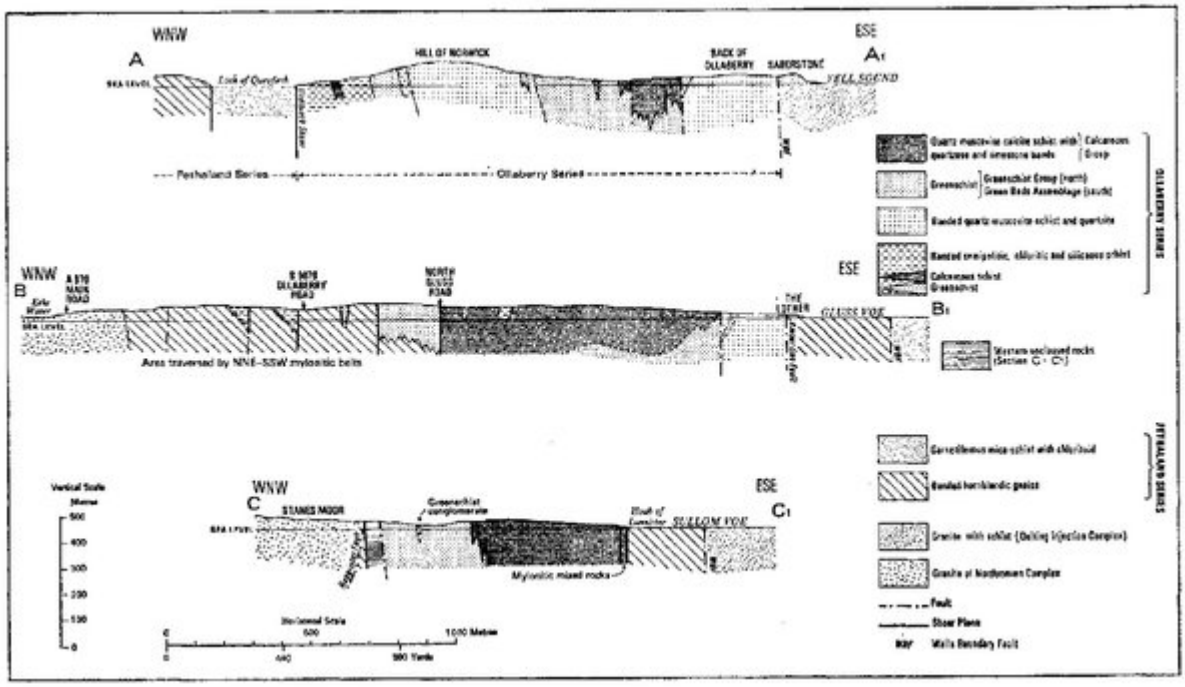


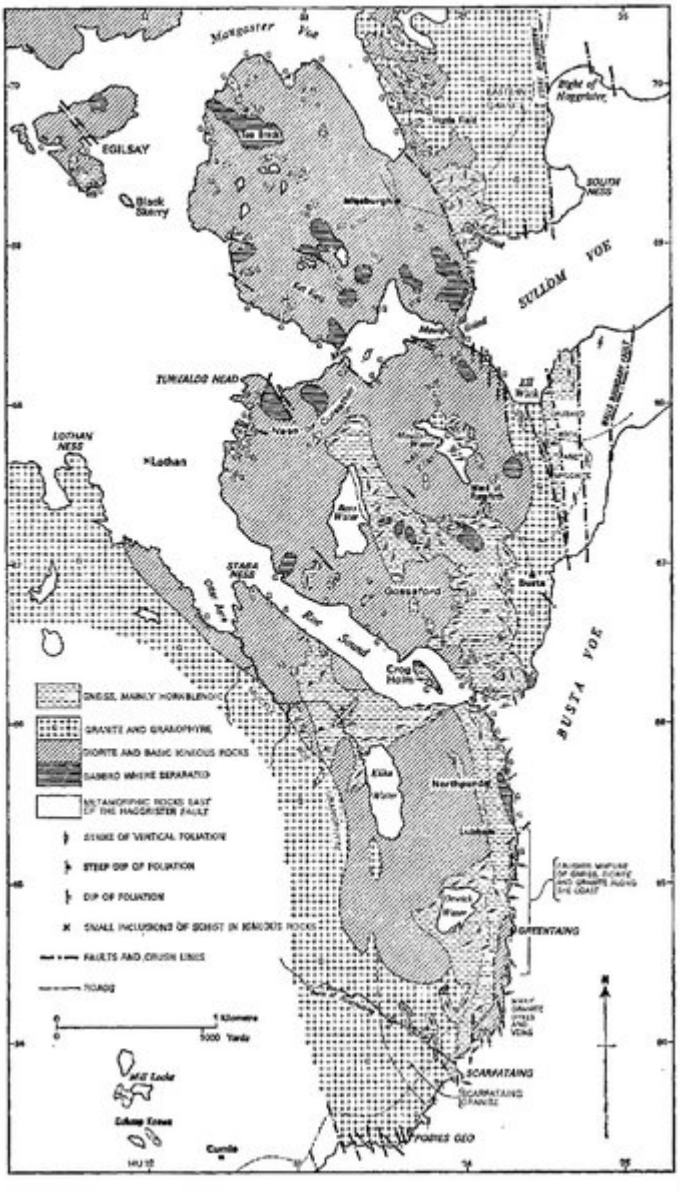
(Figure 3) Geological sketch map of the metamorphic rocks of the Lunnister area For section C–C1 see (Figure 4).



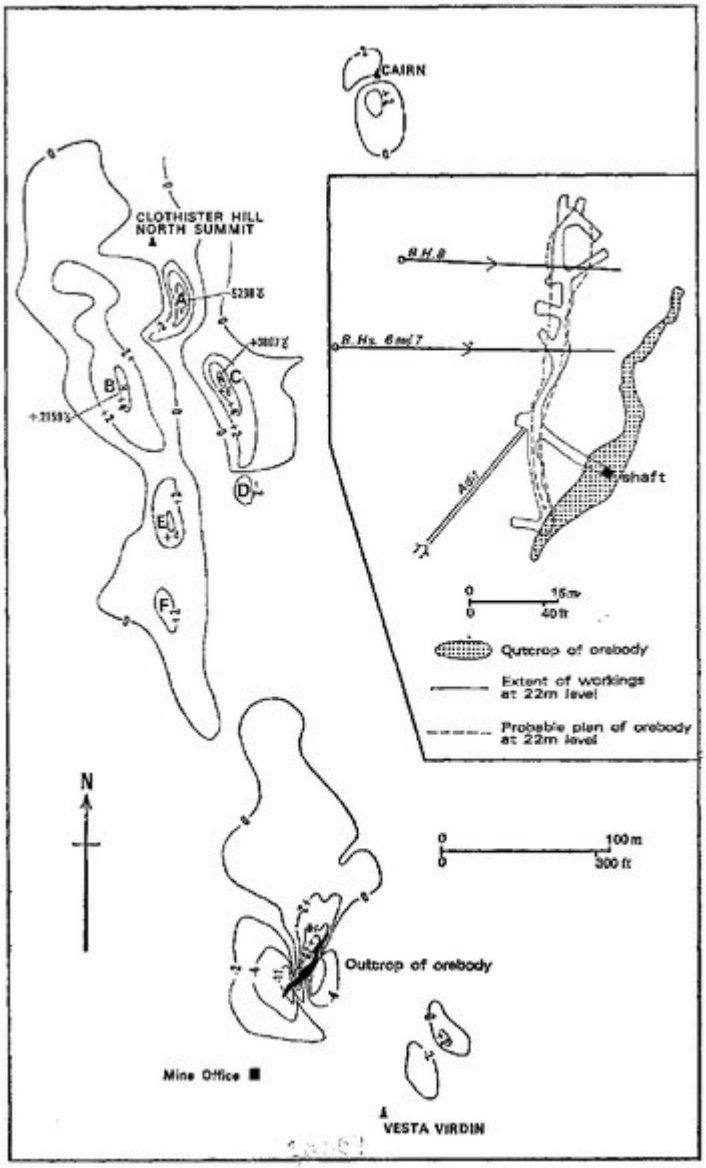
(Figure 27) Major faults in the area north of Busta Yoe.



(Figure 4) Horizontal sections across the metamorphic rocks of Northmaven and the Lunnister area Sections A—A_1 and B—B′ are entirely in the area north of the present sheet. (Locations: A = [HU 349 818], A′ = [HU 377 808], B = [HU 335 793], B′ = [HU 778 365]). The line of section C–C′ is shown in (Figure 3).



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



(Figure 30) Magnetic anomaly map(of the area around and north of Clothister Hill magnetite mine. Contour interval 2 gammas except in areas of high magnetic gradient. Inset: Plan of outcrop of orebody at surface and position of orebody at 22m level. Also positions of three inclined bores sunk to prove orebody at depth.