Chapter 1 Introduction

Location and area

The region described in the following account comprises most of the area shown on the one-inch-to-one-mile Geological Survey map of Western Shetland. It includes the Walls Peninsula and the south-western part of Northmaven, which are part of the main island of Shetland (Mainland), as well as the adjoining islands, the largest of which are Muckle Roe, Vementry, Papa Little, Papa Stour and Vaila (Figure 1). A description of the island of Foula, which is 14 miles (22.5 km) SW of the Walls Peninsula, is also included. The total land area involved is approximately 115 square miles (298 km^2). In addition a brief account is given of the submarine topography of the sea area adjoining Western Shetland.

The narrow strip of metamorphic and igneous rocks east of the Walls Boundary Fault (Figure 2) is not described in this memoir, as it will be dealt with in the account of the Geology of Central Shetland.

Physical features

The area forms a geological and morphological entity, as it is separated from the eastern part of Shetland Mainland by the north–south trending Walls Boundary Fault. This major dislocation, which is considered by Flinn (1961, p. 589; 1969, pp. 290–1) to be the northern continuation of the Great Glen Fault, separates two areas of strongly contrasting geology and topography. The ground to the east is formed of metasediments, migmatites and partially recrystallized 'granites', all of which have a consistent north–south trend at this latitude and give rise to smooth, rounded north–south trending ridges and partially drowned valleys. The country west of the fault has a much more complex structural pattern and is composed of a variety of rock types, each of which has imparted its distinctive character to the landscape.

The northern coastal belt of the Walls Peninsula and Vementry Island, which are formed of a varied suite of metamorphic rocks, have a rugged topography with many rock-knolls and escarpments, reminiscent of the Lewisian Gneiss topography of the north-west Highlands (Plate 5A). South of this belt the Walls Peninsula is to a large extent made up of the Walls Sandstone, an Old Red Sandstone formation composed predominantly of sandstone with subordinate volcanic rocks. Along the northern part of its outcrop the Walls Sandstone has a consistently steep south-south-easterly dip, is composed of massive sandstones with conglomerates and intercalated lavas, and gives rise to a rugged terrain with prominent west-south-west trending ridges and escarpments and a high proportion of exposed rocks. Farther south, particularly in the eastern and central parts of the peninsula, the Walls Sandstone has a much more complex structure and contains fewer massive sandstones and no conglomerates or lavas. In consequence the topography has no regular directional pattern and consists of scattered areas with abundant rocky outcrops separated by large areas of flat or undulating peat bog. In the west of the peninsula the Walls Sandstone forms Sandness Hill (817 ft [249 m] OD) and Stourbrough Hill (567 ft [173 m] OD) the highest hills in the area. In the south-west of the peninsula and in Vaila the more regularly folded Walls Sandstone again produces more abundant rocky outcrops and some rudimentary scarp and dip topography.

In contrast to the irregular landscape produced by the Walls Sandstone, the softer and more gently inclined Melby Sandstone, which crops out at Sandness in the north-west corner of the peninsula, forms low, fertile ground reminiscent of the landscape of Orkney. The Melby Sandstone is overlain by a series of basalt and rhyolite lavas which form almost all of the island of Papa Stour. Because of their near-horizontal disposition the Papa Stour volcanic rocks form a featureless plateau bounded by magnificent sea-cliffs.

The southern part of the Walls Peninsula is formed of igneous rocks of the Sandsting Complex, which gives rise to an undulating topography with a number of prominent rounded hills, and relatively few inland exposures, but with impressive coastal cliffs.

The south-western part of Northmaven is formed principally of diorite with numerous gabbroic bodies and many granite veins. The diorite is bounded on the east by a strip of granite, 0.5 mile (0.8 km) wide, which in turn adjoins a series of north-south trending metamorphic rocks. Both the diorite and granite form rugged rocky outcrops, while the metamorphic rocks to the east have produced a smoother terrain with north-south trending ridges. The third major igneous body of Western Shetland is the granophyre, which forms the greater part of Muckle Roe and gives rise to extremely rugged, rocky terrain with extensive screes that rises to a height of 557 ft (169 m). The granophyre also forms the most continuous sheer sea-cliffs in Western Shetland.

The drainage of the Walls Peninsula has a radial aspect, with nearly all streams flowing directly to the sea from a central east-west trending divide. In the northern part of the peninsula there are a number of drowned valleys, such as those now occupied by Brindister Voe [HU 290 560] and Aith Voe [HU 350 580], whose orientation is determined by north to north-north-east trending faults and in the west the Deep Dale [HU 183 548] and the valley of the Burn of Dale are excavated along bands of relatively soft Old Red Sandstone sediments. Apart from these examples, structural control of drainage is found on Muckle Roe, where a number of streams follow the lines of north-north-west trending crush belts.

The effects of the ice sheets, which overrode the area in the Pleistocene Period, and the subsequent rise of sea level around Shetland have been major factors in the shaping of the present topography. The north-west and westward movement of ice over the greater part of the area has produced a strongly ice-moulded terrain, particularly in the more rocky ground, and has been responsible for the numerous scoured-out hollows which are now occupied by inland lakes. Some of the major straits such as the Swarbacks Minn between Vementry and Muckle Roe may be partially due to glacial overdeepening. The virtually continuous rise of sea level since the last glacial maximum has produced the 'drowned landscape' topography of Shetland. The most characteristic features of this are the numerous long, shallow, at times twisting, sea lochs which are locally termed 'voes'. The continuous subsidence of the land coupled with the strong prevalent westerly winds has also been responsible for the rapid marine erosion along the exposed coasts of the area, which has produced impressive cliffs.

The island of Foula is a roughly pear-shaped island formed mainly of massive gently inclined sandstone. It has a considerably greater relief than western Mainland, and rises in the west into a series of hills with steep north-east-facing escarpments which contain several well-formed corries. The Sneug, the highest of these, attains a height of 1373 ft (418 m). The sandstone forms continuous sheer cliffs along the west coast of the island, and at The Kame the cliff reaches a height of 1220 ft (372 m), which makes it one of the highest sea cliffs in the British Isles. Metamorphic and granitic rocks form the relatively low 2 mile (0.8 km) wide north-eastern coastal strip of the island.

History of research

The earliest references to the rocks of Western Shetland usually deal with isolated records of minerals and semi-precious stones. Thus George Low (Rev. A. Low 1879) who visited the islands in 1774 referred to the presence of bog iron ore on Vaila, and also noted the abundance of tree roots and branches low down in the peat-mosses. The first attempt at a systematic account of Shetland geology is that of Robert Jameson (1798; 1800) who commented on the dependence of the topography on the strike of the rocks and first recognized that the Walls Sandstone is related to the sandstones and conglomerates of the Lerwick–Sumburgh coast. He also put on record that the greater part of Foula is largely composed of sandstone and recognized the presence of metamorphic rocks and granite along the eastern coast of that island. The account of Shetland Mineralogy by Fleming (1811 and *in* Shireff 1817) describes the lavas and tuffs of Papa Stour, which the author took to be 'wacken' (i.e. sedimentary rocks). Fleming considered the associated sandstones to be similar to the Sandstones of Foula and Bressay in which he had found plant impressions.

The most important of the early works on the geology of Shetland are those by Hibbert published in 1819, 1820 and 1822. These include the first geological map of Shetland, which is on the scale of 9.5 miles to the inch, and a more detailed map (1822) on the scale of 3.9 miles to the inch. Hibbert drew attention to the great induration of the Walls Sandstone which so impressed him that, in spite of its resemblance to the sandstones of the east coast, he separated it from the latter and called it 'primitive quartz rock' (1822, p. 158). Ami Boué in his '*Essai géologique sur l'Ecosse'* (1820) incorporated the observations of Jameson, Fleming and Hibbert but also pointed out that the lavas and tuffs of Papa Stour bear a close resemblance to the products of extinct volcanoes. On Nicol's geological map of Scotland published in 1858 the Walls Sandstone is shown as partzite, but the sandstones of Melby and Papa Stour are coloured and named is

Old Red Sandstone. Heddle (1878, pp. 113–8, 124–30) described the geology of the islands of Papa Stour and Foula as well as the areas around Gruting Voe, Seli Voe and Bixter Voe on Mainland. He produced a comprehensive list of linerals found in amygdales and veins in the basalts and rhyolites of Papa Stour.

The next major advance in our knowledge of the geology of Western Shetland resulted from a series of investigations of the glacial and solid geology of the entire island group by Peach and Horne. They established that Shetland had first been overrun by Scandinavian ice and that it later nourished its own local ice cap (Peach and Horne 1879b). Of major importance was their discovery of plant remains in the indurated Walls Sandstone near the village of Walls (Geikie 1870; Peach and Horne 1879b; Peach and Horne *in* Tudor 1883, pp. 381 108), which proved that this sandstone is of Old Red Sandstone age. They also recorded the presence of tuffs and lavas in the Walls Sandstone and produced a short description of the Sandsting Complex. Some of the results of Peach and Horne's work had been incorporated in Geikie's account of the Old Red Sandstone of Western Europe (1879). Geikie had himself examined Papa Stour (1879, pp. 418–21) and demonstrated the contemporaneous character of its tuffs and basic lavas, but concluded that the rhyolite was a large intrusive sill.

At the beginning of this century Lewis (1907; 1911) made a detailed study of the vegetation zones of the peat deposits of the Walls Peninsula and produced the first and, as yet, only account of the post-glacial vegetational and climatic history of Shetland.

The comprehensive account of the Old Red Sandstone of Shetland by Finlay (1926, pp. 553–72; 1930, pp. 671–94) deals with the sediments, contemporaneous volcanic rocks and plutonic complexes of Western Shetland and Foula. Finlay discovered a new plant locality at Watsness in the Walls Sandstone, and established that the rhyolite of Papa Stour is a lava flow. He gave a full description of the petrography of both the contemporaneous igneous rocks and the plutonic complexes of Sandsting, Muckle Roe and Northmaven. Like earlier geologists he concluded that these complexes form part of an intrusive sheet, which probably underlies the Walls Syncline.

The geological mapping of Western Shetland on behalf of the Geological Survey was carried out during the period extending from 1931 to 1934 by G. V. Wilson, D. Haldane, T. Robertson, J. Knox and S. Buchan (Summ. Prog. 1932, p. 63; 1933, pp. 77–9; 1934, pp. 70–3; 1935, pp. 67–9). The results of their work are incorporated in this memoir and on the one-inch Geological Map of Western Shetland. Some of the more significant advances resulting from this survey include the discovery of a fish bed in the Melby Sandstone, whose fauna was shown by Watson (1934, pp. 74–6) to be similar to that of the Achanarras Limestone of Caithness and of the Sandwick Fish Bed of Orkney, the recognition that the northern boundary of the Walls Sandstone is an unconformity over much of its course, and the discovery of a magnetite ore-body of considerable size on Clothister Hill, in the north-eastern corner of the area. A detailed account of the subsequent exploration and the geology of the Clothister magnetite has since been produced by Groves (1952). Charlesworth (1956) briefly summarized the evidence for the presence of conic glaciers in late–glacial times in Western Shetland.

Flinn (1961, p. 581) has suggested that the Walls Boundary Fault is the northward continuation of the Great Glen Fault and has more recently (Flinn 1969, p. 291) claimed that it may have a post-Old Red Sandstone dextral displacement of 65 km. Flinn (1964, pp. 321–40) has also given an account of the coastal and submarine features around the Shetland Islands and has recognized several submarine shelves. Miller and Flinn (1966, p. 107, table 4) obtained radiometric age dates of Shetland rocks. Flinn and others (1968, pp. 10–19) also carried out an investigation into the radiometric age of sediments and volcanic rocks of Western Shetland.

During 1964 a Swedish party headed by Hoppe studied post-glacial lake deposits in Shetland and carried out an investigation into the directions of ice-movement in the islands (Hoppe and others 1965). Samples of lake deposits collected by them were dated by the C14 method.

Mykura and Young (1969) have described the field relationships, petrology and chemistry of the sodic scapolite which occurs in crush belts and veins within and close to the Sandsting Granite–Diorite Complex.

Summary of geology

The following statement sets out the geological formations present in Western Shetland :

SUPERFICIAL DEPOSITS (DRIFT) RECENT AND PLEISTOCENE
Blown sand
Peat
Present beach deposits
Stream- and lake-alluvium
Glacio-fluvial sand and gravel
Boulder clay and morainic drift
SOLID FORMATIONS
SEDIMENTARY AND BEDDED VOLCANIC ROCKS
Old Red Sandstone
Foula Formation (probably Middle or Upper)
Melby Formation (probably high Middle): Papa Stour Rhyolites and Acid Tuffs
Melby Formation (probably high Middle): Papa Stour Basalts
Melby Formation (probably high Middle): Melby Sandstone containing
Melby Formation (probably high Middle): Melby Fish Beds
Walls Formation (probably low Middle)
Sandness Formation (probably low Middle or Lower), including Clousta Volcanic Rocks with basalts, andesites, ignimbrites and agglomerates
METAMORPHIC ROCKS (not in stratigraphic order)
Metamorphic Rocks of Foula
Metamorphic Rocks of the Walls Peninsula
SOUTH: Snarra Ness Group (mainly hornblendic)
SOUTH: West Burra Firth Group (calcareous)
SOUTH: Neeans Group (platy, feldspathic)
NORTH: Vementry Group (mainly homblendic)
Metamorphic Rocks of Lunnister
EAST: Banded Gneiss Group
EAST: Calcareous Group
EAST: Green Beds Assemblage
WEST: Western Unclassed Group
Enclaves of metamorphic rocks in the Northmaven–Muckle Roe igneous complexes
Ve Skerries Gneiss
IGNEOUS ROCKS
Minor intrusions (probably all late-Caledonian post-tectonic)
Basic and sub-basic dykes and sills: basalt, dolerite, quartz-dolerite, porphyrite, microdiorite, spessartite and unclassed dykes.
Acid dykes, sheets, laccoliths and irregular intrusions: felsite, quartz-porphyry, feldspar-porphyry and microgranite.
Caledonian plutonic complexes (mainly post-orogenic)
Sandsting Complex: granite, microgranite, porphyritic micro-adamellite, granodiorite, syenodiorite, diorite, gabbro. Associated minor intrusions of melanic micro-diorite.
Vementry Granite: granite.
Muckle Roe Granophyre: granophyre, leucogranite.
Northmaven Complex: granite, diorite, gabbro-diorite, gabbro and subordinate ultrabasic types.

The superficial deposits are shown on a separate 'Drift' edition of the one-inch map.

Metamorphic rocks

The metamorphic series enumerated above form completely distinct units which cannot be correlated with each other, and whose relative ages are as yet unknown.

The Metamorphic Rocks of the Walls Peninsula crop out in a belt 1 to 2 miles (2–3 km) wide, along the north shore of the peninsula. They comprise four groups of metasediments within all of which the foliation has a predominant east-north-easterly trend and is inclined at 40 to 70 degrees to the south-south-east. Two of the groups (Snarra Ness and Vementry) contain a high proportion of hornblende-schist and the calcareous West Burra Firth Group contains much tremolite-schist and many calc-silicate-rich limestones. The rocks have been involved in at least three phases of folding and four distinct metamorphic episodes, two of which were retrograde. During the main phase of prograde metamorphism the rocks of the succession reached equilibrium under pressure-temperature conditions which characterize the topmost subfacies of the green-schist facies.

The lithology and metamorphic and tectonic development of the Metamorphic Rocks of Foula are closely similar to those of the Walls Peninsula metamorphic rocks, and it is believed that the two successions may originally have been part of a single larger unit.

Muckle Roe–Northmaven area

The metamorphic rocks exposed in the Muckle Roe–Northmaven part of the area form two distinct structural units. The western unit consists of large and small masses of contact-altered paragneiss, composed of hornblendic, pelitic and psammitic beds, within the Northmaven–Muckle Roe igneous complex. The eastern unit, which forms the Metamorphic Rocks of Lunnister, is composed of four groups of gneiss and schist, termed from east to west the Banded Gneiss Group, the Calcareous Group, the Green Beds Assemblage and the Western Unclassed Group. These have a general north-south trend and a near-vertical inclination. They are cut and bounded by at least four major faults which fan out northwards and form the northward continuation of the Walls Boundary Fault. The zone of dislocation formed by these faults is termed the Busta–Lunnister Fault Zone. It has a wedge-shaped outcrop, which widens from 200 yd (180 m) near Busta to 675 yd (617 m) at the Ness of Haggrister and over a mile (1.6 km) at the northern margin of the sheet. The rocks within the zone have been extensively sheared and mylonitized by a series of dislocations which preceded the later brittle movements that produced the faults.

Ve Skerries

The Ve Skerries, a series of low rocky islets situated in the Atlantic Ocean 3.5 miles (5.6 km) NW of Papa Stour, are composed predominantly of granite-gneiss with lenticular masses of foliated granite and two bands of hornblende-schist.

Sedimentary and contemporaneous volcanic rocks

The greater part of the Walls Peninsula is composed of the Walls Sandstone (Finlay 1930) which is of possibly Lower and Middle Old Red Sandstone age. This has been affected by two periods of folding, which produced firstly a complex east-north-east trending synclinorium and later a series of north to north-north-east trending folds, which are only locally developed. The Walls Sandstone consists of two major stratigraphic units which are separated from each other by the east-north-east trending Sulma Water Fault (Figure 2). The lower unit, here called the Sandness Formation, is north of the fault. It rests unconformably on the metamorphic rocks of the Walls Peninsula, has a consistent east-north-easterly trend and a steep dip to the south-south-east. It is composed mainly of massive sandstones with some bands of breccia and conglomerate and contains the Clousta Volcanic Rocks, a suite of basic lavas, ignimbrites, tuffs, and predominantly acid agglomerates, near its top. Its exposed thickness varies from 4500 to 6000 ft (1370–1800 m) in the east to possibly 12 000 ft (3650 m) in the west, and its lithology indicates that it was deposited largely in a fluvial or basin-marginal environment and that the source of the sediments lay to the north-east.

The upper unit of the Walls Sandstone, here termed the Walls Formation, crops out south of the Sulma Water Fault. It comprises up to 30 000 ft (9150 m) of generally hard, indurated sediments, consisting mainly of fine- to medium-grained sandstones with intervening siltstones and shales whose lithology bears some similarity to flysch deposits and turbidites. Its sparse fossil content indicates that it was laid down in fresh water. The outcrop of the Walls Formation contains two intersecting belts of intensely folded sediments, whose axes trend respectively east-north-east and north to north-north-east. The finer-grained sediments within these fold belts have taken on a cleavage and lineation, whose geometry reflects that of the major folds.

Fish-scales and -plates have been found in several localities in the Walls Formation, while poorly preserved plant remains occur both in the Walls and Sandness formations. The fish remains appear to indicate that the Walls Formation is of Middle Old Red Sandstone age, while the plant remains from the Sandness Formation do not rule out a Lower Old Red Sandstone age for the latter.

The Melby Formation crops out in the north-west corner of the Walls Peninsula and on Papa Stour, and is separated from the Walls Sandstone and the metamorphic rocks by the north-east trending Melby Fault. It is composed of a lower sedimentary group and an upper volcanic group. The sedimentary group is made up mainly of soft red and grey sandstones and siltstones of fluviatile origin and contains two fish beds, known as the Melby Fish Beds, which have yielded an abundant fish fauna of high-Middle Old Red Sandstone age. The volcanic group is composed of a lower series of basalts, which are not present on Mainland, and an upper series of thick rhyolite flows which crop out at Melby on Mainland and form the greater part of Papa Stour.

The sediments which form most of Foula consist of soft grey to buff-coloured sandstone with subordinate shales and siltstones. They have an exposed thickness of about 6000 ft (1800 m) and form an open syncline plunging gently southwards. Sedimentary structures indicate that the sandstones were laid down in a mainly fluvial environment and were derived from a west to west-north-westerly source. Though plant fragments have been found at several horizons, they are not sufficiently diagnostic to determine the age of the beds.

Late-Caledonian igneous complexes

Shetland contains a number of late-Caledonian non-foliated granite–diorite complexes which are confined to a north–south trending belt bounded on the east by the Walls Boundary Fault and are probably all to some extent interconnected. The present area contains from north to south: the southern end of the Northmaven–North Roe Complex, which occupies a large part of the Northmaven and North Roe peninsulas north of the area described, the Muckle Roe Granophyre, the Vementry Granite and the Sandsting Complex.

Southern part of the Northmaven Complex

The southern part of the Northmaven Complex consists predominantly of diorite with irregular masses of gabbro-diorite and gabbro and a few very small patches of ultrabasic rock. The diorite is extensively veined by granite, which also forms a continuous outcrop along its eastern side. The Northmaven Complex contains several large irregular masses of contact-altered metamorphic rocks.

Muckle Roe Granophyre

The Muckle Roe Granophyre is a leucocratic microgranite which has a micrographic texture in its western and central parts but passes into a more normal leucocratic granite further east. It is petrographically distinct from the Vementry Granite, which crops out in part of northern Vementry and has an outer rim of coarse-grained leucocratic granite and a small central area of slightly darker porphyritic granite.

Sandsting Complex

The Sandsting Complex crops out in the southern part of the Walls Peninsula and is composed of a varied rock-suite, which includes leucocratic quartz-rich granite, microgranite, porphyritic micro-adamellite, granodiorite, diorite and some small masses of gabbro. Like the Northmaven Complex it contains several enclaves of hornfelsed country rock. There are also a number of areas of diorite and sandstone which are intensely veined by granite. Radiometric age determinations of the granite and diorite by N. J. Snelling have given dates of 360 ± 11 million years and 369 ± 10 million years respectively. This suggests that the complex is of basal Upper or late Middle Old Red Sandstone age. It is intruded into the Middle Old Red Sandstone Walls Formation and has a thermal aureole of varying width. As the minor structures, such as cleavage, minor folding and lineation, of the tectonized parts of the Walls Formation do not extend into this thermal aureole it is concluded that granite emplacement preceded or was contemporaneous with the first phase of folding in this formation.

Minor intrusions

Basic and acid minor intrusions are abundant in Northmaven and Muckle Roe and in the northern part of the Walls Peninsula.

Basic intrusions

The basic intrusions are predominantly dykes with a north-north-west to northerly trend, and they become progressively more abundant in a northerly direction. The following four petrographic suites are present throughout the area:

1. Dolerite and basalt, usually olivine-free and commonly uralitized.
2. Quartz-dolerite
3. Basic porphyrite
4. Spessartite and microdiorite.

In addition there are a large number of dykes of highly altered rocks which have been shown on the geological map as unclassed basic and sub-basic types. No lamprophyres of the types found in Orkney have been recorded, and, though no radiometric age dates are available, it is believed that all the basic dykes and sills of Western Shetland are of late-Caledonian age.

Acid intrusions

Acid intrusions are represented by north-east to north-north-west trending dykes as well as by roughly concordant sills, sheets and laccoliths within the northern part of the outcrop of the Walls Sandstone. The acid intrusions consist of banded and spherulitic felsite, quartz- and feldspar-porphyry and, more rarely, microgranite. The dykes generally occur in swarms, which form two distinct suites, one composed of north-east trending dykes centred on the Vementry Granite, and the other, made up of north to north-north-west trending dykes cutting and centred upon the Muckle Roe Granophyre.

Pleistocene and Recent

In the Shetland Islands the effects of two ice sheets can be recognized. The earlier ice sheet which approached Shetland from the east is thought by some investigators to have originated in Scandinavia. The second formed a local ice cap which was centred on the middle of Shetland and spread outwards from there in all directions. During the final deglaciation of Shetland there was a period when several areas of high ground nourished small local glaciers. In Western Shetland all evidence from glacial striae, ice-moulded topography and glacially-transported pebbles and blocks indicates that ice moved to the southwest in the southern part of the Walls Peninsula, to the north-west in the northern part of the peninsula and in Muckle Roe and to the west in North-maven. The glacial deposits of the area consist of grey to brownish sandy till with abundant stones. At one locality sand and gravel with an interglacial peat bed, probably Hoxnian, underlies boulder clay. Moraines are rare and deposits and features formed by glacial meltwaters are virtually absent. This appears to be due to the fact that Shetland has been subsiding since the last glacial maximum and that all low ground which may have contained such features in late-glacial times is now submerged. It can be shown that the earliest post-glacial lake deposits of Shetland are approximately 10 000 years old and that there has been a rise of sea level of at least 30 ft (9 m) in the last 5500 years.

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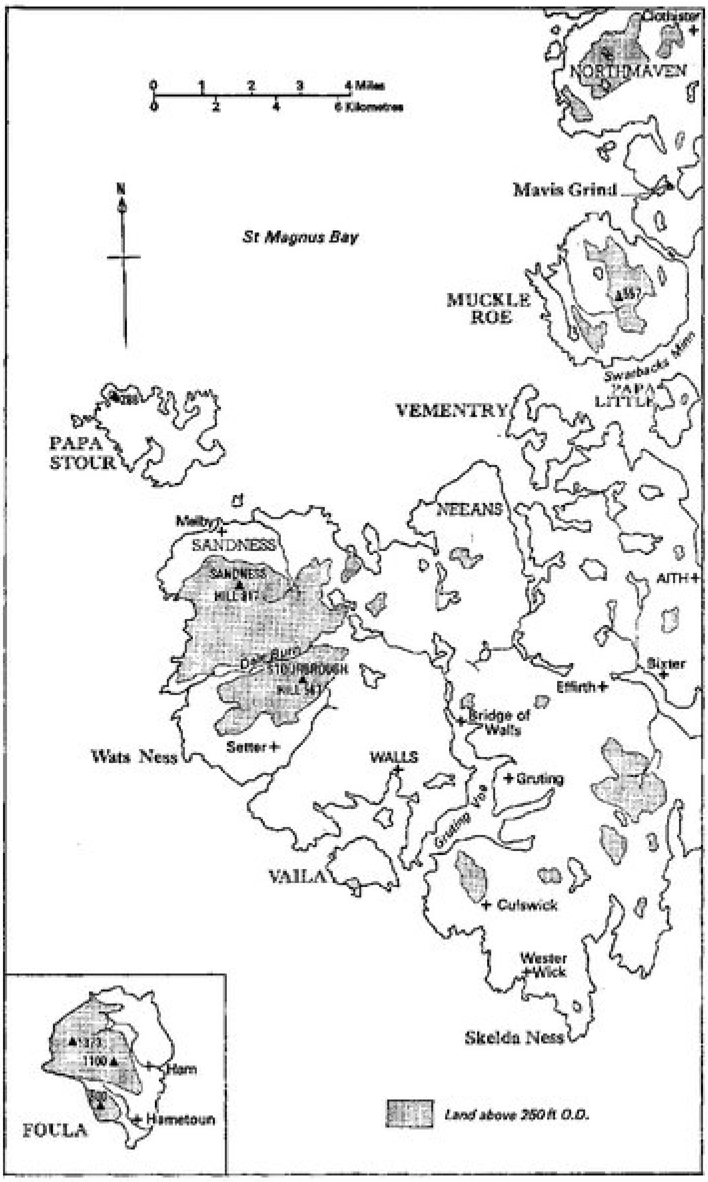
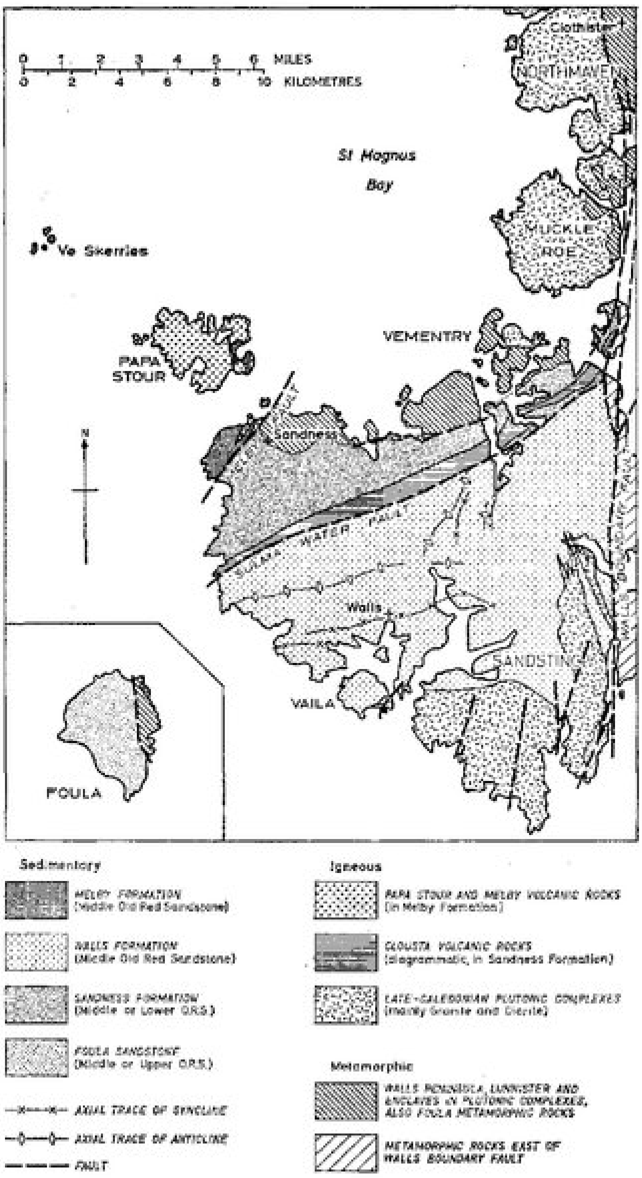
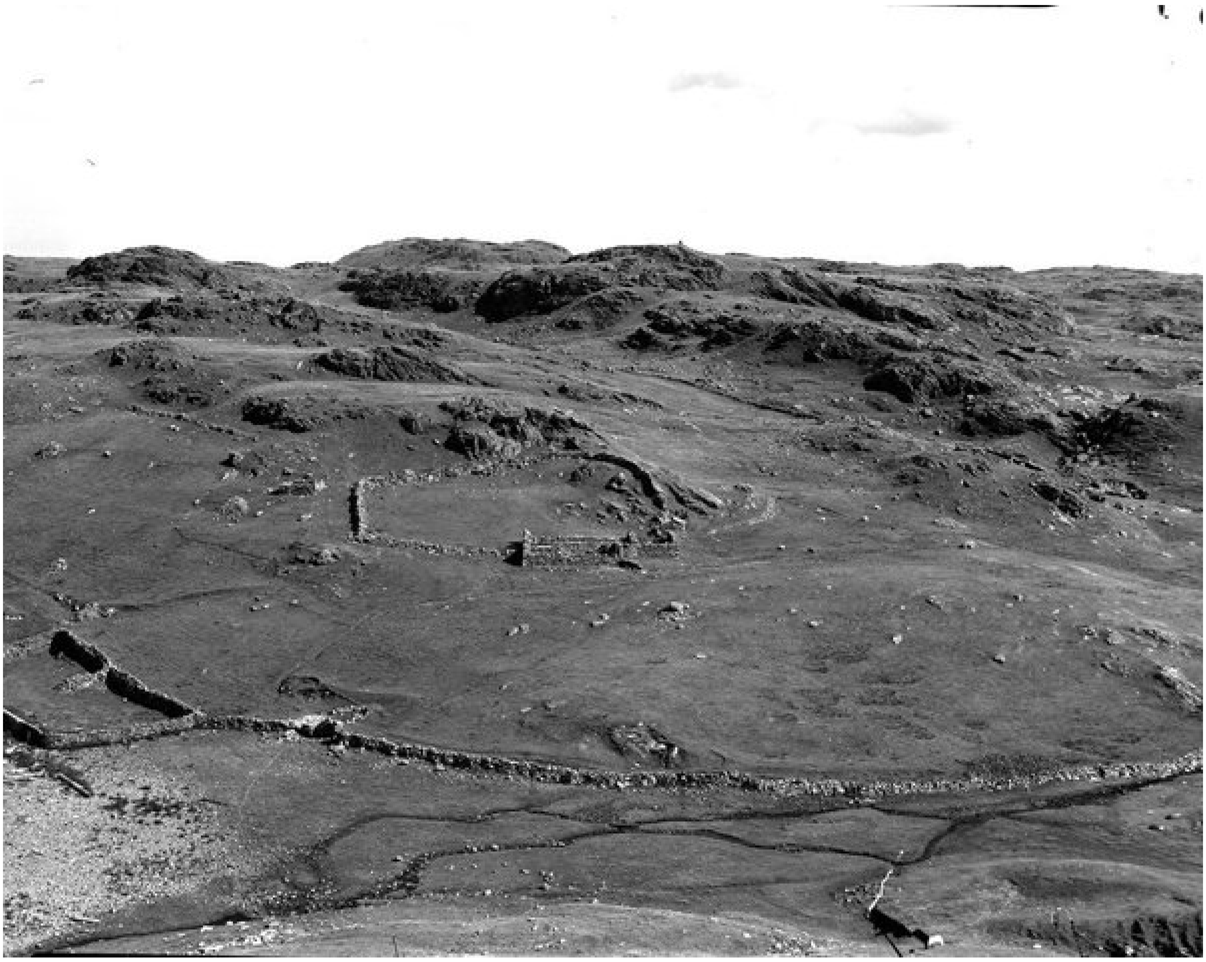


(Figure 1) Sketch-map showing the area covered by One-inch Geological Sheet Western Shetland.



(Figure 2) Distribution of the principal rock groups in Western Shetland.



(Plate 5A) General view of Neeans, looking east from north-east slope of Crockna Vord. [HU 257 583]. Characteristic topography formed by the metamorphic rocks of the Neeans Group. (D950).