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Cover Illustration: Murchison chairing the Geographical section of the British Association; detail from 'The British Association', *Punch*, 49 (1865), 113.
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EDITORIAL

By 1865 Sir Roderick Impey Murchison was 73 years old. In the forty or so Victorian years which he devoted to geology he had travelled far and wide studying geological formations in Britain, Europe and Russia and had become an internationally known figure. Within a heady decade of the late thirties and early forties he had not only played a significant role in the establishment of the Geological Survey but also had been responsible for the naming of three major geological Systems, the Silurian, the Devonian (with Adam Sedgwick) and the Permian. Imagine the satisfaction of having the opportunity to name an aggregate 150 million years-worth of geological history!

Sir Roderick was to become Director-General of the Geological Survey in 1855, and twelve years later he installed Archibald Geikie as first Director of a firmly established Scottish Survey. Honoured by monarchs, governments, learned societies and universities, Sir Roderick played a unique role in advancing the science.

Today's 'Earth Sciences' embrace many disciplines, for example in the field of geophysics and mathematical geology, which 19th Century geologists would find hard to comprehend. New discoveries of great academic and economic importance continue to be made but somehow often become lost in the welter of geological journals publishing for small numbers of specialists who are accustomed to their own esoteric jargon. It takes rather more broadly based geologists of Sir Roderick's enthusiasm (if not influence) to ensure that the public's attention is drawn to the importance of modern geology.

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VOLCANOES IN THE ARCTIC

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Volcanoes in the Antarctic are familiar to us from the stories of explorers in the early part of this century, but the idea of volcanic activity north of the Arctic Circle seems out of character. During a holiday in Spitsbergen this last July, I had the opportunity of visiting, very briefly, the extreme northern end of the the little-known volcanic belt in the north of the island, which extends along the west side of Woodfjorden (Fig. 1). This belt consists of three small volcanic cones and several warm springs, all of which are aligned along a north-south fault.

Our first view of anything unusual was when we journeyed southwards into Bockfjorden in our temporary home, a 70 ft converted fishing boat, the m.v. "Copious" on a typical Spitsbergen summer day – cloudy, but calm, with the odd glimpse of sunshine and a temperature a few degrees above freezing. On our left, peaks of gently folded red Devonian sandstone capped in places by remnants of late Cenozoic plateau basalts appeared out of the clouds, contrasting with the altogether grimmer, sharper hills of grey Hecla Hoek (Caledonian) granites and metamorphic rocks on our right. The name "Spitsbergen" is derived from these sharp pointed peaks. All the hills were festooned with the rapidly melting remains of the winter snow. Just in front of us, on the starboard bow, were two small pale yellowish patches well down on the shore, marking the more northerly of the two groups of warm springs. A sharply defined pyramidal black mountain appeared above the ship's bow. Not having done my homework properly, it took me a few moments to realise that this was the most northerly of the volcanoes, Sverrefjellet. (Plate 1)

Minutes later we landed on the narrow beach at the base of a boulder strewn slope below the more easterly of the springs. There was little vegetation, apart from a few patches of mountain avens and *Cassiope* heath. Like most Spitsbergen beaches, this was lined with cut logs of spruce carried from the Siberian rivers many hundreds of kilometres away by ocean currents and sea ice: we were able later on to have a barbecue exploiting this useful resource. For the moment though we

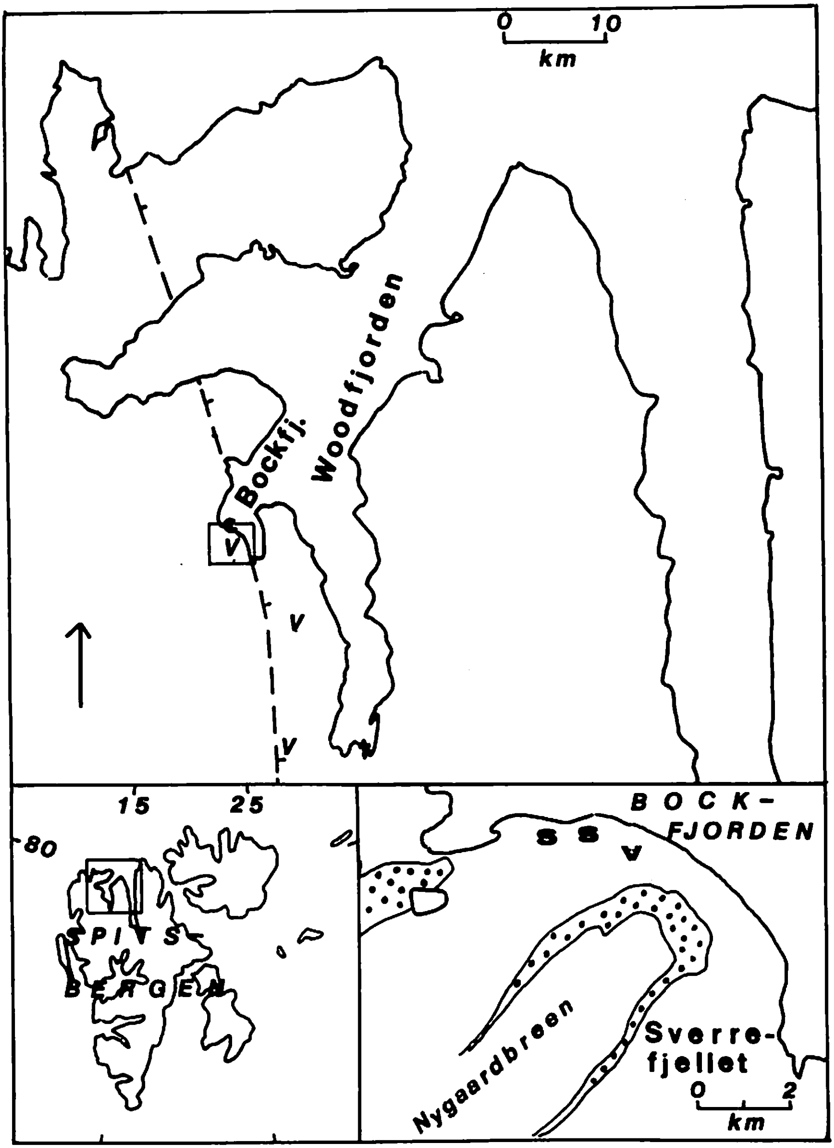

Fig. 1 The volcanic belt in Spitsbergen. Broken line in upper map is a fault separating Hecla Hoek (Caledonian) rocks to the west from Devonian rocks to the east. The sites of three volcanoes are marked by the letter V. In the small inset map, the sites of the two warm springs mentioned in the text are shown (S) together with a small vent (V). Dotted areas are moraines.

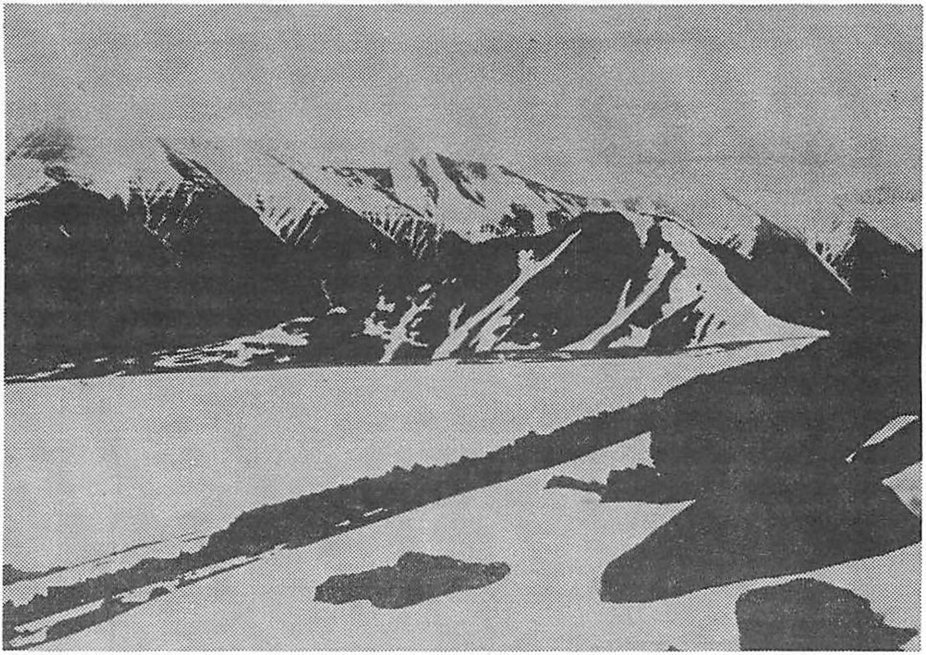

Plate 1.
Sverrefjellet, Bockfjorden, north Spitsbergen.
The extinct volcano Sverrefjellet is in the centre of the photograph. Horizontally bedded Devonian sediments form the mountains on the far (eastern) side of Bockfjorden. Slope of broken Hecla Hoek gneisses in the foreground.

scrambled up to the spring, to find the large boulders emerging from the till slope completely covered in siliceous sinter. The luke-warm spring itself is on an almost flat surface of several square metres, flanked on the up-slope side by a ridge of boulders which seems to have formed as a result of an explosion. We were intrigued to find that the spring was carpeted with a vivid green algal mat on which crawled small green bivalve crustaceans (probably ostracods) and bright red arachnids. I carefully brought home a few of the crustaceans, but they have unfortunately disappeared in the post somewhere between Edinburgh and London, where they were to have been identified.

Time did not permit a visit to the foot of Sverrefjellet, though I was able to examine it through binoculars from a hill on the northwest side of the glacier Nygaardbreen. It reaches a height of 506 metres and, according to the literature, is formed chiefly of basanite lava and scoria with a high proportion of olivine nodules. The crater is apparently on the east side, but has now all but disappeared. Radiometric and palaeomagnetic dating put the age of the volcano as less than 700 000 years. It clearly post-dates any major Pleistocene glaciation in the area, as such a fragile structure would easily be removed by a large glacier, but, on the other hand, volcanic debris is common in the older neoglacial moraines of Nygaardbreen which flank the northwest side of the volcano. This would suggest an age of between 10 000 and 2 000 years ago. Confirmation of a Holocene (i.e. less than 10 000 years ago) age for at least the last eruption comes from the fact that volcanic ash occurs abundantly in the lower raised beaches in the vicinity.

It was disappointing not to be able to explore further, but I did find a small mound of volcanic debris about 2 metres high and a few metres in circumference not far south of the warm spring we visited (Fig. 1). At first sight I thought this might have been a moraine mound, but as it was well away from other moraines and from any other volcanic ash, I concluded that it was the site of a small vent. A piece of lava which I collected from the mound is a basaltic looking, leucite-bearing basanite with olivine nodules. This very small vent, like Sverrefjellet itself, probably expelled its debris on to a till plain and therefore post-dates any Pleistocene glaciation.

The fault in Fig. 1 defines the west side of a rift valley which extends southwards into central Spitsbergen and is one of a number of faults of similar trend, some of which are certainly late-Tertiary and from the evidence of the volcanicity may still be active. The basanitic type of volcanicity however has nothing to do with movement along plate margins, and indeed Spitsbergen lies on the Barents Shelf well to the east of the North Atlantic ridge and its continuation through the polar basin. The three volcanoes in the belt seem to have been visited only rarely by geologists since they were discovered at the beginning of the century, though there has been plenty of work done on the surrounding Hecla Hoek and Devonian rocks. Here is an opportunity for some geological detective work – what better challenge could there be for an Edinburgh Geological Society excursion with 'leaders from the party'?

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A "NEW" GUIDE TO THE SCOTTISH WEST HIGHLANDS AND ISLANDS

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Central to our geologizing is the joy of discovery, whether it be of new fossils found in some hitherto barren strata or new geochemical data about some suite of rocks, or whatever. Because geologists are first and foremost observers whose duty it is to record their discoveries, the literature of our science has come to assume considerable importance. So it is that one can make discoveries in libraries too.

About a year ago, it occurred to me that it might be a good idea to compile an up-to-date guide to Geological Excursion Guides to Scotland, having received over the years many enquiries as to the availability of such literature on specific areas. So I have been especially on the lookout for this kind of publication. Incidentally, the earliest such guide that I have so far found is Rhind's *Excursions illustrative of the Geology and Natural History of the Environs of Edinburgh*, dated 1833.

Towards the end of 1982, I came across *A Geologist's Guide for Amateurs* by Alfred Harker, on *The West Highlands and the Hebrides*, published by Cambridge University Press in 1941. What interests me particularly about this little volume is that it seems never to have been referred to in later publications. Because it was published in war-time, it may well have had rather limited distribution. With no later editions, it seems to have gone into complete obscurity. Even Douglas Bassett of the National Museum of Wales, in his otherwise exhaustive review of such literature which he published in 1966 in the now defunct *Welsh Geological Quarterly*, makes no mention of it. Of course, members of the particular 'invisible university', as Professor Gordon Craig has referred to it, with which Harker was associated, would be expected to know of this very interesting little book.

Alfred Harker, like C.T. Clough, was a native of Yorkshire, having been born in Hull in 1859. He lived most of his long life as a bachelor in Cambridge in St John's College where he died in 1939. More than anybody, he was responsible for the establishment of the science of Petrology at Cambridge and he is known particularly for his textbooks, *Petrology for Students, The Natural History of Igneous Rocks* and *Metamorphism*. His abiding love for field work on Scottish geology led to his decade of part-time work with the Geological Survey from 1895 under Archibald Geikie and it was during this period that he completed his most famous memoir on *The Tertiary Igneous Rocks of Skye.*

Towards the end of his life, Harker mentioned to one or two of his closest associates at Cambridge that he was writing a little guide for amateurs, but at the time of his death the manuscript, although in an advanced state, was left uncompleted. It fell to Dr. J.E. Richey of the Geological Survey to complete the work which, as published, is accompanied by a biography of Harker contributed by Sir Albert Seward and an account of the work by Professor J.S. Boys Smith. Sir Albert Seward describes Harker's guide as 'simple and severely restrained, its style reflecting the almost excessive reserve of the writer'. There is a photograph of Alfred Harker taken on deck on the steam yacht *Killarney* in 1936 during one of his cruises off the western coast of Scotland.

The guide is illustrated by 81 labelled sketches of views, nearly all of these prepared by Alfred Harker himself from his own field sketch books. Like the text, they are simple but very effective for the small scale which they mainly represent. There are also four geological sketch maps including one general one covering the West Highlands and Islands, and four topographical sketch maps drawn by the late Ernie Inkster, formerly Superintendent of the Drawing Office of the Geological Survey in Scotland. The work is completed by an eleven page glossary of geological terms, minerals and rock names.

A MINERALOGIST'S PARADISE – AND A GEOLOGIST'S NIGHTMARE

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Most geologists would probably have their own different candidates for the most mineralogically varied area in Scotland – that is, the smallest area with the greatest variety of mineral species or varieties. My own candidate – and I suspect it would difficult to beat – is a small area on the north side of Glen Urquhart, just west of Drumnadrochit on Loch Ness.

Geologists are accustomed to using the words 'monotonous' and 'repetitive' to describe the Moine rocks which form most of the huge area between the Great Glen and the Moine Thrust. They vary mainly between psammite and pelite (with the odd variation between gneissose and non-gneissose varieties), and so are composed essentially of combinations of only five minerals; quartz, feldspars, muscovite, biotite and garnet. We might add epidote, pyroxene and hornblende, which occur sporadically in thin ribs of calc-silicate rock, and perhaps even aegirine and arfvedsonite (sodic pyroxene and amphibole) which occur more rarely in small bodies of metasomatic rocks. But even with these additions the whole of the Moine ground north-west of the Great Glen (about 5,000 square miles) is made up of combinations of no more than ten minerals.

Glen Urquhart is rather different. Here, in little more than 2 square miles, over 60 different mineral varieties (see Table 1) have been recorded and, depending on exactly how you classify them, several dozens of different rock-types. So great is the variation, that practically every exposure in some parts of the area is a different rock-type with different minerals. Furthermore, many of these minerals occur as *monomineralic rocks* – that is, rocks composed either wholly or almost wholly of a single mineral species – and one or two of these minerals and monomineralic rocks are found in few other localities in the British Isles.

Against such an inviting mineral-collecting prospect, however, must be set some words of caution. Firstly, and most importantly, several

TABLE 1
Mineral species and varieties reported from the Glen Urquhart Complex

Mineral	Mineral	Mineral	Mineral
+*actinolite/actinolitic hornblende	+*clinozoisite	magnetite	saponite
		microcline	
albite	diaspore	muscovite	?scapolite
allanite (orthite)	diopside	+*oligoclase	*serpentine
+almandine-pyrope garnet	dolomite	orthoclase	+sphene
andesine	enstatite	*pectolite	staurolite
anthophyllite	*epidote	[penninite]	*talc
*antigorite	forsterite	phlogopite	+[thulite]
+apatite	+*gedrite (or magnesio-gedrite)	prehnite	tobermorite
[bastite serpentine]	graphite	[prochlorite]	+tourmaline
*biotite	haematite	pyrite	*tremolite/tremolitic hornblende
[bowlingite]	+[hornblende]	pyrope garnet	?wollastonite
calcite	*hydrobiotite	pyrrhotite	+*vermiculite
chalcedony	ilmenite	*quartz	+xonotlite
[chlorite]	+*kyanite	+rutile	*zoisite
chromite	laboradorite	salite	zircon
chrysotile	leucoxene		
	?lizardite		
	magnesite		

There is also at least one currently unidentified mystery mineral!

? unconfirmed
* minerals formerly found as monomineralic or almost monomineralic rocks.
+ minerals formerly found as good macroscopic crystals.

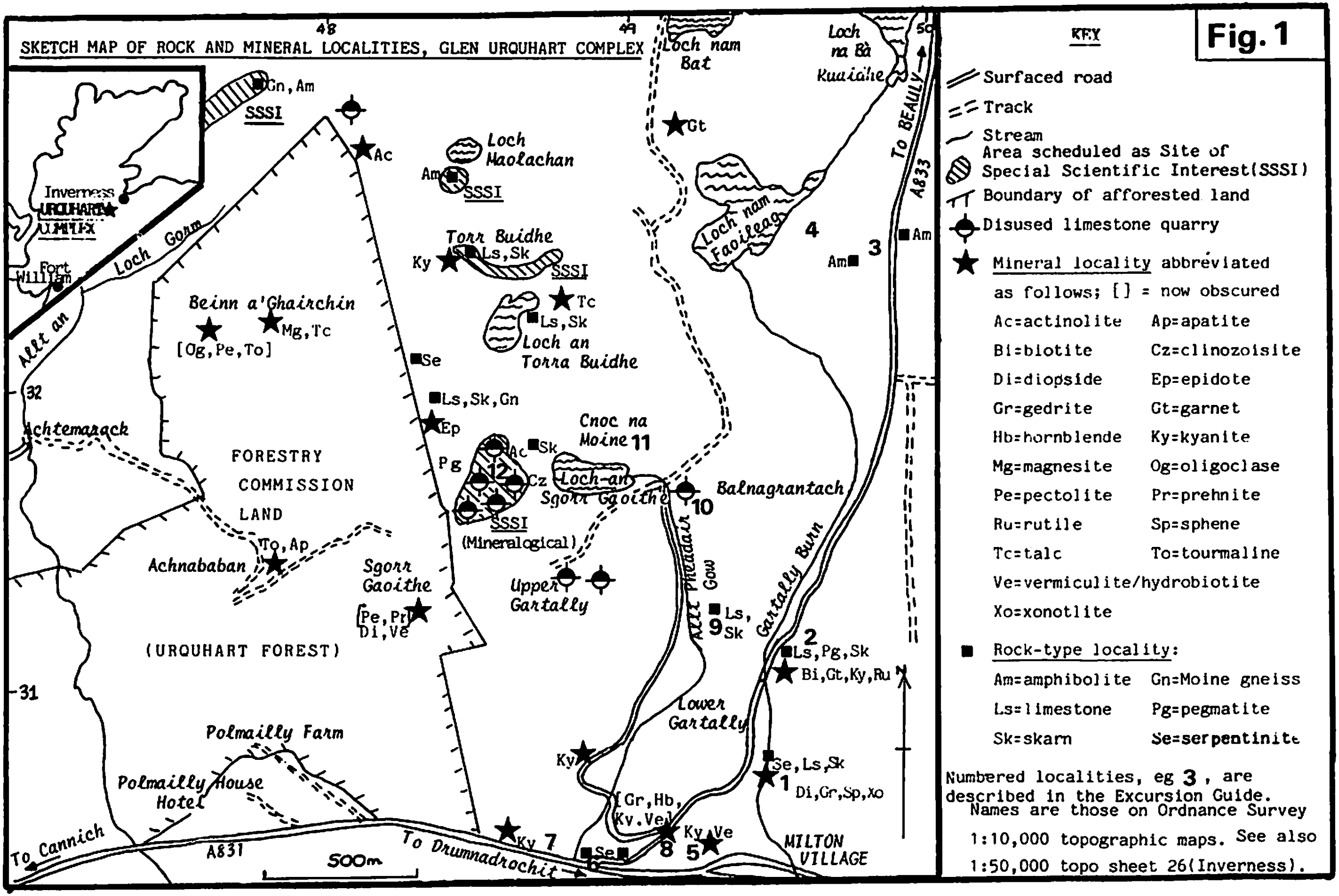
Information taken with minor additions and amendments from thesis (1953) by G.H. Francis. Minerals actually analysed by Francis (eg amphiboles) have been renamed where established modern terminology is different from that used by him but a few of his names are retained even though now recommended to be discontinued, because no actual analysis of the mineral is available [such names are square-bracketed]. No definitive attempt has been made to separate mineral species from variants, types, etc.

parts of the area have recently been declared Sites of Special Scientific Interest (SSSI's) by the Nature Conservancy Council (see Fig. 1). The present writer, who was responsible for recommending most of these SSSI's, would therefore implore anyone intending to visit the area to respect both the letter and spirit of the code of conduct covering such sites, and to restrict any collecting or hammering to an absolute minimum, even in the areas not specifically designated. Secondly, some of these minerals are rather difficult to identify in hand specimen, and have to be confirmed by microscope or even X-ray examination. Thirdly, large parts of the area are now forested (the trees having been planted in the 1950's) and are now practically hopeless for mineral collecting. Fourthly many of the localities which furnished earlier mineralogists (such as Heddle in the last century, or G.H. Francis in the 1950's) with good mineral specimens are now afforested, overgrown, or otherwise no longer useful.

If you feel nevertheless inclined to visit the area, the sketch map (Fig. 1) should be of help. Many of the good exposures are along or very near to the roads, so you should be able to get a good idea of the geology with the minimum of entry onto private land. *Please* obtain permission from the various owners of this land if you do decide to stray from the roads, so as to safeguard the interests of future geologists. If you want to enter the forested area, you should obtain permission from the Forestry Commission local office at Balnain (midway along Glen Urquhart, beside the A831 Drumnadrochit-Cannich road). The remainder of the area is crofting land, and you should ask permission at the individual crofts (Gartally, W. and E. Balnagrantach, etc.).

Geologically, the area comprises a serpentinite body enveloped by a metamorphic complex of limestone (marble), kyanite-schists, amphibolites and psammitic gneisses (Fig. 2). These have all reacted along their mutual contacts to produce a very varied and complex assemblage of calc-silicate rocks (so-called 'skarns'). It is the combination of metamorphism and metasomatism in the metasediments, together with late-stage metasomatism within the serpentinite body itself, which has produced the medley of minerals in Table 1.

So why should this mineralogists' paradise be a geologists' nightmare? Basically it's because the area poses far more problems than


SKETCH MAP OF ROCK AND MINERAL LOCALITIES, GLEN URQUHART COMPLEX
Fig. 1
KEY
Surfaced road
Track
Stream
Area scheduled as Site of Special Scientific Interest (SSSI)
Boundary of afforested land
Disused limestone quarry
Mineral locality abbreviated as follows; [ ] = now obscured
Ac=actinolite
Ap=apatite
Bi=biotite
Cz=clinozoisite
Di=diopside
Ep=epidote
Gr=gedrite
Gt=garnet
Hb=hornblende
Ky=kyanite
Mg=magnesite
Og=oligoclase
Pe=pectolite
Pr=prehnite
Ru=rutile
Sp=sphene
Tc=talc
To=tourmaline
Ve=vermiculite/hydrobiotite
Xo=xonotlite
Rock-type locality:
Am=amphibolite
Gn=Moine gneiss
Ls=limestone
Pg=pegmatite
Sk=skarn
Se=serpentinite
Numbered localities, eg 3, are described in the Excursion Guide.
Names are those on Ordnance Survey 1:10,000 topographic maps. See also 1:50,000 topo sheet 26 (Inverness).
48
49
50
32
31
Inverness
URQUHART COMPLEX
Fort William
Loch Gorm
Allt an
Achtemarack
Beinn a'Ghairchin
[Og, Pe, To]
Mg, Tc
Gn, Am
SSSI
Ac
Loch Maolachan
Am
Torr Buidhe
Ky
Ls, Sk
Tc
Loch an Torra Buidhe
Se
Ls, Sk, Gn
Ep
Pg
12
Cz
Sk
Cnoc na Moine 11
Loch an Sgorr Gaoithe
SSSI (Mineralogical)
FORESTRY COMMISSION LAND
To, Ap
Achnababan
Sgorr Gaoithe
[Pe, Pr Di, Ve
(URQUHART FOREST)
Upper Gartally
Loch nam Bat
Gt
Loch na Bà Ruaidhe
Loch nam Faoileag
4
3
Am
To BEAULY
A833
Balnagrantach
10
Allt Pheadair Gow
Gartally Burn
9 Ls, Sk
2 Ls, Pg, Sk
Bi, Gt, Ky, Ru
N
Lower Gartally
Ky
Se, Ls, Sk
1 Di, Gr, Sp, Xo
[Gr, Hb, Ky, Ve]
Ky, Ve
8
5
MILTON VILLAGE
Polmailly Farm
Polmailly House Hotel
To Cannich
A831
500m
To Drumnadrochit
Ky 7
Se
6

it answers. As you may have gathered, many of the rocks and minerals are peculiar to the area and completely anomalous in relation to the surrounding Moine rocks. But when you try to sort out the geological evidence, you always run into difficulties.

For example, though the exposure is reasonable in places, the structure is rather complex, and the exposure never quite good enough to give the kind of evidence you need to understand the structure completely. Both previous surveys of the area – one in 1903 by officers of the Geological Survey and the other in the 1950's by G.H. Francis of Cambridge University – concluded that the overall structure of the area was anticlinal, with the limestones, at the bottom of a succession, exposed in the core of the anticline. This was all based on a couple of outcrops where the limestone clearly underlies the kyanite-schist. But, if you look hard enough, you can also find outcrops where the reverse is the case, or even where blobs of limestone are found in the middle of kyanite-schist or psammitic gneiss. In fact, some of the rocks, and *especially* the limestones, have in places behaved very plastically, so that the structure is locally chaotic. Thus although these two previous surveys agreed about the *general* structure of the area, their interpretations of the *details* are radically different.

A related problem arises when you try to fit the rocks of Glen Urquhart into one of the 3 main assemblages of Highland metamorphic rocks, viz. Lewisian, Moine or Dalradian. The Geological Survey officers compared the area with metamorphosed sedimentary gneisses (para-gneisses) around Glenelg (Loch Duich) and consider the Glen Urquhart rocks to be the same age – i.e. Lewisian. This was at a time when the Geological Survey was busy establishing the existence of a substantial number of inliers of Lewisian rocks within the Moine, such as those of Loch Monar, Scardroy, Loch Fannich and Glen Strathfarrar. Francis, however, was working at a time when the existence of these Lewisian inliers had been called seriously into question by some very eminent geologists, and when it would perhaps have been foolhardy to step out of line! Nowadays, the Geological Survey officers have been vindicated (as one might expect!) so there is no historical objection to identifying a Lewisian inlier at Glen Urquhart any more. But the identification is unfortunately based in this particular case on some rather shaky premises. For example, the officers assumed that their order of *structural* succession (limestone → kyanite-schist → psammitic

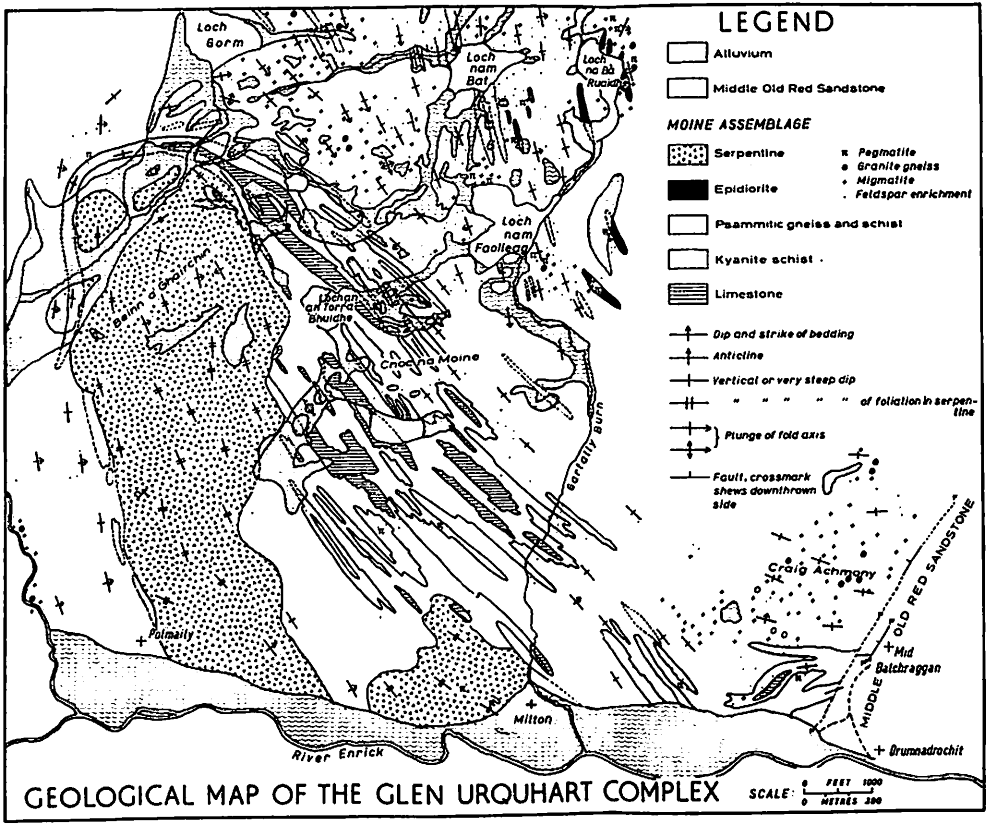


Fig. 2 G.H. Francis' (1964) geological map of the Urquhart Complex (not necessarily accepted by the present author!)

gneiss) was also the same as the *stratigraphic* succession, i.e. that the limestone was older than the psammitic gneiss. Hence if you consider the latter to be Moine, the former might well be Lewisian. But, as we have seen, the structural succession is different in different places, and there are nowhere any sedimentary structures which might help to show which way the structural succession gets younger.

The complex is now being re-examined by the Institute as part of its regional mapping programme. Curiously enough, whatever we conclude as to the age, it will be a novel conclusion. If the rocks prove to be Dalradian, this would be the first confirmation of Dalradian rocks NW of the Great Glen. If they prove to be Moine, it would be the first confirmation of the existence of limestone of Moine age. And if Lewisian, it might tend to suggest that a similar (though much less varied) assemblage of rocks in Gleann Liath near Foyers (across Loch Ness) is the first known case of Lewisian rocks on the SE side of the Great Glen. Fortunately for the mineralogists, the wide variety of minerals to be found in the area remains the same whatever conclusions we geologists, after much sweat and toil, might come to!

Acknowledgements

This article is published by permission of the Acting Director, Institute of Geological Sciences (N.E.R.C.). G.H. Francis' map (Fig. 2) is reproduced by kind permission of the British Museum (Natural History), London. Dr. V.E. Moorhouse of the Nature Conservancy's Geological Conservation Review Unit very kindly vetted the article, and acted on my suggestions for SSSI's at Glen Urquhart.

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Maps covering the Urquhart Complex

Ordnance Survey 1:50,000 topographic sheet 26 (Inverness).
Ordnance Survey 1:10,000 topographic sheets NH43SE and NH53SW.
Ordnance Survey 1:25,000 topographic sheet NH43/53.
Geological Survey 1" sheet 83 (Inverness) – *NB* covers only top one third of Urquhart complex itself. No geological 1" map exists for lower two-thirds.

EDINBURGH UNIVERSITY EAST GREENLAND EXPENDITION 1982
THE KRUUSE FJORD INTRUSION OF EAST GREENLAND.

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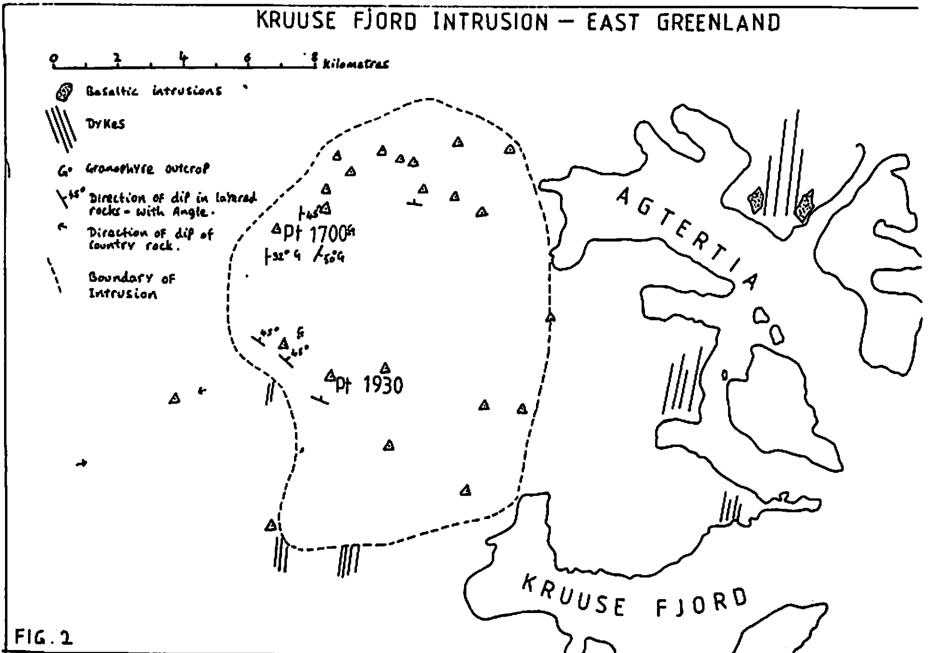
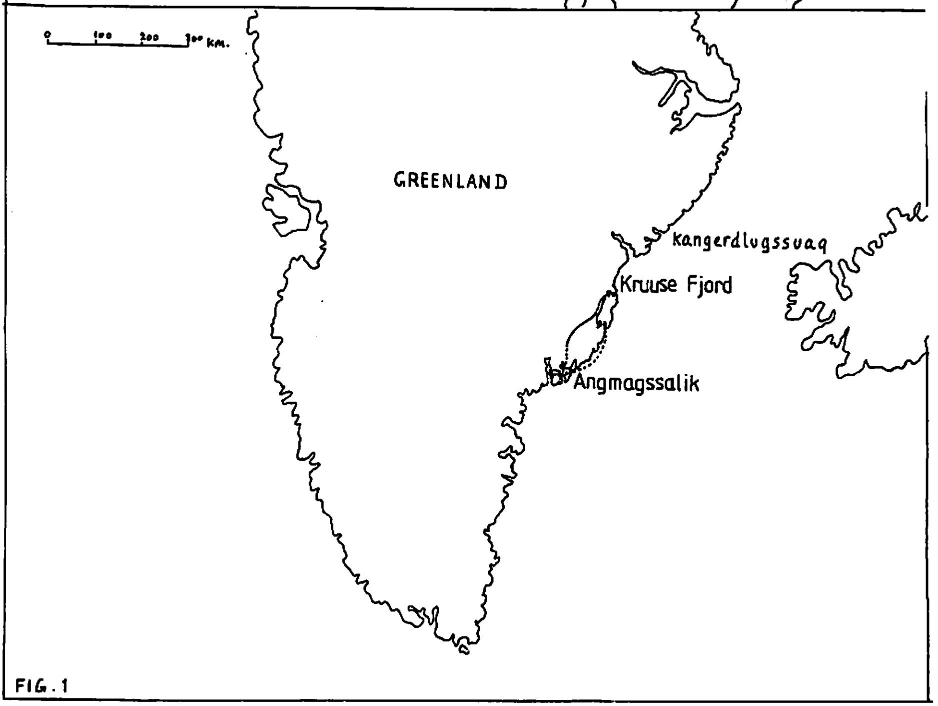
Rising dramatically out of the vast glacier plain, the mountains at the head of the Kruuse Fjord form an impressive sight when approached from the inland ice which sweeps its way right down to the coast in that relatively unexplored part of East Greenland which lies between Angmagssalik and Kangerdlugssuaq (Fig. 1).



KRUUSE FJORD INTRUSION — EAST GREENLAND
0 2 4 6 8 Kilometres
Basaltic intrusions
Dykes
G Granophyre outcrop
Direction of dip in layered rocks - with Angle.
Direction of dip of country rock.
Boundary of Intrusion
Pt 1700ft
Pt 1930
AGTERTIA
KRUUSE FJORD

FIG. 2



0 100 200 300 km.
GREENLAND
Kangerdlugssuaq
Kruuse Fjord
Angmagssalik

FIG. 1

The oval ring of mountains define a little known layered intrusion some 260 square kilometres in size (Fig. 2). It is not the easiest place in the world to visit and, once there, the scale and difficulty of the terrain makes geological fieldwork seem a daunting prospect.

During the ten-week expedition in the summer of 1982 a group of recent graduates from Edinburgh managed to reach the intrusion by means of a three week sledge-haul from the Pourquoi-Pas Glacier 95 miles to the South. Severe weather conditions were encountered throughout the expedition and, as a result, we were only able to achieve five days of productive fieldwork; in addition we were forced to abandon much of our equipment and the bulk of our sample collection on the return journey. Despite these annoyances all the expedition members enjoyed the trip and felt that a worthwhile reconnaissance was made of the intrusion itself.

Topographically the intrusion consists of an outer ring of peaks, oval in shape, with the long axis parallel to the impressive East Greenland Coastal Flexure and associated dyke swarm which represents an early stage of the North Atlantic continental margin.

Our base camp was established on the western edge of the intrusion, since this was the area that contained the most accessible rock exposure.

Most of the area that we studied consists of a layered series, well exposed on radiating ridges on the outer peaks, but poorly exposed in the centre of the basin which consists of a seaward flowing glacier. The layered rocks are cut by granophyre sheets which contain an abundant and varied nodule assemblage; in addition there is some evidence for more extensive granophyre intrusion. We had planned to do some detailed transects of the layering to define chemical trends. However events forced us to confine ourselves to limited collecting. Probe analysis at the Grant Institute of the few samples that we saved will in due course give some indication of magnetic affinities and broad chemical variation; it is sufficient to say at this point that the main rock type was an iron-rich gabbro.

On the Western and Southern margins all the layers dip inwards at angles of between 30° and 45°. One might expect the layering to flatten out towards the centre of the intrusion giving a saucer shaped structure similar to that of the Island of Rhum. However at two localities it is possible to see a definite flexure in the layering as shown in figure 3. This flexure causes the layers to dip more, rather than less steeply towards the centre. In addition observations of the distant Northern region of the intrusion seemed to suggest that the actual depocèntre may have been offset to the North. Clearly the overall structure needs to be unravelled in more detail.

One of our priorities was to try and identify a border group, however we were unsuccessful since no contacts were found and the layered rocks seemed to continue right up to the topographic margin. In addition there was no evidence of fallen blocks of material causing disturbance of the layering, which one might expect in a slowly cooled magma chamber enclosed by an early formed border group.

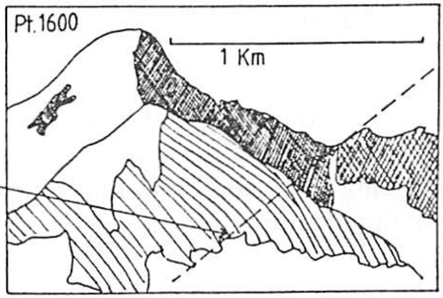
We paid particular attention to the occurrence of Amphibole veins and collected a number of specimens including one with particularly fine development of a fibrous Hornblende up to 1 cm long which is currently being studied at Stanford University. Information derived from studying veins can throw light on the late stage processes and thermal history of the intrusion and its interaction with the surrounding country rock. Vein frequency can also be used as a measure of stress relationships.

Perhaps the most interesting aspect to become apparent during our short stay at the Kruuse Fjord was the variation of the layering itself and the structures within it. The following broad categories of layering are well represented in the intrusion:

1. Uniform layers of mainly feldspathic mesocumulate giving monotonous uniform beds of up to 1.5 metres in thickness.
2. Rhythmic layers with typical sequence of alternating dark and light bands usually with a base of mafic minerals grading up into more feldspathic material, on a scale of up to 25 cms per layer.
3. Layers without well defined cumulate lamination suggesting that crystal settling was of little importance.
4. Pegmatitic layering, consisting of much coarser grained gabbro.
5. Layering due to subtle changes in quantities of certain minerals – essentially a type of rhythmic layering where no dominant cumulus phase could be identified.

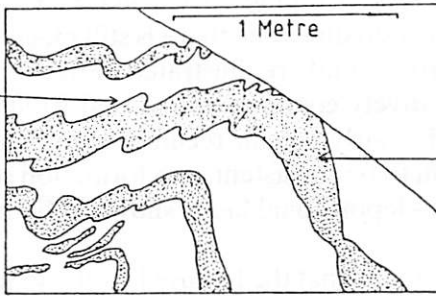
Another interesting feature that we observed was the repetition of

Structural Features of Layered Series – Kruuse Fjord Intrusion



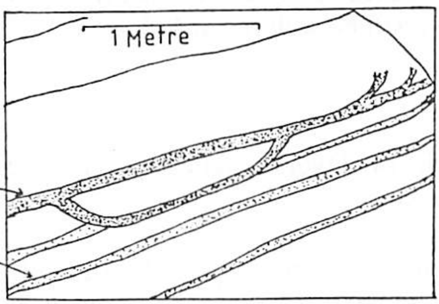
Flexure in Layering

FIG.3



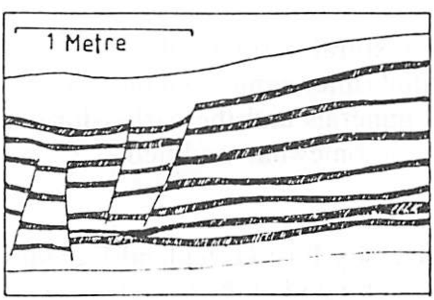
Recumbent Folds

FIG.4



Channel Structure

FIG.5



Syn-depositional Faulting

FIG.6

units, roughly two metres in thickness, separated by weathering surfaces and containing smaller scale internal rhythmic layers. These presumably represent separate pulses of magma that have then undergone crystal settling.

This study brought home to us the great variety of layering found in large intrusions of this type and showed how it is false to assume that layered rocks are all going to be similar to the text-book examples of endlessly repeated rhythmic units.

We also managed to obtain some good documentation of structures within the layered series. Although spectacular Skaergaard-type trough bands are absent, on a smaller scale there is still much that is of interest. Some of the structures found are illustrated in figues 4, 5 and 6. Slump structures were relatively common and varied from highly convolute and disordered to the fairly regular recumbent folds as shown in figure 4. These would seem to be consistent with formation on steeply dipping slopes as are the syn-depositional faults shown in figure 6.

It is certainly true to say that the Kruuse Fjord remains something of a mystery but should someone someday make the effort to reach the area again I am sure they will be well rewarded.

Glossary

Cumulate: a rock of layered igneous mass formed by crystal accumulation.

Cumulus crystal: a unit of the pile of crystals originally precipitated from the magma before any modification by later crystallisation.

Mesocumulate: a textural term to describe a rock in which the interstitial (intercumulus) liquid has crystalised out as one or two minerals and the earlier-formed cumulus crystals have been somewhat modified.

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