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A review of petrological data available for the Reay District and adjacent areas, Caithness, Scotland

Integrated Geological Surveys (North)

Internal Report IR/02/074

BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/02/074

A review of petrological data available for the Reay District and adjacent areas, Caithness, Scotland

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Key words

Petrology; Reay, Caithness.

Bibliographical reference

E. PHILLIPS. 2002. A review of petrological data available for the Reay District and adjacent areas, Caithness, Scotland. *British Geological Survey Internal Report*, IR/02/074. 9800pp.

Keyworth, Nottingham British Geological Survey 2002

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Foreword

This report is the published product of a study by the British Geological Survey (BGS) as part of their regional geological mapping programme. It contains a review of the petrological data available for the Reay District, Caithness, Scotland. The work forms part of a multidisciplinary Caithness Devonian and Quaternary Project.

The a main aim of this project is to investigate the Devonian and Quaternary geology of the far North East of Scotland, represents an important component of the onshore geology of the UK that has a crucial role in understanding the evolution of the West Orkney and Northern North Sea basins. In addition, formulation of local planning policies on landfill, hard rock extraction and groundwater protection, in this sparsely populated but environmentally sensitive region, has demonstrated a requirement for modern geospatial data throughout the project area. This involves the resurvey of the solid and drift geology of the onshore eastern margin of the Orcadian basin (1: 50 000 Sheets 83E, 94W, 110, 115 E 116W & 116E) concentrating on the nature and distribution of the Quaternary and Devonian strata.

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Summary

This report provides a review of the petrological data available for the Reay District and adjacent areas of Caithness (Scotland). This work forms part of the multidisciplinary Caithness Devonian and Quaternary project which is an integral part of the BGS's Integrated Geological Survey's (North) programme. The report includes a summary of the tectonostratigraphy and petrology of the various metasedimentary and meta-igneous rocks belonging to the Precambrian Lewisian and Red Point inliers as well as the Kirtomy, Strathy, Portskerra and Altnabreac complexes. The petrology of the Pre-Devonian in age Reay Diorite and Strath Halladale Granite igneous intrusions are also reviewed. Petrological and geochemical data for the Devonian sedimentary rocks are also included.

1 Introduction and history of research

This report provides a review of petrological data available for the Reay district of Caithness, northern Scotland. The work forms part of the multidisciplinary Caithness Devonian and Quaternary project which is an integral part of the BGS's Integrated Geological Survey's (North) programme.

The first geological map of the Reay district (Sheet 115), resulting from the primary geological survey of the area towards the end of the 19th century, was published by the British Geological Survey in 1898 (see Crampton & Carruthers 1914). Prior to this work, Harkness (1862) recognised that the granites of eastern Sutherland had a metamorphic origin, and that they were emplaced after the deformation of the surrounding metasedimentary rocks. This conclusion was supported by later work by Horne & Greenly (1896) who demonstrated that the granitic rocks were intruded whilst the country rocks were still hot. Further work on the relationships between the granites and the surrounding Moine metasedimentary rocks in Sutherland and Caithness was carried out by Read (1931), Cheng (1944) (Bettyhill area), Collins (1941) (Strathy area) and much latter by Moorhouse and Moorhouse (1979, 1983, 1988). Overviews of the Precambrian geology of eastern Sutherland have been published by Johnstone & Mykura (1989) and Moorhouse & Moorhouse (1988).

Early studies (pre-1800) of the Devonian rocks of the Caithness district mainly concentrated on the fossil fish preserved within this sedimentary sequence. However, subsequent work by Jameson (1800) and others throughout the 1800's meant that by the end of the century the Old Red Sandstone succession had been subdivided into Lower, Middle and Upper groups and the onlapping relationship of this sequence on to the Precambrian basement to the west and south of Reay was well established (see Crampton & Carruthers 1914). Further stratigraphical subdivision of the Caithness Flagstone sequence was made by Michie (1970) and by Mykura & Smith (1973) during their studies of the mineralisation (uranium and base-metals, respectively) in the Devonian rocks of Caithness. The first formal detailed lithostratigraphy of the Devonian sequence was proposed by Donovan *et al*., (1974), based upon coastal exposures of northeastern Caithness. Subsequent work by Donovan (1980) highlighted the cyclic nature of deposition within the Old Red Sandstone sedimentary sequence. The most up-to-date and comprehensive review of the Devonian strata of Caithness is provided by Trewin (1993a, 1993b).

Commercial geological work on the granitic and Precambrian basement rocks in the Altnabreac area, including the drilling of 24 shallow boreholes and 3 deep boreholes (Lintern & Raines 1980; Lintern & Storey 1980) as well as geological mapping (McCourt 1980), was commissioned by the United Kingdom Atomic Energy Authority (UKAEA) between 1978 and 1980. This work, as well as additional published and unpublished information concerning the Precambrian and Devonian geology of the region were subsequently incorporated by the BGS into its 1985 edition of 1:50 000 geological map sheet 115E (Reay). More recently remote-sensing work by Sir Alexander Gibb & Partners (1989) as well as geological mapping (Fletcher & Key 1991), core logging (Barclay *et al*. 1992) and detailed geochemical and petrographical work (e.g. Hyslop 1993; Hyslop & Milodowski 1994; Milodowski *et al*. 1994) has been carried out on both the Devonian and basement sequences as part of a geological investigation for the potential sighting of a deep nuclear waste repository at Dounreay.

2 Available petrological and geochemical data

Available whole-rock geochemical analyses (Moorhouse & Moorhouse 1981; Moorhouse & Moorhouse 1988; Storey & Lintern 1981 Ingham *et al*. 1991; Ingham *et al*. 1992; Hyslop & Milodowski 1994), thin sections (BGS registered collections), mineral and bulk X-ray diffraction data (Prior 1993c; Prior & Kemp 1993; Hyslop & Milodowski 1994), and other petrological information held by the BGS are listed in the Appendix to this report.

3 Geological Setting

The geology of the Reay District and adjacent areas is dominated by Devonian sedimentary rocks, which unconformably overlie an older basement of metamorphosed sedimentary and igneous rocks (Johnstone & Mykura 1989). This basement is largely composed of the Neoproterozoic metasedimentary rocks of the Moine Supergroup (Johnstone 1975) which are intruded by a number of younger basic to acidic igneous rocks. The basement rocks were deformed and metamorphosed during the late Precambrian to early Palaeozoic Caledonian orogeny when the region formed part of the foreland of the Laurentian (North American) continent. This phase mountain building (orogenesis) accompanied the collision of the Laurentian and Baltic (European) continents and the closure of a major early-Palaeozoic ocean known as Iapetus. The Moine rocks are intruded by two large igneous bodies of uncertain age, the Reay Diorite and the Strath Halladale Granite. A summary compiled by Fletcher & Key (1992) of the main tectonothermal and igneous events recognised within the basement rocks of Caithness is shown in Table 1.

The unmetamorphosed Cambrian to early Ordovician calcareous shelf deposits, which rest on basement further to the west are absent in the Reay district, these sedimentary rocks having been removed by erosion prior to the onset of Devonian sedimentation.

During Devonian times, the area of continental crust that now makes up the British Isles formed part of the super-continent of Laurussia (Ziegler, 1988; Woodcock 2000). This developed during the Caledonian Orogeny due to the amalgamation of several pre-existing continents. The crust of Scotland and north eastern England had lain on the margin of the continent known as Laurentia, which also included Greenland and North America. Most of England and Wales were part of the microcontinent of Avalonia (Friend *et al*., 2000).

Throughout the Devonian Laurussia lay to the south of the equator. Most of the British Isles formed part of the southern margin of this super-continent, upon which Old Red Sandstone successions were deposited. However, southern Britain at this time was covered by a shallow sea. The climate was subtropical resulting in the development of an extensive desert with isolated basins with there own internal drainage systems. In northern Britain these basins were probably formed during extension (stretching) of the crust leading to faulting an the formation of upland blocks (horsts) which supplied detritus to the adjacent down-faulted or graben areas. These graben basins locally contained fluctuating freshwater to saline lakes. The faults controlling the sedimentary basins were largely formed due to the reactivation of pre-existing structures within the basement.

The Devonian continent was eventually dismembered during a major phase of crustal extension during early Carboniferous times, followed by uplift. This phase of extension was accompanied elsewhere by volcanic activity and, in the Caithness district by the localised emplacement of alkaline igneous intrusions into the Devonian sedimentary sequence.

4 Precambrian metamorphic and igneous complexes in the region

The Precambrian metamorphic rocks in northeast Sutherland and western Caithness have been subdivided into three main units, namely the Kirtomy, Strathy and Portskerra complexes (see Moorhouse & Moorhouse 1988 and references therein; Fletcher & Key 1992). The Strathy Complex forms a structurally bound wedge which separates the western Kirtomy and eastern Portskerra assemblages on sheet 115W (Strathy Point). Both of these migmatitic complexes are considered to form an integral part of the Moine Supergroup.

The following sections provide a brief summary of the petrology of the various metasedimentary, meta-igneous and igneous rocks exposed principally within the region to the east of the Reay district. These descriptions are based upon a review of the currently available literature. New petrological work on these rocks has yet to be undertaken.

4.1 KIRTOMY COMPLEX

The Kirtomy Complex (originally referred to as the Kirtomy assemblage) was first described by Moorhouse (1978) (also see Moorhouse & Moorhouse 1988; Moorhouse *et al*. 1987) and forms a major unit within the Moine Supergroup on Sheet 115W between Port Mor [NC 774 656] and Strathy Bay [NC 835 663]. Work by Moorhouse (1978), Greenly (1890) and Fletcher & Key (1992) has shown that this complex can be subdivided into a lower unit composed of migmatitic micaceous gneiss or schist (Swordly Pelite of Moorhouse 1978) which is structurally overlain by higher unit of migmatitic feldspathic gneiss (Kirtomy migmatitic biotite gneiss of Moorhouse 1978). The western margin of the Kirtomy Complex is formed by the Swordly Thrust. The eastern margin of the complex where it is in contact with the Portskerra Complex is not exposed. However, due to the absence of any mylonitic rocks in the vicinity of this boundary Fletcher & Key (1992) have suggested that it is not tectonic. The boundary between the Kirtomy Complex and Strathy Complex is always tectonic.

For a more detailed description of the structure of the Kirtomy Complex the reader is referred to Fletcher & Key (1992).

4.1.1 Metasedimentary rocks

All of the metasedimentary rocks within the Kirtomy complex are strongly migmatitic. Migmatisation of these metasedimentary rocks is believed to have occurred during initial middle-upper amphibolite facies regional metamorphism which accompanied the D1 tectonothermal event (Table 1; Fletcher & Key 1992). These pelitic to psammitic migmatitic rocks are mainly composed of an inequigranular assemblage of quartz, plagioclase (oligoclase in composition) and biotite with variable amounts of muscovite and garnet. Accessory phases present include apatite, zircon, titanite, opaque minerals and epidote. Later retrogression (D3) and hydrothermal alteration (D4) resulted in the localised breakdown of these high-grade mineral assemblages.

The basal Swordly Pelite (Moorhouse 1978) comprises coarse-grained migmatitic schists and gneisses which contain abundant mica and small sieve-textured garnet porphyroblasts. Sillimanite has also been recorded within the more pelitic lithologies (e.g. at [NC 757 658]) indicating that temperatures during regional metamorphism were in excess of 500°c, based upon the stability of this high temperature alumino-silicate mineral. Calc-silicate lenses are rare within the pelitic and psammitic migmatites, however where present these rocks are characterised by the presence of epidote and clinopyroxene.

In thin section (S93105) the coarse-grained, feldspathic gneisses are coarsely banded with a well-developed gneissose fabric. This foliation comprises alternating quartzofeldspathic (leucosome, ≤ 15 mm thick) granitic-looking bands and biotite-rich restite layers (melanosome, ≤ 5 mm thick), and was interpreted by Fletcher & Key (1992) to have formed by *in situ* differentiation. However, the locally developed sharp boundaries to the quartzofeldspathic layers suggests that some mobilisation of the leucosome did occur during migmatisation. The feldspar within the leucosome is exclusively composed of sericitised plagioclase indicating that migmatisation occurred due to a process of fluid enhanced segregation, rather than partial melting. The adjacent restite melanosome is mainly composed of euhedral biotite flakes with subordinate quartz and minor plagioclase. Accessory apatite, titanite, monazite, zircon and opaque minerals are present within the melanosome. Biotite possesses a moderate to strong pleochroism (dark brown to straw yellow) and defines a well-developed tectonic foliation which occurs parallel to the gneissose banding. Biotite may exhibit minor alteration/retrogression to chlorite along the basal (001) cleavage planes. Traces of muscovite, titanite and opaque oxides (possibly including ilmenite) are associated with the chloritisation of biotite. The intensity of chlorite retrogression increases towards the margins of the biotite-rich layers.

Whole-rock geochemical data (Holdsworth 1989a, 1989b) for the various schistose and gneissose metasedimentary rocks of the Kirtomy Complex are listed in Appendix 1. These data support the conclusion that the Kirtomy Complex forms an integral part of the Moine Supergroup.

4.1.2 Meta-igneous and igneous rocks

The metasedimentary rocks of the Kirtomy Complex are cut but a number of thin (approximately 1 m thick), concordant, strongly foliated amphibolite sheets as well as a few larger, more massive meta-basic igneous bodies. The amphibolite sheets can be traced laterally for up to 10 m and were considered by Fletcher & Key (1992) to have original formed transgressive dykes and sills. The larger meta-igneous bodies are generally several metres thick and 10's of metres in length. However, rare massive amphibolite bodies up to 10 km in length are present within the Kirtomy Complex. All of the meta-basic igneous rocks were originally composed of an inequigranular assemblage dominated by garnet and amphibole. This upper amphibolite facies metamorphic assemblage has been variably retrogressed to biotite and chlorite. Minor to accessory amounts of quartz, opaque minerals, titanite and apatite are also present within the amphibolites.

The metasedimentary rocks of the Kirtomy Complex are also cut by numerous granitic sheet and veins. In the basal Swordly Pelite these granitic rocks are foliated, whereas lithologically similar rocks in the structurally overlying feldspathic gneisses are typically massive. In thin section these holocrystalline granitic rocks comprise an interlocking, strained and sutured aggregate of quartz and cloudy looking (under plane polarised light) zoned plagioclase (oligoclase) and perthitic K-feldspar, with minor chloritised biotite. Apatite and opaque minerals are common accessory phases within these granites.

4.2 LEWISIAN INLIERS

The Precambrian basement of the Reay district also includes a small number (rare) of infolded or thrust slices of postulated Lewisian type rocks (Fletcher & Key 1992). A mafic gneiss, containing both hornblende and clinopyroxene, is exposed at [NC 755 640] was thought by Moorhouse *et al*., (1987) to be Lewisian in origin.

4.3 STRATHY COMPLEX

The Strathy Complex (Harrison & Moorhouse 1976), which crops out extensively on Sheet 115W comprises a suite of metamorphic and igneous rocks which are geochemically distinct from the surrounding metasediments of the Moine Supergroup (see Appendix 1). The distinctive nature of the metamorphic rocks within this complex was noted by several of the early workers including Horne & Greenly (1896), Read (1934) and Collins (1941). The geology of the Strathy Complex is described in detail by Moorhouse & Moorhouse (1979, 1988), Moorhouse & Moorhouse (1983) and Moorhouse *et al*., (1987). The complex is a fault-bounded block which is interpreted as an autochthonous or para-autochthonous slab of early Proterozoic sub-Moine basement (Harrison & Moorhouse 1976; Moorhouse & Moorhouse 1988). This basement was thrust westwards relatively late in its tectonothermal history into a higher crustal level along a steeply dipping ductile shear zone (approximately 12 m in width). This shear zone (exposed at Port Mor [NC 774 656]) forms the western contact between the Strathy Complex and the structurally underlying Kirtomy Complex. However, the thrust relationship between these two complexes has been questioned by Rathbone & Harris (1979) and Mendum (in Fletcher & Key 1992) who recorded an apparent gradational boundary between the Strathy and Kirtomy complexes. The eastern side of the Strathy Complex is now fault controlled and is juxtaposed against a down-faulted block of Lower to Middle Devonian strata. For a more detailed description of the structure of the Strathy Complex the reader is referred to Fletcher & Key (1992).

Published geochemical data (Moorhouse & Moorhouse 1983; see Appendix 1) for the quartzose gneisses which dominate the Strathy Complex (Appendix 1) shows that they are enriched in SiO_2 and Na_2O, and depleted in TiO_2, K_2O, Rb, Zr, Nb, La, Ce, Pb and Th when compared to the adjacent Moine metasedimentary rocks. Their high Y and strongly depleted light rare-earth element (LREE) abundances are more reminiscent of Mesoproterozoic gneiss terranes than the Archean rocks within the Lewisian foreland. However, Moorhouse *et al*., (1987) do not rule out the possibility that the Strathy Complex gneisses originally formed part of the Moine but posses a distinct lower crustal history. The geochemical signature displayed by these predominantly siliceous gneisses was considered by Fletcher & Key (*op. cit.*) to have been acquired by during the initial stages of upper amphibolite facies metamorphism, during which there was minor removal of partial melt leaving the more-refractory residue.

4.3.1 Metasedimentary and metavolcanic rocks

Lithologically the Strathy Complex is dominated by a migmatitic, weakly banded and foliated, siliceous grey gneiss. Regional upper amphibolite facies metamorphism which accompanied the D1 and possibly D2 tectonothermal events (Fletcher & Key 1992; Table 1) resulted in the formation of the gneissose foliation, as well as localised migmatisation and partial melting. These quartzose, granoblastic gneisses comprise an equigranular assemblage of quartz, sodic plagioclase and biotite, with variable amounts of garnet and hornblende. Accessory phases present within the gneisses include zircon, magnetite, apatite, epidote and titanite, as well as monazite within the more migmatitic lithologies. Importantly, K-feldspar is absent. These siliceous gneisses have previously been interpreted (on geochemical grounds) as highly altered dacitic volcanic rocks (Moorhouse & Moorhouse 1983).

The complex also contains a suite of more mafic, hornblende gneisses (*c*. 25% of the complex) which are petrographically similar to the siliceous gneisses but contain a high modal proportion of amphibole, more calcic plagioclase (andesine) and lower quartz content. These relatively more mafic rocks have geochemical characteristics similar to calc-alkaline basic igneous rocks and have, therefore, been interpreted as metavolcanic in origin (see Fletcher & Key 1992, and references therein).

A distinctive quartz-magnetite rock (the 'quartz-magnetite-schist of Strathy' reported by Read) is characterised by the presence of euhedral magnetite crystals enclosed within a mafic-free corona set in a grey psammitic gneiss matrix (e.g. at [NC 814 688]).

A minor component of the Strathy Complex is a distinctive white weathering garnetiferous quartzose psammitic rock (e.g. near Armadale at [NC 787 654] which contains numerous small garnets set in a quartz-rich matrix which also contains plagioclase (oligoclase), biotite and opaque minerals. Also present are rare exposures (e.g. Strathy Lighthouse at [NC 829 697]) of small, tectonic lenses of coarsely foliated orthoamphibolitic gneiss which contains orthoamphibole and locally late garnet, staurolite and sillimanite set within a matrix of strained quartz, plagioclase (oligoclase) and biotite. Collins (1941) also recorded the presence of cordierite-bearing and K-feldspar-bearing gneisses within the Strathy Complex.

Interbanded (over several metres) calcite-rich marbles and calc-silicate rocks are best developed at Port Mor [NC 774 656] and on Strathy Point [NC 827 694]. These high-grade calcareous rocks are characterised by the assemblage scapolite, diopside and calcite with variable amounts of orange (under plane polarised light) spinel. Accessory phases present include titanite, apatite, opaque minerals and quartz, with secondary (retrogressive) actinolite replacing the larger clinopyroxene crystals.

4.3.2 Meta-igneous and igneous rocks

The meta-igneous rocks are commonly associated with the hornblendic gneisses. They are represented by a suite of fine-grained amphibolite sheets which are both concordant and discordant to the gneissose banding present within the host rock. Fletcher & Key (1992) have recognised two generations of amphibolite sheets. However, both groups consist of the assemblage hornblende, plagioclase and quartz, with or without clinopyroxene and partially chloritised biotite. Geochemical data (Moorhouse & Moorhouse 1983; see Appendix 1) for the oldest amphibolites (in particular Y/Nb ratio) suggests that these rocks represent metamorphosed tholeiitic basalts.

A small ultramafic body exposed at Armadale [NC 777 655] consists almost entirely of hornblende and opaque minerals. Geochemically this metamorphosed meta-igneous rock is similar to the pyroxene-rich ultramafic rocks present within the Lewisian foreland (Moorhouse & Moorhouse 1988; Fletcher & Key 1992).

All the metasedimentary and meta-igneous rocks present within the Strathy Complex are cut by large and small sheets and veins of weakly foliated trondhjemite and by later, easterly-trending sheets of massive, pink microgranite. The trondhjemites contain very little or no K-feldspar. The later microgranites comprise an inequigranular assemblage of quartz, plagioclase and microcline with accessory muscovite and variably chloritised biotite. Several generations of petrographically similar granitic pegmatites are present within the Strathy Complex, forming discordant veins and sheets. Fletcher & Key (1992) interpreted the trondhjemitic veins as representing deeper anatectic melts, contemporaneous with the more K-rich granitic sheets and veins.

4.4 PORTSKERRA COMPLEX

The Portskerra Complex (Fletcher & Key 1992; formerly the Portskerra Assemblage of Moorhouse & Moorhouse 1983) occurs to the east of the Strathy Complex and forms an approximately 8 km wide, northerly trending belt of Moine-type metasedimentary gneissose rocks centred upon Strath Halladale and extending onto the eastern side of Sheet 115E (Reay). To the west the complex tectonically overlies the Kirtomy Complex, with its eastern margin being defined by the Strath Halladale Granite. The Portskerra Complex is also locally unconformably overlain by outliers of the younger Lower to Middle Devonian sedimentary strata (e.g. at Portskerra headland, Baligill and Red Point) and, to the south of Sandside Bay [NC 965 655], cut by the Reay Diorite.

The Portskerra Complex was originally mapped by Greenly during the latter part of the 19th century, with the geology of the complex being briefly described by Crampton & Carruthers (1914). The complex was subsequently partially remapped by McCourt (1980) who recognised several generations of granitic rocks within the gneisses. The complex is dominated by variably migmatitic to gneissose psammitic metasedimentary rocks which range from quartzose psammite to the more common micaceous psammite in composition. Other metasediments present include quartzites, calc-silicate rocks, semipelites and rare pelites. These metasedimentary rocks are intruded by several generations of granitic veins, diorites and amphibolites. Retrogression of these metasediments is considered by Fletcher & Key (1992) to have accompanied the emplacement of the later granites and could be related to Devonian hydrothermal activity.

For a more detailed description of the geology of the Portskerra Complex the reader is referred to Fletcher & Key (1992). This complex was also intersected in the Dounreay borehole number 1 (Glover *et al*. 1991; Barclay *et al*. 1992). The mineralogy, petrology and whole-rock geochemistry of the various metasedimentary, meta-igneous and igneous rocks encountered within this borehole are summarised in Hyslop & Milodowski (1994). Whole-rock geochemical data (Ingham *et al*. 1991) obtained for this complex from the Dounreay borehole are listed in Appendix 1.

4.4.1 Metasedimentary rocks

The metasedimentary rocks of the Portskerra Complex are now formally assigned to the Portskerra Formation. They are predominantly psammitic in composition, with only minor semipelites and quartzites, as well as rare pelites and calc-silicate rocks. The psammites are typically medium- to coarse-grained rocks which range from quartz-rich psammites, feldspathic (containing *c*. 80% feldspar) psammites (S93111; S93103) to micaceous psammite which locally grade into the semipelites. The quartz-rich lithologies possess a glassy weathered surface and contain white plagioclase (oligoclase) crystals which gives the rock a ‘gritty’ appearance. Dark coloured biotite-rich mafic selvages (S93102) are also present within these quartz-rich psammites, in particular where they are associated with the impure meta-quartzites (containing *c*. 80% quartz) south of Portskerra. The micaceous psammites are typically banded and/or laminated rocks which possess a distinctive stripped appearance. In thin section the quartzofeldspathic psammites comprise an inequigranular assemblage of quartz and feldspar with minor amounts (10 to 20% of the total rock) of biotite and muscovite. Biotite exhibits minor retrogression to chlorite and contains small inclusions of zircon. Other accessory phases include titanite and apatite. The more micaceous psammites contain mica-rich bands composed of euhedral biotite, intergrown plagioclase and K-feldspar, and minor quartz. Accessory minerals include small ovoid apatite and zircon.

Bedding within these metasedimentary rocks is defined by sharp lithological changes with individual psammitic beds ranging from 8 cm to 1 m in thickness (Gould 1990). Thin, dark grey biotite-rich laminae (up to several millimetres thick) which occur within these typically mica-poor psammites are interpreted as preserving a primary sedimentary parallel lamination and locally possible cross bedding (e.g. at [NC 8770 6663]). In thin section (S93757; S93758; S93761) these banded rocks which show varying degrees of recrystallisation and, in the least altered samples (S93757), may even contain early biotite (Key 1991). Biotite exhibits a variably developed shape alignment and defines a weakly to moderately well-developed tectonic foliation which occurs parallel to bedding/banding. The quartz-rich nature of these metasedimentary rocks may have precluded substantial recrystallisation and modification of bedding and/or lamination during metamorphism, even at moderate to high metamorphic grades.

Semipelitic layers are most common within the more thinly bedded parts of the Portskerra Formation (e.g. at [NC 9137 6334]) with individual layers ranging up to 2 m in thickness. In thin section (S93758) these pelitic bands are mainly composed of biotite, which wraps around small quartzofeldspathic augen and defines a moderate to well developed foliation. Muscovite typically occurs in discrete foliae within the pelitic bands and forms fibrous, poorly formed crystals. Traces of rutile (associated with chloritised biotite), apatite and rare epidote are also present within these semipelites. The thinly bedded sequences may also contain lenticular pods (2 to 15 cm thick) of calc-silicate rock (e.g. at Golval Hill between [NC 9037 6094] and [NC 9062 6042]) which are composed of an inequigranular assemblage of quartz, plagioclase, garnet, hornblende and epidote (McCourt 1980; Mendum 1991a). The quartzites are fine- to medium-grained, massive rocks (e.g. at [NC 8763 6044] and [NC 8728 6432]) which are locally deformed by tight fold structures. In thin section (S93110) they are mainly composed of variably strained quartz (80% of total rock) and minor feldspar (plagioclase and K-feldspar, 15% of the total rock), as well as minor to trace amounts of chloritised biotite and opaque minerals. Accessory phases include apatite, rutile and zircon, with the latter possibly representing an original detrital heavy mineral.

All the metasedimentary rocks within the Portskerra Formation are variably migmatitic. However, there is strong lithological control on migmatisation with the feldspathic (S93104; S93105) and biotite-rich (S93106) rocks showing the highest degree of metamorphic mineral segregation. The migmatites are typically coarse-grained, locally pegmatitic rocks which contain bedding-parallel, elongate ($\leq$ 1 m in length) to pod-like quartzofeldspathic segregations which are up to 5 cm thick. In thin section the coarse granitic segregations are composed of plagioclase ($\leq$ 3 mm in length) with minor interstitial quartz and chloritised biotite. Muscovite, where present, forms clusters of poorly formed, anhedral crystals which probably developed in response to infiltration by a late hydrous fluid phase. A concentration of opaque minerals along the margins of the granitic segregations may represent a selvedge. The boundaries of the segregations are typically gradational indicative of *in situ* metamorphic segregation. However, some boundaries are sharp suggesting some mobilisation of the leucosome. The adjacent mafic bands are composed of biotite, quartz and subordinate plagioclase. Biotite forms euhedral, pleochroic (dark brown to yellow-brown), variably shape-aligned crystals which define a weak to moderately developed tectonic foliation parallel to the compositional banding/segregation. Within the mica-rich migmatites (S93106) biotite may also form augen-shaped aggregates of crystals. Traces of rutile, white mica and titanite may be present associated with the chloritisation of biotite. Other accessory phases present within the biotite-rich bands include apatite, monazite and zircon.

The tectonothermal evolution of the Portskerra Formation is summarised in Table 1.

4.4.2 Meta-igneous and igneous rocks

The Portskerra Formation is intruded by a suite of amphibolite and later dioritic intrusions, as well as several generations of more acid granitic material. These igneous rocks occur as sheets, dykes, veins and pod-like bodies with the basic rocks typically forming smaller ($\leq$ 10 m in thickness) intrusions than the spatially related acid igneous intrusions. The granitic intrusions range from granodiorite (earliest) to granite (latest) in composition; the latter including numerous sheets and veins associated with the main monzogranitic phase of the Strath Halladale Granite.

The amphibolites are well exposed along the Portskerra coastal section (e.g. at [NC 8770 6663] and [NC 8721 6618]) and range from several metres to over 50 m in thickness. These massive to strongly foliated rocks cross-cut the compositional banding/bedding within the host metasedimentary rocks. These meta-basic igneous rocks are, however, cut by G3 granite veins associated with the Strath Halladale Granite. Fletcher & Key (1992) also report that some of the amphibolite sheets are deformed by F3 fold structures (e.g. at [NC 8704 6376]) which effect the metasedimentary country rocks. The tectonic fabric developed within the amphibolites is typically defined by shape-aligned biotite and may be parallel or discordant to the boundaries of these meta-igneous bodies. However, an L-S tectonic fabric defined by pale coloured feldspathic segregations may be locally developed. In thin section (S93107; S93108) these medium grained amphibolites are composed of an inequigranular assemblage of pale green amphibole (ferro-actinolite to hornblende in composition), variably chloritised (± titanite) biotite, plagioclase and minor to trace amounts of quartz. Both plagioclase and quartz may form rounded, bleb-like inclusions within amphibole. Accessory phases present within the amphibolites include lozenge-shaped crystals of titanite, opaque minerals, apatite and rare zircon.

The isolated dioritic bodies present within the area (e.g. at [NC 8760 6394]) were considered by Fletcher & Key (1992) to form part of a late Caledonian suite or related to the larger Reay Diorite. These diorites clearly pre-date and are cut by the later granitic veins. Several satellites to the Reay Diorite are exposed at [NC 9775 6390] and [NC 9665 6252] (Gould 1990). The diorites are in general massive, holocrystalline rocks which are composed of an inequigranular assemblage of amphibole, plagioclase, pyroxene, quartz and biotite. These macroporphyritic rocks contain large (3 mm in size), euhedral, pale green amphibole phenocrysts which are compositionally zoned, possessing distinctive brown-green cores. Colourless to pale green clinopyroxene (possibly augite) forms anhedral to subhedral crystals which are locally enclosed within a corona of, or intergrown with amphibole. Biotite forms rounded flakes which are included within amphibole and is associated with trace amounts of apatite and granular titanite. The groundmass is composed of variable sericitised plagioclase and intergranular quartz, with minor amphibole and trace zircon. As noted by Key (1990) the crystallisation history of the diorites may involve the early crystallisation of biotite followed by later amphibole and pyroxene, the reverse of that commonly observed in dioritic intrusions.

The earliest granitic veins within the Portskerra Complex are granodioritic in composition and occur as concordant 'lits' within the banded metasedimentary rocks (S93757), cross-cutting veins (S93761), diffuse zones as well as discrete discordant sheets and bosses. McCourt (1980) recognised several phases of granodiorite injection; the oldest G_1 phase which pre-dated migmatisation and later G_2 phase (see Table 1). The G_2 granodiorites contain plagioclase (≤ 3 mm in size) and larger (up to several centimetres) K-feldspar phenocrysts (e.g. at [NC 8863 6328], [NC 9285 6009], NC 9210 6244] and [NC 9285 6009], Giligill Burn between [NC 9197 6344] and [NC 9228 6320], Akran Burn [NC 9106 6193], Golval Hill between [NC 9065 6124] and [NC 9050 6106]) which post-date a pervasive pre-full crystallisation fabric defined by aligned biotite flakes and, in some cases, quartz ribbons (Fletcher & Key 1992). This fabric is parallel to the compositional banding in the country rocks. The larger granodiorite intrusions may also contain biotite schlieren and variably rotated xenoliths of the more refractory parts of the metamorphic country rocks (e.g. calc-silicate rocks and amphibolite). The compositional banding present within the metasediments may be mimetically preserved within the more diffuse granodioritic zones (e.g. at [NC 8995 5114]). Fletcher & Key (1992) suggested that the early G_2 granodiorites formed by 'sodic soaking' to produce diffuse zones which inherit the metamorphic fabric of the country rocks. Mobilisation of this granodioritic partial melt material resulted in the formation of cross cutting G_2 veins. The granodiorite veins are locally folded by F3 folds (e.g. Golval Hill area [NC 906 612]) which affect the country rocks and, therefore, pre-date this phase of deformation (Mendum 1991).

In thin section (S93113) the G_2 granodiorites are composed of plagioclase (oligoclase), variably strained quartz, K-feldspar and variably chloritised biotite. Accessory phases include ilmenite/magnetite, apatite, zircon and titanite. These accessory phases are locally included within the large K-feldspar microphenocrysts, the latter occur within a finer grained (average grain size *c*. 2 mm) groundmass of intergrown plagioclase and quartz.

The formation and emplacement of the granitic veins display a variety of relationships to the migmatisation of country rocks in the region. In some areas (e.g. at [NC 9402 6286], Giligill Burn between [NC 9197 6344] and [NC 9228 6320], Caol Loch [NC 9210 6244]) pale grey to pink granite, granodioritic and orange-pink aplite veins and pods are intruded into with striped, weakly to strongly migmatitic micaceous psammites which also contain amphibolite pods (e.g. at [NC 9402 6286]). Elsewhere, the host metasedimentary rocks are clearly non migmatitic, but still contain abundant pink and white granite and granodiorite veins (e.g. Brackside Burn between [NC 9486 6219] and [NC 9465 6121]).

The most common granitic intrusions within the Portskerra Complex are pink to red weathering granodiorite to leuco-monzonogranite (G_3) veins and sheets which are apophyses of the main Strath Halladale Granite (Fletcher & Key 1992). The area to the west of this granite intrusion is referred to as the Strath Halladale Complex by Johnstone & Mykura (1989) due to the large volume of granitic veins in this area. The N-S-trending (sub-parallel to the regional strike of the host metamorphic rocks) G_3 granitic veins and sheets range from a few centimetres to several hundreds of metres in width with two large bodies, underlying much of Strath Halladale and the area south of Portskerra. These granites post-date much of the folding in the country rocks. Petrographically the G_3 granite veins and sheets are identical to the main biotite-bearing leucocratic monzogranite phase of the Strath Halladale Granite. In thin section (S93098; S93102) the G_3 granites are medium- to coarse-grained, massive equigranular, holocrystalline rocks which are composed of plagioclase, K-feldspar, quartz and biotite. Highly altered, oxidised biotite occurs interstitial to both quartz and feldspar and may contain small inclusions of apatite.

A locally developed penetrative foliation present within the G_3 veins and sheets (e.g. western side of Melvich Bay, Portskerra Pier and at [NC 8825 6192]) is defined by shape-aligned biotite flakes and, in some cases, quartz ribbons. Fletcher and Key (1992) also describe a number of localities where the granites may also mimetically preserve the gneissose foliation developed within the adjacent country rock (e.g. at [NC 8883 6112], [NC 8996 6109] and [NC 8705 6420]). The presence of this relict foliation led Fletcher & Key (1992) to suggest that the granites were derived from the country rocks during "*some form of granitisation process*".

The youngest granitic veins (≤ 3 m thick) in the Portskerra Complex are aplites, microgranites (e.g. at NC 9047 6266] and [NC 9040 6052]) and rare pegmatites (e.g. at [NC 9663 6630]) which intrude all the other metasedimentary, meta-igneous and igneous rocks. Fletcher & Key (1992) record that several generations of these late veins can be observed in a single exposure and that they are locally injected along shear zones which off-set earlier veins. Contemporaneous with the emplacement of these granitic veins is the development of large, rounded anhedral K-feldspar phenocrysts/porphyroblasts (≤ 10 cm in diameter; e.g. at [NC 8669 600]) which overgrow the penetrative fabric present within the earlier granitic intrusions and metasedimentary country rocks. In thin section (S93100) the aplitic veins are dominated by sericitised feldspar (plagioclase and K-feldspar), interstitial quartz and granular biotite. Accessory monazite and zircon are associated with the variably chloritised biotite; the latter also shows minor replacement by white mica. Opaque Fe-oxide is a common accessory phase and exhibits minor alteration along grain margins to secondary hematite.

4.5 RED POINT INLIER

Fletcher & Key (1992) describe an inlier of Portskerra Complex at Red Point [NC 931 659]. This inlier comprises a sequence of thin to medium-bedded psammites which are intruded by numerous red granite pods, veins and sheets. The psammitic metasedimentary rocks are locally migmatitic where they contain prominent quartzofeldspathic segregations. These metasedimentary rocks also contain minor semipelitic bands as well as pods (up to 80 cm thick) of biotite-rich amphibolite (e.g. at [NC 9301 6518] and [NC 9305 65 96]). The Red Point inlier is also intruded by two, thin (10 to 60 cm thick), steeply dipping, E-W-trending green-grey microdiorite dykes which are pervasively altered to secondary carbonate. In thin section (S93763) the original igneous mineral assemblage has been largely replaced by carbonate with only minor relict biotite and pseudomorphs after amphibole.

4.6 ALTNABREAC COMPLEX

The Altnabreac Complex (Fletcher & Key 1992) includes all the metamorphic and associated igneous rocks exposed to the east of the Strath Halladale Granite that crop out in the south-eastern part of Sheet 115E and in the Altnabreac area to the south. To the east the complex is unconformably overlain by Lower and Middle Devonian strata. The geology of the complex was first described by Crampton & Carruthers (1914) and Read (1931), with more detailed accounts being published by McCourt (1980) and Lintern & Storey (1980). Only minor reconnaissance work was carried out by Clark (1990). The Altnabreac Complex is, in general, poorly exposed and comprises a suite of variably migmatitic psammitic, semipelitic and pelitic metasedimentary rocks, possible metavolcanic rocks as well as minor acid and basic igneous sheets and veins.

For a more detailed description of the structure of the Altnabreac Complex the reader is referred to Fletcher & Key (1992).

4.6.1 Metasedimentary rocks

Fletcher & Key (1992) describe two major units of variably migmatitic metasedimentary rocks within the Altnabreac Complex: an eastern unit dominantly composed of striped semipelitic to pelitic gneisses or schists (the Badenloch Pelite of Strachan 1988); and a western unit consisting of psammites and semipelites (the Kildonan Psammite of Strachan 1988). Psammites are rare within the Badenloch Pelite unit. One example of a flaggy, siliceous psammite containing thin semipelites and rare quartzites is exposed to the north-west of Dalnawillian Lodge [ND 030 408] (Lintern & Storey 1980). The micaceous and quartzose psammites which dominate the Kildonan Psammite unit are thinly laminated with the original bedding/sedimentary lamination defined by variation in modal biotite. Cross-bedding has also locally been recognised within these metasandstones (Strachan 1988; Fletcher & Key 1992) suggesting that the Kildonan Psammite youngs away from the underlying Badenloch Pelite. Calc-silicate rocks are only very locally developed within the Altnabreac Complex (see Strachan 1988).

The metasedimentary rocks consist of variable amounts of quartz, sericitised plagioclase (albite to andesine An_{38}), perthitic K-feldspar and chloritised (± white mica) biotite. Small, anhedral garnet porphyroblasts (≤ 2 mm in diameter) are present within the more pelitic lithologies. Accessory phases include opaque minerals, euhedral to subhedral apatite (≤ 0.5 mm in diameter), titanite and zircon. The texture of these metasedimentary rocks varies from equigranular/granoblastic through to highly foliated with a penetrative schistosity defined by shape-aligned biotite. The locally developed, coarser grained migmatitic rocks contain bands of leucosome parallel to the tectonic foliation and composed of intergrown quartz, K-feldspar and plagioclase (± biotite). The tectonothermal evolution of the Altnabreac Complex is summarised in Table 1.

Whole-rock geochemical analyses (Appendix 1) of two samples of garnet-bearing semipelite from the Altnabreac Complex (Storey & Lintern 1981) suggest that these rocks are comparable to semipelitic lithologies found elsewhere within the Moine Supergroup (see Moorhouse & Moorhouse 1988).

4.6.2 Meta-igneous and igneous rocks

The metasedimentary rocks of the Altnabreac Complex contain two generations of basic to intermediate igneous rocks, which may include early metavolcanic rocks, as well as three phases of granitic intrusions (Lintern & Storey 1980). The early, fine- to medium-grained, foliated amphibolites (A_1) form concordant sheets (≤ 3 m thick) and are composed of hornblende and variably chloritised biotite with subordinate to minor amounts of plagioclase, quartz, garnet and rare K-feldspar. Accessory phases include opaque minerals, titanite, apatite and calcite.

Lintern & Storey (1980) also describe a number of concordant, basic and intermediate schistose metavolcanic rocks from the Altnabreac shallow boreholes. These highly altered rocks contain differing amounts of quartz, plagioclase, biotite and rare K-feldspar, as well as irregular aggregates (pseudomorphs) of secondary chlorite, white mica and calcite. Accessory phases within these postulated metavolcanic rocks include opaque minerals, titanite, zircon and apatite.

A second group of basic to intermediate intrusive igneous rocks (A_3 of Lintern & Storey 1980) post-date the imposition of the main metamorphic fabric within the metasedimentary host rocks. A compositional layering within these igneous rocks is defined by the variation in grain size and modal ferromagnesian minerals. This group of intrusions range from coarse-grained ultramafites containing pyroxene, hornblende and biotite, through to fine- to medium-grained diorites which contain sericitised plagioclase (≤ 35% of total rock), K-feldspar (≤ 41% of total rock) and quartz (≤ 2% of total rock). Accessory opaque minerals, titanite and apatite are common. Primary igneous textures are preserved within the ultramafites, although pyroxene has been altered to an aggregate of amphibole, chlorite and white mica (± calcite, titanite and opaque oxides).

The volumetrically restricted early granodiorites (G_1) were interpreted by Fletcher & Key (1992) as probably being coeval with metamorphism/migmatisation of the metasedimentary country rocks. This interpretation is supported by whole-rock geochemical data (Appendix 1) which shows that the G_1 granodiorites are geochemically similar to the host semipelites and, therefore, may represent partial melts of these metasedimentary rocks (Storey & Lintern 1981). These fine- to medium-grained, foliated igneous rocks which are characterised by a well-developed segregation and biotite schistosity which occur parallel to the foliation developed within the adjacent country rocks. The biotite-rich foliae within these granodiorites are separated by felsic segregations composed of granular to shape-aligned quartz, sericitised plagioclase and K-feldspar. Plagioclase may also form anhedral phenocrysts/porphyroblasts which range up to 2.5 mm in size.

The contact between the Altnabreac Complex and Strath Halladale Granite is transitional and denoted by an increase in the abundance of granitic (G_3) veins and sheets (10 cm to > 2 m thick) towards the main body of the granite. The G_3 veins and sheets form a dense/ramifying network immediately adjacent to the main Strath Halladale Granite (Clark 1990) (e.g. at east of Loch Scye [ND 00 55]). In detail the G3 granites are holocrystalline massive rocks which are composed of quartz, plagioclase, K-feldspar and biotite, and are petrographically identical to the main monzogranitic phase of the Strath Halladale Granite.

All of the metasedimentary rocks and earlier igneous and meta-igneous rocks of the Altnabreac Complex are cut by numerous aplite and pegmatite veins. These late granitic intrusions have been subdivided into four types: (1) felsic aplites; (2) felsic aplites containing up to 5% chlorite, biotite and opaque minerals; (3) composite aplites with pegmatitic margins; and (4) rare thin aplites which possess a variably developed pilotaxitic fabric parallel to their contacts.

5 Major Pre-Devonian Igneous Intrusions

5.1 REAY DIORITE

The Reay Diorite was first identified during the primary geological mapping of the Reay district by the Geological Survey (1898 edition of Sheet 115) and briefly described by Crampton & Carruthers (1914). The diorite forms an approximately 1.5 km thick, sub-concordant lenticular sheet which intrudes the psammitic metasedimentary rocks of the Portskerra Formation. Emplacement of the Reay Diorite and the associated satellite intrusions, which occur to the west and south of the main intrusion (Fletcher & Key 1992), post-dated regional metamorphism of the Moine country rocks. The Reay Diorite, however, pre-dated the intrusion of main phase of the Strath Halladale Granite and the northern part of the intrusion is unconformably overlain by the younger Devonian strata. The diorite and its associated thermal aureole (best developed within the psammites to the north-west of the intrusion) are also cut by the later suites of granite veins.

At Creagan Loiste, 1.2 km west of Reay, the western contact of the diorite with the underlying hornfelsed psammites is exposed in "Reay Quarry". Approximately 15 m below the main body of the intrusion is a ENE-trending ductile shear zone (dip 42° SE, strike 066°), which also exhibits some brittle reactivation leading to the development of a chloritic gouge along the shear planes. Amphibolite pods spatially related to this shear zone locally grade into the diorite to form a biotite-rich diorite (10 m thick) containing euhedral plagioclase phenocrysts. Similar amphibolitic diorite occurs as isolated, lenticular pods within the migmatitic psammite country rocks (e.g. at [NC 94 6486]; Mendum 1991a). To the south the western boundary of the Reay Diorite is a faulted contact (Fletcher & Key 1992). The southern contact of the diorite is poorly exposed but was assumed by Gould (1990) to dip gently southwards, based upon the orientation of a foliation developed within the marginal phase of the intrusion.

5.1.1 Petrography of the Reay Diorite

The Reay Diorite ranges from diorite at its base (to the north-west), through monzodiorite and quartz-monzodiorite to quartz-monzonite at the higher levels within the intrusion, to the south-east. Contacts between the various lithologies are gradational, with the diorite becoming progressively coarser grained within the more leucocratic lithologies (grain size: diorites *c*. 2 mm; monzonites 3 to 4 mm). This lithological variation is reflected in plagioclase compositions which ranges from An_{36} in the diorites, to An_{28} in the more evolved quartz-monzonites.

In thin section (S93115) these dioritic to monzonitic rocks are composed of varying amounts of plagioclase, hornblende, pyroxene, biotite and quartz, with minor K-feldspar. K-feldspar and quartz are both interstitial to plagioclase and pyroxene, with myrmekite developed along inter plagioclase-K-feldspar grain contacts. Large augite crystals (≤ 4 mm in size) are partially altered to actinolite and overgrown by hornblendic amphibole. Pyroxene and amphibole form approximately 30% of the total rock, with biotite ranging between 5 and 10% of the mode. Accessory phases include apatite, zircon and titanite. The foliation which is locally developed within the diorites (referred to as sheared diorites by Fletcher & Key 1992) is defined by shape aligned biotite, hornblende and titanite.

For a more detailed description of the petrology of the Reay Diorite the reader is referred to Milodowski *et al*., (1990). Whole-rock geochemical data (Appendix 1) suggests that the Reay Diorite and Strath Halladale Granite form part of an evolving calc-alkaline magmatic sequence, with the diorite representing the earlier less fractionated (early) magma (Storey & Lintern 1981; Fletcher & Key 1992).

5.2 STRATH HALLADALE GRANITE

The Strath Halladale Granite (originally referred to as the Strath Halladale granite-gneiss complex Crampton & Carruthers 1914; Read 1931) forms an essentially concordant intrusive body (*c*. 5 km wide and 48 km in length) within the Moine Supergroup, separating the Portskerra and Altnabreac complexes. Like the Reay Diorite, the Strath Halladale Granite is unconformably overlain by younger Devonian strata. The main body of this foliated intrusion is an injection complex consisting of a number of coalesced granite sheets and veins which contain ubiquitous metasedimentary xenoliths (Fletcher & Key 1992). Lintern & Storey (1980) identified a zone within the main body of the granite near Altnabreac [ND 404 456] which is enriched in xenoliths. The contacts with the host metasedimentary rocks are transitional over several hundred metres and denoted by a decrease in the proportion of concordant and cross-cutting granite veins and sheets (Read 1931; Gould 1990). The metasedimentary rocks to the west of the main Strath Halladale Granite contain numerous granite veins which have been referred to as the Strath Halladale Complex by Johnstone & Mykura (1989).

The Strath Halladale Granite is in general poorly exposed, however, outcrops do occur in Sandside Burn, Mid Hill [NC 977 577], north of Cnoc Mairi Muileir [ND 955 558] and Beinn nam Bad Mor [ND 998 551]. Emplacement of the main monzogranite and earlier sodic granites post-dated deformation and metamorphism of the Moine Supergroup country rocks. The monzogranite was apparently emplaced as a series of sheets and veins which coalesced to form the main part of the Strath Halladale Granite. The absolute age of the granite remains uncertain. An unpublished Rb-Sr whole-rock age of 649 ± 32 Ma (Lintern *et al.* 1982) and published age of 415 Ma based on uraninite analyses (Basham *et al*. 1982) provide contradictory age constraints on the intrusion. The younger date is supported by a recently obtained U-Pb zircon age of 423 Ma (Fowler, pers. comm.. 2001). Fletcher & Key (1992) argue that the absence of a thermal aureole indicates that the Moine metasedimentary rocks were still hot at the time of emplacement; the latter possibly accompanying the D3 regional tectonothermal event.

5.2.1 Petrography of the Strath Halladale Granite

In the northern part of the intrusion the main lithology is a medium- to coarse-grained, inequigranular to macroporphyritic, holocrystalline biotite-monzogranite (Clark 1990; Gould 1990; Robertson 1990) which is petrographically similar to the main G3 phase (McCourt 1980) further to the south (see section 4.2.2). In this northern area, the monzogranite is relatively uniform and composed of an inequigranular assemblage of quartz (30% of the total rock), perthitic K-feldspar (25 to 30%), subhedral plagioclase (30 to 40%) and biotite (< 1%). Large (10 to 20 mm in length, and rarely 40 mm in size), tabular K-feldspar phenocrysts are variably distributed within the monzogranite and may form up to 25% of the total rock. Subhedral magnetite crystals (0.1 to 0.3 mm in size) are a common accessory phase. Quartz phenocrysts and glomerophyric aggregates of smaller quartz crystals are up to 6 mm in size. A weak to moderately developed, steeply dipping (35° to 60° towards the east or south-east) foliation is defined by a preferred shape-alignment of biotite flakes and elongate coarse grained quartz crystals. Where the fabric is most intensely developed (e.g. Allt Loch nan Clach Geala [NC 962 590] and Meur Beinn Ratha [NC 953 597]) it is defined by a preferred alignment of quartz, biotite and feldspar within the groundmass, as well as elongate quartz megacrysts which are 'flattened' in the plane of this foliation. The K-feldspar 'phenocrysts' clearly cross-cut and, therefore, post-date the imposition of this foliation. Without undertaking a detailed petrological study of the available thin sections it is difficult to assess weather the foliation present within the

Strath Halladale Granite is a pre-full crystallisation fabric or developed as a result of subsequent solid-state deformation.

The monzogranite locally contains pegmatitic veins and segregations, and is cut by fine- to medium-grained pink granite sheets (≤ 70 cm wide) and veins. The pegmatitic segregations range from a few centimetres to several metres in size and are mineralogically identical to the monzogranites. The distribution of these pegmatites shows a close spatial relationship to the megacrystic monzogranite. The granite veins and sheets cross-cut the foliation within the main monzogranite, but may themselves be foliated. Xenoliths of metasedimentary rock (few centimetres to 35 m in size) within the monzogranite are mainly composed of migmatitic micaceous psammite and semipelitic gneiss; the latter may locally contain garnet and feldspar porphyroblasts (e.g. at Cnoc Mairi Muileir [NC 9562 5565], Allt Loch nan Clach Geala [NC 9659 5920])). Biotite-rich schlieren were interpreted by Fletcher & Key (1992) as representing relicts of assimilated xenoliths. A rare diorite xenolith (20 m in size) occurs within the monzogranite at [NC 9818 6101] and small exposures of a dark coloured, megacrystic basic igneous rock have also been recorded father to the east; the latter includes the highly altered mica-picrite (scyelite) on Meall Buidhe [ND 0095 5750] (Clark 1990).

In contrast to the northern part of the Strath Halladale Granite, the petrography of the southern part of the intrusion has been more extensively examined and is described in detail by Read (1931), McCourt (1980) and Lintern & Storey (1980). The main part of the intrusion is dominated by the same biotite-monzogranite (G_3 of McCourt 1980), but detailed modal analysis reveals that the granitic rock ranges from tonalite to monzogranite in composition (Lintern & Storey 1980). This monzogranite also locally contains hornblende as well as biotite. Opaque minerals, apatite and titanite are common accessory phases. Hydrothermal alteration of the granite resulted in the development of the secondary assemblage calcite, chlorite and white mica.

In the Altnabreac area, Lintern & Storey (1980) recognised four zones within the main granite based upon the relative proportions and composition of the country rock xenoliths. The westernmost zone is composed of a relatively mafic granodiorite containing basic xenoliths. In contrast the easternmost zone marks the transitional contact with the adjacent Altnabreac Complex. The intervening zones are rich in aplites and pegmatites (east) or metasedimentary xenoliths (west). The granodiorite of the western zone is strongly foliated and has been observed forming xenoliths within the main monzogranite in the Altnabreac deep boreholes (Lintern & Storey 1980).

The whole-rock geochemistry of the Strath Halladale Granite (Appendix 1) has been described in detail by Storey & Lintern (1980). In summary, these authors concluded that all the igneous rocks within the intrusion crystallised from alkaline magmas which share a common origin. The more basic lithologies (corundum normative) represent less fractionated magma and possess high levels of Na_2O), K_2O, Rb, Sr and Ba, enrichment of LREE's and high Ce/Yb ratios.

6 Devonian Sedimentary Rocks

The Devonian sedimentary rocks of the Reay district all belong to the Orcadian Supergroup of the Old Red Sandstone. They comprise a sequence of continental-type fluvial, marginal-lake and lacustrine deposits that formed on the south-western margin of the former Orcadian Basin. Work by Donovan (1978; 1980) subdivided these sedimentary rocks into a four facies.

- *Facies A* – laminated carbonate dominated sedimentary rocks which may take the form of limestone horizons. These include recrystallised micritic carbonate (dolomite or calcite), organic material and siltstone. These laminated limestones were interpreted by Donovan (1975) as having developed close to the basin margins. The siltstone laminae may represent background clastic sedimentation or terrigenous input during wetter seasons

- *Facies B* – Laminated organic-rich siltstones and shales which are interpreted as having been deposited in a permanent lake environment in which clastic sediment supply was restricted.
- *Facies C* – Alternating organic-rich shale and coarse siltstone laminae, the latter commonly cross-bedded. These sediments are interpreted as having been deposited in a shallow, occasionally desiccated lacustrine environment which underwent periodic fluctuations in water level and salinity.
- *Facies D* – Alternating shale, siltstone and fine-grained sandstones with the coarser grained sedimentary rocks containing flaser bedding, subaerial shrinkage cracks. These sedimentary rocks are interpreted as having been deposited in a shallow temporary lake (lake flats) with periods of fluvial sedimentation (e.g. lake shoreline during early stages of lake transgression).
- *Other lithologies* – these include cross-bedded or massive fluviatile sandstones as well as the basal breccias and conglomerates.

In the Reay district the Orcadian Supergroup has been subdivided into three groups, namely the Sarclet (oldest), Caithness Flagstone and Eday groups (Appendix 2), by Auton (unpublished 2001) based upon the previous work by Trewin (1986), Fletcher & Key (1992), NIREX (1994) and Fletcher (1999).

A systematic collection of thin sections from the main lithostratigraphical units present within the Devonian sedimentary rocks of the Reay district has yet to be made. Consequently, no detailed regional petrological study on the composition and provenance of these sedimentary rocks has been undertaken. However, detailed petrological, whole-rock geochemical and X-ray diffraction studies have been carried out upon the Devonian sedimentary rocks present within Dounreay Borehole number 1 [NC 298589 966923]. Examination of this borehole was carried out by BGS as part of a core characterisation programme funded by NIREX (Milodowski *et al*. 1989; Ingham *et al*. 1991; Ingham *et al*. 1992; Prior 1993a; Prior 1993b; Prior 1993c; Prior & Kemp 1993; Hyslop 1993; Barclay *et al*. 1994; Milodowski *et al*. 199a; Milodowski *et al*. 1994b; Milodowski *et al*. 1994c; Pearce 1994a; Pearce 1994b; Pearce 1994c; Hyslop & Milodowski 1994a; Hyslop & Milodowski 1994b; Shepherd 1994). The revised Devonian lithostratigraphy encountered within this borehole is illustrated in Table 2.

The following represents a brief summary of the results of this study. For a more detailed account of the petrology, geochemistry and mineralisation associated with the basement rocks and Devonian sedimentary cover sequence encountered in these boreholes the reader is referred to Hyslop & Milodowski (1994a, 1994b).

6.1 PETROLOGY OF THE DEVONIAN SEDIMENTARY ROCKS

The mineralogy and petrography of the bulk-rock samples from the Devonian sedimentary rocks of Dounreay borehole number 1 was described by Milodowski *et al*., (1994). In thin section the various siltstones and sandstones are typically medium- to well-sorted, grain supported and closely packed rocks. Detrital grains are angular, subangular to subrounded in shape and composed of varying amounts of mono- and polycrystalline quartz, K-feldspar, plagioclase, muscovite and biotite. Other minor to accessory detrital components present include chlorite, opaque minerals (magnetite, ilmenite), rutile, zircon, monazite, mudstone lithic clasts and apatite. The available compositional data (Table 3) for the clastic rocks are limited (restricted to visual estimates of relative abundance) and do not reveal any obvious systematic lithostratigraphical variations in sandstone/siltstone composition and/or provenance.

In contrast to visual estimates of modal composition, semi-quantative X-ray diffraction analysis of bulk rock samples from Dounreay borehole number 1 (Appendix 4) has revealed some lithostratigraphical variation in the mineralogy of the Devonian strata (Kemp *et al*. 1991). The major phases, which include quartz (dominant), calcite, feldspar (plagioclase more common than K-feldspar) and mica, are present throughout the sequence (Fig. 1). However, minor to accessory minerals such as corrensite which occurs interlayered with chlorite-smectite is more common within the upper parts of the sequence (Fig. 2). Dolomite is present in low to moderate amounts in most lithologies above *c*. 125 m within the borehole, but is rare below this depth (Fig. 3). In contrast to dolomite, the carbonate mineral ankerite is absent above 125 m, but is locally present below this depth. Analysis of the clay fraction (< 2 μ size) shows that the rocks are dominated by chlorite, with illite being less common. Illite is, however, more common in samples in the depth range 100 to 200 m (Fig. 2), confirming the observation that corrensite forms a major part of the clay assemblage above *c*. 125 m depth. Smectite is very rare, and the minerals kaolinite, smectite-chlorite and illite-smectite are absent from any of the analysed Devonian sedimentary rocks.

The limestones within the Devonian sedimentary sequence show evidence of having undergone diagenetic recrystallisation, resulting in the replacement of primary micritic carbonate (? aragonite) by non-ferroan calcite microspar. Subsequent, more detailed petrological work, reviewed by Hyslop & Milodowski (1994), focused upon the complex diagenetic history of these sedimentary rocks. In total Milodowski *et al*., (1994) and Hyslop & Milodowski (1994) recognised eight discrete diagenetic events within the various lithofacies types of Donovan (1975). Summaries of these detailed diagenetic histories are presented in Table 4.

In general, however, all the sedimentary rocks have a similar diagenetic history. The earliest diagenetic events resulted in the localised development of dolomite and gypsum, as well as syntaxial overgrowths of quartz and feldspar upon detrital silicate grains. The early formed gypsum has typically been pseudomorphed by pyrite, which may also preserve the needle-shaped and 'swallow-tailed' crystal shapes of this possibly evaporitic phase. The early events were then followed by the development of a replacive ferroan dolomite cement which accompanied the compaction. Subsequent dissolution of both the carbonate cements and silicate detrital grains was followed by the development of replacive low-ferroan calcite. The latter events to affect the rocks accompanied the migration of hydrocarbons (typically resulting in corrosion and associated with pyrite growth) and the precipitation of vein related calcite (± barite, galena, chalcopyrite, sphalerite).

Although the Devonian rocks have undergone dissolution of both carbonate and the silicate detrital grains, only a small percentage contain significant porosity (15 out of 74 samples examined, Hyslop & Milodowski 1994). Primary intergranular porosity is rare and was only recognised in the coarser grained fluvial sandstones. In the majority of cases any porosity is secondary in nature and typically formed due to grain and cement dissolution.

Grain size analysis of the Devonian sedimentary rocks in Dounreay borehole number 1 has revealed the presence of several large scale fining-upward cycles (Hyslop & Milodowski 1994). These cycles occur in the depth ranges 1 – 40 m, 150 – 200 m and 300 – 320 m. The rocks of the lower two cycles are overlain by a thick sequence of relatively clay-rich sedimentary rocks. Hyslop & Milodowski (1994) considered that these cycles reflected long term changes in lacustrine sedimentation, possibly reflecting tectonic uplift of the source area and the input of relatively coarse clastic material, followed by progressive erosion of the hinterland and an increase in finer grained sediment input. Finer scale cycles of sedimentation have also been recognised within the sequence and interpreted as representing seasonal variations in sediment flux (Donovan 1980).

6.2 WHOLE-ROCK GEOCHEMISTRY OF THE DEVONIAN SEDIMENTARY ROCKS

Whole-rock geochemical data obtained for the mudstones, siltstones, sandstones and limestones from the Devonian strata of Dounreay borehole number 1 are listed in Appendix 1 (data from Ingham *et al*. 1991; Hyslop & Milodowski 1994). The lithostratigraphical variation in the major oxides and trace elements are shown in Figs. 4 to 12.

SiO_2 and Al_2O_3 exhibit similar distribution patterns (Fig. 4), with Al_2O_3 probably reflecting the variation in detrital feldspar within the clastic sedimentary rocks. Similarly, Na_2O (Fig. 7) is also considered to record changes in detrital feldspar (in particular plagioclase) content, but overall shows very little variation, possibly reflecting a relatively constant plagioclase content within the clastic rocks. Fe_2O_3 (Fig. 5) and TiO_2 (Fig. 6) show a wide variation and, contrary to what would be expected, do not show obvious enhanced within the mudstones. The clay-rich sediments between 40 – 150 m and 220 – 265 m depth, are, however, distinguished by their consistently high Cr and Ni contents (Fig. 11). In contrast to the mud-rich rocks, the fluvial sandstones within the sequence possess very low Cr and Ni contents (Fig. 11). The limestones within the sequence are distinguished by their high CaO (Fig. 7), Sr (Fig. 9) and low Na_2O, Fe_2O_3, TiO_2, Cr and Ni contents. The elements Nb, La, Ce (Fig. 10), Zr (Fig. 8) and Y are all controlled by the distribution of detrital heavy minerals. Zr (Fig. 8), in particular, show very enrichment within fluvial and facies D sandstones, but is strongly depleted within the limestones.

Ba (Fig. 12) shows a more complex pattern of variation within the Dounreay borehole number 1. Hyslop & Milodowski (1994) recognised three distinct zones of based upon Ba concentrations with boundaries at *c*. 150 m and *c*. 300 m depth (see Fig. 12). Importantly, these changes do not correspond to the main lithostratigraphical boundaries within the logged sequence (Barclay *et al*. 1991), but appear to correspond to mineralogical changes; e.g. boundary at *c*. 150 m corresponds to decrease in corrensite (see Fig. 2). The boundary at *c*. 300 m corresponds to a major fault zone and Hyslop & Milodowski (1994) that such large fault zones and the underlying unconformity at the base of the Devonian strata probably controlled fluid movement and element migration within this sedimentary sequence.

7 Post-Devonian rocks

The only proven post-Devonian rocks in the Reay district are a volumetrically restricted suite of lamprophyric dykes described by Fletcher & Key (1992) from the Dunnet Bay area (e.g. at Red Geo [ND 182 740]; Chapel Geo [ND 187 729]; Pool of Backway [ND 210 710]; House Head [ND 198 685]; Sandstone Geo [ND 190 692]; Castlehill Quarry [ND 193 685])). These dykes are thought to form part of a suite of Permo-Carboniferous monchiquite dykes similar to those which cut through the Devonian strata on Orkney and which have been radiometrically dated at c. 283 ± 9 Ma (Snelling in Mykura 1976). In thin section, the least altered of these fine-grained monchiquite dykes are composed of small olivine phenocrysts, within a groundmass of Ti-augite, red-brown biotite and an interstitial to intersertal, turbid assemblage of calcite, chlorite and analcime. The olivine microphenocrysts are pseudomorphed by serpentine. Augite forms long, narrow crystals with rarely developed simple twins. No obvious primary glass or nepheline have been recorded in these monchiquites. These rocks do, however, contain rounded (≤ 1 mm in diameter) ocelli (commonly associated with lamprophyric camptonites and monchiquites) containing hornblende, plagioclase and analcime. These dykes may also contain amygdales composed of carbonate and possible bitumen (Fletcher & Key 1992).

8 Future Research

The following is a list of potential petrological research topics which might be undertaken as part of the Caithness project:

- A systematic, regional petrological study of the various sedimentary rocks to characterise the composition and lithological variation within the main Devonian lithostratigraphical units within the Reay/Caithness district.
- Heavy mineral provenance study of a selected suite of sandstones to establish weather there are any lithostratigraphical variations in the provenance of the main clastic input into the Orcadian sedimentary basin.
- Microstructural analysis of soft sediment deformation structures within the Devonian sedimentary rocks to establish the mechanism for 'triggering' the development of these features, for example: earthquake induced deformation associated with movement upon basin controlling faults; storm induced soft sediment deformation; or load induced deformation in association with high pore water content.
- Micromorphological, provenance and microstructural analysis of the Quaternary glacial deposits of the Reay/Caithness district. This may also include an investigation of the role of glacial and post-glacial microscopic and small-scale macroscopic structures on ground water flow through these glacigenic sediments. Autoradiography will provide detailed micro-maps of the distribution of uranium and thorium series nuclides within the sediments and provide preliminary evidence for the potential control of pre-existing glacitectonic/neotectonic structures on the migration of radionuclides in the ground water system.
- A petrological study of the various metasedimentary, meta-igneous and igneous rocks of the Reay/Caithness district for inclusion within the sheet description or memoir. This study would be solely based upon existing thin sections present within the BGS collections.

9 Figures

Fig. 1. Diagram showing the variation in the relative proportions of the main mineral components within the Devonian strata encountered in Dounreay Borehole number 1 (data from Kemp *et al*. 1991).

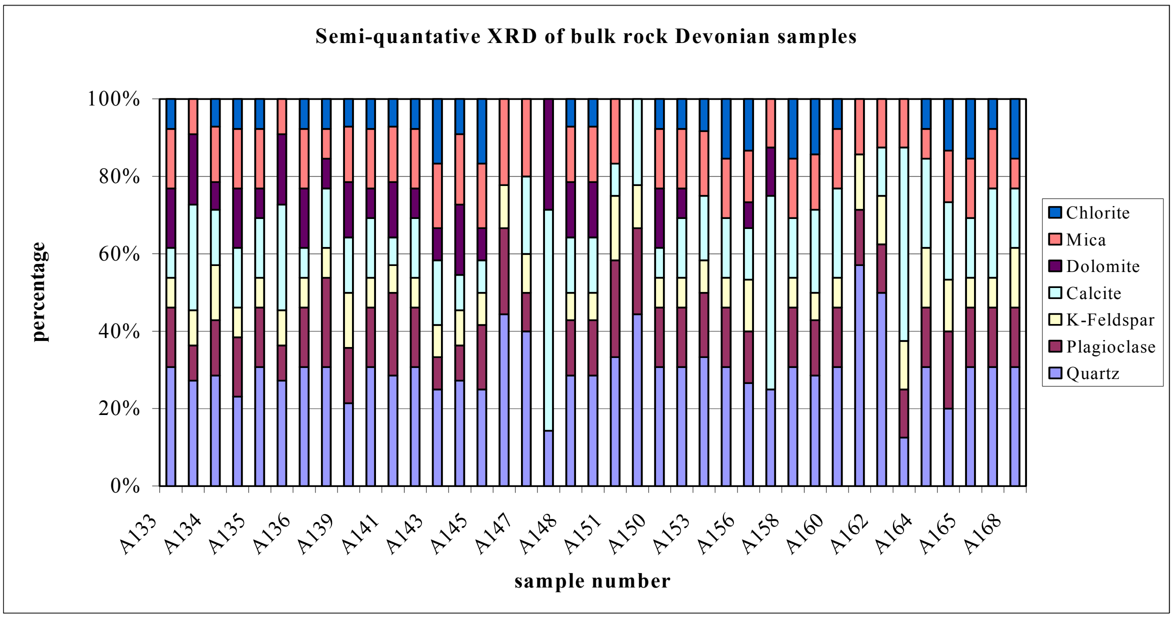


Fig. 2. Diagram showing the variation in the relative proportions of chlorite, illite and corrensite within the Devonian strata encountered in Dounreay Borehole number 1 (data from Kemp *et al*. 1991).

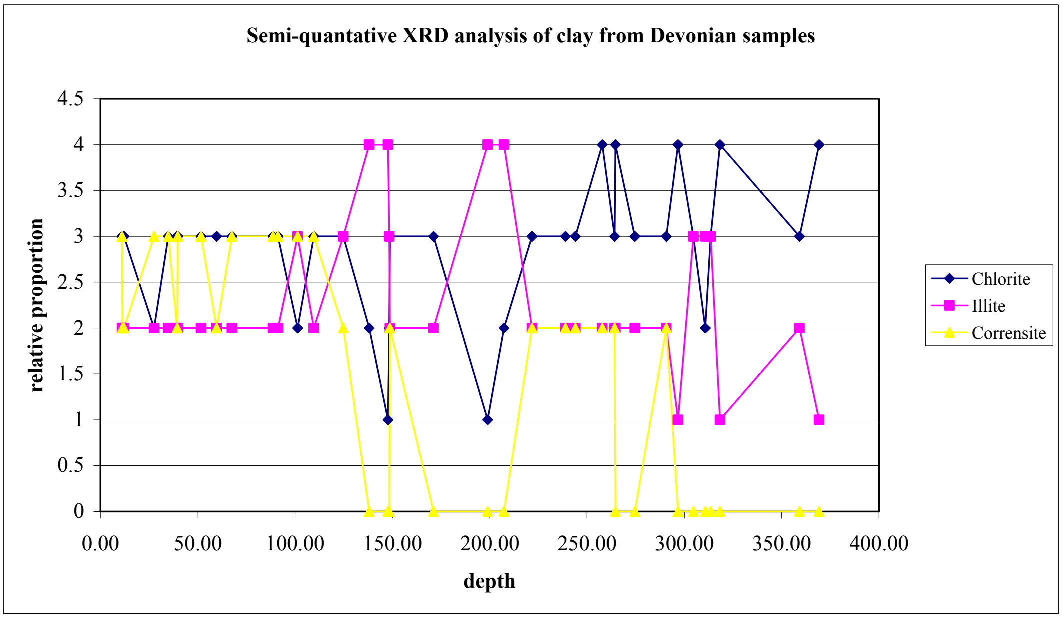


Fig. 3. Diagram showing the variation in the relative proportions of calcite and dolomite within the Devonian strata encountered in Dounreay Borehole number 1 (data from Kemp *et al*. 1991).

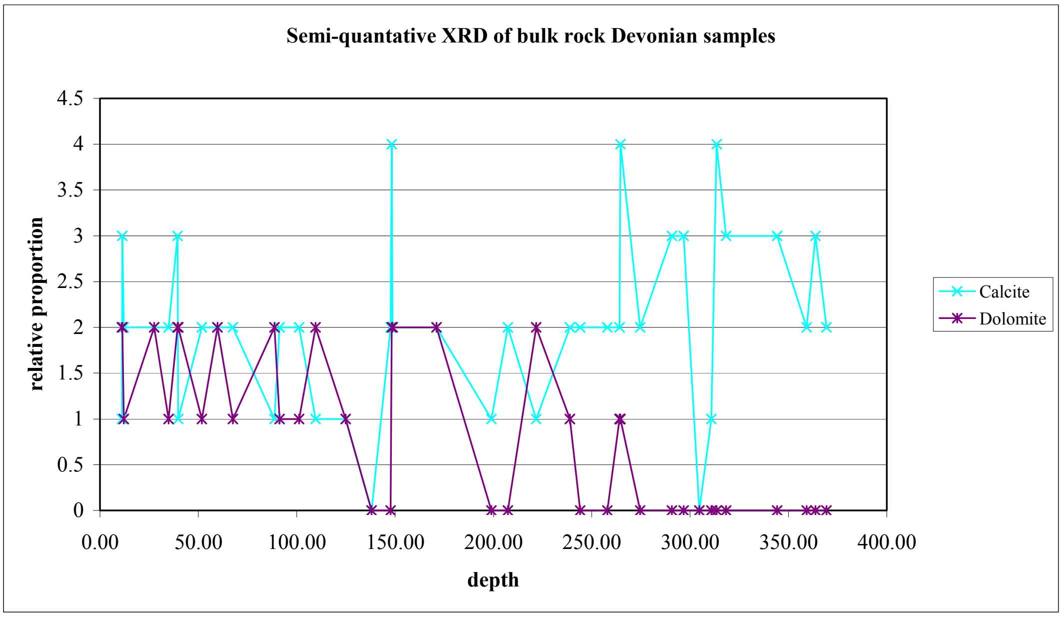


Fig. 4. Diagram showing the lithostratigraphical variation in SiO_2 and Al_2O_3 within the Devonian sedimentary rocks from Borehole number 1 (data from Ingham *et al*. 1991).

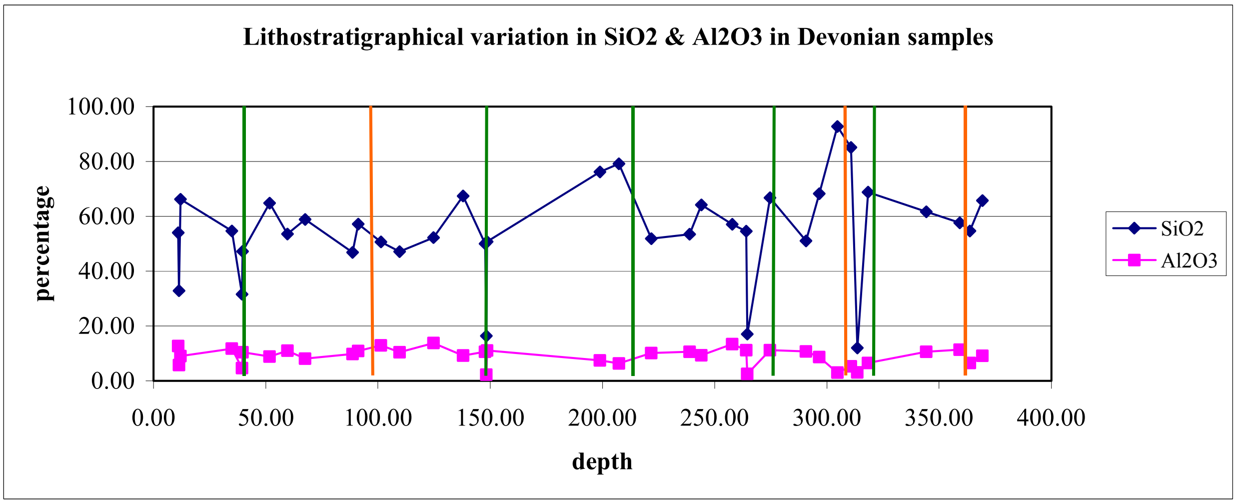


Fig. 5. Diagram showing the lithostratigraphical variation in Fe_2O_3 and MgO within the Devonian sedimentary rocks from Borehole number 1 (data from Ingham *et al*. 1991).

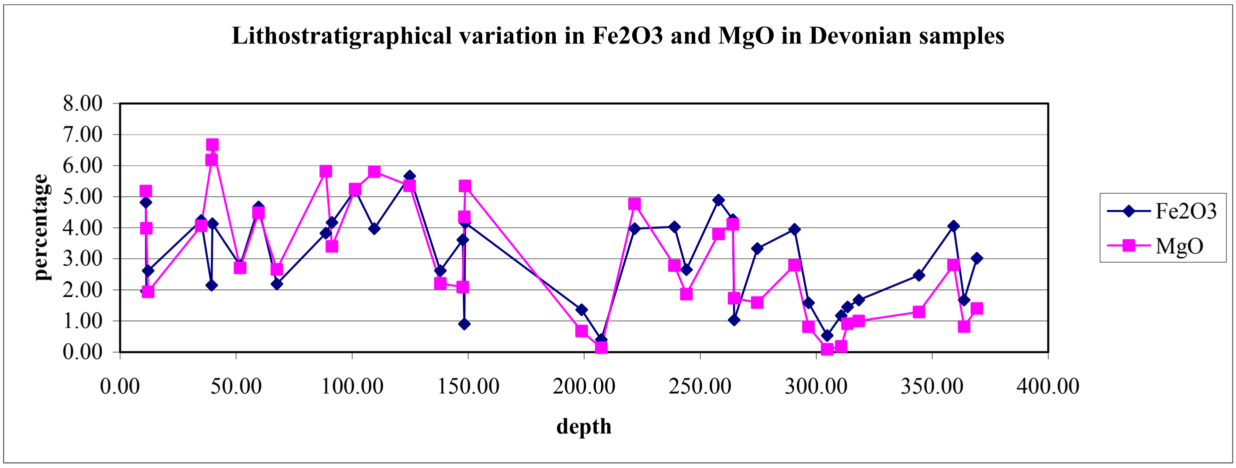


Fig. 6. Diagram showing the lithostratigraphical variation in TiO_2, MnO and P_2O_5 within the Devonian sedimentary rocks from Borehole number 1 (data from Ingham *et al*. 1991).

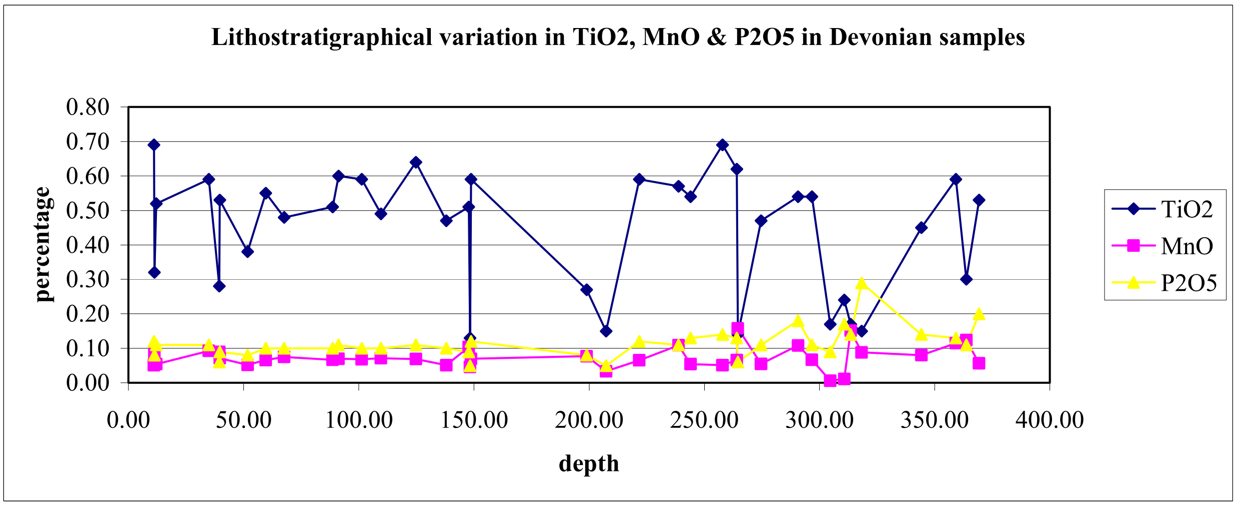


Fig. 7. Diagram showing the lithostratigraphical variation in CaO, Na_2O and K_2O within the Devonian sedimentary rocks from Borehole number 1 (data from Ingham *et al*. 1991).

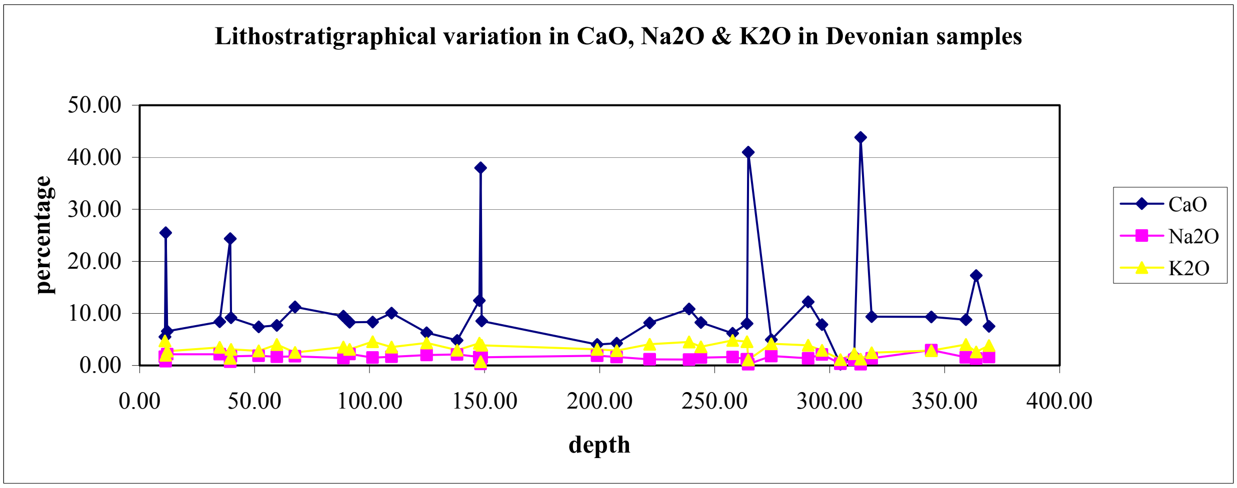


Fig. 8. Diagram showing the lithostratigraphical variation in V, Zn and Zr within the Devonian sedimentary rocks from Borehole number 1 (data from Ingham *et al*. 1991).

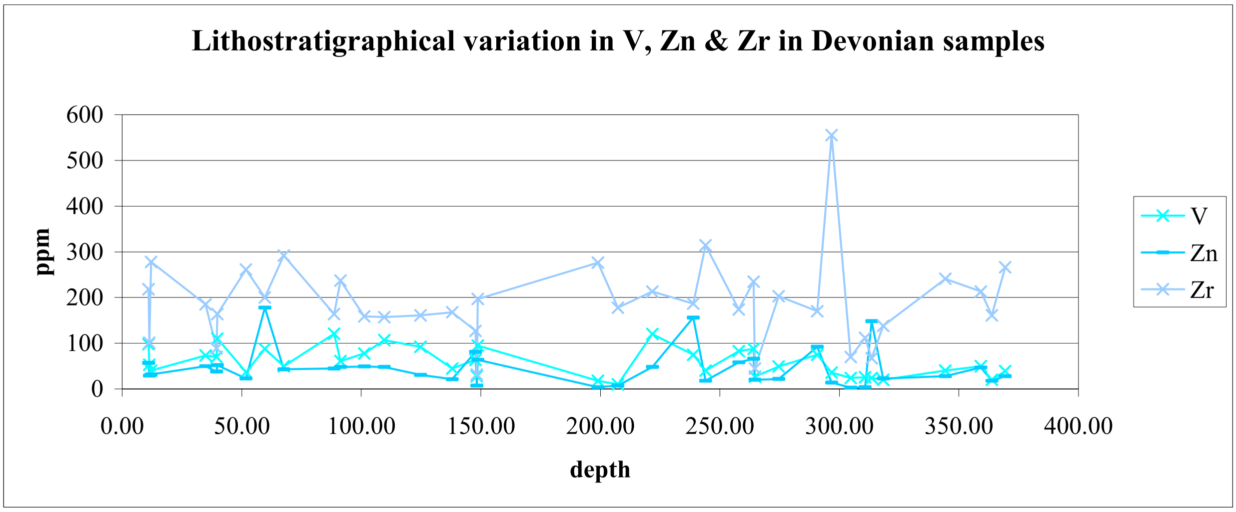


Fig. 9. Diagram showing the lithostratigraphical variation in Rb and Sr within the Devonian sedimentary rocks from Borehole number 1 (data from Ingham *et al*. 1991).

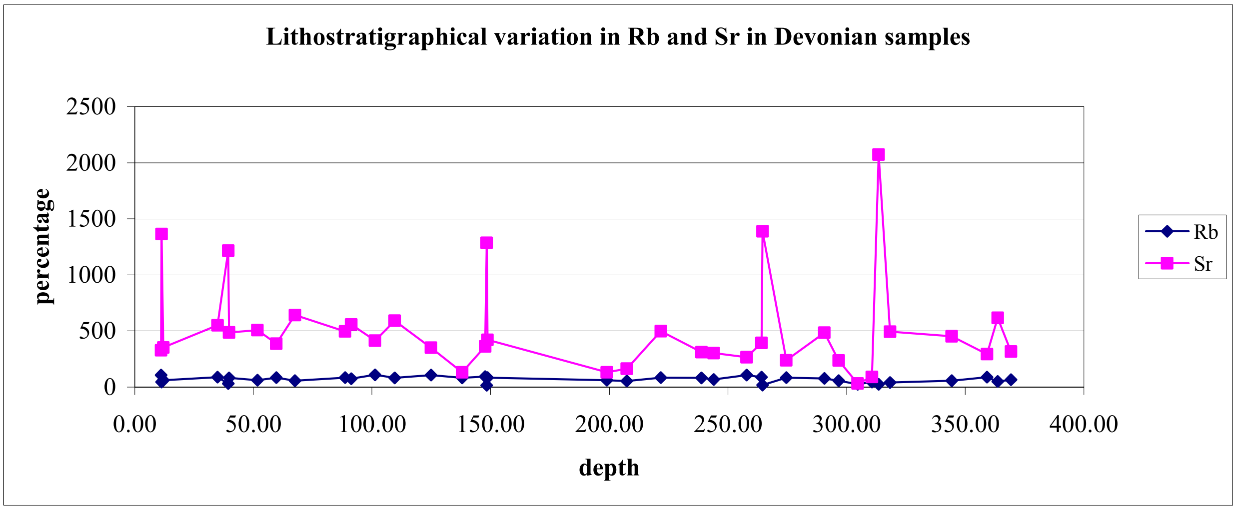


Fig. 10. Diagram showing the lithostratigraphical variation in Nb, La and Ce within the Devonian sedimentary rocks from Borehole number 1 (data from Ingham *et al*. 1991).

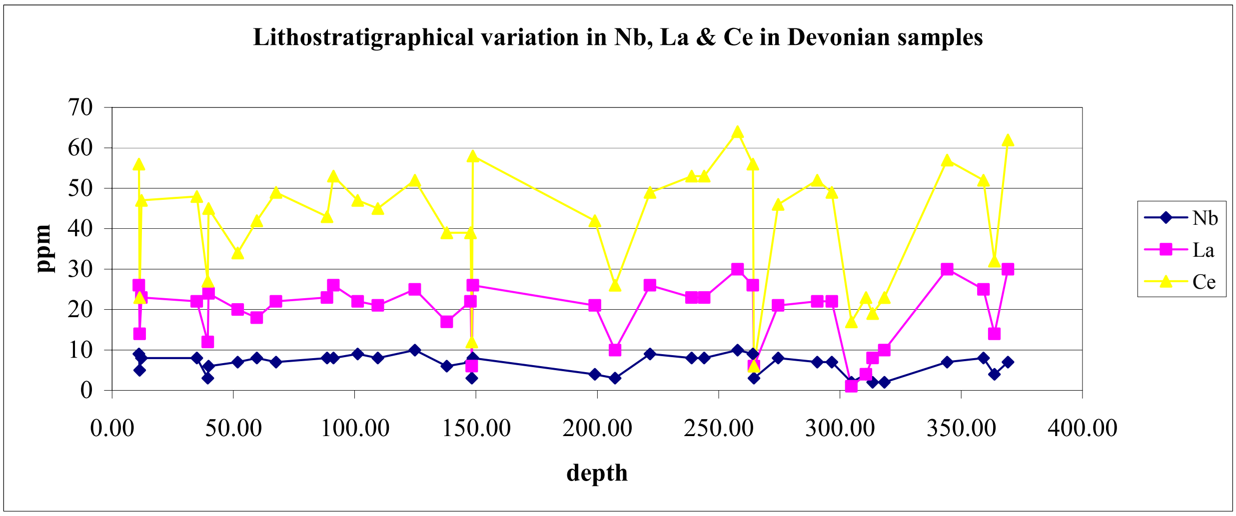


Fig. 11. Diagram showing the lithostratigraphical variation in Cr, Co and Ni within the Devonian sedimentary rocks from Borehole number 1 (data from Ingham *et al*. 1991).

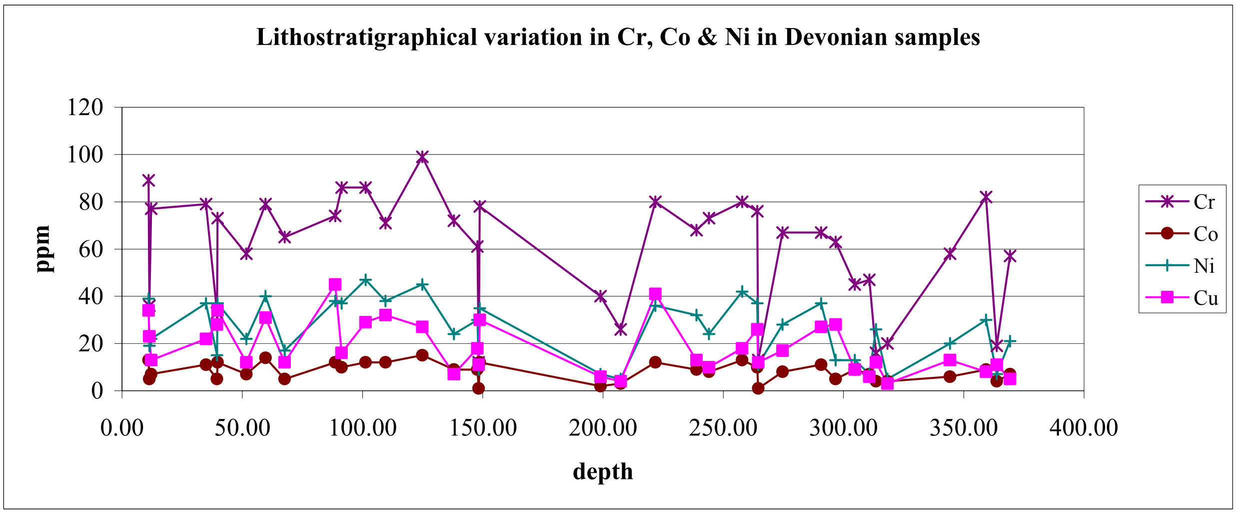
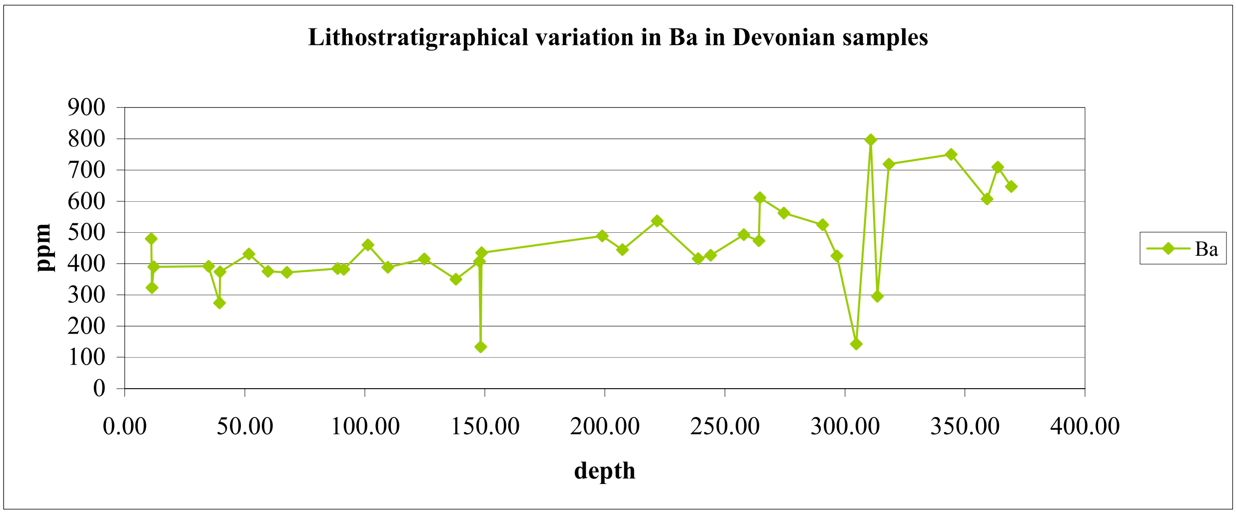


Fig. 12. Diagram showing the lithostratigraphical variation in Ba within the Devonian sedimentary rocks from Borehole number 1 (data from Ingham *et al*. 1991).



10 Tables

Table 1. Summary of main tectonothermal and igneous events in the Moine Supergroup and associated basement rocks (Fletcher & Key 1992).

Table 1. Summary of main tectonothermal and igneous events in the Moine Supergroup and associated basement rocks (Fletcher & Key 1992)

Altnabreac Complex		**Altnabreac Complex to SE of Reay District**		**Kirtomy & Strathy Complexes**		**Portskerra Complex**	
			G_4 Helmsdale Granite (*c.* 420 Ma)	**D5** brittle deformation	microgranite in tension gashes		
D4 brittle fractures kinks & hydrothermal alteration	aplite an pegmatite veins	**D4** open folds & warps, kinks retrogression		**D4** monoforms, shearing. greenschist facies metamorphism		**D4** open disharmonic folds, kinks, brittle shears retrogression	
	Strath Halladale Granite (G_3)		Strath Halladale Granite (G_3)				Strath Halladale Granite, Reay Diorite (G_3)
D3 open & chevron folds, chlorite retrogression	A_3 amphibolite intrusions	**D3** major upright folds. middle greenschist facies metamorphism		**D3** upright folds, thrusting. middle-upper greenschist facies metamorphism	trondhjemite, granite, pegmatite	**D3** open to tight folds. amphibolite facies metamorphism	
	G_2 granodiorite		G_2 granodiorite				
D2 isoclinal folding & thrusting		**D2** tight to isoclinal recumbent folding. amphibolite facies metamorphism		**D2** tight to isoclinal folds. ductile shearing. middle-upper amphibolite facies metamorphism	foliated granite	**D2** tight to isoclinal folds. amphibolite facies metamorphism	G_2 granodiorite
			G_1 augen-granite, granodiorite pegmatite				
D1 bedding-parallel foliation, upper amphibolite-facies metamorphism	G_1 granodiorite	**D1** rare recumbent to isoclinal folds, upper to middle amphibolite-facies metamorphism		**D1** rare isoclinal folds, bedding-parallel foliation, gneissosity & migmatisation. upper amphibolite-facies metamorphism	amphibolite pegmatite	**D1** rare isoclinal folds, bedding-parallel foliation, gneissosity & migmatisation. upper amphibolite-facies metamorphism	pegmatite G_1 granodiorite
	A_1 amphibolite intrusions						

Table 2. Revised Devonian lithostratigraphy for Dounreay Borehole number 1 (after Barclay *et al*. 1992).

Table 2. Revised Devonian lithostratigraphy for Dounreay Borehole number 1 (after Barclay *et al*. 1992)				
Depth	**Group**	**Formation**	**Member**	**Lithology**
0-95.10 m	Upper Caithness Flagstone Group	Sandside Sandstone Formation	Dounreay Siltstone Member	lacustrine silt dominated facies
95.10-308.65 m			Sandside Bay Sandstone Member	sandstone dominated lake shoreline facies
308.65-362.10 m	Lower Caithness Flagstone Group	Bighouse Sandstone Formation	Rubha Sandstone Member	dominantly upwards-fining fluvial sandstones with infrequent lacustrine cycles
362.10-375.60 m	Sarclet Group	Ousdale Arkose Formation	Tobaireach Conglomerate Member	basal breccias and conglomerates

Table 3. Available compositional data for the Devonian strata, Dounreay Borehole number 1 (Hyslop & Milodowski 1994). Detrital components: 3 - major; 2 - minor; 1 - trace; 0 - absent. Qm – monocrystalline quartz, Qp – polycrystalline quartz, Ksp – K-feldspar, Pl – plagioclase, Mu – muscovite, Bio – biotite, Chl – chlorite, Op – opaques, Org – organics, CC – carbonate, Lt – lithic clasts.

Compositional data for the Devonian strata, Dounreay borehole number 1 (Hyslop & Milodowski 1994)															
Sample	**Top depth (m)**	**Bottom depth (m)**	**Lithology**	**Qm**	**Qp**	**Ksp**	**Pl**	**Mu**	**Bio**	**Chl**	**Op**	**Org**	**CC**	**Matrix**	**Lt**
A171	9.68	9.90	shale with feldspathic siltstone laminae	3	0	3	1	2	2	2	0	2	0	3	0
A133	11.06	11.34	laminated siltstone and shale	3	0	3	2	3	2	3	0	2	0	3	0
A132	11.34	11.59	micritic limestone with siltstone laminae	2	0	2	2	2	2	2	1	2	0	2	0
A134	12.07	13.02	feldspathic arenite	3	0	3	3	2	2	0	2	0	0	0	2
A172	18.41	18.71	laminated mudstone and siltstone	3	0	3	2	2	2	0	0	2	0	3	0
A169	27.54	27.90	interlaminated mudstone and siltstone	3	0	3	2	2	2	1	2	2	0	3	0
A173	30.32	30.61	feldspathic oolitic sandstone with shale laminae	3	0	3	1	2	2	0	0	2	0	2	0
A135	34.90	35.19	siltstone with shale, feldspathic siltstone and micaceous mudstone laminae	3	0	3	2	2	2	2	0	2	0	3	2
A137	39.46	37.70	laminated micritic limestone and siltstone	3	0	2	2	2	2	2	0	2	0	0	0
A136	39.73	39.98	shale with siltstone laminae	3	0	2	0	2	2	2	2	2	0	3	0
A174	40.38	40.68	shale with feldspathic siltstone and fine sandstone laminae	3	0	3	2	2	2	0	0	2	0	3	0
A175	42.02	42.27	feldspathic arenite	3	0	3	2	2	2	0	0	2	0	2	0
A138	51.75	52.05	feldspathic arenite	3	0	3	3	2	0	0	0	0	0	2	0
A139	59.68	59.98	interbedded siltstone, very fine sandstone and shale	3	0	3	3	2	2	0	0	2	0	3	2
A176	65.71	66.05	feldspathic siltstone and fine sandstone and shale laminae	3	0	3	2	2	2	0	1	2	0	3	0
A177	67.16	67.46	shale with siltstone and fine sandstone laminae	3	0	2	2	2	2	0	2	2	0	2	0
A140	67.57	67.85	laminated fine sandstone and siltstone	3	0	2	2	2	2	0	2	0	0	2	2
A178	84.06	84.28	siltstone	3	0	2	2	2	2	0	0	1	0	2	0
A179	85.56	85.79	interbedded feldspathic siltstone and shale	3	0	3	2	2	2	0	2	2	0	2	0

Sample	Top depth (m)	Bottom depth (m)	Lithology	Qm	Qp	Ksp	Pl	Mu	Bio	Chl	Op	Org	CC	Matrix	Lt
A141	88.66	88.96	silty shale with siltstone and very fine sandstone laminae	3	0	2	2	2	2	0	0	2	0	3	0
A142	91.27	91.55	litharenite	3	0	2	3	2	0	2	2	0	0	3	3
A143	101.28	101.58	feldspathic wacke siltstone	3	0	2	2	2	2	0	2	0	0	3	3
A180	107.14	107.44	siltstone with shale laminae	3	0	2	2	2	2	0	2	2	0	2	0
A181	108.80	109.06	siltstone with shale laminae	3	0	3	2	2	2	0	2	2	0	2	0
A144	109.59	109.90	shale with siltstone laminae	3	0	3	2	2	2	2	2	2	2	3	0
A182	116.04	116.34	micritic limestone with siltstone laminae	2	0	2	0	0	0	0	0	2	0	2	0
A145	124.82	125.12	shale with siltstone laminae	3	0	2	0	2	0	0	2	2	0	3	0
A183	133.44	133.74	shale with siltstone laminae	3	0	3	2	2	2	0	0	2	0	3	0
A146	138.01	138.30	feldspathic siltstone and fine sandstone	3	0	2	2	2	0	2	2	0	0	0	0
A184	140.39	140.69	shale with siltstone laminae	3	0	2	2	2	2	0	0	2	0	3	0
A185	142.79	143.07	siltstone	3	0	2	2	3	2	0	2	2	0	2	0
A186	146.04	146.36	feldspathic siltstone	3	0	2	2	2	0	0	2	2	0	2	0
A147	147.72	147.97	siltstone with shale laminae	3	0	2	2	3	2	2	0	0	0	3	0
A149	148.30	148.70	limestone with silty laminae	2	0	2	2	2	0	0	0	2	0	0	0
A148	148.70	149.10	shale with siltstone laminae	3	0	3	2	3	2	2	2	0	0	3	0
A187	160.31	160.61	siltstone with shale laminae	3	0	3	2	2	1	0	1	1	0	2	0
A170	171.12	171.42	laminated siltstone and shale	3	0	2	1	2	1	1	0	2	0	3	2
A188	177.11	177.54	feldspathic arenite	3	0	3	2	3	2	0	2	2	0	1	0
A189	182.81	183.11	feldspathic arenite	3	0	3	2	3	2	0	2	0	0	2	0
A190	185.67	186.02	micritic limestone	2	0	2	0	0	0	0	0	2	0	2	0
A191	192.20	192.48	feldspathic arenite	3	0	2	2	2	0	2	2	2	0	0	0
A151	198.95	199.27	feldspathic arenite	3	0	3	3	2	1	0	0	0	1	0	3
A192	205.44	205.71	feldspathic arenite	3	0	2	2	0	0	0	0	0	0	0	0
A152	207.35	207.62	feldspathic arenite	3	0	3	2	0	1	1	0	0	0	0	2
A193	213.74	214.04	feldspathic siltstone	3	0	3	2	2	2	0	2	0	0	2	0
A150	221.75	222.05	shale with siltstone laminae	3	0	3	2	2	2	0	2	2	0	3	0
A194	223.32	223.62	feldspathic sandstone	3	0	3	2	0	0	0	0	0	0	0	0

Sample	Top depth (m)	Bottom depth (m)	Lithology	Qm	Qp	Ksp	Pl	Mu	Bio	Chl	Op	Org	CC	Matrix	Lt
A195	229.73	230.06	shale with siltstone laminae	3	0	3	2	2	0	0	2	2	0	3	0
A154	238.87	239.15	siltstone with shale laminae	3	0	2	2	2	2	2	1	2	0	3	0
A153	244.03	244.33	siltstone	3	0	3	2	2	2	2	2	0	0	0	2
A196	249.27	249.57	shale	3	0	3	0	2	0	0	2	2	0	3	0
A197	256.20	256.51	siltstone with shale laminae	3	0	3	2	3	0	2	2	2	0	0	0
A155	257.86	258.13	shale and silty shale	3	0	3	3	3	3	2	0	0	0	3	0
A156	264.11	264.42	silty shale with very fine sandstone laminae	3	0	3	0	3	1	2	2	2	0	3	0
A157	264.59	264.89	micritic limestone with siltstone laminae	2	0	2	0	2	2	1	1	2	0	2	0
A158	274.61	274.91	feldspathic wacke sandstone	3	0	3	3	2	0	0	2	0	0	3	0
A198	282.76	283.05	shale with siltstone laminae	3	0	3	2	2	0	0	2	0	2	3	0
A199	287.11	287.41	feldspathic arenite	3	0	3	3	0	0	0	2	0	0	0	0
A159	290.70	290.98	shale with siltstone laminae	3	0	3	2	2	2	0	2	2	0	3	2
A200	293.24	293.55	shale with siltstone laminae	3	0	3	0	2	0	0	2	2	2	3	0
A160	296.67	296.97	feldspathic arenite	3	0	2	2	2	1	0	2	0	1	0	2
A201	300.56	300.90	feldspathic siltstone	3	0	3	2	2	0	0	2	0	0	0	0
A161	304.71	305.01	brecciated micritic limestone with shale laminae	3	0	2	0	2	0	0	0	0	0	0	0
A162	310.73	311.27	brecciated fine feldspathic sandstone	3	0	3	3	2	0	0	1	0	0	0	0
A163	313.52	313.83	micritic limestone with siltstone laminae	2	0	2	2	2	2	0	2	2	0	0	0
A164	318.30	318.60	fine feldspathic arenite	3	0	3	3	2	0	0	0	0	0	0	2
A202	321.96	322.27	feldspathic wacke sandstone	3	0	3	3	2	0	0	2	0	0	3	2
A203	327.92	328.19	feldspathic sandstone	3	0	3	2	2	0	0	2	0	0	2	0
A204	329.21	329.51	feldspathic sandstone	3	0	3	2	2	0	0	0	0	0	0	0
A205	344.05	344.29	feldspathic siltstone	3	0	3	2	2	0	0	1	0	0	2	0
A166	344.25	344.55	litharenite	3	0	3	3	2	0	2	0	0	0	0	3
A165	359.20	359.55	shale with siltstone laminae	3	0	2	2	2	2	2	2	2	0	3	3
A167	363.72	364.03	conglomerate	2	0	2	2	1	0	0	1	0	0	0	3
A168	369.26	369.56	conglomerate	2	0	2	2	2	2	2	2	0	0	2	3

Table 4. Summary of the diagenetic history of the Devonian sedimentary rocks from Dounreay Borehole number 1 (Milodowski *et al*. 1994; Hyslop & Milodowski 1994).

Table 4. Summary of the diagenetic histories of the Devonian sedimentary rocks from Dounreay Borehole number 1 (Milodowski *et al*. 1994; Hyslop & Milodowski 1994)

Lithology/Facies	**Main diagenetic events**				
	early				**late**
Limestone (Facies A)	Recrystallisation of micritic carbonate (?aragonite) to non-ferroan calcite microspar (± framboidal pyrite & minor gypsum)	Dolomitisation associated with calcite dissolution & development of porosity vugs	Ferroan dolomite overgrowths	Calcite cementation, infilling of porosity & vugs.	Localised calcite, pyrite & barite (± galena, sphalerite) vein mineralisation
Shales & Siltstones (Facies B)	Replacive non-ferroan dolomite associated with evaporitic phases (gypsum). Very early diagenetic pyrite	Overgrowths of feldspar & syntaxial quartz on detrital silicate grains, associated with or pre-dated by alteration of micas and feldspars	Ferroan dolomite overgrowths	Dissolution of carbonate & detrital silicate grains, resultant porosity filled by low ferroan calcite cement. Localised chalcopyrite, galena, pyrite, barite vein mineralisation	Localised hydrocarbon migration Localised illite and chlorite infill of porosity
Siltstones (Facies C & C/D)	Non-ferroan dolomite cement locally associated with gypsum	Overgrowths of K-feldspar & syntaxial quartz on detrital silicate grains	Compaction & formation of ferroan dolomite cement	Dissolution of detrital silicate grains, resultant porosity filled by replacive ferroan calcite cement	Localised calcite & pyrite vein mineralisation
Fine-grained sandstones and siltstones (Facies D)	Non-ferroan dolomite cement locally associated with gypsum Below 142 m depth – K-feldspar and syntaxial quartz overgrowths pre-date non-ferroan calcite cement	Above 142 m depth - K-feldspar & syntaxial quartz overgrowths on detrital silicate grains	Ferroan dolomite overgrowths & localised dissolution of earlier non-ferroan dolomite	Dissolution of detrital silicate grains, resultant porosity filled by replacive ferroan calcite cement	Carbonate corrosion, localised hydrocarbon migration & pyrite mineralisation
Sandstone Fluvial facies	Localised early alteration of feldspar & formation of pyrite coatings on detrital grains K-feldspar & syntaxial quartz overgrowths on detrital silicate grains	Non-ferroan dolomite cement	Ferroan dolomite overgrowths	Dissolution of carbonate & detrital silicate grains, resultant porosity filled by replacive ferroan calcite cement	Carbonate corrosion, localised hydrocarbon migration & pyrite mineralisation

Appendix 1

Whole-rock geochemical data for the Moine Supergroup, igneous rocks and Devonian sedimentary rocks from the Reay district from Moorhouse & Moorhouse (1983), Moorhouse & Moorhouse (1988), Storey & Lintern (1981) and Hyslop & Milodowski (1994a).

Whole-rock geochemical data from the Kirtomy and Strathy complexes (Moorhouse & Moorhouse 1983; Moorhouse & Moorhouse 1988)

Sample Number	1	2	A	B	C	D	E	F	G	H	I	J
Major Oxides (wt % oxide)												
SiO_2	71.64	62.05	51.48	72.8	69.35	71.54	69.66	55.77	52.63	59.06	50.86	37.03
TiO_2	0.81	0.87	1.04	0.25	0.37	0.24	0.23	0.11	0.61	0.53	0.77	0.88
Al_2O_3	11.87	16.93	15.33	12.46	12.89	13.79	15.79	2.46	16.09	15.06	14.02	16.91
Fe_2O_3	4.89	7.09	9.81	3.46	4.67	2.89	1.98	5.72	10.4	3.73	6.29	8.16
MnO	0.05	0.04	0.12	0.03	0.04	0.02	0	0	0.01	0	0	0.09
MgO	2.02	2.58	6.7	1.62	2.55	1.54	1.42	20.25	7.45	2.84	4.68	4.37
CaO	1.67	2.01	8.23	1.74	2.66	1.89	2.11	13.39	4.89	14.32	16.61	18.89
Na_2O	2.93	2.84	4.18	5.27	5.04	5.63	6.16	0.9	5.1	2.9	3	1
K_2O	2.69	3.47	1.03	1.09	1.08	1.23	1.45	0.2	1.09	0.41	0.72	1.4
P_2O_5	0.16	0.25	0.19	0.07	0.09	0.1	0.14	0.3	0.14	0.15	0.14	0.29
LOI	-	-	-	-	-	-	-	-	-	-	-	-
Total	98.73	98.13	98.11	98.79	98.74	98.87	98.94	99.1	98.41	99	97.09	89.02
Trace Elements (ppm)												
S	502	350	944	824	826	736	604	170	160	1710	1670	2140
Ba	747	690	218	273	262	438	685	68	126	279	906	278
Ce	104	128	62	37	42	39	41	49	46	135	111	143
Cr	63	80	159	28	62	30	34	2168	172	60	93	56
Cu	9	26	55	24	26	17	7	0	0	24	36	4
Ga	11	23	19	7	9	9	13	0	22	19	23	46
La	37	41	9	7	8	10	14	4	4	41	34	34
Nb	13	20	6	4	4	4	4	2	2	13	13	13
Ni	40	64	102	7	29	8	10	1784	106	47	66	21
Pb	22	30	8	11	11	16	23	4	5	20	21	34
Rb	92	155	15	20	19	23	28	1	21	6	11	49
Sr	357	266	283	200	221	442	804	187	124	976	1119	1696
Th	15	17	3	3	3	4	5	1	0	24	16	16
Y	29	40	22	26	25	17	4	2	14	20	23	34
Zn	77	109	101	62	70	54	43	0	102	81	109	67
Zr	409	267	152	140	146	173	222	26	67	168	306	342

Sample: 1 **Lithology:** Biotite gneiss **Unit:** Kirtomy Complex, Swordly Pelite

Sample: 2 **Lithology:** Semipelitic gneiss **Unit:** Kirtomy Complex, Swordly Pelite

Sample: A **Lithology:** Hornblende gneiss **Unit:** Strathy Complex

Sample: B **Lithology:** Siliceous gneiss **Unit:** Strathy Complex

Sample: C **Lithology:** mixed **Unit:** Strathy Complex

Sample: D **Lithology:** mixed **Unit:** Strathy Complex

Sample: E **Lithology:** Trondhjemite **Unit:** Strathy Complex

Sample: F **Lithology:** Armadale ultramafic **Unit:** Strathy Complex

Sample: G **Lithology:** Amphibolite **Unit:** Strathy Complex

Sample: H **Lithology:** Calc-silicate rock **Unit:** Strathy Complex

Sample: I **Lithology:** Calc-silicate rock **Unit:** Strathy Complex

Sample: J **Lithology:** Marble **Unit:** Strathy Complex

Whole rock geochemical data from the Devonian of the Dounreay Borehole number 1 (Hyslop & Milodowski 1994)

Sample Number	A133	A132	A134	A135	A137	A136	A138	A139	A140	A141	A142	A143
Top depth (m)	11.06	11.34	12.07	34.9	39.46	39.73	51.75	59.68	67.57	88.66	91.27	101.3
Bottom depth (m)	11.34	11.59	13.02	35.19	37.7	39.98	52.05	59.98	67.85	88.96	91.55	101.6
Major Oxides (wt % oxide)												
SiO_2	54.04	32.9	66.22	54.65	31.57	47.19	64.81	53.55	58.85	46.85	57.14	50.67
TiO_2	0.69	0.32	0.52	0.59	0.28	0.53	0.38	0.55	0.48	0.51	0.6	0.59
Al_2O_3	12.7	5.8	9.03	11.71	4.68	10.45	8.85	11.02	8.07	9.81	10.85	12.94
Fe_2O_3	4.82	1.95	2.62	4.23	2.15	4.13	2.78	4.67	2.19	3.82	4.17	5.21
MnO	0.051	0.084	0.054	0.093	0.09	0.071	0.052	0.066	0.075	0.067	0.07	0.068
MgO	5.18	3.98	1.94	4.06	6.18	6.67	2.71	4.48	2.66	5.82	3.4	5.24
CaO	5.48	25.49	6.58	8.4	24.38	9.19	7.41	7.71	11.25	9.5	8.29	8.36
Na_2O	1.65	0.83	2.17	2.14	0.76	1.79	1.88	1.65	1.77	1.4	2.2	1.53
K_2O	4.73	1.97	2.77	3.48	1.38	3.11	2.78	4.02	2.51	3.56	3.07	4.55
P_2O_5	0.12	0.08	0.11	0.11	0.06	0.09	0.08	0.1	0.1	0.1	0.11	0.1
LOI	9.82	24.91	6.65	9.84	26.66	15.9	7.51	11.26	11.44	17.6	10.17	9.91
Total	99.28	98.31	98.66	99.3	98.19	99.12	99.24	99.08	99.39	99.06	100.1	99.17
Trace Elements (ppm)												
Ca	3.7	18	4.85	5.76	17.5	6.29	5.3	5.23	8.01	6.74	5.93	5.45
Ti	0.351	0.133	0.26	0.289	0.115	0.26	0.197	0.272	0.229	0.254	0.301	0.283
Mn	0.042	0.055	0.044	0.075	0.061	0.059	0.044	0.054	0.061	0.055	0.056	0.053
Fe	3.39	1.11	1.75	2.88	1.27	2.89	1.95	3.06	1.47	2.69	2.74	3.51
V	98	53	40	73	70	110	37	88	50	121	61	78
Cr	89	36	77	79	33	73	58	79	65	74	86	86
Co	13	5	7	11	5	12	7	14	5	12	10	12
Ni	39	19	22	37	15	37	22	40	17	38	37	47
Cu	34	23	13	22	28	34	12	31	12	45	16	29
Zn	57	29	32	50	38	52	23	178	43	45	48	49
Rb	107	45	62	88	32	81	61	85	57	85	76	110

Sr	328	1364	354	550	1216	487	507	386	643	497	558	415
Y	17	16	18	21	15	18	16	17	20	22	21	19
Zr	218	101	278	185	89	164	261	200	292	164	237	159
Nb	9	5	8	8	3	6	7	8	7	8	8	9
Mo	10	9	0	23	5	8	2	26	0	43	0	1
Ag	3	4	-	2	3	2	0	1	2	2	2	2
Sn	0	0	-	0	-	1	-	0	1	2	1	1
Sb	1	1	0	3	0	3	0	5	1	5	1	1
Ba	480	323	390	392	274	374	431	375	372	384	382	460
La	26	14	23	22	12	24	20	18	22	23	26	22
Ce	56	23	47	48	27	45	34	42	49	43	53	47
Pb	14	6	12	13	18	17	14	81	14	22	15	9
Th	10	7	7	8	6	7	4	7	6	8	7	9
U	7	5	1	3	4	4	-	5	2	6	1	1
As	23	12	81	7	17	30	10	39	6	42	25	15
W	1	2	2	0	0	0	1	-	1	-	-	0
Bi	-	0	0	0	0	1	-	-	0	0	-	-

Sample: A133 **Lithology:** laminated siltstone and shale **Unit:** Caithness Flagstone Group, Dounreay Shore Formation

Sample: A132 **Lithology:** micritic limestone with siltstone laminae **Unit:** Caithness Flagstone Group, Dounreay Shore Formation

Sample: A134 **Lithology:** feldspathic arenite **Unit:** Caithness Flagstone Group, Dounreay Shore Formation

Sample: A135 **Lithology:** siltstone with shale, siltstone and mudstone laminae **Unit:** Caithness Flagstone Group, Dounreay Shore Formation

Sample: A137 **Lithology:** laminated micritic limestone and siltstone shale with siltstone laminae **Unit:** Caithness Flagstone Group, Dounreay Shore Formation

Sample: A136 **Lithology:** shale with siltstone laminae **Unit:** Caithness Flagstone Group, Dounreay Shore Formation

Sample: A138 **Lithology:** feldspathic arenite **Unit:** Caithness Flagstone Group, Dounreay Shore Formation

Sample: A139 **Lithology:** interbedded siltstone, sandstone and shale **Unit:** Caithness Flagstone Group, Dounreay Shore Formation

Sample: A140 **Lithology:** laminated fine sandstone and siltstone **Unit:** Caithness Flagstone Group, Dounreay Shore Formation

Sample: A141 **Lithology:** silty shale with siltstone and sandstone laminae **Unit:** Caithness Flagstone Group, Dounreay Shore Formation

Sample: A142 **Lithology:** litharenite **Unit:** Caithness Flagstone Group, Dounreay Shore Formation

Sample: A143 **Lithology:** feldspathic wacke siltstone **Unit:** Caithness Flagstone Group, Sandside Bay Formation

Whole rock geochemical data from the Devonian of the Dounreay Borehole number 1 (Hyslop & Milodowski 1994)

Sample Number	A144	A145	A146	A147	A149	A148	A151	A152	A150	A154	A153	A155
Top depth (m)	109.6	124.8	138	147.7	148.3	148.7	199	207.4	221.8	238.9	244	257.9
Bottom depth (m)	109.9	125.1	138.3	148	148.7	149.1	199.3	207.6	222.1	239.2	244.3	258.1
Major Oxides (wt % oxide)												
SiO_2	47.11	52.25	67.45	50.04	16.38	50.7	76.14	79.16	51.9	53.42	64.13	57.12
TiO_2	0.49	0.64	0.47	0.51	0.13	0.59	0.27	0.15	0.59	0.57	0.54	0.69
Al_2O_3	10.39	13.81	9.25	10.58	2.19	11.05	7.42	6.3	10.14	10.58	9.32	13.39
Fe_2O_3	3.97	5.66	2.62	3.61	0.9	4.16	1.36	0.4	3.97	4.03	2.65	4.89
MnO	0.071	0.069	0.051	0.104	0.046	0.07	0.077	0.033	0.065	0.109	0.054	0.051
MgO	5.8	5.35	2.21	2.09	4.35	5.34	0.67	0.14	4.77	2.78	1.86	3.8
CaO	10.06	6.27	4.83	12.5	37.99	8.54	4.02	4.28	8.19	10.85	8.27	6.18
Na_2O	1.65	2	2.09	1.64	0.3	1.59	1.85	1.61	1.2	1.13	1.5	1.64
K_2O	3.53	4.34	2.96	4.27	0.73	3.88	3.08	2.85	4.1	4.5	3.58	4.8
P_2O_5	0.1	0.11	0.1	0.09	0.05	0.12	0.08	0.05	0.12	0.11	0.13	0.14
LOI	15.83	8.99	7.57	13.54	35.66	12.96	4.42	4.38	13.97	10.99	7.53	7.44
Total	99	99.49	99.6	98.97	98.73	99	99.39	99.35	99.02	99.07	99.56	100.1
Trace Elements (ppm)												
Ca	6.87	4.06	3.39	8.27	27.53	5.79	2.93	3.11	5.6	7.28	5.7	4.03
Ti	0.242	0.322	0.243	0.235	0.043	0.286	0.147	0.069	0.292	0.272	0.268	0.345
Mn	0.056	0.055	0.044	0.077	0.026	0.055	0.071	0.029	0.052	0.083	0.043	0.04
Fe	2.72	3.85	1.88	2.16	0.45	2.81	0.92	0.26	2.6	2.49	1.76	3.36
V	107	92	45	64	28	95	18	10	120	75	40	83
Cr	71	99	72	61	12	78	40	26	80	68	73	80
Co	12	15	9	9	1	12	2	3	12	9	8	13
Ni	38	45	24	30	9	35	7	5	36	32	24	42
Cu	32	27	7	18	11	30	6	4	41	13	10	18
Zn	48	31	21	81	7	64	4	7	48	156	18	58
Rb	81	108	81	94	16	85	61	55	85	82	69	106
Sr	591	351	132	362	1287	421	131	165	498	311	302	267
Y	21	21	16	23	11	23	10	6	18	22	17	19
Zr	157	161	168	127	32	197	276	178	213	187	314	174
Nb	8	10	6	7	3	8	4	3	9	8	8	10
Mo	62	-	0	6	7	4	0	0	44	5	-	1
Ag	1	2	0	2	5	2	-	0	2	2	1	2
Sn	0	2	0	1	-	2	0	0	0	1	1	1
Sb	2	1	1	2	0	4	1	2	1	0	1	1
Ba	388	415	350	407	134	435	489	445	537	416	427	493
La	21	25	17	22	6	26	21	10	26	23	23	30
Ce	45	52	39	39	12	58	42	26	49	53	53	64

Pb	16	10	12	19	4	22	17	30	24	7	32	12
Th	11	10	5	9	3	11	6	3	9	9	8	9
U	12	12	1	3	5	6	2	2	17	8	2	2
As	32	32	8	29	17	35	15	16	69	35	9	3
W	0	0	0	1	-	0	-	-	-	2	3	3
Bi	1	1	0	1	-	1	-	1	1	-	0	1

Sample: A144 **Lithology:** shale with siltstone laminae shale with siltstone laminae **Unit:** Caithness Flagstone Group, Sandside Bay Formation

Sample: A145 **Lithology:** shale with siltstone laminae shale with siltstone laminae **Unit:** Caithness Flagstone Group, Sandside Bay Formation

Sample: A146 **Lithology:** feldspathic siltstone and fine sandstone **Unit:** Caithness Flagstone Group, Sandside Bay Formation

Sample: A147 **Lithology:** siltstone with shale laminae **Unit:** Caithness Flagstone Group, Sandside Bay Formation

Sample: A148 **Lithology:** limestone with silty laminae **Unit:** Caithness Flagstone Group, Sandside Bay Formation

Sample: A149 **Lithology:** shale with siltstone laminae **Unit:** Caithness Flagstone Group, Sandside Bay Formation

Sample: A151 **Lithology:** feldspathic arenite **Unit:** Caithness Flagstone Group, Sandside Bay Formation

Sample: A152 **Lithology:** feldspathic arenite **Unit:** Caithness Flagstone Group, Sandside Bay Formation

Sample: A150 **Lithology:** shale with siltstone laminae **Unit:** Caithness Flagstone Group, Sandside Bay Formation

Sample: A154 **Lithology:** siltstone with shale laminae **Unit:** Caithness Flagstone Group, Sandside Bay Formation

Sample: A153 **Lithology:** siltstone **Unit:** Caithness Flagstone Group, Sandside Bay Formation

Sample: A155 **Lithology:** shale and silty shale **Unit:** Caithness Flagstone Group, Sandside Bay Formation

Whole rock geochemical data from the Devonian of the Dounreay Borehole number 1 (Hyslop & Milodowski 1994)													
Sample Number	**A156**	**A157**	**A158**	**A159**	**A160**	**A161**	**A162**	**A163**	**A164**	**A166**	**A165**	**A167**	**A168**
Top depth (m)	264.1	264.6	274.6	290.7	296.7	304.7	310.7	313.5	318.3	344.3	359.2	363.7	369.26
Bottom depth (m)	264.4	264.9	274.9	291	297	305	311.3	313.8	318.6	344.6	359.6	364	369.56
Major Oxides (wt % oxide)													
SiO_2	54.54	17.06	66.76	51.05	68.26	92.7	85.13	12.03	68.84	61.6	57.63	54.7	65.76
TiO_2	0.62	0.14	0.47	0.54	0.54	0.17	0.24	0.17	0.15	0.45	0.59	0.3	0.53
Al_2O_3	11.18	2.56	11.14	10.67	8.69	2.98	5.32	3.08	6.52	10.62	11.35	6.55	9.11
Fe_2O_3	4.26	1.03	3.33	3.95	1.58	0.53	1.17	1.45	1.67	2.47	4.05	1.67	3.02
MnO	0.066	0.158	0.055	0.108	0.067	0.006	0.011	0.151	0.088	0.08	0.115	0.124	0.056
MgO	4.11	1.73	1.59	2.8	0.81	0.09	0.18	0.91	1	1.29	2.81	0.82	1.4
CaO	8.07	40.96	4.96	12.25	7.86	0.23	1.86	43.79	9.37	9.35	8.78	17.27	7.53
Na_2O	1.16	0.25	1.84	1.36	2.13	0.34	1.09	0.25	1.39	2.94	1.55	1.32	1.6
K_2O	4.58	1.07	4.19	3.86	2.92	1.13	2.24	1.24	2.45	2.87	4.05	2.61	3.83
P_2O_5	0.13	0.06	0.11	0.18	0.11	0.09	0.17	0.14	0.29	0.14	0.13	0.11	0.2
LOI	10.88	34.05	5.04	12.83	6.71	1.38	2.44	35.19	7.74	8.06	8.88	14.01	6.77
Total	99.6	99.07	99.49	99.6	99.68	99.65	99.85	98.4	99.51	99.87	99.93	99.48	99.81
Trace Elements (ppm)													
Ca	5.23	28.75	3.37	8.12	5.77	0.14	1.26	30.49	6.77	6.99	5.87	12.38	5.2
Ti	0.299	0.051	0.239	0.247	0.263	0.09	0.132	0.061	0.073	0.223	0.288	0.133	0.261
Mn	0.052	0.089	0.046	0.082	0.056	0.004	0.011	0.08	0.076	0.065	0.091	0.09	0.045
Fe	2.78	0.5	2.24	2.52	1.08	0.35	0.71	0.67	1.13	1.66	2.7	0.96	2
V	88	27	49	75	36	24	26	24	20	40	50	20	39
Cr	76	13	67	67	63	45	47	16	20	58	82	19	57
Co	10	1	8	11	5	9	7	4	4	6	9	4	7
Ni	37	11	28	37	13	13	7	26	5	20	30	7	21
Cu	26	12	17	27	28	9	6	12	3	13	8	11	5
Zn	66	20	22	92	14	3	4	148	23	28	47	18	28
Rb	89	18	85	77	57	24	45	24	42	56	89	50	65
Sr	393	1388	240	484	237	31	91	2071	495	453	294	617	316
Y	21	11	15	20	19	8	10	29	27	16	19	13	17
Zr	235	45	203	170	555	70	112	67	138	241	213	161	266
Nb	9	3	8	7	7	2	4	2	2	7	8	4	7
Mo	16	19	2	37	-	7	0	10	-	1	1	1	-
Ag	2	4	1	3	0	0	0	6	1	2	3	2	1
Sn	0	-	0	1	1	1	1	1	-	2	1	0	-
Sb	1	2	1	1	1	4	1	3	0	1	2	1	1
Ba	473	611	562	525	425	143	796	295	719	750	607	709	647
La	26	6	21	22	22	1	4	8	10	30	25	14	30
Ce	56	6	46	52	49	17	23	19	23	57	52	32	62

Pb	23	13	16	26	14	45	15	76	24	10	6	19	7
Th	9	4	8	9	8	10	8	10	12	9	12	6	9
U	15	20	3	23	3	36	37	73	55	1	1	3	0
As	16	26	18	34	6	20	15	107	6	-	1	1	0
W	1	1	0	-	1	0	0	0	-	-	1	-	1
Bi	0	1	-	1	0	-	-	0	0	0	-	-	-

Sample: A155 **Lithology:** silty shale with very fine sandstone laminae **Unit:** Caithness Flagstone Group, Sandside Bay Formation Sample

Sample: A156 **Lithology:** micritic limestone with siltstone laminae **Unit:** Caithness Flagstone Group, Sandside Bay Formation

Sample: A157 **Lithology:** feldspathic wacke sandstone **Unit:** Caithness Flagstone Group, Sandside Bay Formation

Sample: A158 **Lithology:** shale with siltstone laminae **Unit:** Caithness Flagstone Group, Sandside Bay Formation

Sample: A159 **Lithology:** feldspathic arenite **Unit:** Caithness Flagstone Group, Sandside Bay Formation

Sample: A160 **Lithology:** brecciated micritic limestone with shale laminae **Unit:** Caithness Flagstone Group, Sandside Bay Formation

Sample: A161 **Lithology:** brecciated fine feldspathic sandstone **Unit:** Bighouse Sandstone Formation

Sample: A162 **Lithology:** micritic limestone with siltstone laminae **Unit:** Bighouse Sandstone Formation

Sample: A163 **Lithology:** fine feldspathic arenite **Unit:** Bighouse Sandstone Formation

Sample: A164 **Lithology:** litharenite **Unit:** Bighouse Sandstone Formation

Sample: A165 **Lithology:** shale with siltstone laminae **Unit:** Bighouse Sandstone Formation

Sample: A167 **Lithology:** conglomerate **Unit:** Basal breccio-conglomerates

Sample: A168 **Lithology:** conglomerate **Unit:** Basal breccio-conglomerates

Whole rock geochemical data from the Moine and Basement rocks of the Dounreay Borehole number 1 (Hyslop & Milodowski 1994)

Sample Number	A554	A556	A552	A551	A561	A511	A546	A555	A544	A512	A562	A565
Top depth (m)	389.7	437.5	500.7	525.1	548	558	615.7	628.9	645.8	657.5	682.1	699.12
Bottom depth (m)	390	437.8	500.9	525.4	548.2	558.3	616	629.1	646.1	657.7	682.4	699.42
Major Oxides (wt % oxide)												
SiO_2	74.2	79.88	72.71	80.99	70.7	80.91	61.69	55.54	62.8	81.69	73.82	80.85
TiO_2	0.53	0.52	0.51	0.16	0.78	0.52	0.98	1.06	1.18	0.34	0.62	0.39
Al_2O_3	10.14	9.1	7.71	9.08	12.92	9.1	17.53	19.16	15.72	7.83	12.17	9.35
Fe_2O_3	3.45	2.7	3.92	1.71	4.98	2.6	3.54	5.88	5.83	0.61	3.63	1.95
MnO	0.033	0.037	0.06	0.027	0.062	0.044	0.047	0.066	0.049	0.016	0.041	0.034
MgO	1.34	0.63	1.07	0.37	1.4	0.5	1.77	2.77	2.62	0.43	0.93	0.48
CaO	1.77	1.5	4.82	0.65	1.49	1.31	3.08	3.47	1.38	1.72	1.34	2.02
Na_2O	1.62	2.55	1.54	1.79	4.1	2.71	6.07	6.42	5.65	0.11	3.34	3.03
K_2O	4.7	2.55	3.13	4.47	2.78	2.06	3.01	1.92	2.39	5.05	3.52	1.43
P_2O_5	0.11	0.06	0.13	0.06	0.12	0.05	0.37	0.45	0.25	0.06	0.11	0.09
LOI	2.06	0.51	4.31	0.34	0.61	0.35	1.96	3.04	2.7	2.14	0.61	0.68
Total	99.95	100	99.91	99.65	99.94	100.2	100.1	99.68	100.6	100	99.94	100.3
Trace Elements (ppm)												
Ca	1.16	0.92	3.32	0.36	0.9	0.8	1.89	2.27	0.89	1.12	0.8	1.22
Ti	0.271	0.245	0.244	0.078	0.394	0.255	0.499	0.543	0.647	0.177	0.307	0.182
Mn	0.028	0.031	0.052	0.023	0.051	0.036	0.041	0.058	0.043	0.012	0.036	0.029
Fe	2.42	1.73	2.55	1.06	3.23	1.6	2.47	4.18	4.29	0.41	2.31	1.25
V	39	37	46	19	56	37	94	82	96	38	43	25
Cr	60	32	29	19	45	53	21	71	454	27	35	27
Co	7	5	7	3	11	5	86	23	33	4	9	3
Ni	15	8	13	0	15	5	33	32	66	5	11	3
Cu	9	6	6	4	24	1	30	126	39	5	2	15
Zn	33	22	23	13	56	22	36	70	69	7	38	14
Rb	86	44	55	80	95	47	66	49	56	169	81	22
Sr	194	386	198	261	261	205	868	1062	153	113	320	266
Y	11	19	23	7	23	20	9	18	14	14	14	18
Zr	236	201	264	94	255	280	188	466	233	188	229	216
Nb	7	7	8	1	10	9	8	8	13	5	8	7
Mo	2	0	-	1	2	0	-	1	0	0	1	0
Ag	0	0	1	1	2	0	0	1	2	0	-	0
Sn	0	0	0	1	0	1	2	-	0	1	0	0
Sb	0	0	0	0	-	1	1	-	-	-	0	2
Ba	893	729	629	1152	797	594	799	564	375	595	1096	475
La	29	22	36	13	36	22	48	30	36	30	29	22
Ce	53	45	78	33	67	52	81	53	64	64	51	47

Pb	8	9	6	18	13	13	17	8	2	5	14	10
Th	8	6	8	4	8	6	15	3	2	5	6	3
U	1	-	0	0	0	0	4	-	1	5	-	-
As	2	2	5	1	-	0	0	5	1	1	-	0
W	-	-	-	0	-	0	0	-	1	0	-	1
Bi	0	0	-	0	0	-	0	-	0	1	0	1

Sample: A554 **Lithology:** Breccia **Unit:** Moine/Basement rocks

Sample: A556 **Lithology:** Feldspathic gneiss **Unit:** Moine/Basement rocks

Sample: A552 **Lithology:** Breccia **Unit:** Moine/Basement rocks

Sample: A551 **Lithology:** Banded psammite **Unit:** Moine/Basement rocks

Sample: A561 **Lithology:** Banded micaceous psammite **Unit:** Moine/Basement rocks

Sample: A511 **Lithology:** Psammite **Unit:** Moine/Basement rocks

Sample: A546 **Lithology:** Diorite **Unit:** Igneous

Sample: A555 **Lithology:** Diorite **Unit:** Igneous

Sample: A544 **Lithology:** Diorite **Unit:** Igneous

Sample: A512 **Lithology:** Siliceous Psammite **Unit:** Moine/Basement rocks

Sample: A562 **Lithology:** Migmatitic gneiss **Unit:** Moine/Basement rocks

Sample: A565 **Lithology:** Siliceous gneiss **Unit:** Moine/Basement rocks

Whole rock geochemical data from the Moine and Basement rocks of the Dounreay Borehole number 1 (Hyslop & Milodowski 1994)												
Sample Number	**A569**	**A539**	**A529**	**A540**	**A550**	**A531**	**A526**	**A534**	**A567**	**A535**	**A566**	**A528**
Top depth (m)	767.39	816.94	865.01	876.8	903.5	911.6	949.86	983.38	989.2	1031	1057.7	1102.7
Bottom depth (m)	767.7	817.17	865.31	877.1	903.7	911.9	950.11	983.55	989.5	1031	1058.1	1103
Major Oxides (wt % oxide)												
SiO2	59.08	39.6	73.04	78.57	80.01	47.9	60.31	70.57	60.4	71.76	53.01	79.21
TiO2	1.3	0.91	0.74	0.64	0.32	1.8	0.89	0.59	0.72	0.17	1.35	0.52
Al2O3	16.15	12.1	11.53	10.37	10.33	17.07	16.94	13.93	14.89	15.5	14.86	10.15
Fe2O3	8.9	5.96	3.94	2.76	1.65	9.31	4.96	3.58	5.37	1.14	11.08	1.79
MnO	0.11	0.204	0.066	0.036	0.02	0.099	0.06	0.054	0.08	0.012	0.136	0.012
MgO	3.28	4.73	1.07	0.54	0.36	5.41	2.5	1.56	3.53	0.31	6.79	0.43
CaO	2.21	16.13	2.03	1.84	1.12	4.33	2.34	1.69	4.02	1.67	6.89	0.63
Na2O	4.3	1.89	3.25	3.43	3.44	3.67	5.04	4.14	3.78	4.74	3.26	2.58
K2O	3.7	4.38	2.93	1.24	2.32	3.98	3.82	2.73	3.37	2.67	1.91	3.91
P2O5	0.29	0.52	0.13	0.07	0.04	1.51	0.61	0.07	0.32	0.04	0.16	0.03
LOI	0.97	12.92	1.1	1.45	0.39	4.85	2.36	1.05	2.96	0.68	1.24	0.9
Total	100.29	99.24	99.83	99.95	100	99.93	99.83	99.96	99.44	99.69	100.69	100.16
Trace Elements (ppm)												
Ca	1.3	11.05	1.22	1.14	0.67	2.7	1.47	1.04	2.52	0.98	4.1	0.4
Ti	0.671	0.375	0.344	0.313	0.151	0.922	0.46	0.301	0.366	0.082	0.632	0.261
Mn	0.088	0.137	0.055	0.029	0.016	0.08	0.05	0.047	0.067	0.009	0.104	0.01
Fe	5.75	3.25	2.5	1.68	1.01	6.43	3.55	2.54	3.61	0.75	7.06	1.17
V	114	149	53	36	22	178	85	45	88	13	139	24
Cr	66	505	40	40	28	42	43	76	62	13	203	53
Co	23	24	9	5	2	23	13	9	14	2	37	1
Ni	34	59	9	5	3	72	28	18	18	1	107	2
Cu	17	7	59	1	7	3	126	5	30	17	50	8
Zn	106	65	40	22	13	109	73	45	47	11	87	17
Rb	152	195	66	28	45	86	76	72	82	35	47	49
Sr	421	646	320	377	394	479	921	395	1421	893	239	236
Y	232	28	33	25	10	43	21	7	15	2	20	6
Zr	270	125	382	496	178	178	360	232	152	87	129	420
Nb	15	6	13	10	5	17	11	7	8	1	7	6
Mo	1	2	0	1	0	1	-	1	0	1	3	1
Ag	2	4	0	0	0	3	3	0	3	0	4	1
Sn	-	-	1	0	-	0	-	-	-	-	-	-
Sb	-	-	0	0	0	-	0	0	0	0	-	0
Ba	911	641	959	420	589	1203	1916	791	1082	1947	335	928
La	47	48	37	38	17	214	209	36	76	3	15	25
Ce	93	110	75	66	44	437	326	61	139	21	30	60

Pb	12	6	16	241	13	1	19	11	7	24	6	11
Th	11	9	8	9	2	23	18	3	15	0	0	5
U	0	4	3	0	1	2	3	0	0	-	-	0
As	-	-	4	-	2	1	0	0	-	-	-	1
W	-	-	0	1	-	5	-	1	3	0	0	1
Bi	-	0	0	-	0	-	0	0	-	-	-	0

Sample: A569 **Lithology:** Banded psammitic gneiss **Unit:** Moine/Basement rocks

Sample: A539 **Lithology:** Amphibolite **Unit:** Moine/Basement rocks

Sample: A529 **Lithology:** Psammitic gneiss **Unit:** Moine/Basement rocks

Sample: A540 **Lithology:** Psammite **Unit:** Moine/Basement rocks

Sample: A550 **Lithology:** Psammitic gneiss **Unit:** Moine/Basement rocks

Sample: A531 **Lithology:** Diorite **Unit:** Igneous

Sample: A526 **Lithology:** Diorite **Unit:** Igneous

Sample: A534 **Lithology:** Feldspathic gneiss **Unit:** Moine/Basement rocks

Sample: A567 **Lithology:** Feldspathic gneiss **Unit:** Moine/Basement rocks

Sample: A535 **Lithology:** Granitoid **Unit:** Igneous

Sample: A566 **Lithology:** Banded amphibolite **Unit:** Moine/Basement rocks

Sample: A528 **Lithology:** Siliceous psammite **Unit:** Moine/Basement rocks

Whole rock geochemical data from the Moine and Basement rocks of the Dounreay Borehole number 1 (Hyslop & Milodowski 1994)					
Sample Number	**A520**	**A530**	**A522**	**A525**	**A523**
Top depth (m)	1116	1249	1278	1305	1323
Bottom depth (m)	1116.8	1250	1279	1305	1323
Major Oxides (wt % oxide)					
SiO2	57.67	56.48	71.93	45.4	92.4
TiO2	0.59	0.59	0.93	2.99	0.06
Al2O3	20.17	19.7	11.98	14.89	3.81
Fe2O3	4.65	4.75	4.66	13.76	0.33
MnO	0.051	0.061	0.044	0.341	0
MgO	2.2	2.05	1.53	5.9	0.07
CaO	2.46	4.13	1.07	10.37	0.19
Na2O	6.73	6.58	2.87	2.89	0.54
K2O	2.54	2.49	3.79	1.7	2.3
P2O5	0.35	0.34	0.04	0.037	0.03
LOI	2.29	1.94	0.94	1.97	0.31
Total	99.7	99.11	99.78	100.6	100
Trace Elements (ppm)					
Ca	1.52	2.57	0.65	6.29	0.11
Ti	0.314	0.3	0.462	1.306	0.03
Mn	0.045	0.05	0.036	0.222	0
Fe	3.33	3.14	3.01	7.79	0.23
V	63	55	55	217	6
Cr	20	20	44	102	24
Co	9	7	7	31	1
Ni	14	13	7	43	0
Cu	13	14	20	26	3
Zn	61	62	38	134	4
Rb	44	37	66	40	28
Sr	1524	2158	304	509	257
Y	12	8	12	45	3
Zr	421	404	664	183	49
Nb	3	2	10	24	0
Mo	0	0	0	3	0
Ag	3	2	2	5	1
Sn	-	-	-	4	0
Sb	-	0	0	0	0
Ba	2545	3933	1355	323	1320

La	96	74	39	10	17
Ce	145	134	73	28	38
Pb	6	12	14	12	9
Th	7	0	9	0	2
U	2	-	3	2	1
As	0	1	-	-	1
W	-	-	-	-	-
Bi	0	1	1	0	0

Sample: A520 **Lithology:** Diorite **Unit:** Igneous

Sample: A530 **Lithology:** Diorite **Unit:** Igneous

Sample: A522 **Lithology:** Banded psammite **Unit:** Moine/Basement rocks

Sample: A525 **Lithology:** Amphibolite **Unit:** Moine/Basement rocks

Sample: A523 **Lithology:** Quartz-K-feldspar rock **Unit:** Moine/Basement rocks

Whole rock geochemical data for rocks from the Strath Halladale & Altnabreac district (Storey & Lintern 1981)

Sample Number	**A 27.36**	**A 28.79**	**A 52.89**	**A 125.37**	**A 251.0**	**A 277.88**	**A 288.9**	**2 26.7**	**10 8.0**	**10 8.5**	**11 31.88**	**11 38.6**	**14 19.5**
Major Oxides (wt % oxide)													
SiO2	68.22	69.28	68.5	69.47	69.24	69.31	68.97	70.56	69.11	69.16	68.69	68.51	70.57
TiO2	0.32	0.21	0.3	0.32	0.32	0.33	0.31	0.24	0.31	0.3	0.36	0.34	0.27
Al2O3	16.62	16.96	16.88	16.25	16.84	17	16.82	16.99	17.34	17.39	17.43	17.17	16.61
Fe2O3	2.14	1.33	2.07	2.14	2.08	1.87	2.09	1.71	1.86	1.84	2.4	2.21	1.85
MnO	0.17	0.22	0.37	0.62	0.04	0	0.03	0.02	0.02	0.03	0.03	0.02	0.02
MgO	1.01	0.72	0.78	0.76	0.67	0.85	0.79	0.41	0.52	0.55	0.86	0.78	0.51
CaO	1.65	2.18	2.29	2.01	2.36	1.47	2.01	0.95	1.97	1.93	2.18	2.53	1.68
Na2O	5.09	5.9	5.41	5.3	5.44	5.03	5.42	5.71	5.87	5.89	5.49	5.3	5.57
K2O	4.64	3.13	3.39	3.14	3.4	4.13	3.54	3.41	2.89	2.9	3.32	3.15	2.92
P2O5	0.12	0.08	0.1	0.08	0.11	0.09	0.1	0.07	0.08	0.08	0.12	0.11	0.06
LOI	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	99.98	100	100.1	100.1	100.5	100.1	100.1	100.1	99.97	-	100.9	100.12	100.1
Trace Elements (ppm)													
Cr	6	6	0	9	3	4	0	4	0	0	0	3	0
Ni	2	0	2	6	0	0	0	2	0	0	0	0	0
Cu	-	-	-	-	-	-	-	-	-	-	-	-	-
Zn	43	27	42	42	39	28	40	31	37	43	39	58	34
Ga	18	19	19	18	20	19	18	18	17	18	19	19	17
Rb	98	63	71	82	74	92	81	82	60	69	61	62	64
Sr	1038	1142	1131	887	1092	700	1070	913	1209	1186	1292	1393	941
Y	5	16	7	11	8	8	9	11	4	9	7	13	4

Zr	159	151	173	166	175	142	170	153	189	185	187	184	160
Nb	3	8	4	5	5	5	5	4	1	2	4	4	2
Ba	2004	1472	1716	1367	1660	1600	1743	1672	1714	1675	1889	1713	1440
La	24	20	38	41	41	38	40	29	37	36	45	39	28
Ce	41	41	65	74	65	64	67	50	63	63	77	65	50
Nd	16	25	24	28	24	23	23	20	23	24	28	26	18
W	704	712	757	897	747	764	805	943	866	706	844	563	954
Pb	28	22	28	25	28	47	26	29	23	29	23	23	25
Th	5	4	12	12	12	10	12	8	10	13	10	15	4
U	3	1	2	3	1	2	1	2	1	1	1	1	1
Sc	-	8.6	2.9	-	-	2.6	-	1.9	-	-	3	-	-
V	-	10	34	-	-	37	-	32	-	-	32	-	-
Co	-	61	67	-	-	86	-	90	-	-	60	-	-
Cs	-	1	0.9	-	-	1.1	-	1.2	-	-	0.8	-	-
La	-	27	54	-	-	52	-	35	-	-	72	-	-
Ce	-	45	70	-	-	68	-	65	-	-	126	-	-
Nd	-	27	29	-	-	31	-	17	-	-	30	-	-
Sm	-	7.6	5.3	-	-	4.5	-	4.1	-	-	5.3	-	-
Eu	-	2	1.8	-	-	1.6	-	1	-	-	1.5	-	-
Tb	-	0.7	0.3	-	-	0.3	-	0.5	-	-	0.4	-	-
Dy	-	2.8	1.4	-	-	1.1	-	1.6	-	-	1.8	-	-
Yb	-	1.8	0.2	-	-	0.7	-	0.9	-	-	0.7	-	-
Lu	-	0.12	0.07	-	-	0.09	-	0.01	-	-	0.09	-	-
Hf	-	2.9	3.3	-	-	3	-	3	-	-	3.2	-	-
Ta	-	1.5	1.1	-	-	1.3	-	1.5	-	-	1.1	-	-

Sample: A/27.36 **Lithology:** leuco-biotite-quartz monzodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole A **Grid reference:** NC 999 453

Sample: A/28.79 **Lithology:** biotite-hornblende granodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole A **Grid reference:** NC 999 453

Sample: A/52.89 **Lithology:** hornblende-biotite granodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole A **Grid reference:** NC 999 453

Sample: A/125.37 **Lithology:** biotite granodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole A **Grid reference:** NC 999 453

Sample: A/251.0 **Lithology:** biotite granodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole A **Grid reference:** NC 999 453

Sample: A/277.88 **Lithology:** muscovite granodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole A **Grid reference:** NC 999 453

Sample: A/288.9 **Lithology:** leuco-biotite-quartz monzodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole A **Grid reference:** NC 999 453

Sample: 2/26.7 **Lithology:** biotite granodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole 2 **Grid reference:** ND 005 392

Sample: 10/8.0 **Lithology:** leuco-biotite-quartz monzodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole 10 **Grid reference:** NC 985 425

Sample: 10/8.5 **Lithology:** biotite-quartz monzodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole 10 **Grid reference:** NC 985 425

Sample: 11/31.88 **Lithology:** biotite granodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole 11 **Grid reference:** NC 966 447

Sample: 11/38.6 **Lithology:** biotite-quartz monzodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole 11 **Grid reference:** NC 966 447

Sample: 14/19.5 **Lithology:** biotite granodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole 14 **Grid reference:** ND 000 407

Whole rock geochemical data for rocks from the Strath Halladale & Altnabreac district (Hyslop & Milodowski 1994)													
	14	**15**	**15**	**16**	**20**	**23**	**23**	**24**	**24**	**24**	**C**	**C**	**C**
Sample Number	**22.4**	**13.0**	**17.8**	**21.7**	**17.03**	**38.0**	**38.7**	**10.4**	**17.9**	**26.1**	**49.43**	**100.51**	**121.7**
Major Oxides (wt % oxide)													
SiO2	70.11	65.91	66.17	72.38	68.27	67.97	67.24	68.76	68.94	68.39	73.97	74.96	73.98
TiO2	0.29	0.41	0.38	0.21	0.39	0.41	0.4	0.36	0.35	0.37	0.21	0.16	0.13
Al2O3	16.86	16.23	16.16	15.44	17.23	17.36	17.36	16.98	16.82	17.01	15.45	14.12	14.77
Fe2O3	1.74	3.45	3.34	1.21	2.61	2.9	2.87	2.3	2.3	2.49	0.57	0.63	0.59
MnO	0.03	0.07	0.11	0.3	0	0	0	0.11	0.06	0.03	0.01	0.01	0.01
MgO	0.54	1.73	1.66	0.37	0.9	0.95	0.96	0.85	0.78	0.81	0.13	0.31	0.2
CaO	1.72	3.79	3.5	1.03	1.51	2.12	2.19	1.88	2.06	2.07	0.86	0.08	0.3
Na2O	5.94	5.3	5.19	6.09	5.5	5.53	5.52	5.34	5.34	5.6	5.03	4.92	4.74
K2O	2.76	2.27	2.92	3.26	3.27	3.18	3.27	3.44	3.37	3.24	3.09	3.66	4.25
P2O5	0.07	0.18	0.16	0.05	0.13	0.13	0.14	0.12	0.11	0.12	0.07	0.03	0.02
LOI	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	100.06	99.34	99.59	100.1	99.81	100.55	99.95	100.1	100.13	100.13	100.29	99.54	99.71
Trace Elements (ppm)													
Cr	0	48	49	0	2	10	3	7	2	7	0	0	0
Ni	0	28	18	0	6	0	3	2	0	0	0	0	0
Cu	-	-	-	-	-	-	-	-	-	-	7	5	6
Zn	33	106	15	42	47	44	43	40	43	6	17	18	12
Ga	18	16	16	18	19	19	20	18	19	12	20	16	18
Rb	56	187	72	67	67	67	71	72	74	108	76	90	92
Sr	991	779	313	995	1297	1312	1138	1179	1112	272	568	253	337
Y	3	25	4	7	10	10	8	7	9	16	9	8	10
Zr	166	188	183	110	174	201	198	181	183	184	119	84	81
Nb	1	8	11	2	4	3	4	5	4	5	7	8	7
Ba	1635	795	1002	1897	2023	2152	1760	1744	1753	1006	985	717	896
La	35	65	69	26	44	51	47	42	41	47	-	-	-
Ce	58	108	107	44	72	83	79	70	71	77	-	-	-
Nd	22	39	38	17	27	33	30	27	26	29	-	-	-
W	890	99	826	673	748	606	840	824	787	1069	-	-	-
Pb	24	10	14	32	22	23	27	26	22	24	28	115	26
Th	7	15	6	9	11	10	12	11	7	14	14	12	10
U	1	3	5	1	1	1	1	2	2	-	-	-	-
Sc	18	80	-	-	-	3.5	-	-	-	-	-	-	-
V	10	54	-	-	-	45	-	-	-	-	-	-	-
Co	78	70	-	-	-	71	-	-	-	-	-	-	-
Cs	0.8	2.1	-	-	-	1	-	-	-	-	-	-	-
La	52	82	-	-	-	67	-	-	-	-	-	-	-

Ce	75	155	-	-	-	95	-	-	-	-	-	-	-
Nd	20	53	-	-	-	29	-	-	-	-	-	-	-
Sm	3.5	7.5	-	-	-	5.6	-	-	-	-	-	-	-
Eu	1	2.6	-	-	-	1.5	-	-	-	-	-	-	-
Tb	0.2	0.7	-	-	-	0.4	-	-	-	-	-	-	-
Dy	0.7	2.1	-	-	-	0.5	-	-	-	-	-	-	-
Yb	0.3	1.4	-	-	-	0.7	-	-	-	-	-	-	-
Lu	0.04	0.2	-	-	-	0.09	-	-	-	-	-	-	-
Hf	0.3	4.2	-	-	-	3.7	-	-	-	-	-	-	-
Ta	1.1	1.8	-	-	-	3.2	-	-	-	-	-	-	-

Sample: 14/22.4 **Lithology:** leuco-biotite-quartz monzodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole 14 **Grid reference:** ND 000 407

Sample: 15/13.0 **Lithology:** hornblende-biotite tonalite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole 15 **Grid reference:** NC 990 409

Sample: 15/17.8 **Lithology:** hornblende-biotite-quartz monzodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole 15 **Grid reference:** NC 990 409

Sample: 16/21.7 **Lithology:** biotite leuco-monzodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole 16 **Grid reference:** NC 982 407

Sample: 20/17.03 **Lithology:** quartz monzodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole 20 **Grid reference:** NC 973 450

Sample: 23/38.0 **Lithology:** biotite-quartz monzodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole 23 **Grid reference:** NC 959 440

Sample: 23/38.7 **Lithology:** biotite granodiorite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole 23 **Grid reference:** NC 959 440

Sample: 24/10.4 **Lithology:** hornblende-biotite-quartz monzonite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole 24 **Grid reference:** NC 959 440

Sample: 24/17.9 **Lithology:** leuco-biotite-quartz monzonite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole 24 **Grid reference:** NC 959 440

Sample: 24/26.1 **Lithology:** leuco-biotite-quartz monzonite **Unit:** Strath Halladale Granite (G3), Group 1 **Location:** Borehole 24 **Grid reference:** NC 959 440

Sample: C/49.43 **Lithology:** biotite granite **Unit:** Strath Halladale Granite (G3), Group 2 **Location:** Borehole C **Grid reference:** NC 994 429

Sample: C/100.51 **Lithology:** altered biotite granite **Unit:** Strath Halladale Granite (G3), Group 2 **Location:** Borehole C **Grid reference:** ND 994 429

Sample: C/121.7 **Lithology:** altered biotite granite **Unit:** Strath Halladale Granite (G3), Group 2 **Location:** Borehole C **Grid reference:** NC 994 429

Whole rock geochemical data for rocks from the Strath Halladale & Altnabreac district (Storey & Lintern 1981)													
Sample Number	**C 1/50.9**	**C 202.95**	**C 240.11**	**C 297.53**	**9 11.7**	**9 25.31**	**9 25.43**	**9 29.25**	**9 36.27**	**B 110.5**	**B 169.66**	**B 170.05**	**B 192.16**
Major Oxides (wt % oxide)													
SiO_2	72.56	69.5	71.96	69.2	72.54	72.3	75.2	73.8	70.97	73.25	69	69.7	72.5
TiO_2	0.17	0.21	0.17	0.16	0.21	0.19	0.08	0.17	0.17	0.13	0.32	0.08	0.1
Al_2O_3	15.35	15.2	15.34	15.2	15.34	16.1	14	15.1	15.68	15.22	15.8	15.49	15.6
Fe_2O_3	0.98	0.83	1.12	0.67	1.28	1.33	0.22	0.96	1.12	0.95	2.13	0.56	0.8
MnO	0.02	0.03	0.02	0.02	0.02	0.01	0	0.01	0.01	0.04	0.07	0.05	0
MgO	0.34	0.26	0.24	0.23	0.17	0.36	0.02	0.33	0.35	0.21	0.55	0.1	0.14
CaO	1.08	2.39	1.39	1.2	1.02	0.55	0.2	0.71	0.41	1.2	3.35	3.65	1
Na_2O	4.76	5.56	5.16	5.64	5.14	5.36	3.89	4.8	5.75	4.52	5.28	4.15	3.59
K_2O	3.7	3.15	3.32	4.03	3.24	3.55	5.1	3.45	3.94	4.45	3.7	6.23	6.23
P_2O_5	0.03	0.04	0.01	0	0.03	0.04	0.01	0.02	0.02	0.04	0.14	0.04	0.04
LOI	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	99.78	99.7	99.62	99.3	99.81	100	99.3	99.3	99.63	100	100	100.03	100
Trace Elements (ppm)													
Cr	0	0	0	0	0	13	0	0	0	0	4	6	0
Ni	0	0	0	0	79	1	0	0	0	0	0	4	0
Cu	3	7	10	5	-	-	7	7	5	-	-	-	-
Zn	16	18	37	13	20	12	8	18	17	75	330	36	14
Ga	19	19	20	18	21	18	16	18	20	16	12	10	14
Rb	83	84	81	105	82	85	135	85	93	101	144	50	138
Sr	623	374	589	395	657	417	195	747	532	541	316	45	389
Y	9	13	8	9	11	9	26	10	9	21	20	33	23
Zr	99	119	105	97	118	110	64	104	106	103	125	68	48
Nb	7	12	7	7	9	7	9	10	7	8	8	4	6
Ba	1343	896	1075	985	985	997	358	985	1343	1490	825	628	1203
La	-	-	-	-	-	20	-	-	-	16	39	14	12
Ce	-	-	-	-	-	34	-	-	-	35	73	29	24
Nd	-	-	-	-	-	13	-	-	-	15	34	14	10
W	-	-	-	-	-	1054	-	-	-	652	618	866	822
Pb	29	17	31	22	28	22	26	29	19	31	44	7	50
Th	11	12	4	9	8	10	5	12	8	17	8	18	10
U	-	-	-	-	-	-	4	-	-	6.28	11	6	6
Sc	-	-	-	-	-	2.3	-	-	-	-	-	-	3
V	-	-	-	-	-	10	-	-	-	-	-	-	10
Co	-	-	-	-	-	95	-	-	-	-	-	-	109
Cs	-	-	-	-	-	0.8	-	-	-	-	-	-	1.6
La	-	-	-	-	-	37	-	-	-	-	-	-	21

Ce	-	-	-	-	-	116	-	-	-	-	-	-	45
Nd	-	-	-	-	-	27	-	-	-	-	-	-	16
Sm	-	-	-	-	-	3.2	-	-	-	-	-	-	4.1
Eu	-	-	-	-	-	0.9	-	-	-	-	-	-	1.1
Tb	-	-	-	-	-	0.4	-	-	-	-	-	-	0.9
Dy	-	-	-	-	-	1.3	-	-	-	-	-	-	4.1
Yb	-	-	-	-	-	0.7	-	-	-	-	-	-	3.1
Lu	-	-	-	-	-	0.09	-	-	-	-	-	-	0.6
Hf	-	-	-	-	-	2.7	-	-	-	-	-	-	1.3
Ta	-	-	-	-	-	1.7	-	-	-	-	-	-	2.1

Sample: C/150.9 **Lithology:** altered biotite granite **Unit:** Strath Halladale Granite (G3), Group 2 **Location:** Borehole C **Grid reference:** NC 994 429

Sample: C/202.95 **Lithology:** altered biotite granite **Unit:** Strath Halladale Granite (G3), Group 2 **Location:** Borehole C **Grid reference:** NC 994 429

Sample: C/240.11 **Lithology:** biotite granite **Unit:** Strath Halladale Granite (G3), Group 2 **Location:** Borehole C **Grid reference:** NC 994 429

Sample: C/297.53 **Lithology:** biotite granite **Unit:** Strath Halladale Granite (G3), Group 2 **Location:** Borehole C **Grid reference:** NC 994 429

Sample: 9/11.7 **Lithology:** biotite-muscovite granite **Unit:** Strath Halladale Granite (G3), Group 3 **Location:** Borehole 9 **Grid reference:** NC 995 434

Sample: 9/25.31 **Lithology:** biotite-muscovite granite **Unit:** Strath Halladale Granite (G3), Group 3 **Location:** Borehole 9 **Grid reference:** NC 995 434

Sample: 9/25.43 **Lithology:** biotite-muscovite granite **Unit:** Strath Halladale Granite (G3), Group 3 **Location:** Borehole C **Grid reference:** NC 995 434

Sample: 9/29.25 **Lithology:** biotite granodiorite **Unit:** Strath Halladale Granite (G3), Group 3 **Location:** Borehole 9 **Grid reference:** NC 995 434

Sample: 9/36.27 **Lithology:** altered biotite granite **Unit:** Strath Halladale Granite (G3), Group 3 **Location:** Borehole 9 **Grid reference:** NC 995 434

Sample: B/110.5 **Lithology:** biotite leuco-monzogranite **Unit:** granitic sheets in Moine (G3), Group 4 **Location:** Borehole B **Grid reference:** ND 023 417

Sample: B/169.66 **Lithology:** biotite monzogranite **Unit:** granitic sheets in Moine (G3), Group 4 **Location:** Borehole B **Grid reference:** ND 023 417

Sample: B/170.05 **Lithology:** biotite leuco-monzogranite **Unit:** granitic sheets in Moine (G3), Group 4 **Location:** Borehole B **Grid reference:** ND 023 417

Sample: B/192.16 **Lithology:** biotite leuco-monzogranite **Unit:** granitic sheets in Moine (G3), Group 4 **Location:** Borehole B **Grid reference:** ND 023 417

Whole rock geochemical data for rocks from the Strath Halladale & Altnabreac district (Storey & Lintern 1981)

Sample Number	B 194.93	B 197.25	B 251.73	B 279.04	B 76.21	B 229.7	GX629	GX634
Major Oxides (wt % oxide)								
SiO_2	72.5	73.2	70.21	70.46	62.53	66.21	58.8	47.3
TiO_2	0.14	0.08	0.35	0.35	1.08	0.91	0.91	0.92
Al_2O_3	15.7	15.7	16	16.46	16.03	15.13	14.9	12.4
Fe_2O_3	1.09	0.61	2.59	2.37	8.2	6.92	5.95	9.37
MnO	0	0	0.04	0.01	0.06	0.05	0.09	0.13
MgO	0.2	0.13	0.97	0.94	2.54	1.96	5.28	12.6
CaO	0.81	0.81	1.35	1.22	1.95	1.75	5.15	8.23
Na_2O	3.7	4.09	5.13	4.93	2.76	2.74	4.25	2.9
K_2O	5.85	5.44	3.39	3.27	4.84	4.73	3	2.27
P_2O_5	0.04	0.04	0.08	0.07	0.13	0.16	0.41	0.66
LOI	-	-	-	-	-	-	-	-
Total	100	100	100.11	100.08	100.1	100.6	101	99.9
Trace Elements (ppm)								
Cr	2	0	13	9	55	42	0	274
Ni	0	0	3	0	24	25	79	472
Cu	-	-	-	-	-	-	15	56
Zn	11	7	19	25	7	74	82	114
Ga	14	14	17	19	15	18	22	21
Rb	127	130	94	93	117	187	100	80
Sr	315	305	530	595	248	221	1233	1880
Y	24	20	9	8	29	43	23	27
Zr	79	51	164	168	255	224	254	133
Nb	6	4	6	6	18	15	17	14
Ba	867	856	1304	1310	702	917	1075	1523
La	17	9	34	34	43	37	-	-
Ce	35	16	63	61	88	75	-	-
Nd	16	7	23	23	40	36	-	-
W	849	837	594	575	1043	460	-	-
Pb	45	46	16	19	31	23	23	15
Th	5	5	18	14	8	17	19	27
U	5	5	7	8	4	4	-	-
Sc	-	2.1	3.7	3.5	-	-	-	-
V	-	10	43	27	-	-	-	-
Co	-	65	57	49	-	-	-	-
Cs	-	1.4	1.3	2.3	-	-	-	-
La	-	24	47	57	-	-	-	-

Ce	-	19	67	70	-	-	-	-
Nd	-	5	30	26	-	-	-	-
Sm	-	2.8	4.9	5.3	-	-	-	-
Eu	-	1	1.2	1.7	-	-	-	-
Tb	-	0.4	0.1	0.4	-	-	-	-
Dy	-	2.9	1.2	1.5	-	-	-	-
Yb	-	2.7	0.3	1	-	-	-	-
Lu	-	0.4	0.15	0.11	-	-	-	-
Hf	-	1.2	4.1	3.9	-	-	-	-
Ta	-	1.2	1.4	1.2	-	-	-	-

Sample: B/194.93 **Lithology:** biotite leuco-monzogranite **Unit:** granitic sheets in Moine (G3), Group 4 **Location:** Borehole B **Grid reference:** ND 023 417

Sample: B/197.25 **Lithology:** biotite leuco-monzogranite **Unit:** granitic sheets in Moine (G3), Group 4 **Location:** Borehole B **Grid reference:** ND 023 417

Sample: B/251.73 **Lithology:** biotite granodiorite **Unit:** Granodiorite (G1), Group 7 **Location:** Borehole B **Grid reference:** ND 023 417

Sample: B/279.04 **Lithology:** biotite granodiorite **Unit:** Granodiorite (G1), Group 7 **Location:** Borehole B **Grid reference:** ND 023 417

Sample: B/76.21**Lithology:** garnet semipelite **Unit:** Moine semipelites, Group 9, Altnabreac Complex **Location:** Borehole B **Grid reference:** NC 9012 5077

Sample: B/229.7**Lithology:** garnet semipelite **Unit:** Moine semipelites, Group 9, Altnabreac Complex **Location:** Borehole B **Grid reference:** NC 9012 5077

Sample: GX629 **Lithology:** pyroxene-hornblende-biotite diorite **Unit:** Reay Diorite, Group 12 **Location:** Creganhoisgt **Grid reference:** NC 9466 6465

Sample: GX634 **Lithology:** biotite-hornblende amphibolite **Unit:** Amphibolites, Group 13 **Location:** Portskerra **Grid reference:** NC 8823 6593

Whole rock geochemical data for rocks from the Strath Halladale & Altnabreac district (Storey & Lintern)											
	B	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**
Sample Number	**209.28**	**64.5**	**66.49**	**111.0**	**186.8**	**277.46**	**280.6**	**286.7**	**155.94**	**161.0**	**161.9**
Major Oxides (wt % oxide)											
SiO_2	73.17	71.88	74.42	74.42	74.09	74.19	74	74.09	69.06	70.21	70.19
TiO_2	0.11	0.12	0.08	0.07	0.06	0.04	0.05	0.08	0.33	0.31	0.3
Al_2O_3	15.53	15.68	14.62	14.7	14.84	14.91	15.21	15.01	16.59	16.35	16.31
Fe_2O_3	0.83	1.07	0.69	0.61	0.47	0.4	0.26	0.65	1.6	1.55	1.52
MnO	0	0.15	0.01	0.37	0.1	0	0	0	0.85	0	0
MgO	0.19	0.37	0.12	0.1	0.07	0.06	0.02	0.11	0.5	0.49	0.58
CaO	0.85	0.92	0.83	0.77	0.9	0.81	0.64	0.91	1.53	1.45	1.22
Na_2O	4.03	5.22	4.36	3.97	4.34	4.17	4.5	4.42	5.11	4.91	4.9
K_2O	5.28	4.63	4.88	5.37	5.17	5.44	5.33	4.72	4.44	4.76	4.95
P_2O_5	0.04	0.05	0.001	0.01	0.01	0.01	0.02	0.01	0.09	0.08	0.09
LOI	-	-	-	-	-	-	-	-	-	-	-
Total	100	100.1	100	100.1	100.1	100	100	100	100.1	100.1	100.06
Trace Elements (ppm)											
Cr	0	17	0	0	0	0	0	0	2	0	4
Ni	1	5	0	0	3	0	0	0	0	0	1
Cu	-	-	-	-	-	-	-	-	-	-	-
Zn	-	16	69	4	3	4	3	4	28	27	27
Ga	-	17	22	14	14	15	16	15	19	20	20
Rb	-	97	155	113	113	132	119	131	101	97	101
Sr	-	785	243	223	249	194	82	254	774	714	672
Y	-	11	45	22	18	15	30	19	5	4	4
Zr	57	134	61	62	52	42	43	70	211	200	194
Nb	6	13	12	12	7	10	26	14	1	0	1
Ba	-	1610	1067	781	812	432	151	954	1367	1165	1115
La	11	32	14	17	11	11	10	13	51	45	47
Ce	20	66	25	34	20	21	20	24	83	78	78
Nd	10	27	11	15	9	6	9	11	29	27	26
W	-	842	352	1093	981	1075	965	991	611	717	626
Pb	-	29	32	29	35	45	47	28	32	32	30
Th	-	31	15	8	6	6	9	7	22	25	24
U	3	13	7	1	5	7	10	7	3	1	4
Sc	-	-	-	2.9	-	-	4	-	-	20	15
V	-	-	-	10	-	-	10	-	-	10	10
Co	-	-	-	96	-	-	86	-	-	68	43
Cs	-	-	-	0.7	-	-	0.6	-	-	0.8	0.6
La	-	-	-	34	-	-	11	-	-	61	35

Ce	-	-	-	56	-	-	27	-	-	107	67
Nd	-	-	-	20	-	-	10	-	-	31	22
Sm	-	-	-	3.6	-	-	11	-	-	4.9	2.7
Eu	-	-	-	0.9	-	-	0.4	-	-	1.1	1.9
Tb	-	-	-	0.5	-	-	0.6	-	-	0.3	0.1
Dy	-	-	-	2.2	-	-	3.8	-	-	0.8	0.3
Yb	-	-	-	3	-	-	5.5	-	-	0.1	0.1
Lu	-	-	-	0.4	-	-	1.1	-	-	0.05	0.03
Hf	-	-	-	1.8	-	-	1.7	-	-	0.4	3.5
Ta	-	-	-	2.8	-	-	4.2	-	-	1.2	0.7

Sample: B/209.28 **Lithology:** biotite leuco-monzogranite **Unit:** granitic sheets in Moine (G3), Group 4 **Location:** Borehole B **Grid reference:** ND 023 417

Sample: A/64.5 **Lithology:** aplite **Unit:** Aplites and microgranites (G3), Group 5 **Location:** Borehole A **Grid reference:** NC 999 453

Sample: A/66.49 **Lithology:** aplite **Unit:** Aplites and microgranites (G3), Group 5 **Location:** Borehole A **Grid reference:** NC 999 453

Sample: A/111.0 **Lithology:** aplite **Unit:** Aplites and microgranites (G3), Group 5 **Location:** Borehole A **Grid reference:** NC 999 453

Sample: A/186.8 **Lithology:** aplite **Unit:** Aplites and microgranites (G3), Group 5 **Location:** Borehole A **Grid reference:** NC 999 453

Sample: A/277.46 **Lithology:** aplite **Unit:** Aplites and microgranites (G3), Group 5 **Location:** Borehole A **Grid reference:** NC 999 453

Sample: A/280.6 **Lithology:** aplite **Unit:** Aplites and microgranites (G3), Group 5 **Location:** Borehole A **Grid reference:** NC 999 453

Sample: A/286.7 **Lithology:** aplite **Unit:** Aplites and microgranites (G3), Group 5 **Location:** Borehole A **Grid reference:** NC 999 453

Sample: A/155.94 **Lithology:** biotite microgranodiorite **Unit:** Xenoliths (G3), Group 6 **Location:** Borehole A **Grid reference:** NC 999 453

Sample: A/161.0 **Lithology:** biotite microgranodiorite **Unit:** Xenoliths (G3), Group 6 **Location:** Borehole A **Grid reference:** NC 999 453

Sample: A/161.9 **Lithology:** biotite microgranodiorite **Unit:** Xenoliths (G3), Group 6 **Location:** Borehole A **Grid reference:** NC 999 453

Whole rock geochemical data for rocks from the Strath Halladale & Altnabreac district (Storey & Lintern 1981)											
Sample Number	**GX632a**	**GX632b**	**GX633a**	**GX633b**	**GX635a**	**GX635b**	**GX626b**	**GX640a**	**GX640b**	**GX641**	**GX642**
Major Oxides (wt % oxide)											
SiO_2	68.38	67.88	69.78	70.17	69.38	72.82	67.62	67.35	66.09	63.5	65.5
TiO_2	0.43	0.39	0.32	0.43	0.39	0.29	0.77	0.8	0.83	0.65	0.5
Al_2O_3	16.72	16.41	15.8	15.9	16.85	15.08	14.89	17.39	15.39	17.4	16.06
Fe_2O_3	2.18	2.09	1.85	2.62	1.83	1.43	5.12	5.42	5.38	4.09	3.05
MnO	0.03	0.03	0.03	0.04	0.01	0.02	0.07	0.08	0.06	0.06	0.06
MgO	0.97	0.95	0.72	0.97	0.68	0.46	1.72	2.64	1.98	1.87	1.44
CaO	1.96	1.13	1.81	2.06	1.73	1.48	2.23	1.95	2.57	2.53	1.69
Na_2O	5.49	5.74	5.2	5.25	5.33	4.71	3.56	5.28	4.43	5.15	6.5
K_2O	2.53	3.2	2.87	2.72	3.11	3.1	2.67	2.67	2.25	3.04	4.04
P_2O_5	0.12	0.11	0.12	0.14	0.11	0.04	0.06	0.29	0.17	0.22	0.2
LOI	-	-	-	-	-	-	-	-	-	-	-
Total	99.84	99.09	99.14	101	100.65	100.08	99.88	99.67	100	100.1	100.55
Trace Elements (ppm)											
Cr	342	0	0	0	0	0	0	0	0	0	0
Ni	0	0	0	0	0	0	0	16	0	79	0
Cu	6	9	3	5	3	7	23	29	33	16	6
Zn	63	49	51	58	51	38	73	80	74	63	60
Ga	24	22	24	21	21	18	21	21	19	22	20
Rb	78	91	79	90	76	75	107	103	83	96	114
Sr	1102	1004	804	869	1019	1004	571	1525	1158	1730	1473
Y	10	10	8	13	11	11	31	24	16	19	17
Zr	241	217	176	185	222	156	267	263	285	344	197
Nb	13	11	13	15	12	12	17	11	8	11	8
Ba	1164	1254	806	1254	1254	1075	806	1343	1523	2956	2060
La	-	-	-	-	-	-	-	-	-	-	-
Ce	-	-	-	-	-	-	-	-	-	-	-
Nd	-	-	-	-	-	-	-	-	-	-	-
W	-	-	-	-	-	-	-	-	-	-	-
Pb	26	30	25	23	26	25	28	18	17	26	27
Th	28	22	20	20	29	16	17	8	11	13	17
U	-	-	-	-	-	-	-	-	-	-	-
Sc	-	-	-	-	-	-	-	-	-	-	-
V	-	-	-	-	-	-	-	-	-	-	-
Co	-	-	-	-	-	-	-	-	-	-	-
Cs	-	-	-	-	-	-	-	-	-	-	-
La	-	-	-	-	-	-	-	-	-	-	-
Ce	-	-	-	-	-	-	-	-	-	-	-

Nd	-	-	-	-	-	-	-	-	-	-	-
Sm	-	-	-	-	-	-	-	-	-	-	-
Eu	-	-	-	-	-	-	-	-	-	-	-
Tb	-	-	-	-	-	-	-	-	-	-	-
Dy	-	-	-	-	-	-	-	-	-	-	-
Yb	-	-	-	-	-	-	-	-	-	-	-
Lu	-	-	-	-	-	-	-	-	-	-	-
Hf	-	-	-	-	-	-	-	-	-	-	-
Ta	-	-	-	-	-	-	-	-	-	-	-

Sample: GX632a **Lithology:** biotite granodiorite **Unit:** Granodiorite (G1), Group 7 **Location:** Portskerra **Grid reference:** NC 8825 6572

Sample: GX632b **Lithology:** biotite granodiorite **Unit:** Granodiorite (G1), Group 7 **Location:** Portskerra **Grid reference:** NC 8823 6593

Sample: GX633a **Lithology:** biotite granodiorite **Unit:** Granodiorite (G1), Group 7 **Location:** Portskerra **Grid reference:** NC 8823 6538

Sample: GX633b **Lithology:** biotite granodiorite **Unit:** Granodiorite (G1), Group 7 **Location:** Portskerra **Grid reference:** NC8823 6538

Sample: GX635a **Lithology:** biotite granodiorite **Unit:** Granodiorite (G1), Group 7 **Location:** Portskerra **Grid reference:** NC8823 6538

Sample: GX635b **Lithology:** biotite granodiorite **Unit:** Granodiorite (G1), Group 7 **Location:** Portskerra **Grid reference:** NC 8823 6538

Sample: GX626b **Lithology:** biotite granodiorite **Unit:** Tonalite (G2), Group 8 **Location:** Strath Halladale **Grid reference:** NC 9099 5940

Sample: GX640a **Lithology:** hornblende-biotite tonalite **Unit:** Tonalite (G2), Group 8 **Location:** Strath Halladale **Grid reference:** NC 8998 5113

Sample: GX640b **Lithology:** hornblende-biotite tonalite **Unit:** Tonalite (G2), Group 8 **Location:** Strath Halladale **Grid reference:** NC 8995 5089

Sample: GX641 **Lithology:** hornblende-biotite tonalite **Unit:** Tonalite (G2), Group 8 **Location:** Strath Halladale **Grid reference:** NC 9012 5077

Sample: GX642 **Lithology:** biotite granodiorite **Unit:** Tonalite (G2), Group 8 **Location:** Strath Halladale **Grid reference:** ND 023 417

Whole rock geochemical data for rocks from the Strath Halladale & Altnabreac district (Storey & Lintern 1981)													
	A	A	B	15	14	14	14	14	14	14			
Sample Number	**29.58**	**33.0**	**191.89**	**17.45**	**24.76**	**24.95**	**25.15**	**28.07**	**28.34**	**28.64**	**GX623b**	**GX623d**	**GX624**
Major Oxides (wt % oxide)													
SiO_2	60.89	51.8	80.69	50.5	50.09	46.1	48	52.3	49.22	51.94	60.9	51.84	55.5
TiO_2	0.51	0.98	1.42	1.33	1.16	1.25	1.19	0.92	1.14	1.17	0.79	1.21	0.93
Al_2O_3	10.51	10.7	6.29	12.2	9.37	8.67	9.2	11.9	6	7.59	15	13.66	16.5
Fe_2O_3	4.37	6.1	6.65	9.17	7.71	9	9.52	7.74	8.59	6.97	5.24	8.01	6.85
MnO	0.2	0.34	0.1	0.18	0.14	0.16	0.17	0.15	0.14	0.13	0.08	0.14	0.13
MgO	9.67	15	2.27	12.3	17.84	22.1	18.6	13.6	21.28	16.49	4.5	7.77	5.84
CaO	6.07	7.61	0.71	7.79	8.67	8.06	7.46	7.13	11.4	11.32	4.8	7.88	6.42
Na_2O	1.98	1.25	0.23	2.54	1.47	0.57	1.17	5.84	0.52	1.48	4.61	3.46	5.3
K_2O	5.74	5.15	1.38	3.48	3.56	3.88	4.24	3.2	1.84	2	3.24	3.64	1.85
P_2O_5	0.06	0.78	0.26	0.5	0.48	0.42	0.36	0.56	0.27	0.48	0.3	1.04	0.48
LOI	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	100	99.7	100	99.9	100.5	100	99.9	101	100.4	99.58	100	99.82	101
Trace Elements (ppm)													
Cr	712	647	45	523	1404	1194	571	1566	975	681	0	0	68
Ni	462	463	19	253	588	789	695	459	824	545	79	157	157
Cu	-	-	-	-	-	-	-	-	-	-	7	15	2
Zn	69	91	8	78	73	105	140	79	83	78	71	95	94
Ga	12	14	15	18	11	12	14	14	9	11	20	19	22
Rb	97	132	145	77	82	79	112	122	40	61	100	139	79
Sr	1026	1131	287	1334	743	341	968	890	209	679	1203	1605	1495
Y	12	29	30	17	18	15	23	21	13	14	22	36	40
Zr	118	404	539	221	190	140	163	235	82	149	191	391	235
Nb	10	14	17	17	17	13	20	13	7	12	15	32	22
Ba	1791	1789	739	1472	1647	1324	1145	973	490	706	1343	1881	537
La	23	84	68	50	61	47	48	74	24	41	-	-	-
Ce	45	182	125	105	127	99	115	146	56	81	-	-	-
Nd	25	92	55	47	52	46	60	61	31	35	-	-	-
W	158	132	867	607	71	39	40	73	42	69	-	-	-
Pb	25	23	50	25	5	12	26	13	2	8	26	27	19
Th	9	38	7	16	17	10	10	23	4	10	19	32	14
U	3	9	2	2	1	2	2	5	1	4	-	-	-
Sc	16	19	10	20	24	-	-	1.9	-	-	-	-	-
V	75	153	101	195	151	-	-	154	-	-	-	-	-
Co	43	55	78	37	59	-	-	50	-	-	-	-	-
Cs	1	1.6	2.5	6	2.1	-	-	3.9	-	-	-	-	-
La	31	176	34	70	85	-	-	120	-	-	-	-	-

Ce	66	270	127	120	169	-	-	205	-	-	-	-	-
Nd	36	125	59	46	68	-	-	80	-	-	-	-	-
Sm	8.3	24	5.3	5.4	12	-	-	14	-	-	-	-	-
Eu	2.5	7.2	2.7	1.9	3.5	-	-	4	-	-	-	-	-
Tb	0.4	1.6	1.2	0.9	0.8	-	-	1	-	-	-	-	-
Dy	2.5	6	5.9	4.6	2.9	-	-	3.9	-	-	-	-	-
Yb	1	1	4.3	1.2	1	-	-	1.3	-	-	-	-	-
Lu	0.11	0.21	0.5	0.21	0.18	-	-	0.22	-	-	-	-	-
Hf	2.6	9.7	15	3.7	4.2	-	-	4.7	-	-	-	-	-
Ta	0.7	1	2.5	0.8	1	-	-	0.9	-	-	-	-	-

Sample: A/29.58 **Lithology:** biotite hornblende amphibolite **Unit:** Amphibolites, Group 10 **Location:** Borehole A **Grid reference:** NC 999 453

Sample: A/33.0 **Lithology:** biotite hornblende amphibolite **Unit:** Amphibolites, Group 10 **Location:** Borehole A **Grid reference:** NC 999 453

Sample: B/191.89 **Lithology:** quartz-rich biotite amphibolite **Unit:** Amphibolites, Group 10 **Location:** Borehole B **Grid reference:** ND 023 417

Sample: 15/17.45 **Lithology:** pyroxene-hornblende-biotite amphibolite **Unit:** Amphibolites, Group 10 **Location:** Borehole 15 **Grid reference:** NC 990 409

Sample: 14/24.76 **Lithology:** biotite hornblende amphibolite **Unit:** ultramafites (A3), Group 11 **Location:** Borehole 14 **Grid reference:** ND 000 407

Sample: 14/24.95 **Lithology:** biotite hornblende amphibolite **Unit:** Ultramafites (A3), Group 11 **Location:** Borehole 14 **Grid reference:** ND 000 407

Sample: 14/25.15 **Lithology:** biotite hornblende amphibolite **Unit:** Ultramafites (A3), Group 11 **Location:** Borehole 14 **Grid reference:** ND 000 407

Sample: 14/28.07 **Lithology:** biotite hornblende amphibolite **Unit:** Ultramafites (A3), Group 11 **Location:** Borehole 14 **Grid reference:** ND 000 407

Sample: 14/28.34 **Lithology:** biotite hornblende amphibolite **Unit:** Ultramafites (A3), Group 11 **Location:** Borehole 14 **Grid reference:** ND 000 407

Sample: 14/28.64 **Lithology:** biotite hornblende amphibolite **Unit:** Ultramafites (A3), Group 11 **Location:** Borehole 14 **Grid reference:** ND 000 407

Sample: GX623b **Lithology:** pyroxene-hornblende-biotite diorite **Unit:** Reay Diorite, Group 12 **Location:** Bolum Rock **Grid reference:** NC 9751 6409

Sample: GX623d **Lithology:** pyroxene-hornblende-biotite amphibolite **Unit:** Reay Diorite, Group 12 **Location:** Bolum Rock **Grid reference:** NC 9751 6409

Sample: GX624 **Lithology:** pyroxene-hornblende-biotite diorite **Unit:** Reay Diorite, Group 12 **Location:** Milton **Grid reference:** NC 9769 6468

Appendix 2

List of rock samples and thin sections from the Reay district (Sheet 115)

Thin sections of sedimentary rocks from the Reay (Sheet 115) geological map sheet

Prefix	Number	NGR(E)	NGR(N)	Grid Square code	Locality	Comments
S	613	-	-	-	-	SILLIMANITE GNEISS
S	3002	-	-	-	-	HORNBLENDE BIOTITE GNEISS
S	3017	-	-	-	-	BIOTITE GNEISS
S	3030	-	-	-	-	HORNBLENDE BIOTITE PYRITE GNEISS
S	3031	-	-	-	-	ALTERED DOLERITE
S	3037	-	-	-	-	HORNBLENDE GNEISS
S	3054	-	-	-	-	HORNBLENDE BIOTITE GNEISS
S	4153	-	-	-	-	BIOTITE DIORITE
S	4154	-	-	-	-	BIOTITE GNEISS
S	4160	-	-	-	-	BIOTITE GRANITE
S	4161	-	-	-	-	GNEISSOSE BIOTITE GRANITE
S	4162	-	-	-	-	GNEISSOSE BIOTITE GRANITE
S	4163	-	-	-	-	BIOTITE GNEISS
S	4164	-	-	-	-	BIOTITE GNEISS
S	4165	-	-	-	-	BIOTITE GNEISS
S	4166	-	-	-	-	BIOTITE AMPHIBOLITE
S	4167	-	-	-	-	HORNBLENDE BIOTITE GNEISS
S	4168	-	-	-	-	HORNBLENDE BIOTITE GNEISS
S	4169	-	-	-	-	BIOTITE GRANITE
S	4170	-	-	-	-	BIOTITE AMPHIBOLITE
S	4171	-	-	-	-	BIOTITE GNEISS
S	4282	-	-	-	-	BIOTITE GRANITE
S	4283	-	-	-	-	BIOTITE GNEISS
S	4284	-	-	-	-	GARNET AMPHIBOLITE
S	4329	-	-	-	-	BIOTITE GNEISS
S	4330	-	-	-	-	BIOTITE GNEISS
S	4331	-	-	-	-	AUGITE BIOTITE DIORITE
S	4332	-	-	-	-	AUGITE BIOTITE DIORITE

Thin sections of sedimentary rocks from the Reay (Sheet 115) geological map sheet						
S	4333	-	-	-	-	AUGITE BIOTITE DIORITE
S	4334	-	-	-	-	AUGITE BIOTITE DIORITE
S	4384	-	-	-	-	AUGITE DIORITE (?)
S	4388	-	-	-	-	PERIDOTITE
S	4389	-	-	-	-	PERIDOTITE
S	4667	-	-	-	-	ROCK ?
S	4668	-	-	-	-	DIORITE
S	4669	-	-	-	-	BIOTITE GNEISS
S	4670	-	-	-	-	BIOTITE GRANITE
S	4671	-	-	-	-	OLIGOCLASE BIOTITE GNEISS
S	4672	-	-	-	-	GNEISS ?
S	4673	-	-	-	-	HORNBLENDE BIOTITE SCHIST
S	4674	-	-	-	-	BIOTITE GNEISS
S	4676	-	-	-	-	AUGEN GNEISS
S	4677	-	-	-	-	BIOTITE GNEISS
S	4678	-	-	-	-	DIORITE (?)
S	4679	-	-	-	-	SYENITE
S	4680	-	-	-	-	AUGITE DIORITE
S	4681	-	-	-	-	GRANITE
S	4682	-	-	-	-	GRANITE
S	4683	-	-	-	-	AUGITE DIORITE
S	4720	-	-	-	-	HORNBLENDE GNEISS
S	5137	-	-	-	-	HORNBLENDE GNEISS
S	5138	-	-	-	-	GARNET AMPHIBOLITE
S	5139	-	-	-	-	HORNBLENDE GNEISS
S	5140	-	-	-	-	BIOTITE GRANITE
S	5141	-	-	-	-	BIOTITE GRANITE
S	5142	-	-	-	-	BIOTITE GRANITE
S	5143	-	-	-	-	SYENITE LAMPROPHYRE
S	5144	-	-	-	-	BIOTITE MUSCOVITE GRANITE
S	5145	-	-	-	-	BIOTITE GNEISS
S	5146	-	-	-	-	BIOTITE GNEISS
S	5147	-	-	-	-	BIOTITE GNEISS
S	5148	-	-	-	-	BIOTITE GNEISS
S	5149	-	-	-	-	BIOTITE GNEISS
S	5150	-	-	-	-	BIOTITE GNEISS
S	5151	-	-	-	-	BIOTITE GNEISS
S	5152	-	-	-	-	BIOTITE GNEISS
S	5153	-	-	-	-	BIOTITE GNEISS

Thin sections of sedimentary rocks from the Reay (Sheet 115) geological map sheet						
S	5154	-	-	-	-	HORNBLENDE BIOTITE GNEISS
S	5155	-	-	-	-	BIOTITE GNEISS
S	5156	-	-	-	-	BIOTITE GNEISS
S	5157	-	-	-	-	GRANITOID GNEISS
S	5158	-	-	-	-	BIOTITE GNEISS
S	5159	-	-	-	-	BIOTITE HORNBLENDE GNEISS
S	5160	-	-	-	-	SCAPOLITE BEARING CIPOLIN
S	5161	-	-	-	-	BANDED CIPOLIN
S	5162	-	-	-	-	HORNBLENDE SCHIST
S	5163	-	-	-	-	BIOTITE GNEISS
S	5164	-	-	-	-	PYROXENITE
S	5165	-	-	-	-	HORNBLENDE SCHIST
S	5166	-	-	-	-	CALCAREOUS HORNBLENDE SCHIST
S	5226	-	-	-	-	HORNBLENDE BIOTITE GNEISS
S	5227	-	-	-	-	BIOTITE DIORITE
S	5228	-	-	-	-	HORNBLENDE BIOTITE GNEISS
S	5229	-	-	-	-	HORNBLENDE SCHIST
S	5230	-	-	-	-	BIOTITE GNEISS
S	5231	-	-	-	-	HORNBLENDE BIOTITE GNEISS
S	5709	-	-	-	-	HORNBLENDE SCHIST
S	5710	-	-	-	-	GRANITITE
S	5711	-	-	-	-	BIOTITE GNEISS
S	5712	-	-	-	-	HORNBLENDE GNEISS
S	5713	-	-	-	-	PEGMATITE
S	5714	-	-	-	-	CALCAREOUS HORNBLENDE APATITE SCHIST
S	5715	-	-	-	-	MUSCOVITE BIOTITE GNEISS
S	5716	-	-	-	-	MUSCOVITE GNEISS
S	5717	-	-	-	-	MUSCOVITE BIOTITE GNEISS
S	5718	-	-	-	-	MUSCOVITE BIOTITE GNEISS
S	5719	-	-	-	-	OMPHACITE HORNBLENDE ROCK
S	5720	-	-	-	-	OMPHOCITE SCAPOLITE ROCK

Thin sections of sedimentary rocks from the Reay (Sheet 115) geological map sheet						
S	5721	-	-	-	-	BIOTITE HORNBLENDE SCHIST
S	5722	-	-	-	-	AUGEN HORNBLENDE GNEISS
S	5723	-	-	-	-	AUGEN HORNBLENDE GNEISS
S	5724	-	-	-	-	AUGEN HORNBLENDE GNEISS
S	5725	-	-	-	-	APLITE
S	5726	-	-	-	-	BIOTITE GNEISS
S	5727	-	-	-	-	BIOTITE GNEISS
S	5728	-	-	-	-	HORNBLENDE GNEISS
S	5729	-	-	-	-	BIOTITE GNEISS
S	5730	-	-	-	-	BIOTITE GNEISS
S	5731	-	-	-	-	BIOTITE GRANITE
S	5732	-	-	-	-	MICA HORNBLENDE PIERITE
S	13942	-	-	-	-	
S	13943	-	-	-	-	
S	13944	-	-	-	-	
S	13945	-	-	-	-	
S	13946	-	-	-	-	
S	13947	-	-	-	-	
S	13948	-	-	-	-	
S	27113	-	-	-	-	
S	32358	-	-	-	-	GRANODIORITE
S	33180	-	-	-	-	MUSCOVITE BIOTITE GNEISS
S	39707	-	-	-	-	Fine Grained ?Granite
S	39708	-	-	-	-	Fine Grained Banded Gneiss
S	39709	-	-	-	-	Quartz Biotite Gneiss
S	59549	274600	964800	NC	-	Breccia Of Moine Sandstone
S	63314	282910	969740	NC	-	Biotite Garnet Semi Pelite
S	63315	280300	966180	NC	-	Garnet Epidote + Gneiss
S	63316	272540	957130	NC	-	Hornblende Acid Gneiss
S	63317	274130	959020	NC	-	Augen Gneiss Pelite
S	63554	278970	964710	NC	-	Tonalite Acid Gneiss
S	63555	273400	961200	NC	-	Calc Silicate (Greenish Rib)
S	63556	282830	969640	NC	-	Garnetiferous Quartz Rich Gneiss
S	63557	282830	969620	NC	-	Garnetiferous Quartz Gneiss
S	63558	282820	969600	NC	-	Garnet Quartz Gneiss
S	63559	283450	962270	NC	-	Garnetiferous Quartz Rich Pod

Thin sections of sedimentary rocks from the Reay (Sheet 115) geological map sheet						
S	63560	283480	962130	NC	-	Calc Silicate
S	63561	279800	950200	NC	-	Ultrabasic
S	63562	282860	957240	NC	-	Calc Silicate
S	63563	283100	959100	NC	-	Calc Silicate
S	63567	278200	965540	NC	-	Garnetiferous Acid Gneiss
S	63568	278200	965540	NC	-	Garnetiferous Acid Gneiss
S	63569	278190	965550	NC	-	Amphibolite
S	63570	278160	965550	NC	-	Garnetiferous Amphibolite
S	63571	277650	965520	NC	-	Flaggy Psammite
S	63572	274660	962640	NC	-	Calc Silicate
S	63573	283370	967000	NC	-	Garnetiferous Quartz Feldspathic Gneiss
S	63574	283420	967000	NC	-	Dyke (Biotite Amphibolite) In Acid Gneiss
S	63577	273360	962060	NC	-	Appinitic Rock
S	63578	272890	960400	NC	-	Ultrabasic
S	63579	270000	946600	NC	-	Ultrabasic
S	63581	287160	965870	NC	-	Migmatitic Psammite
S	64545	273440	959060	NC	-	Hornblende Appinite
S	65298	294700	964700	NC	-	Reay Diorite
S	65299	294700	964700	NC	-	Diorite
S	65737	283370	966990	NC	-	Strathy Gneiss
S	65738	283360	967000	NC	-	Strathy Gneiss
S	65739	283420	967000	NC	-	Basic Dyke In Strathy Gneiss
S	65740	282940	969750	NC	-	Pelitic Zone
S	65741	282940	969750	NC	-	
S	65742	281520	966170	NC	-	Strathy Gneiss (Gneissose Psammite)
S	65743	281520	966170	NC	-	Strathy Gneiss (Gneissose Psammite)
S	65744	281620	965760	NC	-	Strathy Gneiss (Gneissose Psammite)
S	65745	282230	964970	NC	-	Strathy Gneiss (Gneissose Psammite)
S	65746	282230	964950	NC	-	Strathy Gneiss (Gneissose Psammite)
S	65747	278180	965510	NC	-	Amphibolite
S	65748	277890	965770	NC	-	Garnetiferous Acid Gneiss
S	65749	277860	965790	NC	-	Garnetiferous Acid Gneiss
S	65750	277780	965810	NC	-	Garnetiferous Acid Gneiss
S	65751	277660	965880	NC	-	Strathy Gneiss (Gneissose Psammite)
S	65752	277380	965550	NC	-	Banded Amphibolite (?Calc)

Thin sections of sedimentary rocks from the Reay (Sheet 115) geological map sheet						
S	65753	277380	965550	NC	-	Calc Silicate
S	65754	277300	965500	NC	-	Semi Pelite/Micaceous Psammite
S	65767	278970	964710	NC	-	Meta Igneous Rock (Strathy) ?
S	65768	278960	964790	NC	-	Meta Granite (Strathy Complex) ?
S	65769	278910	964900	NC	-	Amphibole Discordant Dyke
S	65770	277700	963510	NC	-	Migmatitic Micaceous Psammite
S	65771	277670	963540	NC	-	Migmatitic Micaceous Psammite
S	65772	277320	963790	NC	-	Migmatitic Psammite
S	65773	277300	963750	NC	-	Migmatitic Psammite
S	65774	277150	964230	NC	-	Migmatitic Psammite
S	65775	277140	964170	NC	-	Migmatitic Semi Pelite
S	65776	276800	964600	NC	-	Migmatitic Psammite
S	65777	276810	964570	NC	-	Migmatitic Psammite
S	65778	276250	964640	NC	-	Migmatitic Micaceous Psammite
S	65779	276530	964470	NC	-	Migmatitic Micaceous Psammite
S	65780	276710	963870	NC	-	Migmatitic Micaceous Psammite
S	65781	276750	963550	NC	-	Migmatitic Micaceous Psammite
S	65967	282910	969750	NC	-	Strathy Gneiss
S	65968	278210	965440	NC	-	Calcic Strathy Gneiss
S	65969	273380	960330	NC	-	Calc Silicate
S	65970	273200	960360	NC	-	Calc Silicate
S	65971	280280	966190	NC	-	Sodic Granite Vein ?
S	65972	290120	953390	NC	-	Pyroxene Hornblende Appinite ?
S	65973	290200	958350	NC	-	Calc Silicate
S	65974	290320	958600	NC	-	Garnet Cpx(?) Calc Silicate
S	67012	290560	959030	NC	-	Migmatitic Granite Phase
S	67013	290770	958900	NC	-	Semi Pelites With Granite
S	67014	290770	958900	NC	-	Semi Pelites With Granite
S	67015	290740	958850	NC	-	
S	67016	290800	958770	NC	-	Microgranite Sheet
S	67017	290740	959140	NC	-	Biotite Granite Migmatitic
S	67018	290350	959300	NC	-	Granite Phase Assoc Migmatites
S	67019	290350	959300	NC	-	Granite Phase Assoc Migmatites

Thin sections of sedimentary rocks from the Reay (Sheet 115) geological map sheet						
S	67020	291380	962050	NC	-	
S	67021	290000	951120	NC	-	Migmatitic Granite Biotite Partings
S	67022	290000	951120	NC	-	Striped Metabasic Xenolith
S	67023	289960	950880	NC	-	Foliated Granite
S	67024	289960	950880	NC	-	Foliated Granite
S	67025	289900	951400	NC	-	Migmatitic Granite Mica Clots
S	67026	290100	950260	NC	-	Alkali Granite
S	67027	290090	950680	NC	-	Augen
S	67028	290510	951300	NC	-	Migmatitic Granite Biotite Partings
S	67029	289530	957680	NC	-	Granite Sheet Cuts Migmatites
S	67030	289150	956470	NC	-	Biotite Granite
S	67031	289150	956470	NC	-	Biotite Granite Mafic Clots
S	67032	289150	956470	NC	-	Biotite Granite
S	67033	289150	956470	NC	-	Migmatitic Gneiss
S	67034	290100	957350	NC	-	Hornblende Schist Granite ?
S	67035	289950	956330	NC	-	Migmatitic Granite With Magnetite
S	67036	287100	966290	NC	-	Hornblende Schist
S	67037	287120	966370	NC	-	Alkali Granite
S	67038	287600	966680	NC	-	Granite Gneiss/Psammite
S	67039	290100	953410	NC	-	Appinite/Hornblende Diorite ?
S	67040	290150	953400	NC	-	Biotite Tonalite
S	67041	289530	957680	NC	-	Granite Cutting Migmatites
S	67097	290400	961030	NC	-	Calc Silicate Magmatic Moine
S	67098	290520	961120	NC	-	Calc Silicate Magmatic Moine
S	67099	290200	958720	NC	-	Calc Silicate Magmatic Moine
S	67100	290630	953490	NC	-	Calc Silicate Magmatic Moine
S	67187	290920	953640	NC	-	Metabasic Pod In Migmatite
S	67188	291030	959310	NC	-	Mafic (? Metabasic) Xenolith In Granite
S	67189	291030	959310	NC	-	Mafic (? Metabasic) Xenolith In Granite
S	67190	290140	952650	NC	-	Basic Pod In Migmatites
S	67191	297480	963520	NC	-	Appinitic Sheet In Migmatites ?
S	67192	297420	962700	NC	-	Biotite Granodiorite
S	67193	298330	963200	NC	-	Alkali Granite
S	67194	298170	963190	NC	-	Alkali Granite
S	67195	292040	952290	NC	-	Biotite Granodiorite
S	67196	289970	949800	NC	-	Dyke Psammite/Granite Gneiss

S	67197	289970	949800	NC	-	Granite Margin To Dyke
Thin sections of sedimentary rocks from the Reay (Sheet 115) geological map sheet						
S	67198	290020	949760	NC	-	Faulted Granite
S	67199	290040	948250	NC	-	Alkali Granite
S	67200	290050	948100	NC	-	Basic Pod/Xenolith In Granite
S	67201	292910	947520	NC	-	Edge Granite? Sheet
S	67202	292910	947520	NC	-	Centre Of Granite? Sheet
S	67203	289990	946150	NC	-	Alkali Granite
S	67204	298290	964430	NC	-	Hornblende Biotite Monzodiorite
S	67205	296400	964400	NC	-	Biotite Quartz Diorite Granite
S	67206	290790	959680	NC	-	Alkali Biotite Granite
S	67207	294550	959300	NC	-	Halladale Complex
S	67208	293430	952140	NC	-	F/Granite Granodiorite
S	67209	293220	952380	NC	-	Granite
S	67210	295990	963670	NC	-	Reay Diorite
S	67211	296640	962540	NC	-	Diorite
S	67212	296640	962540	NC	-	Xenolith And Granite Vein
S	67213	296500	959150	NC	-	Granite ?Sheet
S	67214	295540	955670	NC	-	Granite
S	67215	297880	962080	NC	-	Granite
S	67216	298070	958470	NC	-	Blebby Quartz Granite
S	67217	297880	958110	NC	-	Biotite Granodiorite
S	67218	294650	964650	NC	-	Reay Diorite
S	67219	294650	964650	NC	-	Psammite/Granulite
S	67220	294520	964410	NC	-	Hornblende Diorite
S	67223	290990	959390	NC	-	Xenolith In Migmatitic Granite
S	67224	288230	965830	NC	-	Amphibolite Sheet
S	67227	299210	956190	NC	-	Granite
S	67229	297500	964030	NC	-	Hornblende Xenolith/Patch
S	67236	288230	965830	NC	-	Granite
S	67237	288230	965830	NC	-	Boulder (?Local) Of Granite
S	67542	288250	965360	NC	-	Foliated Granite Sheet
S	67543	288250	965360	NC	-	Foliated Granite Sheet
S	67544	288240	965860	NC	-	Amphibolitic Dyke
S	67545	287400	966500	NC	-	Foliated 'Augen' Granite
S	67546	287400	966500	NC	-	Foliated 'Augen' Granite
S	67547	290110	958650	NC	-	Microgranite Sheet
S	67548	291000	959370	NC	-	Basic Xenolith Migmatitic Granite
S	67549	291000	959370	NC	-	Basic Xenolith Migmatitic Granite

S	67550	297400	963550	NC	-	Siliceous Psammite
Thin sections of sedimentary rocks from the Reay (Sheet 115) geological map sheet						
S	67551	297400	963550	NC	-	Micaceous (?Hornblendic) Quartzite
S	67552	297370	963460	NC	-	Micaceous (?Hornblendic) Quartzite
S	67553	299170	962560	NC	-	Biotite Granodiorite
S	67554	297790	963960	NC	-	Siliceous Psammite
S	67555	288240	965920	NC	-	Foliated Granite
S	67556	288240	965920	NC	-	Psammite In Granite
S	67557	288240	965990	NC	-	Microgranite Dyke In Moine
S	67558	288240	966000	NC	-	Basic Dyke Cuts Hot Moine
S	68105	294630	964690	NC	-	Calc Silicate
S	68106	283530	962120	NC	-	Calc Silicate (Garnet)
S	68107	200920	954640	NC	-	Calc Silicate
S	68108	270760	959230	NC	-	Garnetiferous Pelite
S	68109	270710	959140	NC	-	Calc Silicate
S	68114	283450	963550	NC	-	Biotite Granitoid Feldspar
S	70879	277380	965390	NC	-	Calc Silicate ?
S	70880	277380	965390	NC	-	Pelitic Schist
S	70881	277860	965390	NC	-	Micaceous Psammite
S	83287	301970	962400	ND	Pit A1, Broubster Analogue site, old quarry and kiln	Manganese wad in soil horizon
S	93094	298630	960040	NC	New forestry road, 850m SSW of limekiln on old road	Strath Halladale Granite
S	93095	298180	961010	NC	300m due S of Lochan nan Eun	Diorite xenolith in Strath Halladale Granite
S	93097	295550	961540	NC	Beinn Ratha, E slopes, 1km NW of ruined bothy in Helsletter Strath	Granite with gritty texture
S	93098	289760	963500	NC	-	Granite
S	93100	288830	961120	NC	-	Microgranite
S	93102	288830	961120	NC	-	Foliated granite
S	93103	288720	960920	NC	-	Banded gneiss
S	93104	288160	960700	NC	-	Quartz rich gneiss
S	93105	285100	960270	NC	-	Granitic gneiss
S	93106	286950	963590	NC	-	Banded gneiss
S	93107	285570	962070	NC	-	Amphibolite
S	93108	287040	963760	NC	-	Hornblende plagioclase gneiss
S	93109	287600	963940	NC	-	Dioritic rock
S	93110	287420	963420	NC	-	Psammitic gneiss
S	93111	291150	960030	NC	850m 246deg from W edge of Loch Akram	Granitoid gneiss

Thin sections of sedimentary rocks from the Reay (Sheet 115) geological map sheet						
S	93112	292490	960110	NC	50m E of S tip of Loch Akram	Foliated migmatitic amphibolite
S	93113	292810	960410	NC	Rocky knoll 220m E of Loch Akram	Granite with wispy ghost fabric and k feldspar megacrysts
S	93114	292630	963150	NC	40m WSW of summit cairn of Beinn Ruadh	Granite derived breccio-conglomerate
S	93115	294500	963940	NC	740m 190deg from Reay Quarry	Slightly foliated diorite
S	93116	294380	963210	NC	In burn section, Lone Torrigal	Hornfelsed psammite
S	93117	294040	962860	NC	In burn section, 800m SW from ford on Lone Torrigal track	Amphibolite
S	93118	290470	960610	NC	SSW end of Golval Hill crags	Calc silicate
S	93120	291920	968470	NC	Giligill Burn, 600m upstream from Freestone Quarry	Silicified zone along joints in ORS breccio-conglomerate
S	93121	292100	962440	NC	250m E of N tip of Caol Loch	Striped highly migmatitic psammite
S	93122	291560	962320	NC	270m 244deg from N end of Caol Loch	Amphibole pyroxene plagioclase ultramafic
S	93123	294610	964680	NC	N part of W wall of Reay Quarry	Biotite diorite pod
S	93126	297680	964610	NC	-	Foliated Reay diorite with granite veins
S	93127	287600	963950	NC	Small isolated outcrop	Hbl-plag-px diorite non foliated coarse grained
S	93130	300650	959520	ND	-	Strath Halladale Granite
S	93131	300940	957550	ND	-	Scyelite
S	93132	300690	957760	ND	-	Amphibolite lens in granite
S	93133	297890	959670	NC	Meur a' Chrochain Ghil	Strath Halladale Granite
S	93135	297170	959890	NC	350m W of Sandside Burn	Porphyritic Strath Halladale Granite
S	93136	296240	959000	NC	Allt Loch nan Clack Geala	Microgranite, Strath Halladale Granite
S	93137	295910	957620	NC	Clackgeal Hill	Weakly foliated Strath Halladale Granite
S	93138	299780	955450	NC	Beinn nam Bad Mor	Strath Halladale Granite
S	93139	296330	956810	NC	150m NE of Lochain a' Chleirich	Strath Halladale Granite with scattered megacrysts
S	93140	295610	955650	NC	600m NW of Lochain a' Chleirich	Strath Halladale Granite
S	93141	265850	956550	NC	Upper Sandside Burn	Very weakly foliated Strath Halladale Granite

Thin sections of sedimentary rocks from the Reay (Sheet 115) geological map sheet						
S	93142	296980	958860	NC	Sandside Burn	Porphyritic Strath Halladale Granite
S	93143	296770	957410	NC	Gleann Chorcaill	Strath Halladale Granite
S	93751	307220	966300	ND	Tendale Park	Dolomitic limestone, Old Red Sandstone
S	93752	307430	961290	ND	E shore of Loch Calder	Laminated mudstone impregnated with bitumen, M Devonian
S	93753	397880	964790	ND	SW bank of Burn of Isauld 330m SE of Bridge of Isauld	Feldspathic reddened diorite, grain size 2-4mm, Caledonian
S	93756	287730	966550	NC	-	Joint coating at unconformity, Portskerra Unconformity
S	93757	287500	966470	NC	-	Psammitic gneiss
S	93758	286530	966560	NC	-	Banded grey gneiss
S	93761	287600	966570	NC	-	Psammitic gneiss
S	93763	293080	960970	NC	Red Point	Dark green hornblende-bi rock (microdiorite); irregular dyke cuts granite and gneiss. Kappameter value 0.2
S	93770	297680	966710	NC	Geo Cuinge SE end	Calcite - pyrite infill in small fault (vein)
S	96385	297330	963490	NC	Borlum House	Psammitic Moine with reddening along joints, c/ref MC 5435
S	96386	293000	965950	NC	Red Point	Fault breccia; calcite, quartz, galena, baryte, c/ref MC 5308
S	96387	287990	966270	NC	Portskerra	Weathered amphibolite, 10-15cm below unconformity, c/ref MC 5395
S	96388	287990	966270	NC	Portskerra	Weathered amphibolite, 20-30cm below S.96387, c/ref MC 5396
S	96389	287990	966270	NC	Portskerra	Weathered amphibolite, 50cm below unconformity, MC 5397
S	96390	288060	966190	NC	Portskerra	Regolith, top of basic basement, c/ref MC 5403
S	96391	288060	966190	NC	Portskerra	Unweathered Regolith top of basic basement, c/ref MC 5404
S	96392	285660	966270	NC	Baligill	Regolith or weathered top of granite, 0-10cm below unconformity, c/ref MC 5424
S	96393	285660	966270	NC	Baligill	Less rotten granite 20-35cm below regolith, c/ref MC 5425
S	96394	285660	966270	NC	Baligill	Rotten granite 55-70cm below MC.5424, c/ref MC 5426

Thin sections of sedimentary rocks from the Reay (Sheet 115) geological map sheet						
S	96395	285660	966270	NC	Baligill	Fresh granite 107-120cm below MC.5424, c/ref MC 5427
S	96396	285660	966270	NC	Baligill	Rotten granite 10-20cm from unconformity (intermediate between MC.5424 and MC.5425), c/ref MC 5428
S	96797	287950	966300	NC	Portskerra	Unweathered granite, 50cm below unconformity
S	96798	287950	966300	NC	Portskerra	Altered granite, 30cm below unconformity
S	96799	287950	966300	NC	Portskerra	Regolith of granite beneath unconformity (10cm below)
S	96800	287950	966300	NC	Portskerra	Sandy crust on top of regolith
S	35440	-	-	-	-	
S	35442	-	-	-	-	
S	35911	-	-	-	-	
S	35985	-	-	-	-	
S	46017	305000	969000	ND	-	
S	59550	285600	966300	NC	-	Calcite Limestone
S	70875	277380	965390	NC	-	Limestone
S	70876	277380	965390	NC	-	Limestone
S	70877	277380	965390	NC	-	Limestone
S	70878	277380	965390	NC	-	Limestone
S	80307	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 11.45-11.56m	Latheron subgroup, Upper Caithness Flagstones
S	80308	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 12.00-12.17m	Latheron subgroup, Upper Caithness Flagstones
S	80309	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 15.66-15.78m	Latheron subgroup, Upper Caithness Flagstones
S	80310	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 16.27-16.48m	Latheron subgroup, Upper Caithness Flagstones
S	80311	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 16.91-17.04m	Latheron subgroup, Upper Caithness Flagstones
S	80312	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 19.48-19.55m	Latheron subgroup, Upper Caithness Flagstones
S	80313	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 19.59-19.73m	Latheron subgroup, Upper Caithness Flagstones
S	80313	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 19.59-19.73m	Latheron subgroup, Upper Caithness Flagstones
S	80314	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 24.48-24.63m	Latheron subgroup, Upper Caithness Flagstones
S	80315	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 28.17-28.28m	Latheron subgroup, Upper Caithness Flagstones
S	80316	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 28.73-28.81m	Latheron subgroup, Upper Caithness Flagstones

Thin sections of sedimentary rocks from the Reay (Sheet 115) geological map sheet						
S	80317	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 30.25-30.30m	Latheron subgroup, Upper Caithness Flagstones
S	80318	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 32.55-32.66m	Latheron subgroup, Upper Caithness Flagstones
S	80319	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 32.66-32.76m	Latheron subgroup, Upper Caithness Flagstones
S	80320	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 32.77-32.89m	Latheron subgroup, Upper Caithness Flagstones
S	80321	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 33.21-33.29m	Latheron subgroup, Upper Caithness Flagstones
S	80322	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 37.80-37.95m	Latheron subgroup, Upper Caithness Flagstones
S	80323	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 49.39-49.57m	Latheron subgroup, Upper Caithness Flagstones
S	80324	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 49.82-49.88m	Latheron subgroup, Upper Caithness Flagstones
S	80325	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 51.18-51.32m	Latheron subgroup, Upper Caithness Flagstones
S	80326	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 53.09-53.20m	Latheron subgroup, Upper Caithness Flagstones
S	80327	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 55.50-55.64m	Latheron subgroup, Upper Caithness Flagstones
S	80328	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 60.10-60.27m	Latheron subgroup, Upper Caithness Flagstones
S	80329	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 60.67-60.90m	Latheron subgroup, Upper Caithness Flagstones
S	80330	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 63.87-63.97m	Latheron subgroup, Upper Caithness Flagstones
S	80331	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 64.44-64.52m	Latheron subgroup, Upper Caithness Flagstones
S	80332	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 66.31-66.42m	Latheron subgroup, Upper Caithness Flagstones
S	80333	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 66.81-66.92m	Latheron subgroup, Upper Caithness Flagstones
S	80334	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 67.11-67.24m	Latheron subgroup, Upper Caithness Flagstones
S	80335	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 67.84-67.95m	Latheron subgroup, Upper Caithness Flagstones
S	80336	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 70.36-70.46m	Latheron subgroup, Upper Caithness Flagstones
S	80337	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 74.60-74.60m	Latheron subgroup, Upper Caithness Flagstones
S	80338	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 75.43-75.54m	Latheron subgroup, Upper Caithness Flagstones
S	80339	218600	967400	NC	A.E.R.E. Dounreay BH 46, depth; 76.78-76.87m	Latheron subgroup, Upper Caithness Flagstones
S	83214	293000	965950	NC	Red Point	Calcite breccia fragments

Thin sections of sedimentary rocks from the Reay (Sheet 115) geological map sheet						
S	83215	293000	965950	NC	Red Point	Breccia debris in siltstone
S	83216	293000	965950	NC	Red Point	Tube structure? in siltstone
S	83248	295800	965850	NC	Sandside Bay	Facies `A' laminated limestone containing active fish remains
S	83249	295800	965850	NC	Sandside Bay	Sand dyke cutting laminated limestone and fish remains
S	83255	297000	965650	NC	Isauld Burn	Calcite vein in limestone
S	83257	297000	965650	NC	Isauld Burn	Conglomerate
S	83259	297000	965650	NC	Isauld Burn	Stromatolite coating
S	83275	301370	962140	ND	Broubster Forest, track exposure	Caithness flagstone, fissile organic shale - uranium enriched, weathered
S	83276	301370	962140	ND	Broubster Forest, track exposure	Caithness flagstone, calcareous siltstone
S	83277	301370	962140	ND	Broubster Forest, track exposure	Caithness flagstone, calcareous siltstone/sandstone
S	83278	301400	962000	ND	Broubster Forest, quarry	Caithness flagstone, laminated limestone
S	83279	301400	962000	ND	Broubster Forest, quarry	Caithness flagstone, weathered black shale
S	83280	301400	962000	ND	Broubster Forest, quarry	Caithness flagstone, weathered black shale
S	83281	301970	962400	ND	Pit A1, Broubster Analogue site, old quarry and kiln	Caithness flagstone, slickenslided shale - uranium enriched
S	83281	301400	962000	ND	Broubster Forest, quarry	Caithness flagstone, laminated limestone
S	83283	301970	962400	ND	Pit A1, Broubster Analogue site, old quarry and kiln	Caithness flagstone, section through fine black uraniferous shale parting on surface of sandstone
S	83284	301970	962400	ND	Pit A1, Broubster Analogue site, old quarry and kiln	Caithness flagstone, weathered sandstone in fault zone
S	83285	301970	962400	ND	Pit A1, Broubster Analogue site, old quarry and kiln	Caithness flagstone, weathered sandstone in fault zone
S	83286	301970	962400	ND	Pit A1, Broubster Analogue site, old quarry and kiln	Caithness flagstone, weathered sandstone in fault zone
S	83288	302020	962440	ND	Broubster Analogue site	Fractured siltstone in fault zone
S	83289	302020	962440	ND	Broubster Analogue site	Blocky siltstone in fault zone
S	83290	301970	962400	ND	Pit A1, Broubster Analogue site	Caithness flagstone, Partly decalcified uraniferous sandstone in fault zone
S	83291	301970	962400	ND	Pit A1, Broubster Analogue site	Caithness flagstone, recrystallised fault breccia

Thin sections of sedimentary rocks from the Reay (Sheet 115) geological map sheet						
S	83292	301970	962400	ND	Pit A1, Broubster Analogue site	Caithness flagstone, calcareous sandstone with weathered crust
S	83293	302020	962440	ND	Broubster Analogue site	Caithness flagstone, decalcified siltstone
S	83294	301970	962400	ND	Pit A1, Broubster Analogue site	Caithness flagstone, transition from base of laminated limestone - shale
S	93096	299670	962890	NC	Creag Liath 580m ENE of Creag Mhor summit	Dark grey sandstone with calcite veinlets
S	93099	289210	964990	NC		Calcareous sandstone
S	93119	294870	960700	NC	245m 205deg from summit of Ceann Mor	Buff sandstone (Middle ORS)
S	93124	391070	960310	ND	Holborn Head	Flagstone
S	93125	390350	961000	ND	Broubster Bridge	Fine grained sandstone with porous horizons
S	93128	304970	956850	ND	-	Grey carbonate bearing sandstone
S	93129	301850	959880	ND	-	Conglomerate at base of M-ORS
S	93134	299560	959890	NC	Achvarasdale	Flaggy laminated fine sandstone (middle?) ORS
S	93144	299540	959600	NC	Achvarasdel Burn	Calc siltstone, ORS
S	93747	308630	966280	ND	W of Janetstown	Laminated siltstone and fish fragments, Old Red Sandstone
S	93748	304800	965700	ND	Water of Forss	Siltstone, Old Red Sandstone
S	93749	304390	965610	ND	450m NW of Baillie	Laminite, Old Red Sandstone
S	93750	304390	965610	ND	450m NW of Baillie	Calc siltstone, Old Red Sandstone
S	93754	291640	961910	NC	Balligil	Granite breccia with limestone matrix
S	93755	233200	961000	NC	Reay Golf Course nr Isauld Burn	Diorite breccia with banded limestone matrix support
S	93759	285610	965410	NC	-	Sandstone
S	93760	285610	965410	NC	-	Upper laminated sandstone
S	93762	291920	965310	NC	-	Limestone
S	93764	293080	965970	NC	Red Point W side	Pale grey buff medium grained quartz sandstone. Kappameter value 0.03
S	93765	297040	965590	NC	Reay Golf Course 285m at 329deg from Mary's Cottage	Dolomitic limestone/diorite breccia. Kappameter value 0.03
S	93766	296830	965780	NC	Coastal cliff E of Sandside Bay 210m N of Isauld Burn mouth	Quartz rich sandstone ?aeolian

Thin sections of sedimentary rocks from the Reay (Sheet 115) geological map sheet						
S	93767	295570	966370	NC	Small quarry by cliffs 220m at 117deg from Sandside Head	Blue-green-grey carbonate siltstone with pseudomorph gypsum clasts
S	93768	294000	965710	NC	SE corner of Geodh' na Moine	Fish bed
S	93769	298480	967170	NC	By sluice on Dounreay shore 270m NE of Dounreay Castle	Bituminous sandstone
S	93771	296730	965990	NC	E side of Sandside Bay	Neptunian dyke in fish bed
S	93772	297020	966600	NC	Foreshore W of Dounreay	Stromatolites in purplish grey mudstone
S	93773	297280	966740	NC	Foreshore W of Dounreay, Ling Geo area	Stromatolites in purplish grey mudstone

Appendix 3

Revised lithostratigraphy for the Devonian sedimentary rocks of the Caithness district. Revision carried out by C. A. Auton (unpublished 2001).

WEST OF FORSS FAULT				
GROUP/SUBGROUP	**FORMATION (FM)**	**MEMBER (MB)/BED**	**CODE**	**PREVIOUS/OTHER NAME(S)**
UPPER CAITHNESS FLAGSTONE **UCF**	SANDSIDE SANDSTONE FORMATION (Fletcher & Key 1992) **SAND**	DOUNREAY SILTSTONE MEMBER (Fletcher & Key 1992)	**DNSM**	DOUNREAY SHORE FM (NIREX 658, 1994)
		SANDSIDE BAY SANDSTONE MEMBER (includes **FSB**)	**SBSM**	BAY SANDSTONE MB (Fletcher & Key 1992) SANDSIDE BAY FM (NIREX 658, 1994)
		Fresgeo Sandstone (bed) (not mapped)	**FRSB**	FRESGEO SANDSTONE MB (NIREX 658, 1994)
LOWER CAITHNESS FLAGSTONE **LCF**	BIGHOUSE SANDSTONE FORMATION (Fletcher & Key 1992) **BIG**	RUBHA SANDSTONE MEMBER (includes **GLB**)	**RBSM**	BIGHOUSE SANDSTONE FM (Fletcher & Key 1992)
		Gunnscroft Limestone (bed) (not mapped)	**GLB**	BIGHOUSE LIMESTONE MB (NIREX 658, 1994)
SARCLET GROUP **SAR**	OUSDALE ARKOSE FORMATION (Fletcher 1999) **OA**	LUACHAIR SANDSTONE MEMBER	**LUSM**	LUACHAIR SANDSTONE FM (Fletcher & Key 1992) LUACHAIR FM (NIREX 658, 1994)
		TOBAIREACH CONGLOMERATE MEMBER	**TCM**	BASAL CONGLOMERATE (Fletcher & Key 1992) (NIREX 658, 1994)

EAST OF FORSS FAULT

GROUP/SUBGROUP	FORMATION (FM)	MEMBER (MB)/BED	CODE	PREVIOUS/OTHER NAME(S)
EDAY GROUP **EDY**	JOHN O'GROATS SANDSTONE FORMATION (Fletcher 1999) **JOG**	TANG SANDSTONE MEMBER	**TANG**	TANG SANDSTONE FM (Fletcher & Key 1992) (NIREX 658, 1994)
UPPER CAITHNESS FLAGSTONE **UCF** (upper part of the Caithness Flagstone Group **CNFL**)	MEY FLAGSTONE FORMATION (Fletcher 1999) **MEY**	BRIMS LIMESTONE MEMBER	**BRLI**	KYLE LIMESTONE FM (Fletcher & Key 1992) & (NIREX 658, 1994) Note: this is not the KYLE Limestone/Group of the Central North Sea Graben
		SCARDEN SANDSTONE MEMBER	**SCSM**	SCARDEN SANDSTONE FM (Fletcher & Key 1992) (NIREX 658, 1994)
		SHOPS SANDSTONE MEMBER	**SHSM**	SHOPS SANDSTONE FM (Fletcher & Key 1992) (NIREX 658, 1994)
		HOLBORN SANDSTONE MEMBER	**HOSM**	HOLBORN SANDSTONE FM (Fletcher & Key 1992) (NIREX 658, 1994)
		SCRABSTER FLAGSTONE MEMBER	**SFM**	SCRABSTER FLAGSTONE FM (Fletcher & Key 1992) (NIREX 658, 1994)
		PENNYLAND SANDSTONE MEMBER	**PYSM**	PENNYLAND SANDSTONE FM (Fletcher & Key 1992) (NIREX 658, 1994)
	SPITAL FLAGSTONE FORMATION (Fletcher 1999) **SPI**	ACHSCRABSTER FLAGSTONE MEMBER	**ACFM**	ACHSCRABSTER FLAGSTONE FM (Fletcher & Key 1992) (NIREX 658, 1994)
		ACHANARRAS FISH BED MEMBER	**AFB**	ACHANARRAS FISH BED MB (Fletcher 1999) (Trewin 1986)
LOWER CAITHNESS FLAGSTONE **LCF** (lower part of the Caithness Flagstone Group **CNFL**)	LYBSTER FLAGSTONE FORMATION (Fletcher 1999) **LYBR**	CALDER MUDSTONE MEMBER	**CDMM**	CALDER MUDSTONE FM (Fletcher & Key 1992) (NIREX 658, 1994)
		DORRERY SANDSTONE MEMBER	**DRSM**	DORRERY SANDSTONE FM (Fletcher & Key 1992) (NIREX 658, 1994)

		BEN DORRERY CONGLOMERATE MEMBER	**BDCM**	Un named conglomerate within the Dorrery Sandstone Fm (Fletcher & Key 1992)
SARCLET GROUP **SAR**	ULBSTER SANDSTONE FORMATION (Fletcher 1999) **ULBS**	MULTEADH SANDSTONE MEMBER	**MUSM**	MULTEADH SANDSTONE FM (Fletcher & Key 1992) (NIREX 658, 1994)
	OUSDALE ARKOSE FORMATION (Fletcher 1999) **OA**	LUACHAIR SANDSTONE MEMBER	**LUSM**	LUACHAIR SANDSTONE FM (Fletcher & Key 1992) (NIREX 658, 1994)
		TOBAIREACH CONGLOMERATE MEMBER	**TCM**	BASAL CONGLOMERATE (Fletcher & Key 1992) (NIREX 658, 1994)

UNUSED NAMES: (Fletcher & Key 1992)

Achreamie Sandstone (Formation/Member); Buldoo Sandstone (Formation/Member); Crosskirk Flagstone (Formation/Member)

UNUSED NAMES: (NIREX 658, 1994)

Ham-Scarfskerry (Subgroup/Formation); Latheron (Subgroup/Formation); Cyth (Subgroup/Formation)

OTHERS

Passage beds; Thurso beds/flags; Wick beds/flags

CODES = code in BGS lexicon

Note: TANG SANDSTONE MEMBER assigned to **UCF** by Fletcher & Key (1992) and to **JOG** by NIREX 658 (1994)

Appendix 4

Bulk-rock and mineral X-ray diffraction data for the Moine basement rocks and Devonian sedimentary rocks (Prior 1993c; Prior & Kemp 1993; Hyslop & Milodowski 1994). Key: 1 - present; 2 - minor; 3 - major; 4 - dominant; tr - trace; nd - not detected.

Semi-quantative XRD data of bulk-rock Devonian samples from Dounreay Borehole number 1

Sample	Top Depth (m)	Bottom Depth (m)	Lithology	Group/Formation	Quartz	Plagioclase	K-feldspar	Calcite	Dolomite	Ankerite	Pyrite	Mica	Chlorite	Corrensite
A133	11.06	11.34	laminated siltstone and shale	Caithness Flagstone Group, Dounreay Shore Formation	4	2	1	1	2	nd	tr	2	1	tr
A132	11.34	11.59	micritic limestone with siltstone laminae	Caithness Flagstone Group, Dounreay Shore Formation	3	1	1	3	2	nd	tr	1	tr	tr
A134	12.07	13.02	feldspathic arenite	Caithness Flagstone Group, Dounreay Shore Formation	4	2	2	2	1	nd	nd	2	1	nd
A169	27.54	27.90	interlaminated mudstone and siltstone	Caithness Flagstone Group, Dounreay Shore Formation	3	2	1	2	2	nd	tr	2	1	1
A135	34.90	35.19	siltstone with shale, feldspathic siltstone and micaceous mudstone laminae	Caithness Flagstone Group, Dounreay Shore Formation	4	2	1	2	1	nd	nd	2	1	tr
A137	39.46	37.70	laminated micritic limestone and siltstone	Caithness Flagstone Group, Dounreay Shore Formation	3	1	1	3	2	nd	tr	1	tr	nd
A136	39.73	39.98	shale with siltstone laminae	Caithness Flagstone Group, Dounreay Shore Formation	4	2	1	1	2	nd	tr	2	1	nd
A138	51.75	52.05	feldspathic arenite	Caithness Flagstone Group, Dounreay Shore Formation	4	3	1	2	1	nd	tr	1	1	1
A139	59.68	59.98	interbedded siltstone, very fine sandstone and shale	Caithness Flagstone Group, Dounreay Shore Formation	3	2	2	2	2	nd	tr	2	1	nd
A140	67.57	67.85	laminated fine sandstone and siltstone	Caithness Flagstone Group, Dounreay Shore Formation	4	2	1	2	1	nd	tr	2	1	nd
A141	88.66	88.96	silty shale with siltstone and very fine sandstone laminae	Caithness Flagstone Group, Dounreay Shore Formation	4	3	1	1	2	nd	tr	2	1	nd
A142	91.27	91.55	litharenite	Caithness Flagstone Group, Dounreay Shore Formation	4	2	1	2	1	nd	tr	2	1	nd
A143	101.28	101.58	feldspathic wacke siltstone	Caithness Flagstone Group, Sandside Bay Formation	3	1	1	2	1	nd	nd	2	2	1
A144	109.59	109.90	shale with siltstone laminae	Caithness Flagstone Group, Sandside Bay Formation	3	1	1	1	2	nd	tr	2	1	nd
A145	124.82	125.12	shale with siltstone laminae	Caithness Flagstone Group, Sandside Bay Formation	3	2	1	1	1	nd	nd	2	2	nd
A146	138.01	138.30	feldspathic siltstone and fine sandstone	Caithness Flagstone Group, Sandside Bay Formation	4	2	1	nd	nd	2	nd	2	nd	nd

Sample	Top Depth (m)	Bottom Depth (m)	Lithology	Group/Formation	Quartz	Plagioclase	K-feldspar	Calcite	Dolomite	Ankerite	Pyrite	Mica	Chlorite	Corrensite
A147	147.72	147.97	siltstone with shale laminae	Caithness Flagstone Group, Sandside Bay Formation	4	1	1	2	nd	1	tr	2	nd	nd
A149	148.30	148.70	limestone with silty laminae	Caithness Flagstone Group, Sandside Bay Formation	1	tr	tr	4	2	nd	1	tr	nd	nd
A148	148.70	149.10	shale with siltstone laminae	Caithness Flagstone Group, Sandside Bay Formation	4	2	1	2	2	nd	1	2	1	tr
A170	171.12	171.42	laminated siltstone and shale	Caithness Flagstone Group, Sandside Bay Formation	4	2	1	2	2	nd	tr	2	1	1
A151	198.95	199.27	feldspathic arenite	Caithness Flagstone Group, Sandside Bay Formation	4	3	2	1	nd	1	1	2	nd	nd
A152	207.35	207.62	feldspathic arenite	Caithness Flagstone Group, Sandside Bay Formation	4	2	1	2	nd	1	tr	tr	nd	nd
A150	221.75	222.05	shale with siltstone laminae	Caithness Flagstone Group, Sandside Bay Formation	4	2	1	1	2	nd	1	2	1	nd
A154	238.87	239.15	siltstone with shale laminae	Caithness Flagstone Group, Sandside Bay Formation	4	2	1	2	1	nd	1	2	1	nd
A153	244.03	244.33	siltstone	Caithness Flagstone Group, Sandside Bay Formation	4	2	1	2	nd	tr	tr	2	1	nd
A155	257.86	258.13	shale and silty shale	Caithness Flagstone Group, Sandside Bay Formation	4	2	1	2	nd	tr	tr	2	2	nd
A156	264.11	264.42	silty shale with very fine sandstone laminae	Caithness Flagstone Group, Sandside Bay Formation	4	2	2	2	1	nd	1	2	2	nd
A157	264.59	264.89	micritic limestone with siltstone laminae	Caithness Flagstone Group, Sandside Bay Formation	2	tr	tr	4	1	nd	tr	1	tr	nd
A158	274.61	274.91	feldspathic wacke sandstone	Caithness Flagstone Group, Sandside Bay Formation	4	2	1	2	nd	tr	tr	2	2	nd
A159	290.70	290.98	shale with siltstone laminae	Caithness Flagstone Group, Sandside Bay Formation	4	2	1	3	tr	nd	1	2	2	nd
A160	296.67	296.97	feldspathic arenite	Caithness Flagstone Group, Sandside Bay Formation	4	2	1	3	tr	nd	tr	2	1	nd
A161	304.71	305.01	brecciated micritic limestone with shale laminae	Caithness Flagstone Group, Sandside Bay Formation	4	1	1	tr	tr	nd	tr	1	nd	nd
A162	310.73	311.27	brecciated fine feldspathic sandstone	Bighouse Sandstone Formation	4	1	1	1	tr	nd	1	1	tr	nd
A163	313.52	313.83	micritic limestone with siltstone laminae	Bighouse Sandstone Formation	1	1	1	4	nd	nd	1	1	tr	nd
A164	318.30	318.60	fine feldspathic arenite	Bighouse Sandstone Formation	4	2	2	3	nd	tr	1	1	1	nd
A166	344.25	344.55	litharenite	Bighouse Sandstone Formation	3	3	2	3	nd	tr	tr	2	2	nd
A165	359.20	359.55	shale with siltstone laminae	Bighouse Sandstone Formation	4	2	1	2	nd	tr	nd	2	2	tr
A167	363.72	364.03	conglomerate	Basal breccio-conglomerates	4	2	1	3	nd	tr	nd	2	1	nd
A168	369.26	369.56	conglomerate	Basal breccio-conglomerates	4	2	2	2	nd	tr	2	1	2	nd

Semi-quantative XRD data of clay fraction from Devonian samples, Dounreay Borehole number 1

Sample	Top Depth (m)	Bottom Depth (m)	Lithology	Group/Formation	Smecite	Chlorite	Illite	Kaolinite	Corrensite	Smectite-Chlorite	Illite-Smectite
A133	11.06	11.34	laminated siltstone and shale	Caithness Flagstone Group, Dounreay Shore Formation	nd	3	2	nd	3	nd	nd
A132	11.34	11.59	micritic limestone with siltstone laminae	Caithness Flagstone Group, Dounreay Shore Formation	nd	3	2	nd	2	nd	nd
A134	12.07	13.02	feldspathic arenite	Caithness Flagstone Group, Dounreay Shore Formation	nd	3	2	nd	2	nd	nd
A169	27.54	27.90	interlaminated mudstone and siltstone	Caithness Flagstone Group, Dounreay Shore Formation	nd	2	2	nd	3	nd	nd
A135	34.90	35.19	siltstone with shale, feldspathic siltstone and micaceous mudstone laminae	Caithness Flagstone Group, Dounreay Shore Formation	nd	3	2	nd	3	nd	nd
A137	39.46	37.70	laminated micritic limestone and siltstone	Caithness Flagstone Group, Dounreay Shore Formation	nd	3	2	nd	2	nd	nd
A136	39.73	39.98	shale with siltstone laminae	Caithness Flagstone Group, Dounreay Shore Formation	nd	3	2	nd	3	nd	nd
A138	51.75	52.05	feldspathic arenite	Caithness Flagstone Group, Dounreay Shore Formation	nd	3	2	nd	3	nd	nd
A139	59.68	59.98	interbedded siltstone, very fine sandstone and shale	Caithness Flagstone Group, Dounreay Shore Formation	nd	3	2	nd	2	nd	nd
A140	67.57	67.85	laminated fine sandstone and siltstone	Caithness Flagstone Group, Dounreay Shore Formation	nd	3	2	nd	3	nd	nd
A141	88.66	88.96	silty shale with siltstone and very fine sandstone laminae	Caithness Flagstone Group, Dounreay Shore Formation	nd	3	2	nd	3	nd	nd
A142	91.27	91.55	litharenite	Caithness Flagstone Group, Dounreay Shore Formation	nd	3	2	nd	3	nd	nd
A143	101.28	101.58	feldspathic wacke siltstone	Caithness Flagstone Group, Sandside Bay Formation	nd	2	3	nd	3	nd	nd
A144	109.59	109.90	shale with siltstone laminae	Caithness Flagstone Group, Sandside Bay Formation	nd	3	2	nd	3	nd	nd
A145	124.82	125.12	shale with siltstone laminae	Caithness Flagstone Group, Sandside Bay Formation	nd	3	3	nd	2	nd	nd
A146	138.01	138.30	feldspathic siltstone and fine sandstone	Caithness Flagstone Group, Sandside Bay Formation	nd	2	4	nd	nd	nd	nd
A147	147.72	147.97	siltstone with shale laminae	Caithness Flagstone Group, Sandside Bay Formation	nd	1	4	nd	nd	nd	nd
A149	148.30	148.70	limestone with silty laminae	Caithness Flagstone Group, Sandside Bay Formation	nd	2	3	nd	nd	nd	nd
A148	148.70	149.10	shale with siltstone laminae	Caithness Flagstone Group, Sandside Bay Formation	nd	3	2	nd	2	nd	nd

Sample	Top Depth (m)	Bottom Depth (m)	Lithology	Group/Formation	Smecite	Chlorite	Illite	Kaolinite	Corrensite	Smectite-Chlorite	Illite-Smectite
A170	171.12	171.42	laminated siltstone and shale	Caithness Flagstone Group, Sandside Bay Formation	nd	3	2	nd	nd	nd	nd
A151	198.95	199.27	feldspathic arenite	Caithness Flagstone Group, Sandside Bay Formation	1	1	4	nd	nd	nd	nd
A152	207.35	207.62	feldspathic arenite	Caithness Flagstone Group, Sandside Bay Formation	nd	2	4	nd	nd	nd	nd
A150	221.75	222.05	shale with siltstone laminae	Caithness Flagstone Group, Sandside Bay Formation	nd	3	2	nd	2	nd	nd
A154	238.87	239.15	siltstone with shale laminae	Caithness Flagstone Group, Sandside Bay Formation	nd	3	2	nd	2	nd	nd
A153	244.03	244.33	siltstone	Caithness Flagstone Group, Sandside Bay Formation	nd	3	2	nd	2	nd	nd
A155	257.86	258.13	shale and silty shale	Caithness Flagstone Group, Sandside Bay Formation	nd	4	2	nd	2	nd	nd
A156	264.11	264.42	silty shale with very fine sandstone laminae	Caithness Flagstone Group, Sandside Bay Formation	nd	3	2	nd	2	nd	nd
A157	264.59	264.89	micritic limestone with siltstone laminae	Caithness Flagstone Group, Sandside Bay Formation	nd	4	2	nd	nd	nd	nd
A158	274.61	274.91	feldspathic wacke sandstone	Caithness Flagstone Group, Sandside Bay Formation	nd	3	2	nd	nd	nd	nd
A159	290.70	290.98	shale with siltstone laminae	Caithness Flagstone Group, Sandside Bay Formation	nd	3	2	nd	2	nd	nd
A160	296.67	296.97	feldspathic arenite	Caithness Flagstone Group, Sandside Bay Formation	1	4	1	nd	nd	nd	nd
A161	304.71	305.01	brecciated micritic limestone with shale laminae	Caithness Flagstone Group, Sandside Bay Formation	nd	3	3	nd	nd	nd	nd
A162	310.73	311.27	brecciated fine feldspathic sandstone	Bighouse Sandstone Formation	nd	2	3	nd	nd	nd	nd
A163	313.52	313.83	micritic limestone with siltstone laminae	Bighouse Sandstone Formation	nd	3	3	nd	nd	nd	nd
A164	318.30	318.60	fine feldspathic arenite	Bighouse Sandstone Formation	nd	4	1	nd	nd	nd	nd
A165	359.20	359.55	shale with siltstone laminae	Bighouse Sandstone Formation	nd	3	2	nd	nd	nd	nd
A168	369.26	369.56	conglomerate	Basal breccio-conglomerates	nd	4	1	nd	nd	nd	nd

Appendix 5

Compositional data for the Devonian sedimentary rocks (Hyslop & Milodowski 1994). Detrital Components: 3 - major; 2 - minor; 1 - trace; 0 - absent.

Compositional data from the Devonian strata from the Dounreay Borehole number 1															
Sample	**Top depth (m)**	**Bottom depth (m)**	**Lithology**	**Monocrystalline quartz**	**Polycrystalline quartz**	**K-Feldspar**	**Plagioclase**	**Muscovite**	**Biotite**	**Chlorite**	**Opaques**	**Organics**	**Carbonate**	**Matrix**	**Lithics**
A171	9.68	9.90	shale with feldspathic siltstone laminae	3	0	3	1	2	2	2	0	2	0	3	0
A133	11.06	11.34	laminated siltstone and shale	3	0	3	2	3	2	3	0	2	0	3	0
A132	11.34	11.59	micritic limestone with siltstone laminae	2	0	2	2	2	2	2	1	2	0	2	0
A134	12.07	13.02	feldspathic arenite	3	0	3	3	2	2	0	2	0	0	0	2
A172	18.41	18.71	laminated mudstone and siltstone	3	0	3	2	2	2	0	0	2	0	3	0
A169	27.54	27.90	interlaminated mudstone and siltstone	3	0	3	2	2	2	1	2	2	0	3	0
A173	30.32	30.61	feldspathic oolitic sandstone with shale laminae	3	0	3	1	2	2	0	0	2	0	2	0
A135	34.90	35.19	siltstone with shale, feldspathic siltstone and micaceous mudstone laminae	3	0	3	2	2	2	2	0	2	0	3	2
A137	39.46	37.70	laminated micritic limestone and siltstone	3	0	2	2	2	2	2	0	2	0	0	0
A136	39.73	39.98	shale with siltstone laminae	3	0	2	0	2	2	2	2	2	0	3	0
A174	40.38	40.68	shale with feldspathic siltstone and fine sandstone laminae	3	0	3	2	2	2	0	0	2	0	3	0

Sample	Top depth (m)	Bottom depth (m)	Lithology	Monocrystalline quartz	Polycrystalline quartz	K-Feldspar	Plagioclase	Muscovite	Biotite	Chlorite	Opaques	Organics	Carbonate	Matrix	Lithics
A175	42.02	42.27	feldspathic arenite	3	0	3	2	2	2	0	0	2	0	2	0
A138	51.75	52.05	feldspathic arenite	3	0	3	3	2	0	0	0	0	0	2	0
A139	59.68	59.98	interbedded siltstone, very fine sandstone and shale	3	0	3	3	2	2	0	0	2	0	3	2
A176	65.71	66.05	feldspathic siltstone and fine sandstone and shale laminae	3	0	3	2	2	2	0	1	2	0	3	0
A177	67.16	67.46	shale with siltstone and fine sandstone laminae	3	0	2	2	2	2	0	2	2	0	2	0
A140	67.57	67.85	laminated fine sandstone and siltstone	3	0	2	2	2	2	0	2	0	0	2	2
A178	84.06	84.28	siltstone	3	0	2	2	2	2	0	0	1	0	2	0
A179	85.56	85.79	interbedded feldspathic siltstone and shale	3	0	3	2	2	2	0	2	2	0	2	0
A141	88.66	88.96	silty shale with siltstone and very fine sandstone laminae	3	0	2	2	2	2	0	0	2	0	3	0
A142	91.27	91.55	litharenite	3	0	2	3	2	0	2	2	0	0	3	3
A143	101.28	101.58	feldspathic wacke siltstone	3	0	2	2	2	2	0	2	0	0	3	3
A180	107.14	107.44	siltstone with shale laminae	3	0	2	2	2	2	0	2	2	0	2	0
A181	108.80	109.06	siltstone with shale laminae	3	0	3	2	2	2	0	2	2	0	2	0
A144	109.59	109.90	shale with siltstone laminae	3	0	3	2	2	2	2	2	2	2	3	0
A182	116.04	116.34	micritic limestone with siltstone laminae	2	0	2	0	0	0	0	0	2	0	2	0
A145	124.82	125.12	shale with siltstone laminae	3	0	2	0	2	0	0	2	2	0	3	0

Sample	Top depth (m)	Bottom depth (m)	Lithology	Monocrystalline quartz	Polycrystalline quartz	K-Feldspar	Plagioclase	Muscovite	Biotite	Chlorite	Opaques	Organics	Carbonate	Matrix	Lithics
A183	133.44	133.74	shale with siltstone laminae	3	0	3	2	2	2	0	0	2	0	3	0
A146	138.01	138.30	feldspathic siltstone and fine sandstone	3	0	2	2	2	0	2	2	0	0	0	0
A184	140.39	140.69	shale with siltstone laminae	3	0	2	2	2	2	0	0	2	0	3	0
A185	142.79	143.07	siltstone	3	0	2	2	3	2	0	2	2	0	2	0
A186	146.04	146.36	feldspathic siltstone	3	0	2	2	2	0	0	2	2	0	2	0
A147	147.72	147.97	siltstone with shale laminae	3	0	2	2	3	2	2	0	0	0	3	0
A149	148.30	148.70	limestone with silty laminae	2	0	2	2	2	0	0	0	2	0	0	0
A148	148.70	149.10	shale with siltstone laminae	3	0	3	2	3	2	2	2	0	0	3	0
A187	160.31	160.61	siltstone with shale laminae	3	0	3	2	2	1	0	1	1	0	2	0
A170	171.12	171.42	laminated siltstone and shale	3	0	2	1	2	1	1	0	2	0	3	2
A188	177.11	177.54	feldspathic arenite	3	0	3	2	3	2	0	2	2	0	1	0
A189	182.81	183.11	feldspathic arenite	3	0	3	2	3	2	0	2	0	0	2	0
A190	185.67	186.02	micritic limestone	2	0	2	0	0	0	0	0	2	0	2	0
A191	192.20	192.48	feldspathic arenite	3	0	2	2	2	0	2	2	2	0	0	0
A151	198.95	199.27	feldspathic arenite	3	0	3	3	2	1	0	0	0	1	0	3
A192	205.44	205.71	feldspathic arenite	3	0	2	2	0	0	0	0	0	0	0	0

Sample	Top depth (m)	Bottom depth (m)	Lithology	Monocrystalline quartz	Polycrystalline quartz	K-Feldspar	Plagioclase	Muscovite	Biotite	Chlorite	Opaques	Organics	Carbonate	Matrix	Lithics
A152	207.35	207.62	feldspathic arenite	3	0	3	2	0	1	1	0	0	0	0	2
A193	213.74	214.04	feldspathic siltstone	3	0	3	2	2	2	0	2	0	0	2	0
A150	221.75	222.05	shale with siltstone laminae	3	0	3	2	2	2	0	2	2	0	3	0
A194	223.32	223.62	feldspathic sandstone	3	0	3	2	0	0	0	0	0	0	0	0
A195	229.73	230.06	shale with siltstone laminae	3	0	3	2	2	0	0	2	2	0	3	0
A154	238.87	239.15	siltstone with shale laminae	3	0	2	2	2	2	2	1	2	0	3	0
A153	244.03	244.33	siltstone	3	0	3	2	2	2	2	2	0	0	0	2
A196	249.27	249.57	shale	3	0	3	0	2	0	0	2	2	0	3	0
A197	256.20	256.51	siltstone with shale laminae	3	0	3	2	3	0	2	2	2	0	0	0
A155	257.86	258.13	shale and silty shale	3	0	3	3	3	3	2	0	0	0	3	0
A156	264.11	264.42	silty shale with very fine sandstone laminae	3	0	3	0	3	1	2	2	2	0	3	0
A157	264.59	264.89	micritic limestone with siltstone laminae	2	0	2	0	2	2	1	1	2	0	2	0
A158	274.61	274.91	feldspathic wacke sandstone	3	0	3	3	2	0	0	2	0	0	3	0
A198	282.76	283.05	shale with siltstone laminae	3	0	3	2	2	0	0	2	0	2	3	0
A199	287.11	287.41	feldspathic arenite	3	0	3	3	0	0	0	2	0	0	0	0
A159	290.70	290.98	shale with siltstone laminae	3	0	3	2	2	2	0	2	2	0	3	2

Sample	Top depth (m)	Bottom depth (m)	Lithology	Monocrystalline quartz	Polycrystalline quartz	K-Feldspar	Plagioclase	Muscovite	Biotite	Chlorite	Opaques	Organics	Carbonate	Matrix	Lithics
A200	293.24	293.55	shale with siltstone laminae	3	0	3	0	2	0	0	2	2	2	3	0
A160	296.67	296.97	feldspathic arenite	3	0	2	2	2	1	0	2	0	1	0	2
A201	300.56	300.90	feldspathic siltstone	3	0	3	2	2	0	0	2	0	0	0	0
A161	304.71	305.01	brecciated micritic limestone with shale laminae	3	0	2	0	2	0	0	0	0	0	0	0
A162	310.73	311.27	brecciated fine feldspathic sandstone	3	0	3	3	2	0	0	1	0	0	0	0
A163	313.52	313.83	micritic limestone with siltstone laminae	2	0	2	2	2	2	0	2	2	0	0	0
A164	318.30	318.60	fine feldspathic arenite	3	0	3	3	2	0	0	0	0	0	0	2
A202	321.96	322.27	feldspathic wacke sandstone	3	0	3	3	2	0	0	2	0	0	3	2
A203	327.92	328.19	feldspathic sandstone	3	0	3	2	2	0	0	2	0	0	2	0
A204	329.21	329.51	feldspathic sandstone	3	0	3	2	2	0	0	0	0	0	0	0
A205	344.05	344.29	feldspathic siltstone	3	0	3	2	2	0	0	1	0	0	2	0
A166	344.25	344.55	litharenite	3	0	3	3	2	0	2	0	0	0	0	3
A165	359.20	359.55	shale with siltstone laminae	3	0	2	2	2	2	2	2	2	0	3	3
A167	363.72	364.03	conglomerate	2	0	2	2	1	0	0	1	0	0	0	3
A168	369.26	369.56	conglomerate	2	0	2	2	2	2	2	2	0	0	2	3

Glossary

Amphibolite – A metamorphosed basic igneous rock with a mineral assemblage comprised largely of amphibole and plagioclase, usually with quartz and epidote.

Atoll structure – A structure developed in metamorphic rocks consisting of a core of one mineral entirely surrounded by a rim of another mineral. For example garnet forming a core entirely surrounded by plagioclase.

Augen gneiss – A gneissose metamorphic rock with abundant *augen* (eyes) represented by porphyroblasts (typically K-feldspar) enveloped by the foliation.

Alkali – A prefix applied to igneous rocks which contain either: (a) modal feldspathoids and/or alkali amphibole or pyroxenes; or (b) normative feldspathoids or acmite.

Alkali basalt – Term originally used for basalts containing accessory feldspathoids. These rocks typically contain a Ti-augite and olivine as their main ferromagnesian phases. Now defined geochemically using the Total Alkali-Silica diagram as a variety of basalt.

Alkali gabbro – A variety of gabbro which is alkaline in character due to the presence of analcime or nepheline and ferromagnesian phases such as barkevikite, kaersutite and/or Ti-augite.

Andesite – An intermediate volcanic rock, usually porphyritic, consisting of plagioclase (frequently zoned from labradorite to oligoclase), pyroxene, hornblende and/or biotite. Now defined modally on a Quartz-Alkali feldspar-Plagioclase-Feldspathoid diagram or geochemically using the Total Alkali-Silica diagram.

Basalt – A volcanic rock consisting essentially of calcic plagioclase and pyroxene. Olivine and minor feldspathoids may also be present. Now defined modally on a Quartz-Alkali feldspar-Plagioclase-Feldspathoid diagram or geochemically using the Total Alkali-Silica diagram.

Basaltic andesite – A volcanic rock with plagioclase compositions expected for andesites but containing ferromagnesian minerals more commonly found in basalts. Now defined geochemically using the Total Alkali-Silica diagram.

Benmoreite – A variety of basaltic igneous rock defined geochemically as the sodic variety of trachyandesite using the Total Alkali-Silica diagram.

Bow-tie structure – Aggregates of elongate prismatic and acicular crystals in a metamorphic rock which are arranged to give the appearance of a bow-tie. Commonly exhibited by amphiboles in *garbenschiefer* that have grown in the foliation plane under low stress.

Calc-silicate rock – A metamorphic rock with a chemistry dominated by calcium and silica (e.g. a metamorphosed calcareous mudstone, marl), consisting of the hydrous or anhydrous calc-silicate minerals such as tremolite, diopside and grossular garnet. Carbonate minerals may also be present.

Cleavage – A fabric developed within a metamorphic rocks defined by a sub-parallel set of closely spaced approximately planar surfaces produced during rock deformation. Defined by the preferred alignment of platy or elongate mineral grains (usually phyllosilicate minerals such as muscovite, biotite, chlorite).

Corona or reaction rim – A texture developed in metamorphic rocks composed of a monomineralic or polymineralic rim totally surrounding a core of another mineral phase. It typically represents an arrested reaction between the core phase and other components within the rock.

Camptonite – A variety of lamprophyre composed of phenocrysts of combination of olivine, kaersutite, Ti-augite and Ti-biotite in a matrix of the same minerals (except olivine) with plagioclase and sometimes subordinate alkali feldspar and feldspathoids.

Cement supported – Describes a fragmentary deposit where the detrital grains are, to varying degrees, isolated/supported within the cement.

Cement – The material bonding the fragments of clastic sedimentary rocks together and which was precipitated between the grains after deposition.

Clast supported – Describes a fragmentary deposit where all the detrital grains are in contact.

Crinanite – A variety of olivine-analcime dolerite or gabbro composed of olivine, Ti-augite and labradorite with minor analcime. Although it has less analcime and more olivine than teschenite the two names have been used interchangeably.

Cryptocrystalline – A term used to describe crystals in an igneous rock which are too small to be identified even with the petrological microscope.

Crystallinity – (a) H*olocrystalline*, an igneous rock composed of 100% crystals; (b) *holohyaline*, an igneous rock composed of 100% glass; and (c) *hypocrystalline*, intermediate between the two end-members and can be described more precisely by stating the relative proportions of crystals and glass.

Dacite – A volcanic rock composed of quartz and sodic plagioclase with minor amounts of biotite and/or hornblende and/or pyroxene. Now defined modally on a Quartz-Alkali feldspar-Plagioclase-Feldspathoid diagram or geochemically using the Total Alkali-Silica diagram.

Decussate structure – A term used to describe interlocking, randomly orientated, elongate, prismatic or subhedral crystals in a metamorphic rock which are generally of a single mineral phase.

Detritus – A general term for fragmentary material, such as gravel, sand, clay, worn from rock by disintegration. Detrital grains in clastic sedimentary rocks may be composed of single mineral grains (e.g. monocrystalline quartz, plagioclase), polycrystalline mineral grains (e.g. polycrystalline quartz) or lithic fragments including sedimentary, igneous and metamorphic rock fragments.

Dolerite – An igneous rock of intermediate grain size between a basalt and gabbro (i.e. synonym for *microgabbro*), and composed of essentially plagioclase, pyroxene and opaque minerals. Often contains an ophitic texture. If olivine is present may be called an olivine-dolerite; if quartz, a quartz-dolerite.

Equigranular – All the crystals in an igneous rock are approximately the same size.

Essexite – A variety of nepheline monzogabbro or nepheline monzodiorite containing Ti-augite, kaersutite and/or biotite with labradorite, lesser alkali feldspar and nepheline.

Felsite – A rock term initially used for the microcrystalline groundmass of porphyritic igneous rocks. Now commonly used for microcrystalline rocks of granitic composition (i.e. dacite to rhyolite).

Gneiss – A coarsely banded high-grade metamorphic rock consisting of alternating, mineralogically distinct layers.

Granoblastic texture – An aggregate consisting of equidimensional, typically rounded to anhedral crystals in a metamorphic rock which are of approximately equal size.

Granulite – A high-grade metamorphic rock typically with a granoblastic texture and with an assemblage containing pyroxene and anorthite-rich plagioclase.

Greenschist – A low-grade metamorphosed basaltic rock consisting of the assemblage actinolite, chlorite, epidote, albite, quartz and accessory titanite (sphene).

Grain size – Refers to the size of fragmentary material present in unconsolidated sediments and sedimentary rocks: (a) clay < 0.0039 mm in size; (b) silt, 0.0039 to 0.0625 mm in size; (c) fine sand, 0.0625 to 0.25 mm in size; (d) medium sand, 0.25 to 0.5 mm in size; (e) coarse sand, 0.5 to 1.0 mm in size; (f) very coarse sand, 1.0 to 2.0 mm in size; (g) granules 2.0 to 4.0 mm in size; (h) pebbles 4.0 to 64 mm in size.

Grain size – Refers to the size of crystals present in igneous rocks: (a) coarse-grained, crystals > 5.0 mm in size; (b) medium-grained, crystals 1.0 to 5.0 mm in size; (c) fine-grained, crystals < 1.0 mm in size.

Hornfels – A hard, fine- to medium-grained granoblastic metamorphic rock produced by high-grade contact metamorphism.

Hawaiite – A variety of basaltic igneous rock defined geochemically as the sodic variety of trachybasalt using the Total Alkali-Silica diagram.

Inequigranular – Term used to describe crystals present within an igneous rock which are of substantially different grain sizes. Common variety, porphyritic texture, can be subdivided into: (a) *microporphyritic*, phenocrysts ≤ 2.0 mm in size; and (b) *macroporphyritic*, phenocrysts > 2.0 mm in size.

Kersantite – A variety of lamprophyre consisting of phenocrysts of Mg-biotite, with or without hornblende, olivine or pyroxene in a groundmass of the same minerals plus plagioclase and occasionally alkali feldspar.

Matrix – Material, usually clay minerals or micas, forming a bonding substance to grains in a clastic sedimentary rock. The matrix material was deposited with the other grains or developed authogenically by diagenesis or slight metamorphism. Also used more generally for finer grained material in any rock in which large components are set.

Matrix supported – Describes a fragmentary deposit where the detrital grains are, to varying degrees, isolated/supported within a finer grained matrix.

Microcrystalline – crystals in an igneous rock which can only be identified with a petrological microscope. Crystals only just large enough to show polarisation colours (< 0.01 mm in size) are called *microlites*.

Minette – Term used for a variety of lamprophyre consisting of phenocrysts of phlogopite-biotite and occasionally amphibole in a groundmass of the same minerals plus orthoclase and minor plagioclase. Mg-olivine and diopsidic pyroxene may also be present.

Olivine-basalt – A commonly used term for a basalt containing olivine as an essential constituent.

Packing – Describes, as the term suggests, how closely the individual detrital grains are packed together within a fragmentary deposit. The term closely packed is used where all the grains are in contact and there is very little obvious matrix or cement; moderately packed and open packed are used with an increase in the porosity, matrix and/or cement.

Porosity – The volume of voids expressed as a percentage of the total volume of the sediment or sedimentary rock.

Phyllite – A well-cleaved metamorphosed mudstone characterised by a distinctive sheen on foliation surfaces; generally of intermediate grain size and metamorphic grade between slate and schist.

Poikiloblast – A term used to describe porphyroblasts present within a metamorphic rocks which contain abundant mineral inclusions.

Porphyroblast – A metamorphic mineral (e.g. garnet) that has grown to much larger size than the minerals of the surrounding matrix.

Porphyroblastic – A term used to describe a metamorphic rock containing large porphyroblasts within a finer grained matrix.

Porphyroclast – A large relict crystal, or crystal fragment in a fine-grained matrix of a deformed rock.

Post-tectonic growth – Growth of metamorphic minerals or parts of a mineral which occurred after deformation had ceased.

Pressure shadow – A region of low strain developed immediately adjacent to a rigid or competent object in a rock (e.g. a garnet porphyroblast).

Pre-tectonic growth – Metamorphic mineral growth before deformation has occurred.

Pseudomorph – A mineral or aggregate of minerals having taken the form/shape of another mineral phase that it/they have replaced.

Quartz-dolerite – A variety of *microgabbro* (dolerite) composed mainly of plagioclase and pyroxenes with interstitial quartz. The rock has tholeiitic affinities and its pyroxenes are usually sub-calcic augite accompanied by pigeonite or orthopyroxene.

Rounded – Describes the smoothness of the surface of a detrital grain present within a sediment or sedimentary rock. The terms *well-rounded*, *rounded*, *subrounded*, *subangular*, *angular*, *very angular* are used to describe the increasingly angular/irregular/rough nature of the surface of detrital grains.

Seriate texture – Refers to a continuous range in crystal size of principal minerals in an igneous rock.

Sorting – Well sorted describes a fragmentary deposit in which all the detrital grains are of approximately uniform size. In reality most fragmentary deposits contain a range of grain sizes and can be described as moderately sorted, poorly sorted or in extreme cases unsorted.

Spessartite – Term used for a variety of lamprophyre consisting of phenocrysts of hornblende with or without biotite, olivine or pyroxene in a groundmass of the same minerals plus plagioclase and minor K-feldspar.

Sphericity – Describes the how closely a detrital grains present within a sediment or sedimentary rock approximates to a sphere. The terms low sphericity, moderate sphericity and high sphericity are used to describe how spherical (ball-like) the detrital grains are.

Schist – A metamorphic rock of broadly pelitic composition (i.e. a metamorphosed mudstone) with a well-developed schistosity.

Schistosity – A planar structure developed in a metamorphic rock defined by the alignment of elongate minerals such as micas and amphibole.

Teschenite – A variety of analcime gabbro consisting of olivine, Ti-augite, labradorite and analcime.

Tholeiitic basalt – Commonly used term for a variety of basalt composed of labradorite, augite, hypersthene or pigeonite with olivine (often showing reaction relationship) or quartz, and often with interstitial glass.

Trachyte – A volcanic rock consisting essentially of alkali feldspar. Now defined modally on a Quartz-Alkali feldspar-Plagioclase-Feldspathoid ternary diagram or geochemically using the Total Alkali-Silica diagram.

Trachyandesite – A term originally used for volcanic rocks intermediate in composition between trachyte and andesite and containing equal amounts of alkali feldspar and plagioclase. Later used for volcanic rocks containing feldspathoids as well as alkali feldspar and plagioclase. Now defined geochemically using the Total Alkali-Silica diagram.

Trachybasalt – Term mainly used for basaltic volcanic rocks containing labradorite and alkali feldspar. Now defined geochemically using the Total Alkali-Silica diagram.

Trachytic texture – The sub-parallel alignment of microcrystalline feldspar in the groundmass of a *holocrystalline* or *hypocrystalline* igneous rocks. Sub-divided into pilotaxitic texture and *hyalopilitic* texture depending on whether the material between the feldspar is crystalline or glassy. *Trachytoid* texture, alignment of tabular, bladed or prismatic crystals which is visible to the naked eye. The terms *flow* and *fluxion* texture are sometimes used as synonyms for trachytic and trachytoid textures. However, they are best avoided due to their genetic implications

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