The Edinburgh Geologist

Magazine of the Edinburgh Geological Society

Issue No. 44 Spring 2005

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Cover illustrations

Front cover: the Inaccessible Pinnacle on the Cuillin Ridge, Skye, the remains of a basaltic dyke cutting through the surrounding gabbro.

This photograph is chosen to complement the theme of the 'back to basics' articles on ***Mountain geology*** (page 4), ***Ardnamurchan*** (page 12) and ***Geo-vineyards*** (page 40).

Back cover: Pico, a volcanic peak in the Azores, the highest mountain in Portugal.

The island of Pico is a classic volcanic cone. The vines that grow on its slopes are featured in ***Geo-vineyards*** on page 40.

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Editorial

All change, yet back to basics

This issue sees more changes in format. Following on from the decision by Council that the magazine should be printed with a colour cover, the Autumn 2004 issue sported colour on the front. In order to make better use of the opportunity, however, I decided that we should have colour on the back too. From there, it was a natural progression to flood colour on to the inside of the cover as well... and here is the result.

These changes have other implications, of course— one of these is that the ***Contents*** now have to hide inside. The natural place seemed to be on the first page, which shunted the ***Editorial*** on to page 2 (you must have discovered this by now, I suppose!). At the same time, I decided to make the ***Contents*** just a little more lively and, having got the bit between my teeth, have ended up giving the whole magazine something of a facelift. I hope that readers like it! Apart from minor changes in titles, running headers and so on, the only other major change is the introduction of double columns.

But all that aside, I wanted to change more than simply the presentation. I have run themes from time to time, but I would like to develop this and the theme for this issue is 'back to basics', which is not intended to be an electoral slogan but to tell you that we'll be looking at basic igneous rocks...

To start the ball rolling, this issue begins with a contribution by Suzanne Miller on ***the Skye Cuillin***, whose gabbroic crags are known to both climbers and hill-walkers. This is the second in the current series of articles on ***Mountain geology***. If any readers would like to send in a contribution to this series, the Editor (and no doubt Suzanne) would be delighted.

I was sent a letter from Richard Batchelor of the University of St Andrews. He has found a map of Ardnamurchan lurking in the archives of the department. This might be no great surprise, but this one was signed on the back by all the participants of the Geologists' Association excursion there in 1932. This was led by J. E. Ritchie, who was responsible for the original mapping of the geology of the peninsula. Norman Butcher tells us some tales, including the romance that flourished there.

A more recent excursion to Ardnamurchan was that run by the Edinburgh Geological Society in 2004. Henry Emeleus and Brian Upton led twenty three of us over the same ground as James Ritchie had no doubt led the particpants in 1932. It is not recorded that the event was in any way a romantic encounter for any Fellows of the Society, but in ***Ardnamurchan revisited***, Henry, who has recently been elected as an Honorary Fellow of the Society, tells us of the changes in geological thinking in the last seventy years.

While on the subject of excursions, our thoughts may turn to the publication of geological excursion guides. Did you know that the Edinburgh Geological Society's first excursion guide was to Assynt and

was published in 1937? What is more, that guide has been almost continuously in print ever since. Ian Jackson uncovers some other interesting aspects in his history of the Society's publications.

The next contribution is by Suzanne Miller and Nigel Ruckley on ***Pictish geo-archaeology***. Suzanne and Nigel have looked at a number of carved standing stones, together with ancient quarries and other source areas for the stone. They draw some interesting conclusions on the way in which the ancient stonemasons worked.

Some things never change, of course, and we have another ***Rocksword*** from Angela Anderson. This is number 13 but it is not the only puzzle in this issue. As a diversion at the Society's social evening in December, Valerie and David McAdam provided Fellows and their guests with a cryptic quiz entitled ***A geological story***. By popular request, it is reproduced here, though with some images revamped. The answers to both the ***Rocksword*** and the ***Geological story*** are found on a later page.

Poet's Corner for this issue is taken from a popular source of geological verse, the ***Grizzly Bear Books*** held in the library in Murchison House. These are a record of the annual dinners that the Survey held from 1869 to 1970 and the signed menus, cartoons, verse and prose provide a century's worth of unofficial history of the Geological Survey in Scotland.

I am always glad to receive letters and though Alyn Jones felt that he was a little late to enter into a discussion on Archie Lamont (see issue 42, Spring 2004), he has posed an interesting question on raised beaches on the west coast of Scotland. If any readers would like to enter this discussion, they are welcome to write to me at the addresses below.

Finally, ***Geo-vineyards*** has been shunted to the end in this issue. The reason is quite simple. When David Stephenson sent in his two colourful wine labels from the Azores, it struck me that here would be a good use of the extra colour. So the labels themselves are printed on the inside of the back cover and David's description of the geology of the Azores and its effect on the wine-growing areas is on the opposite page.

I hope that you like the changes to the format, but what really makes the magazine is the articles that people send in. Please consider writing something yourself. I am always glad to receive contributions... and don't feel that you have to leave it until the copy date printed below!

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The copy date for the next issue of THE EDINBURGH GEOLOGIST **is Saturday 1st October 2005.**

Mountain Geology

The Skye Cuillin

In the second article on Mountain geology, ***Suzanne Miller*** *leads us into the world of Sir Walter Scott's Cuchulin and over the most famous ridge in Scotland, popular with climbers and hillwalkers (the intrepid ones) alike.*

Introduction

Skye is an island of superlatives: measuring 80 by 32 kilometres, it is the largest of the Hebrides; it boasts the largest expanse of basaltic plateau in the UK; it has the grandest mountain group in the UK – the Cuillin, rhapsodised by Scott and recaptured by Turner's paintings.

The Cuillin Hills are among the steepest mountains in the UK, include 20 peaks above 900 m and contain the only Munro which requires the use of rock climbing techniques (the Inaccessible Pinnacle). There are two main ridges. The magnificent Black Cuillin, some peaks of which remained unclimbed until the late nineteenth century, stretches for 12 km, possesses more than thirty peaks (eleven of them Munros) and is primarily composed of gabbro and peridotite. Infamous for their rough, crystalline cloth-tearing nature, they contrast with the red-coloured granite of the Red Hills to the east extending from Glamaig to Beinn na Caillich.

The Geology

The Cuillin Hills are the remains of the roots of an early Palaeogene volcanic centre. The igneous rocks on Skye have been studied since the 1800s by the likes of Sir Archibald Geikie and John Wesley Judd (1879 - 1914), with both making headway into understanding the nature of the rocks. But it was Dr Alfred Harker (1859 - 1939) who studied, mapped and interpreted these igneous rocks in the early 1900s, who first recognised the island's true importance.

Much of the Isle of Skye is composed of basaltic lava flows, erupted during the earliest phase of volcanic activity in the area - known as the Skye Main Lava Series. These were erupted from numerous early volcanic centres and not from the volcanoes above the main Cuillin Centre. From an estimated thickness of 1200 m for the Skye Lava Field and a duration of volcanic activity of c. 250 000 years, it has been calculated that magma production was in the region of 1 metre per 200 years (Bell & Jolley, 1997). These early basaltic lava plains, which underlie the drift mounds and peat bogs around Sligachan, were subsequently intruded by successive volcanic centres which would have fed volcanoes. These volcanoes were subsequently eroded.

The highland massif of central Skye can be divided into four mountain groups, each corresponding to a separate plutonic centre (Figure 1). First, the basic/ultrabasic hills of the Black Cuillin (the Main Cuillin Centre). In essence, the Black Cuillin is an arcuate mass of ultrabasic peridotite which has subsequently been intruded by a large number of olivine-rich gabbro sheets. The

main features are:

- outer gabbros: coarse grained (oldest)
- an inner and outer layered series: mostly allivalite, peridotite and eucrite
- minor intrusions: dykes, cone sheets, agglomerates and explosion breccias

Second, a complex group comprising the isolated peak of Bla Bheinn and the granite of Meall Dearg and Ruadh Stac. This, the Strath na Crèitheach centre, was intruded into the main Cuillin Centre and so is exposed in the Black Cuillin.

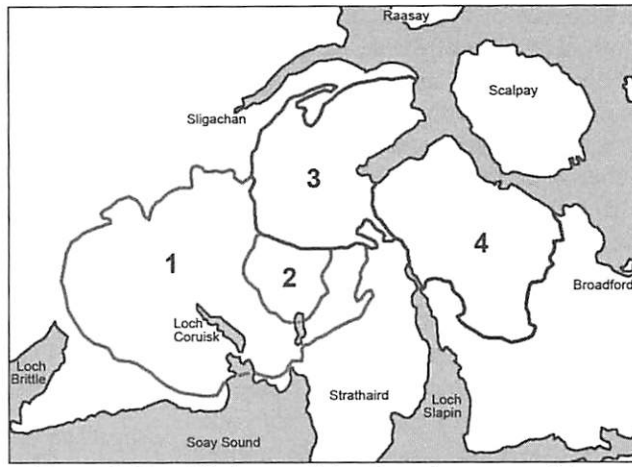

Figure 1. Simplified map of the plutonic centres of the Skye Cuillin (after Bell & Williamson 2002): 1. Black Cuillin : 2. Strath na Crèitheach : 3. Western Red Hills 4. Eastern Red Hills.

Third, the granitic Western Red Hills (also known as Lord Macdonald's Forest). This occupies an area of c. 35 km² and comprises ten granites, a composite ring dyke, a number of explosion breccias and a gabbro.

Fourth, the granitic Eastern Red Hills including Beinn na Caillich. Many of these granites were emplaced into sedimentary country rock giving rise to metamorphic thermal aureoles.

Although dominantly granitic bodies, the Red Hills centres also show evidence of mixed magma (acid-basic) intrusions, felsites, ignimbrites, tuffs and agglomerates.

These centres represent, in age, a generally eastward and progressively more acidic shift of activity of the intrusive complexes (Bell, 1976). The ultrabasic and basic rocks of Skye are dated at around 58-59 million years whilst the Red Hills give dates of 55–58 million years. It is believed that many of the Palaeogene volcanic centres were emplaced along fault systems. For example, the central intrusive complexes on Skye are associated with the Camasunary-Skerryvore Fault – the deep-seated fractures providing weaknesses in the crust that were exploited during the intense igneous activity (Butler & Hutton, 1994).

The intrusion of dolerite dykes occurred throughout the history of the formation of both the Black and Red Cuillin. The ravines and vertical gullies which seam the bare rock faces of the Black Cuillin have been eroded into the basic dykes. Where these intersect the ridges and ice-steepened arêtes they often form notches in the skyline (as in the Waterpipe Gully of Sgurr an Fheadain), which accounts in part for the serrated

appearance of the peaks themselves. On the Red Hills, however, the basic dykes are not as numerous and are generally more resistant to erosion than the surrounding granite, so that they tend to stand out in relief. This is occasionally true of the Black Cuillin dykes also, the most famous example being the Inaccessible Pinnacle, which stands up as a narrow wall on the summit of Sgurr Dearg (977m).

The crest of the main Cuillin ridge is a sawtooth arête (Figure 2) curving southwards until it plunges directly into the sea at Loch Scavaig. The highest peak of Sgurr Alasdair (1009 m) and the southernmost peak, Gars-Bheinn, are capped by basaltic lava. According to Harker (1941) these isolated lava summits represent the remnants of the roof of the plutonic intrusion, dating from the time when the plateau basalts were updomed by the ultrabasic and basic magma injected below. It was Harker, too, who noted the very marked inclination of structures in the gabbro ridges, which take the form of pseudo-stratification. At Sgurr nan Gillean, at the ridge's northern end, the steep dip is towards the south; along the main Cuillin ridge it is towards the east; at Sgurr na Stri it is towards the north, while on Bla Bheinn it is towards the west. Thus all the structures dip inwards to a central point beneath Glen Sligachan, because they are made up partly of the gabbro banding and partly of the inclined cone-sheets. The cone sheets are the most classic example of this type in the UK and are restricted to the gabbro.

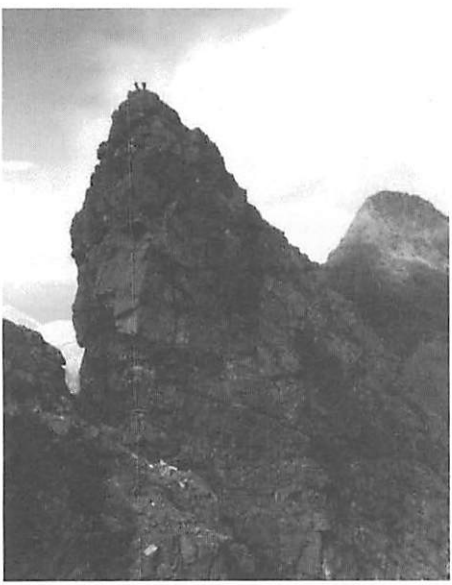

Figure 2. Am Basteir – part of the sawtooth arête of the Black Cuillin

The Western Red Hills (Figure 3) are separated from the Black Cuillin by the long funnel of Glen Sligachan. They are composed of a number of granitic injections which were intruded concentrically as major ring structures in a cauldron complex similar to those of Arran and Mull. The grantic complex caused a local updoming of the basaltic lavas, as demonstrated by the steeply dipping lava cap that has survived on the summit and eastern slopes of Glamaig which towers 773m above Loch Sligachan. Elsewhere the basaltic cover has been almost entirely stripped off by erosion. Similar basaltic remnants can also be seen on the slopes of the Eastern Red Hills, which have been carved from granites emplaced by similar mechanisms but from a separate intrusion centre. Each of the intrusive centres represents the roots of major volcanic centres with up to 2 km of rock having been eroded, removing most

of the volcanic edifice (Figure 4). The only remnants of the lavas extruded onto the surface may be the Preshal More flows that are exposed in Central Skye. Their geochemical affinities with the intrusive rocks of the Cuillin Centre suggest that they developed above this centre.

The emplacement of the intrusive complexes resulted in the contact (thermal) metamorphism of the country rocks – both earlier lavas and sedimentary rocks. This has produced hornfelses, metalimestones and skarn formation.

The volcanic activity was triggered by the opening of the Atlantic around 65 million years ago. By 52 million years ago, the igneous activity was over and sedimentary rocks of Palaeogene age were deposited on top of (and in places between) the lavas.

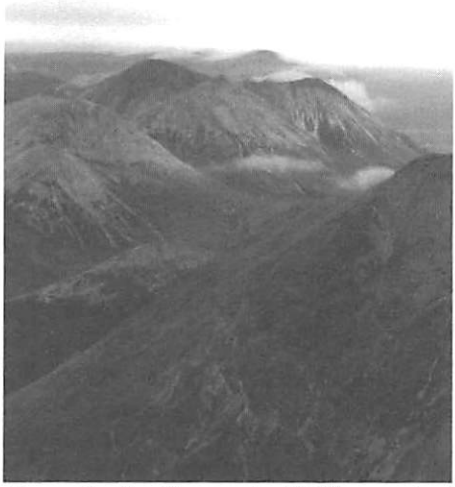

Figure 3. The Western Red Hills – conical summits draped with scree

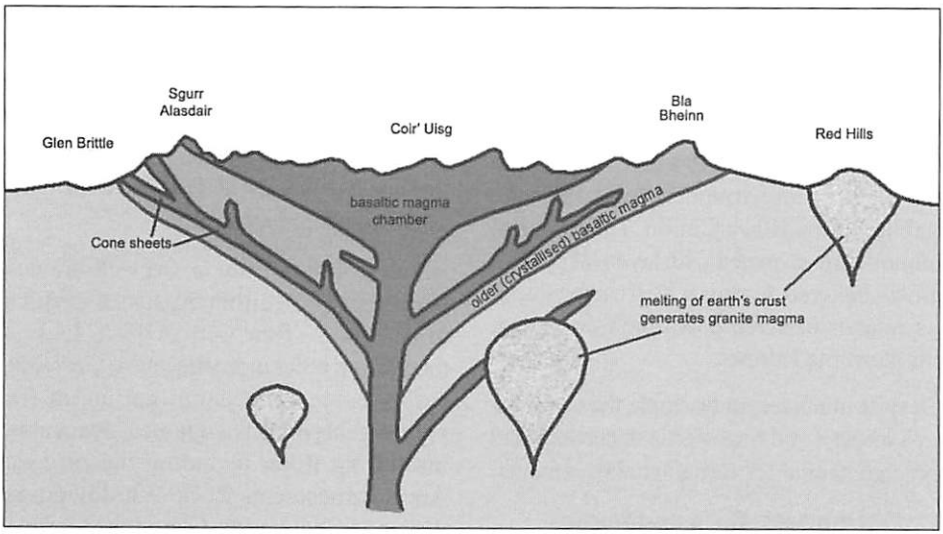

Figure 4. Structure of the intrusive complex beneath the Cuillin, showing intrusion of basaltic magma from beneath the crust and formation of granite plutons by crustal melting (after Stephenson & Merrit, 1993)

Mountain geology

Needless to say, the final form of the Cuillin owes much to the work of ice and frost. The Cuillin Hills is the classic area in Britain for erosional landforms associated with mountain glaciers. It includes unquestionably the finest assemblage of arêtes, corries, rock steps, ice-moulded topography and roches moutonnees, together with the 'textbook' glacial trough and basin occupied by Loch Coruisk. Periglacial rock weathering forms and a range of ice-depositional features including classic end and lateral moraines, boulder moraines and hummocky moraines complete the key interest of one of the most outstanding mountain areas in Britain for glacial geomorphology. The ultimate veneer has resulted from frost-shattering on the oversteepened cliffs and pinnacles, so that the main ridge is everywhere draped with scree slopes. The most spectacular of these is the Great Stone Shoot (Figure 5), which plummets for over 450m from Alasdair's summit to the tiny corrie lake of Coire Lagan. The granites of the Red Hills have weathered to a paler colour and smoother, more rounded form than the gabbro of the Black Cuillin. Their conical summits are crowned with layers of pinkish frost-shattered detritus which can be traced as runnels of scree down their sweeping, uninterrupted slopes.

Despite much recent research, the Complex as a whole is still imperfectly understood and much potential for further studies remains.

Habitats, flora and fauna

The gabbro of the main block of the Cuillin contrasts with the limestone areas of Bla Bheinn and the granite of Marsco.

Figure 5. The Great Stone Shoot – scree running from Sgurr Alasdair

Bla Bheinn has a remarkably rich flora, both vascular plants and bryophytes, including several national rarities. Fine examples of undisturbed peatlands are found in Glen Sligachan. The site as a whole contains an exceptional variety of habitats, including the coastal woods at Ulfhart with their interesting lepidopteran fauna.

Above c. 400 m altitude, the well-drained slopes support either Agrostis-Festuca grasslands, often with Alpine Lady's mantle and other montane herbs. Crevices, earthy screes and damp gullies in the higher gabbro cliffs support a sparse but interesting flora, including the rarities: Arctic Mouse-ear, Rock Whitlowgrass, Alpine Meadow-grass, Glaucous Meadow-grass, Alpine Saxifrage and Alpine Rock-cress in its only known British locality. Alpine Hair-grass grows on the summits.

The sparse vegetational cover of the gabbro cliffs contrasts sharply with the luxuriant vegetation on the Jurassic limestone cliffs in Coire Uaigneich. The north-west facing cliffs support rich, ungrazed, tall-herb communities with numerous rare mosses and liverworts. The lower slopes are covered by a range of bog and fen communities.

On north-facing ravine walls, especially by the upper waterfalls, there are good heather communities. Two blocks of semi-natural woodland occur on steep south-facing coastal slopes and cliffs of two contrasting geological formations between An Leac and Ulfhart Point. They support good examples of Birch-Hazel and Birch-Oak stands on Olivine basalt and Torridonian sandstone respectively. The interesting butterfly and moth fauna includes the woodland species, Speckled Wood and Scotch Argus, both nearing the northern limits of their distribution.

Glen Sligachan is an impressive example of peatland little disturbed by man. Along the broad valley bottom, running north to south between the Cuillin and Marsco, are a series of flushes, fens, flood-plain mires and blanket bog. Sedge species are abundant, including the uncommon Slender Sedge.

The Cuillin supports a high density of breeding birds of prey, including Golden Eagles. A rare Carabid beetle occurs on the mountain tops towards the northern end of the site. Its distribution in Britain is described as rare or very local.

Further reading

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Emeleus, C.H. & Gyopari, M.C. 1992. *British Tertiary Volcanic Province, Geological Conservation Review, Series No. 4*. Joint Nature Conservation Committee, Peterborough.

Harker, A., 1941. *The West Highlands and the Hebrides*. Cambridge University Press.

Stephenson, D. & Merritt, J., 1993. *Skye: a landscape fashioned by geology*. produced by Scottish Natural Heritage & British Geological Survey.

For a guide to the approaches of the Cuillin go to:
cgi.mountaineer.plus.com/scotland-mountains/skye/

Suzanne Miller *works in the Natural Sciences Department at the National Museums of Scotland. She is currently convener of the Society's Publications Committee.*

Ardnamurchan 1932

A slice of geological history

While browsing in the archives of the Geology Department at St Andrews University, ***Richard Batchelor*** *came across a map of Ardnamurchan dating from the 1930s. On the reverse of the map were the signatures of those who had attended a field excursion to the peninsula in 1932. The Editor discussed the participants with* ***Norman Butcher*** *who was able to provide some interesting historical details on this gem of a find. On the reverse of the map is inscribed:*

First Geologists' Association Excursion to Ardnamurchan

22nd July - 1st August 1932

Leader: J E Richey

and below this are the signatures of those who attended the excursion. They are (in order and deciphered as best as can be):

Arthur Holmes
H H Read
J Eastwood
W Campbell Smith
Kingsley Dunham
Colin C Rose
David Kerr
? Innes
W B R King
Andrew Stenhouse
Thomas Peel
[Chinese script]
A Burton
E M Goodman
C G Tomkeieff
J G C Leech
Anne Leech
W H Wilcockson
J Randolph ??
W G Rose
Frank ??
John Pringle
Arthur Raistrick
George Mockler
Janet M M Dingwall
Aidan ??
J S Tomlinson
W R Watson
'The Bat' (E B Bailey)
H Bassett
H Pirie
F G H Blyth
J E Richey
S Tomkeieff

to which these names were added by James Richey:

J F Scott
D Reynolds
? Stevens
Dr & Mrs Mitchell
Dr & Mrs MacGregor

The name at the head of this list is familiar to all of us in the Edinburgh Society. At the time, Arthur Holmes was a lecturer at Durham University and had attended this excursion together with his student, Kingsley Dunham. According to Cherry Lewis in her book, *The Dating Game*, they had driven all the way from Durham to Ardnamurchan in Kingsley's two-seater Morris Cowley. But what was significant about his attendance at this excursion was that it was here that Arthur Holmes met Doris Reynolds. They fell in love on this trip and by the end of the year were

involved in an affair, in those days quite exceptional for an academic with sights set on higher things. But the two were inspired by a mutual love of geology as well as by physical attraction and it was a natural match.

Who else was on that meeting? There was James Richey, of course, and Edward Bailey, both from the Geological Survey and both having spent many months mapping the area. Other Survey geologists included John Pringle, who had joined the Survey as a fossil collector in 1901 and retired as *Palaeontologist to the Survey* in 1937 (see Issue No 40 of *The Edinburgh Geologist*, Spring 2003). With them was G.H. Mitchell and his wife, A.G MacGregor and his wife, and Colin Rose, who had been appointed as a geologist in 1930.

Also there was William King, who had left the Survey in 1920 to pursue a career in academia, first in Cambridge and, by the time of this excursion, as the Yates Goldsmith Professor of Geology at University College, London. Doris Reynolds was also at University College and one wonders how William King viewed the burgeoning romance of his colleague.

Among the other interesting characters was H.H. Read, there with an associate from Imperial College, F.G.H Blyth. Read worked on the Dalradian on the east coast of Scotland, while Blyth was an engineering geologist.

Henry Bassett was from Reading, principally a chemist but with an interest in minerals. He tended to latch on to geological field excursions which his students were attending. W.H. Wilcockson, a lecturer at Sheffield, was working on the Cross Fell Inlier at about that time. Later, during the war, he spent many hours in the field in the Pennines. It was said that much of this time was spent not in doing geological research but in some sort of secret work involving radar stations.

Amongst the others were Arthur Raistrick, a lecturer at Newcastle with a particular interest in economic geology. He pioneered the links between geology and archaeology and often published in the Northern England magazine *The Dalesman*, a similar publication to the *Scots Magazine*. Also from Newcastle was Sergeii Tomkeieff. Sergeii was a Russian emigré who settled in the north of England and was involved in the departments in Newcastle and Durham. The other Tomkeieff on the trip was probably his son, who is known to have attended trips such as these. There is a story of another excursion, a field trip to Arran, where two groups of students, one from Durham, one from Oxford, happened to meet up. The tale goes that one of the Oxford students approached one of the Durham students and asked, "Is that funny old fellow Tomkeieff with you?" to which the reply came, "No — my father is not feeling very well today!"

Richard Batchelor *is a Reader in the Department of Earth Sciences at the University of St Andrews.* ***Norman Butcher*** *is well-known to Fellows, having been on Council for many years and President of the Society in 1983 - 1985.*

Ardnamurchan revisited

Re-assessment of an area of classic geology

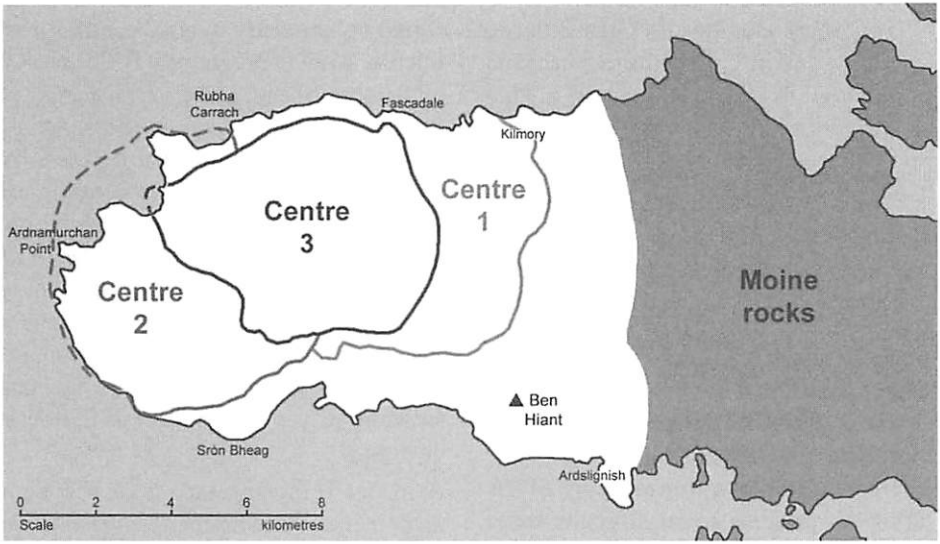
In 2004, the Society held its week-long excursion to Ardnamurchan. The excursion was led by ***Henry Emeleus*** *of the University of Durham and Brian Upton of the University here in Edinburgh. Here Henry re-assesses J. E. Richey's ideas of the 1920s.*

Ardnamurchan was one of the last of the major Palaeogene (formerly early Tertiary) central igneous complexes in NW Scotland to be mapped by the Geological Survey. The work was carried out by James Richey in the 1920s, with some assistance from Edward Bailey and John Simpson. The classic memoir, *The Geology of Ardnamurchan, North-West Mull and Coll*, was published in 1930 with Herbert Thomas as a joint author, responsible for the detailed petrographic work. A special geological map was included with the memoir since only one of the two 'one-inch' maps covering the area had been completely surveyed by that date.

Over recent years the writer has undertaken a re-examination of Ardnamurchan, northern Mull and part of Morvern as part of the British Geological Survey – Universities Collaboration Programme. The aim has been to check selected areas in the field, then compile any new data together with that already on the original 'six-inch' maps at a scale of 1:25 000. The compiled data are to be used to make a new 1:50 000 map covering the whole of the central complex together with the adjoining areas of Mull and Morvern. As might be expected, there are few changes to Richey's original lines, but, as will be seen, some interpretations have changed. Likewise, there will be no new edition of the 1930 memoir, simply a short, explanatory publication.

Richey's mapping revealed the presence of a complex assemblage of intrusive and extrusive rocks emplaced into metasedimentary rocks of the Pre-Cambrian Moine Supergroup overlain by Mesozoic sedimentary rocks and Palaeocene basaltic lavas. The country rocks are domed in the vicinity of the central complex. Within the central complex a bewildering array of major and minor intrusions was resolved into a number of sets of thin, centrally-inclined cone-sheets, predominantly doleritic in texture and basaltic in composition, and several distinct groups of ring-dykes made of gabbro, dolerite and rocks of intermediate and granitic composition. Using criteria such as chilled, intrusive margins to the intrusions and cross-cutting relationships, Richey determined that igneous activity had been concentrated at three major centres. The youngest of these centres, 'Centre 3' of the memoir, contains notable examples of gabbroic ring-dykes, including the 'Great Eucrite'. This gabbro intrusion is up to 2 km in thickness and forms the nearly complete circle of low hills that are such a prominent feature on aerial views of the complex (as illustrated on the cover of the Society's *Field Guide to Ardnamurchan*, Gribble *et al.*, 1976).

A complete contrast to these intrusive rocks is provided by the earliest Paleocene igneous activity in the district. On the



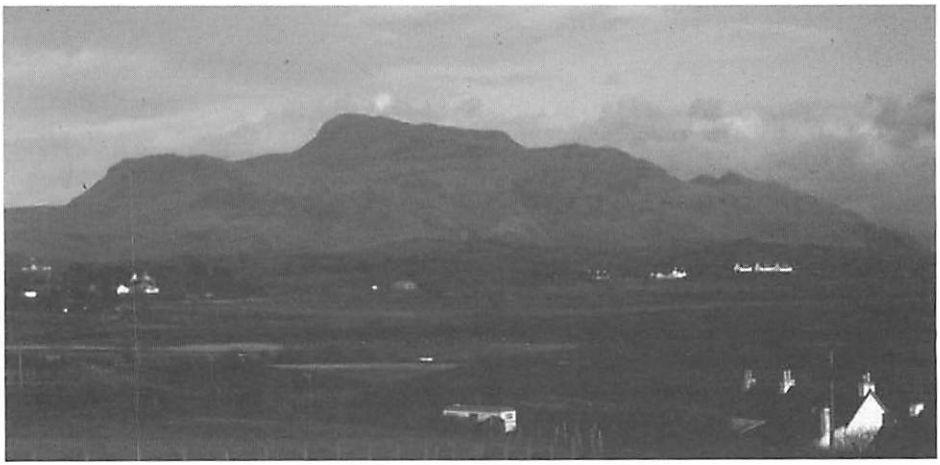
Map of Ardnamurchan showing Richey's 'volcanic centres' and places referred to in text.

eastern edge of the complex, at Ben Hiant and northwards to the coast east of Fascadale as far as Kilmory, Richey mapped a great swathe of fragmental rocks cut by numerous westward-dipping cone-sheets. The fragmental rocks were regarded as vent agglomerates, the products of violent, explosive volcanic activity. The clasts include material derived from the country rocks (schists, sandstones, limestone and basalt) and igneous rocks such as basalt, andesite and rhyodacite ignimbrite. Although the deposits commonly appear chaotic, Richey discovered localities on Ben Hiant where the they are well bedded, a feature he attributed to the accumulation of ejecta from a succession of rhythmic volcanic eruptions.

Since publication of the memoir and associated maps, Ardnamurchan has been regarded as one of the classic places to see cone-sheets and ring-dykes and consequently the venue for many field excursions. However, relatively little new work was carried out in the district for the next twenty years. During and after the 1950s there was renewed interest in the Palaeocene igneous rocks of NW Scotland and several PhD studies were undertaken on Ardnamurchan. The late M. K. Wells examined the Hypersthene Gabbro intrusion of Centre 2 and noted the occurrence of layered structures which he compared with those of the layered Skaergard Intrusion (Wells, 1954). This intrusion was also examined by S. J. Day as part of a PhD study at the University of Durham in 1989, who demonstrated, amongst other things, that there had been high-temperature metamorphism of the Jurassic country rocks with, in extreme instances, their melting and mobilisation, for example near Rubha Carrach and north of Sròn Bheag.

N. Bradshaw studied the Great Eucrite and other 'eucrites' (gabbros rich in calcic plagioclase) in Centre 3 as part of a PhD at University of Manchester in 1961. From this he concluded that little time had elapsed between the emplacement of the various eucrites distinguished by Richey and he suggested that it was much more likely that much of Centre 3 was not a succession of ring-dykes but possibly a single intrusion of elliptical or funnel-like shape. Recently it has been proposed that Centre 3 may be a set of nested funnel-like intrusions (Bell & Williamson, 2002). The considerable width of many of the intrusions presents a real difficulty when interpreting them as ring-dykes, where the space for these annular bodies is considered to have been made by subsidence of a central block of earlier rocks. If the margins dip outwards at steep angles improbable amounts of subsidence are required and even if they dip outwards at an angle as low as 45°, subsidence of the order of 2 km would be necessary to emplace the Great Eucrite. Work in progress by B. O'Driscoll of Trinity College, Dublin on the eucrites of Centre 3 has shown the presence of inward-dipping structures defined by rock magnetisation and by mineralogical and textural layering. These structures are difficult to reconcile with the presence of ring-dykes with steep, outward-dipping margins, but are compatible with gently inward-dipping contacts. Thus, a major reinterpretation of the intrusive igneous structure of the Ardnamurchan Centre is emerging.

A major reinterpretation of the vent agglomerates that extend from Ben Hiant to the north coast of Ardnamurchan has emerged from a detailed investigation by David Brown in a PhD thesis for University of Glasgow in 2003. Rather than originating through violent explosions in volcanic vents, Dr Brown has shown that the deposits are most likely the products of debris flows and avalanches. Although



Ben Hiant from Kilchoan

generally heterogenous, even chaotic, the conglomerates and sedimentatry breccias contain rare, flat-lying beds of tuffaceous sandstone and siltstone which were clearly water-lain. These features are best displayed in the south-east cliffs of Ben Hiant but good examples occur elsewhere, as at Rubha Carrach on the north coast. Gigantic blocks ('megablocks') of the Jurassic country rocks are a striking feature of the deposits on the north coast. These blocks, which may be many tens of metres in length, commonly have the bedding oriented near vertical, with the strike in adjacent blocks in various, discordant directions. The published geological maps show large areas of basalt and brecciated basalt associated with the vent agglomerates. From an examination of these basaltic rocks, Dr Brown has suggested that they, too, are in fact megablocks rather than relics of *in-situ* lava flows. Thus, it is likely that the only undisturbed basalt lava flows are those on Ben Hiant, and at Ardslignish and the hills immediately to the north. 'Vent agglomerates' and 'explosion breccias' are common in all the Scottish Palaeogene central complexes with the exception of St Kilda and, as Dr Brown has pointed out, features attributed to mass flow on Ardnamurchan may be matched elsewhere. Clearly, his investigations, and those of others working on Rum (Donaldson *et al.*, 2001), show that another fundamental reassessment of long-held views on the origins of these fragmental rocks is necessary.

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Geological excursion guides of Scotland

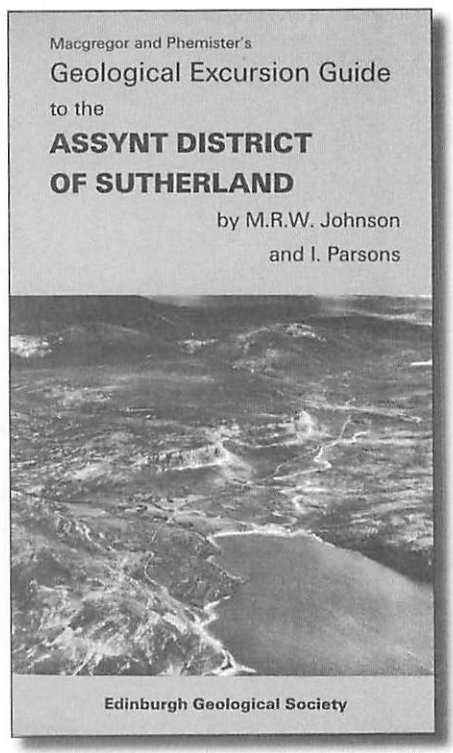
and the Edinburgh Geological Society

The Publications Sales Officer, ***Ian Jackson****, looks into the history of publication of geological excursion guides by our Society and others in Scotland.*

Among the regional geological societies in the UK, the Edinburgh Geological Society is atypical in publishing or co-funding a wide range of attractive geological excursion guides, currently nine in print, plus two leaflets describing geological highlights in Edinburgh (Figure 1). Remarkably, although most of the guides have been through various editions and/or reprints, several with change in authorship, virtually all of them are still in print; the most extreme example is the Assynt guide which has been in print for most of the last 68 yrs. How has this come about?

The birth of the Society's geological guides probably began in 1937 when Murray Macgregor and James Phemister of the Geological Survey of Great Britain (now British Geological Survey) produced the *Geological excursion guide to the Assynt district of Sutherland* on behalf of the Society. Their second edition of the guide was published by Oliver & Boyd for the Society in 1958, and was followed by a third edition, also by Macgregor and Phemister, in 1972. This was essentially a reprint of the 1958 edition with minor amendments by James Phemister, principally taking advantage of the geological exposures revealed by new road cuttings. In addition, an appendix of two new excursions was written by Mike Johnson of Edinburgh University. These were in areas not previously covered, the Stack of Glencoul and the Sgonnan Mòr syncline.

The whole guide was then rewritten by Mike Johnson & Ian Parsons in 1979 (with reprints in 1989 and 2000). Their revision was necessary because in the intervening years, great advances had been made in the understanding of Assynt geology. The book describes one of the classic areas of Scottish geology and focuses on the evidence for major westward transport of large rock sheets above sub-horizontal dislocations or thrusts; the unconformities between both the Cambrian and Torridonian



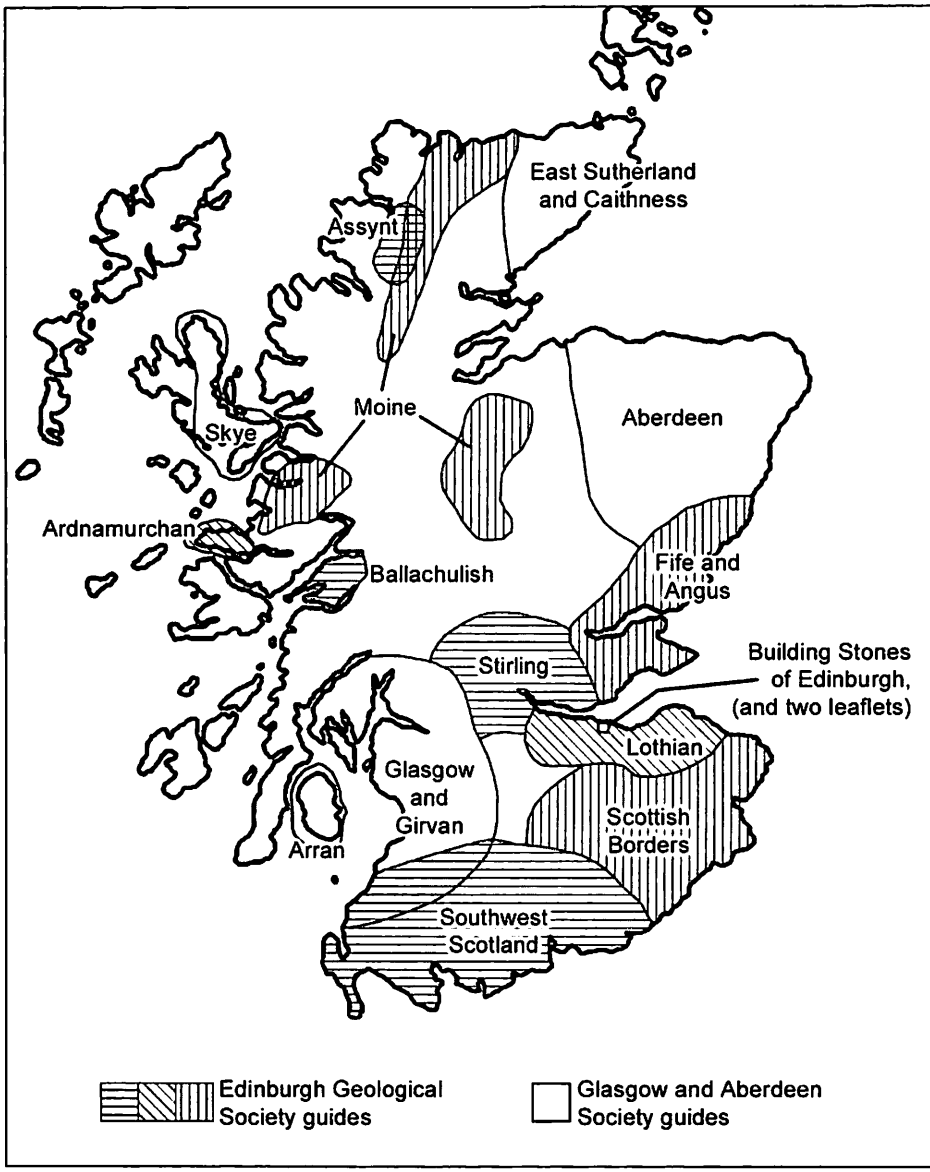


Figure 1. Areas covered by geological excursion guides published by the Edinburgh, Glasgow and Aberdeen geological societies (the original version of this map was compiled by David Land, to whom my thanks are due).

sedimentary rocks, and the underlying Lewisian gneisses are also featured. The guide includes a geological summary of the region to accompany the more detailed treatment of the eight excursions, as well as a log of the roadside exposures between Ullapool and Lochinver. Traditionalists will be pleased to see that the update still retains the four full-colour simplified extracts of the wonderfully evocative 1907 Peach & Horne geological maps of the area.

In the same year as the appearance of the second edition of the Assynt guide (1958), Doug Bassett single-handedly wrote the *Geological excursion guide to the Glasgow district* published by the Glasgow Geological Society. As with the guide for Edinburgh two years later, the publication described the summer excursions visited by the Glasgow Society and ranged far and wide from Glasgow. Bassett's guide was thoroughly revised in 1973 by twenty contributory authors under the editorship of Brian Bluck, retitled *Excursion guide to the geology of the Glasgow district*, and was again published by our cousins in the west. A planned companion guide for the Girvan area did not reach fruition, so in 1992 with Judith Lawson and Doug Weedon as co-editors, excursions from both areas were combined in *Geological excursions around Glasgow and Girvan.*

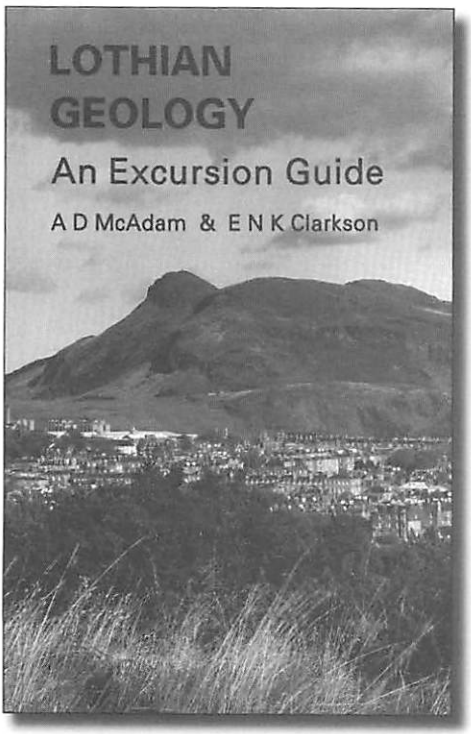
In 1960, two years after Bassett's excursion guide for the Glasgow Society, George Mitchell, Ken Walton and Douglas Grant did the same for Edinburgh and edited the first edition of *Edinburgh geology: an excursion guide*, which was published by Oliver & Boyd for the Society. Despite its 'Edinburgh' tag, the title was a misnomer since the excursions covered a wide area of southern Scotland from the Eildon Hills and Leadhills in the south to the Ochils and Elie-St Monance in the north. Essentially, it was a book describing excursions on which the Society took itself at weekends in the summer.

The first edition of Edinburgh geology lasted fifteen years before its replacement (termed the second edition), *The geology of the Lothians and south east Scotland: an excursion guide*, was published in 1975 under two new editors, Gordon Craig and Donald Duff, both of Edinburgh University. Despite its more wide-ranging title, this guide, published for the Society by the Scottish Academic Press, was more restricted in extent. There were several reasons for this, not least of which was the publication in 1968 of *Fife and Angus geology: an excursion guide*, by Roy MacGregor, which covered the northern excursions of the original guide.

The first major revision of *The geology of the Lothians* was edited by David McAdam and Euan Clarkson in 1986 and labelled the third edition (of the original *Edinburgh geology*); it was again published by Scottish Academic Press. This version bore the simpler title, *Lothian geology: an excursion guide.* And it was just that – the excursions were restricted to those in Lothian Region – more or less; there were a couple of excursions just over the border into Berwickshire, but Hutton's unconformity at Siccar Point could hardly be left out, could it? Among the innovations in this issue was a chapter by Ian Bunyan

of the Royal Scottish Museum on building stones of Edinburgh. David and Euan also wrote a new introduction to the rocks, minerals, fossils and structures to be found in the region and the geological processes which produced them.

This print run lasted another ten years until 1996, before being reprinted as the 'Hutton Bicentenary edition', published by the Society for the first time, and with a page of addenda. A copy of the guide was given to each delegate attending the international conference hosted by the Royal Society of Edinburgh to celebrate the Hutton Lyell Bicentenary of 1997. Like its immediate predecessor, the guide visits many geological highlights amongst the dominantly Carboniferous and Devonian sedimentary and igneous rocks of east-central Scotland. These include the Pentland, Lammermuir, Bathgate and Garleton hills and the coastal exposures of East Lothian, in addition to classic localities within the City of Edinburgh.



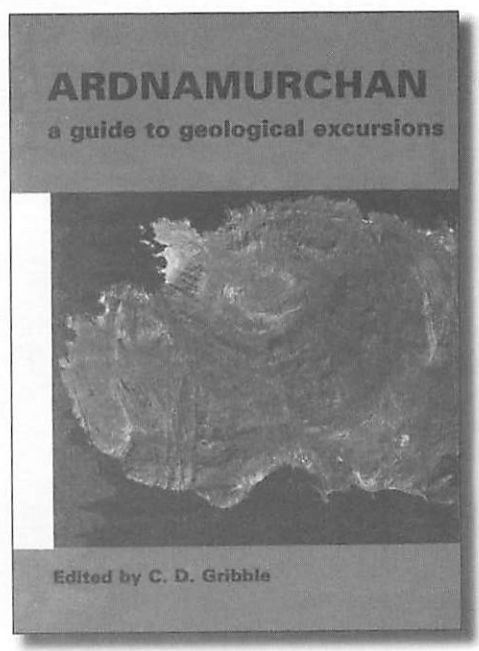
The island of Arran, a geologist's paradise visited by nearly every earth sciences undergraduate in Scotland as well as many from south of the border, lies on Glasgow's doorstep. Thus in 1965, Murray Macgregor, with contributions from Alec Herriot and Basil King, published the *Excursion guide to the geology of Arran* on behalf of the Geological Society of Glasgow. So popular was this guide that it was reprinted in 1968, and then brought out as a second edition in 1972. The current, third, edition is now entitled *Macgregor's excursion guide to the geology of Arran*, with James MacDonald and Alec Herriot as editors.

Increasing numbers of geology students in the 1960s generated a market for regional guides around other universities, such as *Fife and Angus geology: an excursion guide* by Roy MacGregor of St Andrews University, published in 1968 by the University Press. The varied solid geology of the Fife and Angus region ranges from the metamorphic rocks of the Southern Highlands to sedimentary and volcanic rocks of Devonian and Carboniferous age in the Midland Valley. A second edition followed in 1973 and the book is now in its third edition (1996), each written by Roy MacGregor; the last edition was published by the Pentland Press with financial support from both the Edinburgh and Glasgow societies, and our Society may now hold the

sole remaining stock. The 1996 edition is extensively re-written and contains eighteen well-illustrated itineraries; the contrasts in Quaternary geology are also highlighted.

In 1969, the Edinburgh Geological Society published a guide by Brian Upton, his *Field excursion guide to the Carboniferous volcanic rocks of the Midland Valley of Scotland.* This was a slim volume and the five excursions were chosen to demonstrate the breadth of Carboniferous igneous geology. They were: Arthur's Seat, the Campsie Fells, Elie and St Monance, North Queensferry to Braefoot Point and East Lothian.

Over in the west, 1969 also saw the publication of a *Field excursion guide to the Tertiary volcanic rocks of Ardnamurchan* and *The Tertiary igneous geology of the Isle of Skye*, both by the Geologists' Association, and later, in 1979, the *Field excursion guide to the Tertiary igneous rocks of Rhum, Inner Hebrides*. The Ardnamurchan and Skye guides were both precursors to publications by the sister Scottish societies: *Ardnamurchan: a guide to geological excursions*, published in 1976 by the Edinburgh Geological Society with Colin Gribble as senior author and editor (and co-authors Eric Durrance and Nick Walsh), and *An excursion guide to the geology of the Isle of Skye*, by Brian Bell and J W Harris published by the Geological Society of Glasgow in 1986. The former publication was the fourth excursion guide of our Society, but may have been the first for which the Society was the actual publisher (in which copyright was vested with the Society, rather than with a commercial firm); the trend today is for most guides to be published by the Society. The Ardnamurchan guide was reprinted in 1996 with the addition of a list of post-1976 references, and a short commentary by Colin Gribble updating the chronology of events in the 'Tertiary' volcanic province. The Society's pocket-sized Ardnamurchan field guide provides an introduction to the Palaeogene igneous rocks of the peninsula. The various intrusive rock types, and their age relationships and petrogenesis are described in the introductory chapters, while the seven excursion itineraries cover the three main centres of igneous activity. The guide also deals with the metasedimentary Moine country rocks and their Mesozoic cover sequence, and includes a full colour geological map of the peninsula in a back cover pocket.



Over the years, the Geologists' Association has brought out several guides to Scottish geology, including *North East Scotland: the Dalradian* in 1960, *Moine schists and Lewisian gneisses around Mallaig, Inverness-shire* in 1964, *The Lewisian and Torridonian rocks of North West Scotland* in 1978, *Isle of Arran: a field guide for students of geology* (as if we needed another one!) in 1989, *The Late Precambrian geology of the Scottish Highlands and Islands* in 1991, and *A geological field guide to the Island of Bute, Scotland* in 1994.

As well as the Geological Society of Glasgow and the Geologists' Association, another society has published Scottish guides, the Aberdeen Geological Society. In 1987, Nigel Trewin, Ben Kneller and Con Gillen edited *An excursion guide to the geology of the Aberdeen area*, and in 1993, Nigel Trewin and Andrew Hurst were the authors of an *Excursion guide to the geology of East Sutherland and Caithness*. Both guides are now out of print.

Unlike the second edition, the third edition of *The geology of the Lothians* lacked a 'building stones' chapter which was omitted in view of the publication by the Society in 1987 of the seminal work, *Building stones of Edinburgh* by Ian Bunyan, John Fairhurst, Alex Mackie and Andrew McMillan (who also edited the publication). The guide is dedicated to Alex Mackie who died shortly before its publication. The book, which is not an excursion guide *per se*, but which can be so adapted, was the culmination of many years' investigative work carried out by Society members led by Richard Gillanders, following a request by the Council of the Society. It was followed in 1999 by a second edition, expanded and fully updated with many more illustrations, and written by Andrew McMillan, Richard Gillanders and John Fairhurst.

Edinburgh, 'Grey Athens of the North', owes much of its splendour to the high quality sandstone from which many of its finest buildings are constructed. *Building stones of Edinburgh* focuses on the geological characteristics of these sandstones, commonly extracted from local quarries, and illustrated in this second edition by numerous photographs of the city's famous buildings. The chapters concentrate on the location and stratigraphy of the quarry source, quarrying methods, walling techniques, and the durability and physical characteristics of the sandstones. The authors also produced a comprehensive set of technical data appendices.

A new venture in 1988, was the publication by the Scottish Academic Press of *An excursion guide to the Moine geology of the Scottish Highlands*, edited by Iain Allison, Frank May & Rob Strachan. The Moines underlie the greater part of the Scottish Highlands and the 1980s witnessed a large number of research workers engaged in deciphering their complex geology who put forward a proposal to the Glasgow and Edinburgh societies for an excursion guide. The guide broke new ground in four ways — it was jointly funded by both societies, it dealt with a particular stratigraphical unit rather than the diverse stratigraphy of a Scottish region, the excursions ranged

over seven widely scattered areas of the Scottish Highlands (simplified in Figure 1), and the publication has a waterproof cover to keep out the 'Scotch mist' prevalent in the Highlands. Like the Ardnamurchan guide, it was published as a handy pocket-sized volume. It describes the varied lithologies and complex structure of the largely metasedimentary pile of the Moine Supergroup of the Northern and Central Highlands of Scotland. There are twelve excursions, mostly lying along major roads, allowing easy access to some of the finest outcrops of deformed and metamorphosed arenites in Scotland.

By 1990, the total number of publications in which the Edinburgh Society was involved, either as publishers, or co-funders or offering financial support, still only stood at six, but the coming decade was to see this rise to twelve. The pivotal year for Society publications was in fact 1996 when four new guides and two reprints were added to the catalogue; the stock value of publications rose six-fold from £4 000 to over £25 000.

The progress made during the 1980s and 1990s in understanding the highly complex structure of the Southern Uplands, and in discovering the varied provenance of superficially monotonous turbiditic greywackes in structural tracts bounded by major strike-slip faults, is reflected in the next two guides published by the Society.

Firstly, in 1992, David McAdam, Euan Clarkson & Phil Stone edited a guide entitled *Scottish Borders geology: an excursion guide*, published by Scottish Academic Press. This was the first geological excursion guide devoted principally to the Borders Region of Scotland, and the seventh publication of the Society. The varied geology, explored in twenty-one excursions, ranges from graptolite-bearing Ordovician and Silurian rocks of the Southern Uplands, through the Old Red Sandstone of the Jedburgh-Lauder area to the Carboniferous (Dinantian) rocks of the Northumberland Trough and a Quaternary esker at Bedshiel Kames. Visits to the world famous localities of Dob's Linn and Hutton's Unconformity at Siccar Point are also included. This guide is now completely sold out (though BGS may still have a small stock). Unfortunately several of the excursions are no longer viable because of changes in land use and quarry development, and this, combined with changes in geological interpretation for some other excursions, dictates that the guide needs substantial revision. The Publications Committee of the Society feels that a simple reprint cannot be justified in the circumstances and it may be some time before the second edition becomes available.

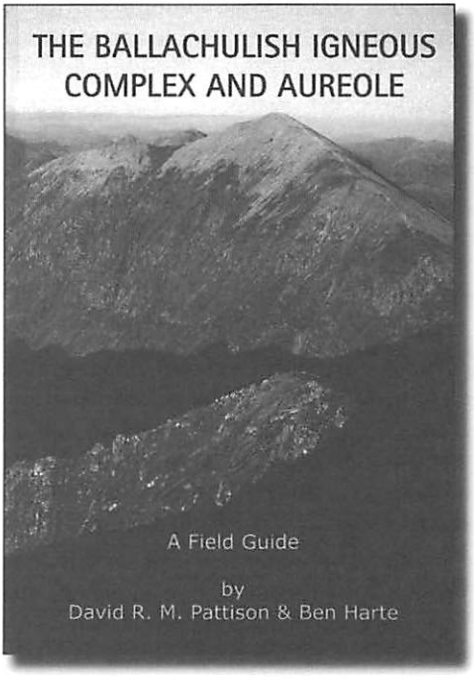
Nevertheless, a guide currently exists for the area covering the south-western part of the Scottish Borders, *Geology in south-west Scotland: an excursion guide*, edited by Phil Stone and published by the British Geological Survey with financial support from the Society. The guide, published in 1996, is the first for the area and is dedicated to the memory of Dr Byron Lintern (British Geological Survey) who died at a tragically early age but who accomplished much in the region in a short period. It contains an introduction to the geology of the Southern

Uplands, which records the development and eventual closure of the long-vanished Iapetus Ocean. The eighteen itineraries describe the stratigraphy and geological structure developed within this Ordovician to Silurian sedimentary sequence as well as the later Criffell-Dalbeattie and Cairnsmore of Fleet granite intrusions.

Also in 1996, the Society produced another publication on the Assynt area, *Assynt - the geologists' Mecca*. This booklet, written by Peter Dryburgh, Roy MacGregor, Sinclair Ross & Christine Thompson describes concisely and in non-technical language the geology and history of research of this classic area of Scottish geology visited by geologists and tourists from all over the world. It is a tribute to the brilliant and dedicated pioneers Ben Peach and John Home (officers of the Geological Survey of Great Britain) who first unravelled the true complexities of the geology of Assynt. The impetus for its publication arose from the Society's 1993 week-long May excursion to Assynt; the story behind the refurbishment by the Society of the visitors' book at the Inchnadamph Hotel is also told. The longest section of the booklet describes the background to the famous 1912 British Association excursion to Assynt led by Peach and Horne, and concludes with thumbnail biographies of all the excursion participants.

Mention should also be made in this history of excursion guides of two leaflets describing the geology of a much smaller area – firstly of the broadsheet leaflet (A15 size) *Discovering Edinburgh's volcano* by David Land and Robert Cheeney published by the Society in 1996, which was based partly on the 1966 book by George Black entitled *Arthur's Seat: a history of Edinburgh's volcano* and partly on David McAdam's 1986 leaflet *Geological guide to the Arthur's Seat volcano*, and secondly of David Land's 1999 leaflet (A3 folded to $^1/_3$ A4) covering the *Hermitage of Braid and Blackford Hill*. Following the huge sales success of *Discovering Edinburgh's volcano*, an improved and revised second edition was published in 2000.

Finally, the Society's thirteenth and most recent guide, written by David Pattison & Ben Harte, is *The Ballachulish igneous complex and aureole: a field guide*, published in 2001. The Ballachulish igneous complex in Glen Coe is a relatively simple, granitoid intrusion of calc-alkaline affinity emplaced



425 million years ago into lithologically varied Dalradian metasedimentary rocks; the highly diverse contact metamorphic aureole overprints regional metamorphic assemblages. This well exposed igneous complex was the focus of an international multidisciplinary study from 1981 to 1991, one of whose aims was to provide a description of a type example of intrusive processes at moderate crustal depths. This guide provides a comprehensive geological overview followed by detailed description of five field excursions, all illustrated with clear location maps, numerous photographs and a full colour geological map in the back pocket.

And what of the future? A new publication for the Assynt area edited by Suzanne Miller is at an advanced stage of preparation, together with a second edition of the Moine guide that has been completely overhauled under the editorship of Rob Strachan and others. Other guides covering new areas, including the Stirling region, for which co-funding by the various local geological societies of Scotland is becoming a notable trend, are at an early stage of compilation and lie farther down the pipeline.

Acknowledgements

Thanks are due to David Land, now a Distinguished Fellow of the Society, who compiled the original version of Figure 1 when he held the post of Publication Sales Officer several years ago. It is this map that initially sparked off this review. The writer has unashamedly and without permission purloined phrases and sentences from the prefaces and forewords of the various publications; he offers his considerable thanks to the numerous authors concerned.

Appendix

EGS excursion guides currently in print

Ardnamurchan: a guide to geological excursions, edited by C.D. Gribble, 120pp [ISBN 0-904440-02-8]. Price: £6.50 (Fellows £5.20), £1.10 p&p.

Macgregor and Phemister's geological excursion guide to the Assynt district of Sutherland by M.R.W. Johnson & I. Parsons, 76pp [ISBN 0- 904440-03-6]. Price: £5.50 (Fellows £4.40), £1.10 p&p.

Assynt: the geologists' Mecca, by P.M. Dryburgh, A.R. MacGregor, S.M. Ross & C.L. Thompson, 33pp [ISBN 0-904440-08-7]. Price: £2.50 (Fellows 2.00), £1.00 p&p.

The Ballachulish igneous complex and aureole: a field guide, by D.R.M. Pattison & B. Harte, 148pp [ISBN 0-904440-11-7]. Price: £9.50 (Fellows £7.50), £1.50 p&p.

Building stones of Edinburgh, by A.A. McMillan, R.J. Gillanders & J.A. Fairhurst, 235pp [ISBN 0-904440-10-9]. Price: £10.00 (Fellows £8.00), £1.80 p&p.

Fife and Angus Geology: an excursion guide, by A.R. MacGregor, 29lpp [ISBN 1-85821-353-3]. Price £13.00 (Fellows £10.40), £1.80 p&p.

Lothian geology: an excursion guide, by A. D. McAdam & E.N.K. Clarkson, 221pp [ISBN 0-904440-06-0]. Price: £10.00 (Fellows £8.00), £1.50 p&p.

An excursion guide to the Moine Geology of the Scottish Highlands, edited by I. Allison, F. May & R.A. Strachan, 270pp [ISBN 0-7073-0514-4]. Price: £8.50 (Fellows £6.80), £1.50 p&p.

Geology in south-west Scotland: an excursion guide, edited by P. Stone, 214pp [ISBN 0-85272-261-3]. Price £10.00 (Fellows £8.00), £1.80 p&p.

Discovering Edinburgh's volcano, leaflet by D.H. Land & R.F. Cheeney, [ISBN 0-904440-05-2]. Price: £1.50 (Fellows £1.20), £0.50 p&p.

Hermitage of Braid and Blackford Hill, leaflet by D. H. Land, [ISBN 0-9044400-9-5]. Price: £1.50 (Fellows £1.20), £0.40 p&p.

EGS excursion guides out of print

Scottish Borders geology: an excursion guide, edited by A. D, McAdam, E. N. K. Clarkson & P. Stone.

Carboniferous volcanic rocks of the Midland Valley of Scotland, by B. G. J. Upton.

EGS stock of Glasgow guides:

Macgregor's excursion guide to the geology of Arran, by J.G. MacDonald & A. Herriot (eds), 210pp, [ISBN 0-902892-07-X]. Price: £6.00, (Fellows £5.00), £1.40 p&p.

An excursion guide to the geology of Isle of Skye, by B. R. Bell & J. W. Harris, 317pp, [ISBN 0-902892-08-8]. Price: £6.00, (Fellows £5.00), £1.60 p&p.

Geological excursions around Glasgow & Girvan, by J.D. Lawson & D.S. Weedon (eds), 495pp, [ISBN 0-902892-09-6], Price: £9.00, (Fellows £6.00), £2.40 p&p.

Excursion guide to the geology of Southern Kintyre, by C.J. Burton & J.J. Doody, 19pp, [ISBN 0-902892-10-X] Price £2.50 (only available to Fellows, £2.00). Reprinted from the Proceedings of the Geological Society of Glasgow, Session 136 & 137, 1993/1995.

Ordering excursion guides

You might like to purchase the relevant guide from the Publication Sales Officer, Ian Jackson. Ian can be contacted direct on 0131-445 2921 or by writing to him c/o British Geological Survey, Murchison House, West Mains Road, Edinburgh, EH9 3LA. The full price of the guides and the price to members were slightly increased earlier this year. If you are putting in a mixed order or purchasing more than one volume, you will probably gain (slightly) financially, if you wait until the arrival of your purchase before sending off your cheque; the enclosed invoice will show the postage and packing calculated on your individual parcel, rather than what would have been charged on an aggregate basis from summing the postage on individual books.

Ian Jackson *joined the Institute of Geological Sciences in London in 1968, carrying out field mapping in Central and South Wales. In 1981, he was transferred to Edinburgh, became a seismic interpreter and swapped his geological hammer for a set of coloured pencils. Following early retirement from BGS, he has organised the annual weekend excursion of the Society and became Publications Sales Officer in 2002.*

Pictish geoarchaeology

Did the Pictish craftsmen who created the carvings on standing stones understand anything about geology? ***Suzanne Miller*** and ***Nigel Ruckley*** *look at standing stones and other monuments and the carvings that appear upon them. The stonemasons of the time certainly knew which stones were best for carving and which to avoid. Read on to find out more...*

Introduction

Throughout Scotland there are a remarkable number of beautifully and sometimes intriguingly carved stone monuments. These monuments range in age and style but all can tell us something about the people who carved them and those who commissioned them. The collections of carved stones also have the potential to tell us something about the centres of importance to people of a particular time, especially from periods when few written records exist.

For a number of years, archaeological interpretation of such monuments has suggested that master carvers and their apprentices were located in one place, referred to as 'schools of carving', and that monuments were made to order and then transported to the purchaser. However, is it credible that the carvers imported blocks of stone over long distances for their work or carved slabs from one source and then had them transported to their new owner? Stone is heavy and expensive to transport. Most craftsmen would surely have wished to have been closely involved with selecting the actual slabs they were going to carve. There would presumably have been a significant amount of wastage in the process of shaping and carving the slabs, best left at the quarry itself. It therefore seems much more likely that the stonemasons would be based at local quarries for individual commissions and that long land journeys would have been the exception rather than the rule.

But how do we assess this? Well, a stone's a stone, whether it's outcrop, in your back garden or is a carved monument. As such, the tools we use as geologists to identify and characterize any rock can equally be applied to the *in situ* rock, the stone in your back garden or a sculpture. Well, almost... based on this basic premise, it should be possible to identify the provenance of the raw materials of carved monuments at different sites and assess whether it was the rock or the mason that moved. Interestingly, archaeological thinking supported the former.

Medieval sculpture in central eastern Scotland (Angus, Perthshire and Tayside) is exemplified by some 120 eighth to tenth century sculptures and sculptural fragments (e.g. Figure 1). These have been published and catalogued by Cruden (1964) and the Royal Commission for Ancient and Historical Monuments Scotland (RCAHMS) are in the process of drawing and photograph-ing these collections.

Many of the sculptures are in the care of Historic Scotland (e.g. the St Vigeans

Figure 1. Examples of Pictish stone sculpture
(a) St Vigeans No. 7 (b) Meigle No. 3 (c) Aberlemno No. 2

collection) whilst others are parts of museum collections, are in local authority care or are held privately.

The present project was initiated with the aim of improving previous interpretation of early medieval sculpture related to the outstanding collection at St Vigeans in Angus by bringing geological knowledge and skills to bear on the subject and comparing the sculpture with possible source material. We were hopeful that this would lead to a reassessment of where the sculpture was carved and result in a new understanding of power and patronage in medieval Scotland. The project was funded by Historic Scotland and involved close collaboration with RCAHMS.

A petrological survey, backed up by magnetic susceptibility readings, of the most representative sculptures has been undertaken. Sculpture collections surveyed include: St Vigeans, Aberlemno, Meigle, Pictavia and Meffan, together with individual sculptures at other sites (Figure 2). Comparison of the rock types used for sculpture is then made with local outcrop. The sculptures that form the basis of this project are located within the north-eastern part of the midland valley of Scotland. This area lies entirely within the Old Red Sandstone (ORS). The term 'Old Red Sandstone' has been used in the UK since 1822 (Conybeare & Philips, 1822) to denote the terrestrial sediments which are roughly equivalent in age to the Devonian

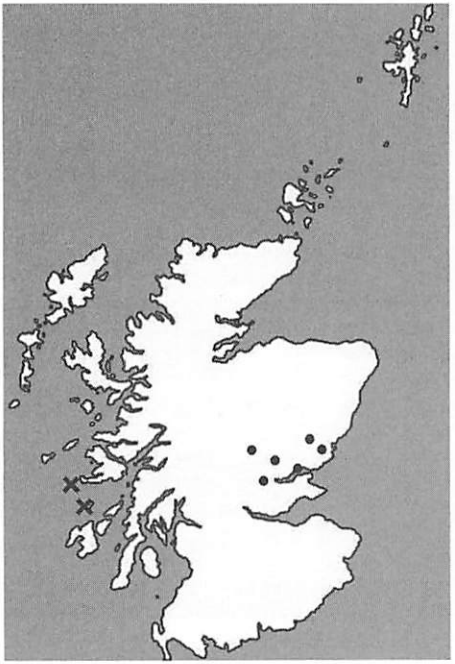


Figure 2. Map of Scotland showing the localities of early medieval sculpture in Central Scotland

marine deposits in SW England and continental Europe. These are generally recognized as being approximately 400 to 360 million years old, although there is still considerable debate as to the exact age of the Scottish ORS (McKerrow et al., 1985).

Associated with the sedimentary units are a number of volcanic rocks (particularly lavas) of similar age. No sculptures have been found to comprise volcanic rocks. The sedimentary rocks in the area of study have been classified as Lower ORS (LORS), derived from the erosion of the Caledonian mountains to the north in a semi-arid environment. The rocks in the area have been folded into two, asymmetrical folds – the Strathmore syncline and the Sidlaw anticline. The stratigraphy of the LORS in this area is based on a synthesis by Armstrong and Peterson (1970). The rocks of the area belong to one of three groups: the Arbuthnott Group, the Garvock Group or the Strathmore Group. The rocks comprise conglomerates, sandstones, siltstones, mudstones and shales.

Methodology

In assessing carved monuments there are two main constraints. The first is that one generally has to go to the monument. It is not easy, if not impossible, to take the sculpture to the labs so all techniques applied have to be mobile. The second is that any mobile techniques used must be non-destructive. Archaeologists and art historians generally do not like the idea, let alone the reality, of taking a sample, so a 'no hammering' (or drilling, or coring, or dropping of acid) policy is pretty much a pre-requisite. So we rely on some core geological skills and the use of that time-honored geological tool – the hand lens.

We examined over 120 sculptured stones using non-destructive petrological techniques in order to provide a 'field identification' of the rock type and distinguish between general rock types. All examinations included:

(a) colour (with reference to Munsell standard colour charts),

(b) grain size (with reference to standard grain size measurements on the mm scale),

(c) macroscopic mineralogy (i.e. mineralogical content that can be ascertained by hand lens),

(d) textural and structural characteristics such as bedding, cross-bedding, jointing, other planar fabric, grain size variation and sediment maturity,

(e) clast distribution and composition,

(f) weathering characteristics.

The specimens are divided into 'rock types' primarily based on the textural characteristics. Colour can be used only as a general guide to overall appearance since, in many cases, the sculptures have undergone varying degrees of weathering and/or cleaning, both activities that could significantly alter the colour of the surface of the specimen.

Over 180 outcrop specimens (i.e. potential source rocks) have been examined using petrological techniques in order to classify rock type. In addition to the measurements taken for the sculptures, the mineralogical and textural characteristics of all outcrop specimens were also identified in thin section. We also undertook a fairly extensive examination of local building materials, providing a useful guide to local stone sources (particularly in early medieval buildings) and, somewhat embarrassingly, more than a little amusement for local residents.

As well as the basic mineralogical and textural examination of the rocks, we also employed another non-destructive technique – measurement of magnetic susceptibility. Most igneous and metamorphic rock types contain varying amounts of ferromagnetic minerals such as magnetite. To a lesser extent sedimentary rocks, especially where they have been formed from the erosion of igneous and metamorphic material, also contain limited amounts of ferromagnetic material. Measurements of magnetic susceptibility are by nature closely related to the content of magnetite and other iron minerals and can be used in characterizing rock outcrops. By comparing the physical properties and magnetic susceptibility of the rock outcrop with those of the carved stone it is possible to further evaluate the source(s) of the carved stones.

This technique has been employed in the provenancing of igneous rocks e.g. Roman granite columns (Williams-Thorpe and Thorpe, 1993), greenstone axes (Markham, 1997) and Charlemagne's 'black stones' (Peacock, 1997) but rarely for sedimentary rocks. Here, we had an opportunity to assess the usefulness (or otherwise) of this technique for sandstone provenancing.

The magnetic susceptibility was measured with an Exploranium KT-9 Kappameter giving a measurement of the true susceptibility. The instrument is held like a torch, is powered by a 3V battery and gives a digital readout of susceptibility in non-dimensional SI units. A rubber pin protruding out of the front face of the Kappameter is held touching the stone and gently pressed until an automatic reading is recorded (Figure 3).

A series of a dozen readings were taken from the front and rear faces of the carved stones away from all possible sources of magnetic contamination (such as metal

supports, repairs, weathered patches and concrete plinths on which the sculptures might be sitting).

Results

The geological analyses of the early medieval sculptures indicate that all the stones are sandstone with the exception of one siltstone and one granite. We are able to assign the raw material used in the carvings into sandstone types using a combination of petrological features and magnetic susceptibility values (Figure 4). For the sandstones, the features are consistent with sources in the LORS of the area and would indicate that, from within the LORS, a number of different geological units have been utilized for the procurement of the stones. At individual medieval sites, rock types are generally specific to each site. Where the same rock type features at different sites, this can be accounted for in the nature of the structure and exposure of the LORS. Specifically, with the northeast-southwest trending fold axes, the same units crop out along strike at various locations close to more than one site.

Figure 3. Taking magnetic susceptibility measurements with the Exploranium KT-9 Kappameter

It does not seem hugely surprising that local sources were used. After all, it would not have been easy to transport large blocks of rock around the country nor sensible to transport already carved and therefore valuable monuments over long distances especially when the local geology provides ideal raw materials.

The feasibility of local production of the sculptures at each site is supported by local quarrying evidence and written records of quarrying and stone extraction. There are a number of sandstone quarries in the immediate area of each of the sites visited and a detailed study of the history of quarrying throughout the area suggests more numerous early working quarries across the region. In addition, the nature of the LORS units would allow very local, non-quarry sources such as outcrop in river-cuttings to be utilized for the production of stone.

In addition, the work carried out so far has also been very useful in distinguishing fragments of sculpture that have originally been part of the same monument and, in the process, settling some very long-running

(and sometimes heated) debates amongst the archaeologists.

Conclusions

Initial conclusions for early medieval sculpture in Central Scotland are that the majority of the sculpture is located very close to the stone source. It appears that little, if any, large scale movement of raw materials or carved sculpture took place at this time.

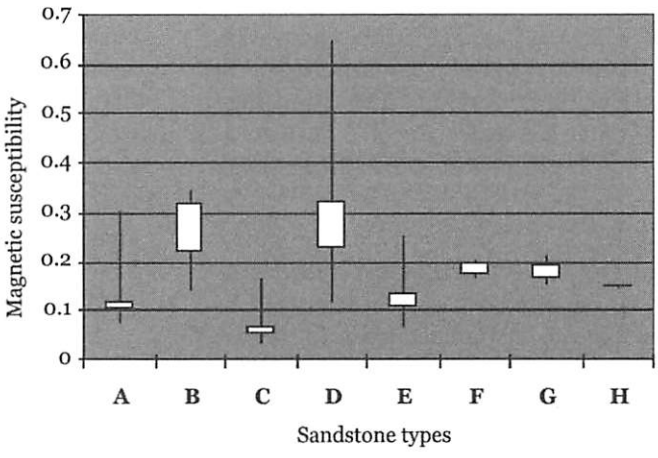


Figure 4. Range of magnetic susceptibility values of the sandstone groups characteristic of the early medieval carved sculpture form Central Scotland.

Rather than a small number of schools of carving based at fixed locations we are building up a more complex picture of individual craftsmen or workshops based at several quarries, or indeed opening up quarries from time to time to deal with local commissions (Miller & Ruckley, in press). After all, why take the mountain to Mohamed?

Working with such beautiful objects and in close collaboration with archaeologists has ensured that this project has been a most interesting and enjoyable one. It is, however, only just the beginning... we are now in a position to move forward with more detailed analysis of the Pictish monuments. We are also applying these techniques to late medieval grave slabs and crosses in the west Highlands and to Roman sculpture.

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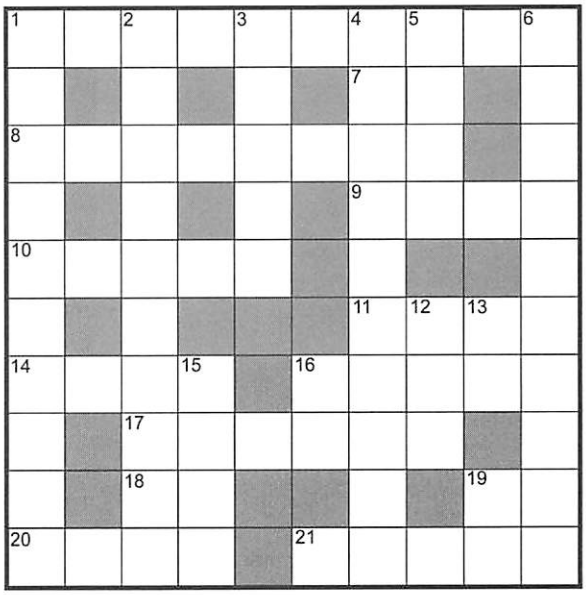
Suzanne Miller *works in the Natural Sciences Department at the National Museums of Scotland in Chambers Street. Her research includes application of geological techniques to provenancing carved stone artefacts.*

Nigel Ruckley *worked in the British Geological Survey for many years both in the land survey and offshore. Before taking early retirement in 1997 he was acting as BGS Geoarchaeology co-ordiator in Scotland. For the past 15 years he has been involved in geoarchaeological and historical researches on Islay culminating in the ongoing recording of the Islay graveyards. He has also been involved with geoarchaeological projects run by the National Museums of Scotland. These included a geological survey of Pictish stones in Angus and ongoing researches into the provenacing of West Highland medieval gravestones.*

Rocksword puzzle no. 13

Some things do not change. This is the thirteenth Rocksword *puzzle that* **Angela Anderson** *has compiled for* The Edinburgh Geologist *and it follows the same format as the last twelve. For those who can't manage to solve all the clues, the answers to this puzzle, along with the solution for the geological quiz on the next page, are on page 38.*



Clues across

1. Coring East etc. over old-fashioned view of the cosmos (10 letters)
7. Initially religious instruction (3)
8. A starry echinoderm (8)
9. A biological prison unit (4)
10. Metallically mocking phrase (5)
11. Scarcely underdone (4)
14. Soft cosmetic material (4)
16. Wearied, so drilled a hole (5)
17. It is cold up there (6)
18. Thus (2)
19. Not off (2)
20. Scottish turnip sounds like a small tide (4)
21. Abrasive mineral (5)

Clues down

1. A lot a' icing up for a long cold spell (10)
2. K-feldspar (10)
3. Not late, really (5)
4. I storm rich exhibition of three colours (10)
5. Dire motion (4)
6. Cryptocrystalline silica (10)
12. Curved part of 17 across (3)
13. Between do and me (2)
15. Cut short the harvest (4)
16. Initially British Telecom (2)
19. Alternative (2)

A geological story

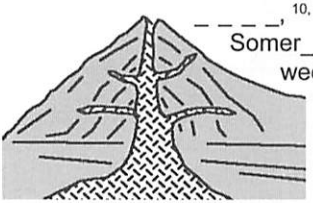
The following 'geology quiz' was created by ***Valerie*** *and* ***David McAdam*** *for the annual Social Evening last December. To complete the story, fill in each space with a term used in geology, geomorphology or physical geography and having the appropriate number of letters. Use the correct spelling of the term, ignoring spaces... and don't groan too loudly. As an example, here is the solution to a similar musical instrument quiz:*

> Joe and Ena met on a PIANO cruise. She looked marvellous in an ACCORDIAN-pleated skirt and Joe was attracted by her BELL-like voice. He said "Would you like to go to the CONCERT INA?" and she said "Yes, I would like to hear the BANJO"

And if that is still not clear, the first two clues have been completed for you!

This is the tale of two family members of the Edinburgh Geological Society, P E A T er[1] and M A R L ene[2] Clyne, and their beloved dog Basil, a _ _ _ _ _ _ er[3] spaniel.

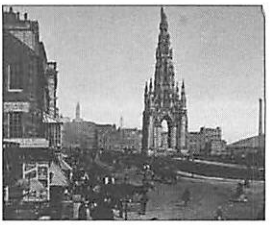
In the morning, Marlene applied a _ _ _ -pack[4] to her face, and washed it all off again in a _ _ _ _ _ .[5] She _ _ _ _ _ d[6] her hair, and dusted with _ _ _ _ um[7] powder.



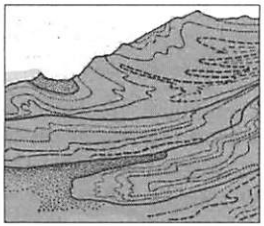
Peter had started to study _ _ _ logy[8] at University, but now found more profit as a _ _ _ _ _ broker,[9] Marlene used to work mornings as a teller in _ _ _ _ _ _ _ _ 's _ _ _ _ ,[10, 11, 12] but recently started in the new supermarket Somer_ _ _ _ _ _ _ _ _ ing[13] on the _ _ _ _ .[14] Last week, the temporary workers refused to _ _ _ _ _ [15] the shelves and went on _ _ _ _ _ [16] for a day. This caused the _ _ _ _ [17] to _ _ _ _ [18] his ange_. "_ _ _he[19] staff's Christmas pay-packet is smaller it's their own _ _ _ _ _."[20]

It was Saturday and Marlene had to go to the Church baz_ _ r[21] to run the _ _ _ _ _ _ _[22] though some of the elders thought gambling wrong in church. Peter stayed behind this time as he had to take _ _ _ _ _ _o[23] the vet for his booster jag.

They met for lunch at the West End outside the _ _ _ _ _ _ _ _ _ _ _[24] Hotel. However, they went to a nearby caf□ for beef, peas and m_ _ _ ed[25] potatoes. For _ _ _ _ _ _[26] they bought double ice-cream _ _ _ _ s.[27]



Afterwards, they went shopping. Peter was looking for a boring _ _ _ _ _ _[28] coat, to go with the balac_ _ _ _[29] his mother had knitted. Marlene's most favourite clothes shop was _ _ _ _ _ _ _ _ _ _[30] in Stafford Street. She bought

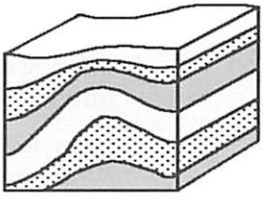


new shoes with _ _ _ _ _ _ _ _ _ _ _ _ s,[31, 32] and a nice _ _ _ _ _ _[33] watch. "That's a n_ _ _-_ _ _[34] you're wearing on your head," the assistant said to Peter as they left, "and have a _ _ _ _ _ _[35] day".

Marlene's _ _ _ _ _ s[37] were aching after trailing round all the shops and she had a stiff _ _ _ _[38] from trying on so many hats. She was tempted to go for a _ _ _ _ _[39] in _ _ _,[40] but that would be lazy.

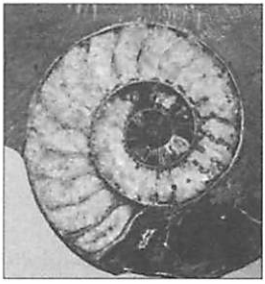
They had returned back home, just as dusk _ _ _ _ _ _ _ _ _ _ _ _ s[41] needed putting on for the tea. Peter started preparing vegetables but had to stop as he had cut himself and his _ _ _ _[42] was _ _ _ _ ing[43] blood. "_ _ _ _ _ _ _ _ an,[44] said Peter, I can't get it to stop bleeding. You'll have to finish the preparation Marlene."

They discussed holidays. Peter was determined, whatever the _ _ _ _ _ _ _ _ _ reece[45] this year, to go to Athens. Marlene preferred to laze on the _ _ _ _ _.[46] Her niece, Anna, was coming too; she liked making _ _ _ _ castles[47] and she was fond of her dear _ _ _ _ _ _ _ _ _[48] too.



In the evening they relaxed by watching, an _ _ _ _ _ _ _[49] of their favourite TV Soap, _ _ _ _ _ _ _[50] on their wide-_ _ _ _ _ n[51] television. They did not like Australian soaps nor _ _ _ _ _ _ _ _ _[52] soaps. Tonight's was a bit tense and ended with a _ _ _ _ _ hanger.[53] The members of the _ _ _ _ _[54] got a fair bit of _ _ _ _ _ _ _ _[55] in the celebrity magazines (not the type of _ _ _ _ _[56] gran used to read). Some of the pictures of the female stars showed too much _ _ _ _ _ _ _ _.[57] It was a wonder they put up with this _ _ _ _ _ _ _ _ _[58] into their private lives. Marlene's favourite film star was _ _ _ _ _ East_ _ _ _[59, 60] but Peter preferred films like 'True _ _ _ _[61] or listening to _ _ _ _ _ a[62] Kitt records.

To round his evening off, Peter fancied a wee drap o' the _ _ _ _ _ _.[63] It would not take much to _ _ _ _[64] him to sleep. In contrast, Marlene left to go clubbing, saying "I'm not a day person, _ _ _ _ _ _ _ _ _[65] person"



Answers (if you need them) are on page 38, along with the solution for Rocksword puzzle no 13.

Poet's corner

The following poem was sent to me by Bob McIntosh of the British Geological Survey. It comes from the ***Grizzly Bear Books****, which are a record of Survey dinners held over the years. After dinner, there were songs and recitations and the author of this poem, Huon Walton, was clearly a talented rhymster. The folk of whom the poem tells have all passed on, the latest being Harry Wilson, who died at the turn of the year at the age of 83. The poem is published with permission of the Executive Director of the British Geological Survey.*

The Midlothian saga (with apologies to Robert Service)

There are strange things done in Midlothian
By the men who map the coal.
The Lowlands trails have their secret tales,
That would make your blood run cold.
The local lights had seen queer sights,
But the strangest they ever did see,
Was when out of the town and into the field,
Strode Wilson and Tulloch and me.

Harry Wilson by name from Ireland came,
Where the granitisers go.
What made him leave his home and Queens,
The Lord alone must know.
He was always queer but the Penicuik beer
Seemed to act on him like a spell
And he'd often say in his homely way
He would rather be in Hell.

Bill Tulloch too knew a thing or two
About how to fill up a map.
He was not the sort who had ever been caught
In a quarry having a nap.
A strong silent bird as you may have heard
Is this man from the frozen North;
And he knows by now a fake from a blaes,
And so on, and so forth.

On a wet summer day I was hacking my way
Through the thickets down by the Esk
And my thoughts would range to that house in the Grange
With my comfortable chair and my desk.

But the show must go on so I struggled on,
With feet that were clogged with clay;
For it must be said, that though half dead,
I was one to fall by the way.

I had made a tryst which couldn't be missed
With Harry and our D.G.,
So I made for the place with mud-covered face
To see what I could see.
Then from the haze where I fixed my gaze
Came a mobile sardine tin,
With a series of jerks which jolted the works
It stopped with a squeal and much din.

By levers and force the two men perforce
Were extracted without too much pain;
And the sigh of relief, that came from the chief,
Reached the ears of those watching quite plain.
"Let battle commence without more suspense,"
Said J.B., "And this is the way,
You show us the ground the plants you have found
And a tea place you know is OK."

The account of this day, would, if I had my way,
With its toil and its sweat and its sport,
Be recorded to date for the annals of State
In the Survey Progress Report.

Then the A.D. came down from the capital town,
His geologists' work to see.
He was armed for the fray with an auger grey
But it augered bad for me,
For where with my hand I'd recorded sand,
Proved just to be boulder clay.
But he said, "My lad now don't be sad
The best men go astray."

So on this happy note of the A.D.'s quote,
This saga must surely end.
So to the young who are yet unsung
Our sympathies we send.

Huon S. Walton, 1950

Solution to Rocksword Puzzle No. 13

Clues across

1. GEOCENTRIC
7. RI
8. ASTEROID
9. CELL
10. IRONY
11. RARE
14. TALC
16. BORED
17. ARCTIC
18. SO
19. ON
20. NEEP
21. EMERY

Clues down

1. GLACIATION
2. ORTHOCLASE
3. EARLY
4. TRICHROISM
5. RIDE
6. CHALCEDONY
12. ARC
13. RE
15. CROP
16. BT
19. OR

Solution to Geological story puzzle

1. PEAT
2. MARL
3. SPRING
4. MUD
5. BASIN
6. COMBE
7. TALC
8. GEO
9. STOCK
10. BAR
11. CLAY
12. BANK
13. FIELD WORK
14. TILL
15. STACK
16. STRIKE
17. BOSS
18. VENT
19. RIFT
20. FAULT
21. AA
22. TOMBOLO
23. BASALT
24. CALEDONIAN
25. ASH
26. DESERT
27. CONE
28. TRENCH
29. LAVA
30. PENEPLAIN
31. PLATFORM
32. SOLE
33. QUARTZ
34. ICE-CAP
35. GNEISS
36. ORE
37. JOINT
38. NECK
39. NAPPE
40. BED
41. KAME AND KETTLE
42. VEIN
43. OOZE
44. TRIASSIC
45. WEATHERING
46. BEACH
47. SAND
48. ANTICLINE
49. EPISODE
50. CORRIE
51. SCREE
52. ARMORICAN
53. CLIFF
54. KARST
55. EXPOSURE
56. CLEAVAGE
57. MAGMA
58. INTRUSION
59. CLINT
60. WOOD
61. GRIT
62. EARTH
63. CRATER
64. ROCK
65. AMMONITE

Letter to the Editor

The article Archie Remembered *by Eric Robinson in the Spring 2004 issue of this magazine has prompted several people to tell me more about Archie Lamont.* ***Alyn Jones*** *has written to me on the subject of Archie and at the same time opens a discussion on raised beaches on the west coast of Scotland.*

Dunoon
Argyll

1st December 2004

Dear Alan

I enjoyed Eric Robinson's reminiscences on Archie Lamont. As I understood it at the time, he published in the *Quarry Managers Journal* and similar because they paid him and the learned societies didn't. I suspect that he needed the money. As you know, he lived at Jess Cottage in Carlops and still had a room in the Grant Institute in Edinburgh (despite having Arthur Holmes as professor and Doris Reynolds also in the department) when I was a student around 1950. He always seemed to be an amiable person, large and shambling as I remember.

Recently I have been thinking about the raised beaches, especially those around Oban and I cannot see how the cliffs and stacks were eroded since the ice melted. I suggest that they are pre-Quaternary and have been revealed by the removal of glacial debris which here would have been mainly sand and gravel. There is a good example of similar un-burial of a cliff a few miles south of Aberystwyth which I saw many years ago on a Liverpool Geological Society excursion.

Would this be a good subject for debate?

Yours sincerely

Alyn Jones

Well, how about it then?!

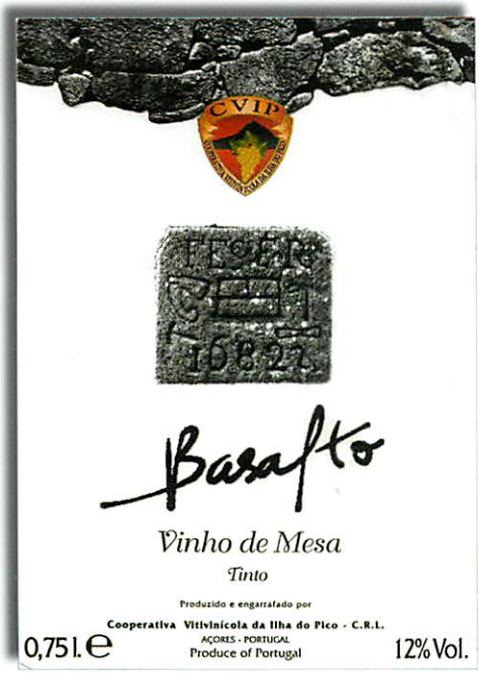
Geo-vineyards

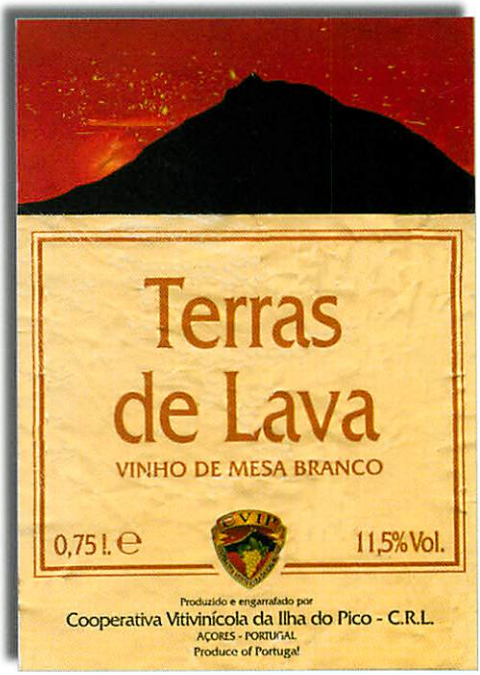
Like all conscientious readers of this magazine, when ***David Stephenson*** *saw these two labels while on holiday in the Azores, he just had to have them. Below he tells us something of the geology of the Azores and how good the wine tastes because of it.*

Portuguese wines are 'different', full of character and always an interesting experience. We are told that this is because they still use the same local varieties of grape that have been grown for centuries and the wines have developed almost in isolation. There are none of the bland cabernet sauvignon- and chardonnay-based wines that dominated the rest of the world and it has been said that the Portuguese make the types of wine that they themselves like to drink, rather than those that the mass market demands.

This was once nowhere more true than in the Azores, a group of nine volcanic islands, straddling the Mid-Atlantic Ridge and hence far away from any continental influence, geological or cultural. However, this did not protect them from the fungal diseases and parasites that ravaged most of the vines of Europe in the mid nineteenth Century. The vineyards that had been established by the first settlers in the sixteenth Century were wiped out and had to be replanted with resistant varieties from North America. Now EU regulations prohibit the sale of the more traditional local wines and new grape varieties have had to be introduced. The most extensive commercial vineyards seem to be on the island of Pico, which is crowned by a beautifully symmetrical volcanic cone that rises to 2351 m above sea level and hence is the highest mountain in Portugal. This largely basaltic volcano, commonly veiled by ethereal wispy clouds, dominates the view from the other central islands of the archipelago, none of which rise to much more than 1000 m. The last eruptions were in 1720 and now its lower slopes are criss-crossed by low walls of jagged lava blocks that protect the small vineyards from the wind and give this young landscape its most distinctive character.

The two wines, one red and one white, whose 'volcanological' labels are illustrated here, typify the new, more commercial varieties and seem to be the most popular locally. They are the house wines in most restaurants throughout the islands and are widely available in the supermarkets. I can testify that they are both most eminently quaffable, having consumed many bottles during our recent two-week visit; we even brought some home as presents. Unfortunately we never got to sample some of the higher quality wines which, it is said, once graced the tables of the Tsars of Russia.





The classic volcanic cone of Pico in the Azores

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