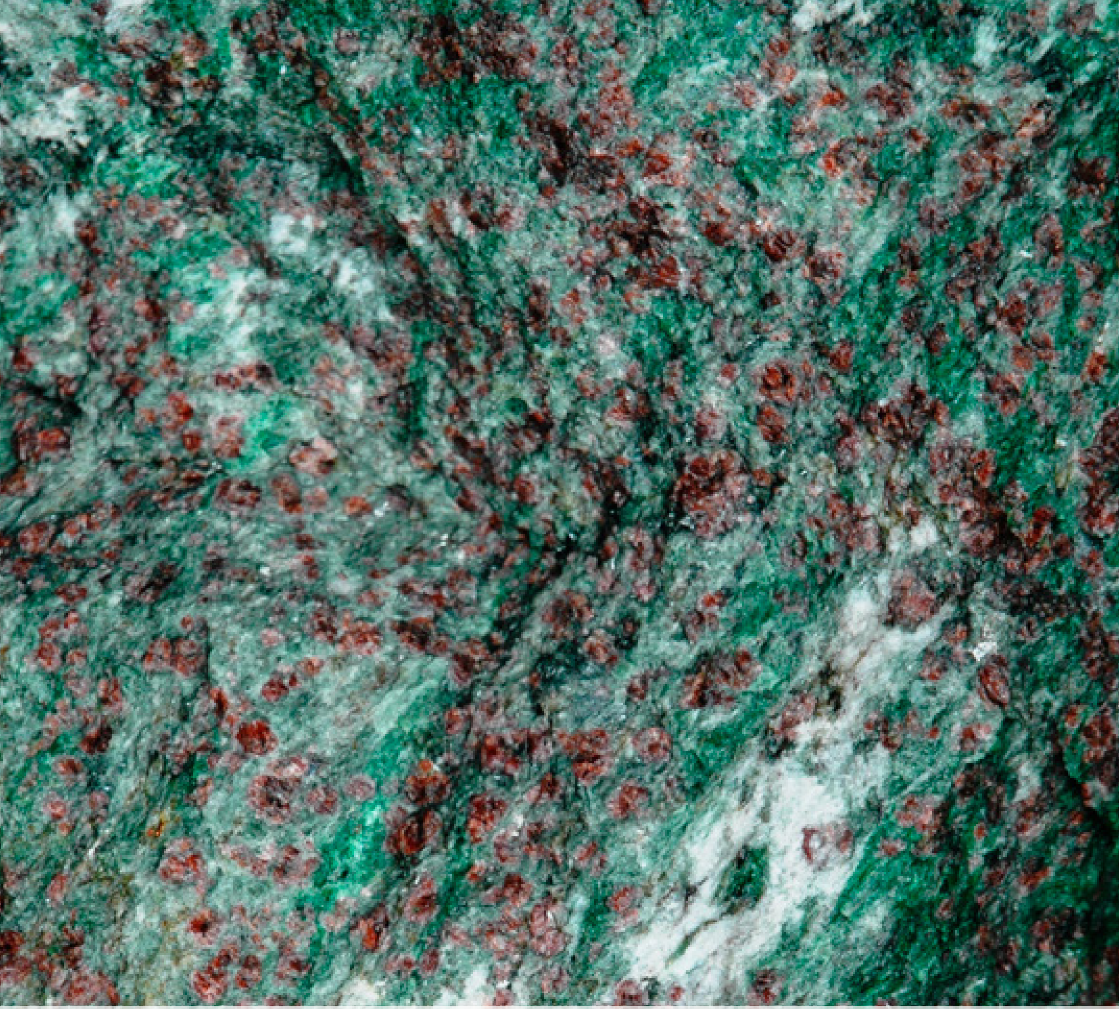

The Edinburgh Geologist

Magazine of the Edinburgh Geological Society

Issue No 59 Spring 2016

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Cover Illustration

An aluminous eclogite from Verpeneset, Nordfjord (Central Norway), composed of omphacite (bright green), garnet, clinozoisite, quartz and kyanite. Parts are altered to phengite, talc and tremolitic amphibole. The amphibole-bearing cores of the garnet have been dated at c. 425 Ma and their eclogite–facies rims at c. 405 Ma. The mineralogy shows that the rocks reached pressures of 28.7 kilobars and temperatures of about 700°C. For more on eclogites see the excursion article by Beverly Bergman and others. Photograph by John Mendum.

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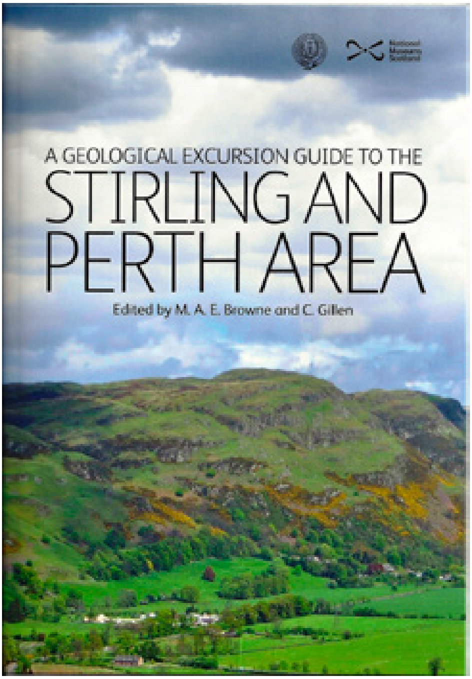
Here's tae us; wha's like us?

An editorial ramble by Phil Stone

This issue of *The Edinburgh Geologist* has evolved into a celebration of the activities of the Edinburgh Geological Society, touching on the Society's history, excursions, publications, lecture programme, awards and financial support for geological fieldwork. We can be justly proud of the achievements made in all these areas, as illustrated by the selection of articles herein.

First, something of the Society's history is celebrated by Hamish Johnston, who describes the involvement of the eminent mineralogist Matthew Heddle (his great-great-grandfather) soon after the founding of the Society in 1834; Heddle became President in 1851. Back in January this year, Hamish lectured to the Society on Heddle's life and achievements, and his recently published biography of the great mineralogist can be thoroughly recommended. As an aside, but remaining on a presidential theme, this seems like a good opportunity to welcome back Stuart Monro for his second stint as EGS President.

And thinking of books, there are two deserving of mention that reflect, in different ways, on the EGS. Our book review for this issue is the second edition of Brian Upton's *Volcanoes and the Making of Scotland*, whilst *A Geological Excursion Guide to the Stirling and Perth area* is the latest in the Society's series of regional handbooks intended to encourage the exploration and enjoyment of Scotland's geology. Brian is a long-standing member of the Society perhaps best know for leading many field excursions and as the 2000/2001 Clough Medallist; his contributions were recently recognised by promotion to a Society Distinguished Fellowship. Another EGS member elevated to a Distinguished Fellowship at the same time, Mike Browne, was responsible, in collaboration with Con Gillen, for pulling together the Stirling and Perth guide. It has been a long-term project for the two of them and it is good to see the finished product turning out so well. The book is well laid-out and illustrated in colour, with an eclectic mix of eighteen excursions drawn-up by combinations of sixteen contributors. The geology of the area affords much geological variety: Dalradian, Highland Border Complex, Devonian and Carboniferous sedimentary and igneous rocks, and Quaternary deposits and landforms. All this is supplemented by features on the building stones of Perth and Stirling, and on the mineralisation at Alva.



The Stirling and Perth excursion guide represents the traditional face of EGS publications, but these days an online approach is also necessary. In his article, Bob McIntosh explains how the Society's publications are being incorporated into an interactive, web-based platform, *Earthwise*, devised and hosted by the British Geological Survey. The EGS content supports an anthology of Scottish geological walks, and the format allows easy additions of access or locality information, with the tempting facility to upload notes, comments and photographs immediately after — or even during — a field excursion. What will they think of next?

Staying with the excursions theme, we have an interesting, multi-author account of the geology experienced by participants in last summer's Society excursion to the Norwegian Caledonides; thanks to Beverly Bergman for pulling it all together. Eclogites clearly featured prominently (hence our cover picture) but were not the only fascinating and attractive rocks to be seen, with the back story of high-grade metamorphism and polyphase structure adding bewildering complexity. It's obvious from the 'daily diaries', each written-up by a different contributor, that the excursion leader, Simon Cuthbert, proved remarkably adept at explaining it all — even in the rain!

A very different geological experience is described by two M. Earth Sc. students at the University of Edinburgh. Rachel Whitty and Isla Simmons travelled to Iceland during the summer of 2015 as volunteer assistants in the island's volcano monitoring programme, an enterprise for which the EGS provided some financial support through its Clough Fund. Some of us enjoyed a summary of their volcanic experiences at Fellows' Night and their contribution to this issue of *EG* is most welcome — it's also informative and entertaining and demonstrates good use of 'Clough' resources. Just to remind everyone (and to alert any potential future applicants), grants from the Clough Fund are normally of the order of a few hundred pounds and are available to support geological work at home or abroad. Grants may be awarded for fieldwork or other geological enterprise in any area, provided that a suitable Scottish connection can be demonstrated through the recipient or their institution, or through the work itself.

Goodbye Murchison, hello Lyell

You might have noticed that inside our front cover the editors have a change of address. As *EG* goes to press, the British Geological Survey is abandoning Murchison House, its Edinburgh home since 1976, and moving out to the new Lyell Centre at Heriot-Watt University's Riccarton campus. The EGS has enjoyed a supportive, fraternal relationship with the Survey for many years but, inevitably, with the move our links will be strained or perhaps even severed, at least in the short term. Maintaining or rebuilding those links will be one of the challenges facing Stuart Monro as he resumes presidential office. It's encouraging to note that his two newly-elected vice-presidents, Bob Gatliff and Emrys Phillips, both occupy senior positions within BGS and so are ideally placed to restore the proper state of affairs. Good luck gentlemen.

The Lyell Centre nearing completion early in January 2016.

John Horne's Memoir—Signatures from the 1912 & 1914 Assynt excursions

By John Mendum

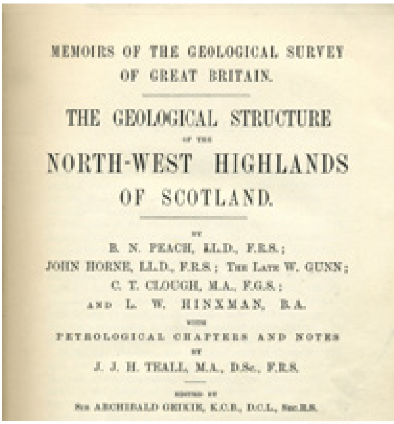
During recent stocktaking at Murchison House a copy of the Northwest Highlands Memoir (Peach et al, 1907) was found in the Palaeontological Department. It has been rebound but is in excellent condition with little signs of use and no obvious foxing. The memoir contains detailed descriptions of the Lewisian, Torridonian, Moine and Cambrian-Ordovician rocks in the Durness to Kyle of Lochalsh area, summarising the results of the survey's detailed work there in the late 19th century. This copy patently belonged to John Horne who was Assistant Director in the Geological Survey in Scotland from 1901 until his retirement in 1911.

The flyleaf of the memoir contains the signatures of 29 attendees of the renowned 1912 excursion to Assynt, which followed on from a British Association meeting in Dundee in mid-September that year. This excursion, led by Peach and Horne, was attended by 31 notable European and British geologists (see Barber, 2010).

The flyleaf also contains the signatures relating to an excursion undertaken in 1914, when John Horne took a further party to Assynt. Attendees included Sir Alexander and Lady (Rachel Workman) MacRobert, but also included the well-known geologists Reginald A Daly and Professor Molengraaf. Rachel Workman, the daughter of the noted American mountaineers William and Fanny Workman, was educated at Cheltenham Ladies College and gained a degree in geology from the University of London in 1902. She undertook research and published papers on alkaline igneous rocks (e.g. carbonatite and nepheline syenite) and was one of the first women to be elected a fellow of the Geological Society in 1919. Information on the MacRobert Trust, including her ladyship's contribution to the Second World War effort, can be found at http://www.themacroberttrust.org.uk/. The memoir is to be archived by BGS.

Peach, B N., Horne, J, Gunn, W., Clough, C T, Hinxman, L W and Teall, J J H. 1907. *The geological structure* *of the northwest Highlands of Scotland*. Memoirs of the Geological Survey, U.K.

Barber, A J. 2010. Peach and Horne: the British Association excursion to Assynt September 1912. *In* Law, R D, Butler, R W H, Holdsworth, R E, Krabbendam, M and Strachan, R A. (editors) *Continental Tectonics and Mountain Building: The Legacy of Peach and Horne*. Geological Society, London, Special Publications, **335**, 29–49.

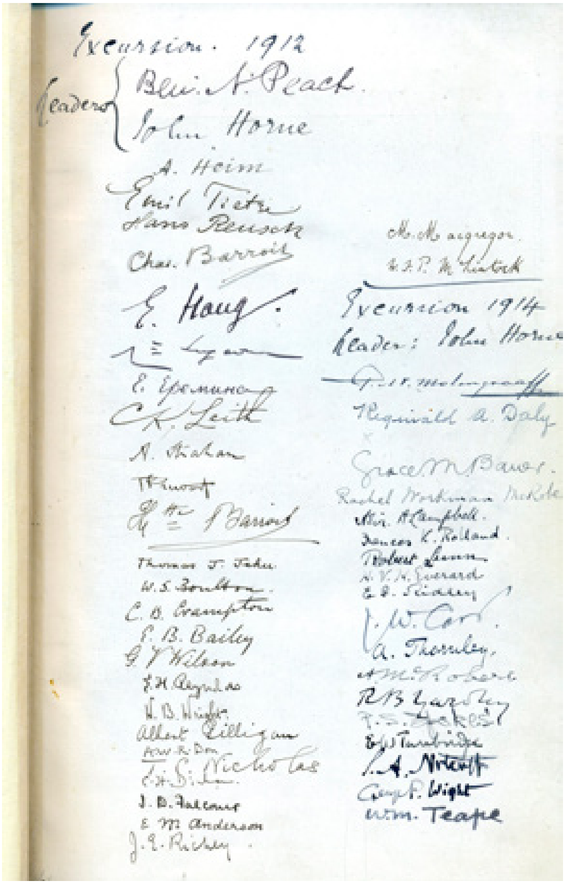


MEMOIRS OF THE GEOLOGICAL SURVEY
OF GREAT BRITAIN.

THE GEOLOGICAL STRUCTURE
OF THE
NORTH-WEST HIGHLANDS
OF SCOTLAND.

BY
B. N. PEACH, LL.D., F.R.S.;
JOHN HORNE, LL.D., F.R.S.; THE LATE W. GUNN;
C. T. CLOUGH, M.A., F.G.S.;
AND L. W. HINXMAN, B.A.
WITH
PETROLOGICAL CHAPTERS AND NOTES
BY
J. J. H. TEALL, M.A., D.Sc., F.R.S.

EDITED BY
SIR ARCHIBALD GEIKIE, K.C.B., D.C.L., Sec.R.S.



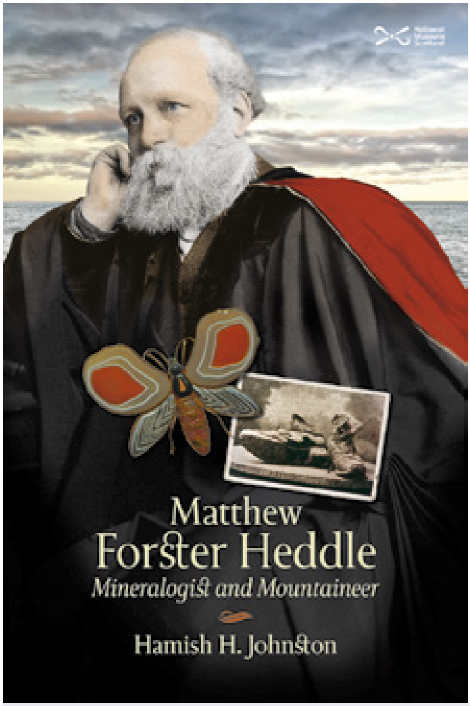
Excursion. 1912
Leaders { Ben N. Peach
John Horne
A. Heim
Emil Tietze
Hans Reusch
Chas. Barrois
E. Haug
C. K. Leith
Excursion 1914
Leader: John Horne
Reginald A. Daly
C. B. Crampton
E. B. Bailey
A. Thornley
Wm. Teape

The 1914 excursion group. Lady MacRobert is seated third from right, middle row, next to John Horne. BGS image P883132.

Matthew Forster Heddle and the Edinburgh Geological Society

By Hamish H Johnston

Matthew Forster Heddle (1828–1897), author of the classic work *The Mineralogy of Scotland* (1901), is a name familiar to members of the Edinburgh Geological Society (EGS). In 2002 I was able to help Peter Dryburgh, whose paper on the story behind his copy of Heddle's great work was published in *Edinburgh Geologist* number 39. The book originally belonged to Heddle's daughter Cecilia, who was my great-grandmother. Since then, retirement has given me the time to research and write the first-ever biography of Heddle. *Matthew Forster Heddle: Mineralogist and Mountaineer* combines original research and family records to provide much new material and the fullest available account of Heddle's life and work. It includes the full story of Heddle's involvement with the EGS, of which he was President from 1851 to 1853.



The biography is published by NMS Enterprise Ltd., ISBN 978 1 905267 98 9. 270 pp. Price £14.99. 2015.

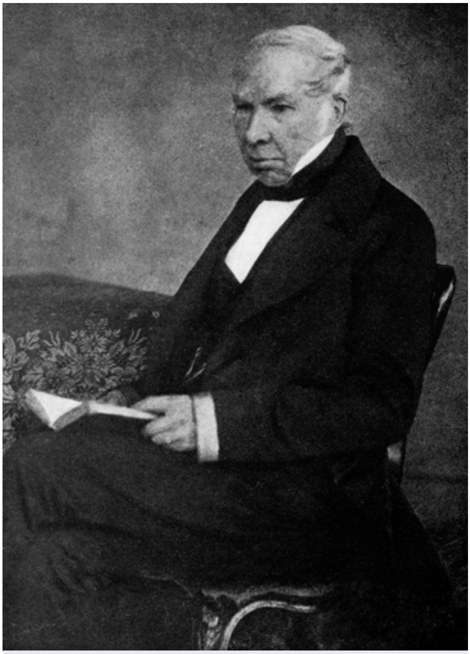
The book also gives a full account of Heddle's childhood, education and medical career, his time (and troubles) at St Andrews University, his comprehensive exploration of Scotland's mainland and islands, his scientific work, his role in founding the Mineralogical Society, his prolific papers in the *Mineralogical Magazine* and for the Royal Society of Edinburgh (which led to the award of its prestigious Keith Prize), his mountaineering achievements, his role in the controversy over the geology of North-West Scotland, his involvement in the goldfields of South Africa, the destination of his great mineral collection, and the writing of his encyclopaedic *The Mineralogy of Scotland* (1901).

Heddle's parents came from Orkney. With a large fortune made from trading in West Africa his father bought the Melsetter estate on Hoy in 1818, and married the daughter of its bankrupt owner. Heddle and his siblings were orphaned in 1842, by which time he was at school in Edinburgh, first at the Academy and then at Merchiston Castle, to which he was moved by his Curators. In 1844 Heddle began medical studies at the University where he was taught by such eminent professors as James Young Simpson (1811–1870). The medical curriculum included Natural History, of which the Professor was the great Robert Jameson (1774–1854). With William Gregory (1803–1858), Professor of Chemistry, Jameson was to be a major influence on Heddle, who had already developed a collecting habit—first plants, and then rocks and minerals. The first documented record of Heddle's mineralogy is in 1846 when he gave a collection to a newly established museum in Kirkwall. In 1850, encouraged by Jameson, Heddle spent several months in the German mining and teaching centres of Clausthal and Freiberg, where he studied and returned with valuable mineral specimens. He catalogued his collection of some 560 items in a notebook entitled Cabinet of Minerals 1850. On his return Heddle completed his M.D. thesis, The Ores of the Metals. Heddle graduated in 1851 and for the next five years worked, somewhat reluctantly, as a doctor in the Grassmarket area of Edinburgh. His home was in Clarence Street in Stockbridge. A contemporary wrote later that while at University Heddle had given almost exclusive attention to mineralogy. Another remarked on the size and quality of his collection, and the laboratory he set up in his home. Mineralogy, not medicine, was Heddle's true interest.

This was the young medical student who, enthused by his German travels, joined the EGS in late 1850. Earlier Heddle had met the collector and teacher Alexander Rose (1781–1860) whose classroom in Drummond Street was used for EGS meetings. It was here that Heddle first met Archibald Geikie. Rose had been a co-founder of the EGS in 1834, but by now the Society was rather moribund, with no minutes kept for the two years from December 1849. In October 1850, the Vice-

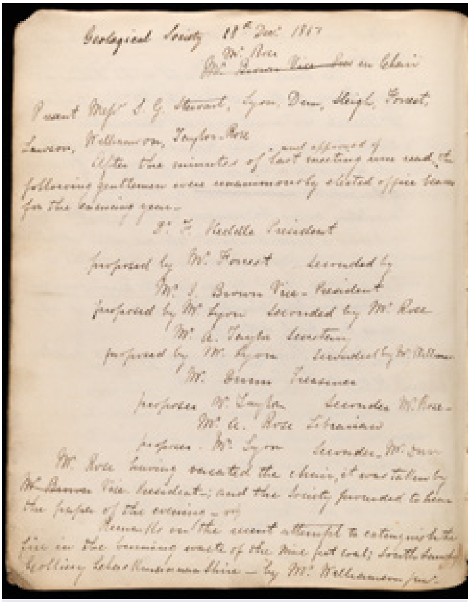
President, James Brown, submitted a lengthy report on the poor state of the Society. While the Society had low fees, a meeting room and museum, its membership was only 27, including the 5 office bearers. Attendance at meetings was poor. Sometimes speakers did not turn up. There were no organised excursions. Importantly, the Society did not publish Transactions, and academics and gentlemen did not deign to join. Brown told the Society that it must change, and aspire to compete with other recognised scientific Societies.

The first published reference to Heddle and EGS is a report in *The Scotsman* of a meeting in February 1851 at which Heddle spoke on the chemistry of imported guano, and on the mineral prehenite found in Scotland. Heddle was soon noticed for his ability and for instructing other Society members, so when at the meeting on 4th December 1851 the time came for annual elections, Alexander Rose, probably responding to Brown's criticisms, nominated Heddle for the post of President. Despite this the 5 members present (Heddle not being among them) elected Rose but he declined the post. The meeting closed with no decision reached. Rose must then have leaned on those opposed to Heddle (who was only 23, and straight out of University) because he was elected President unanimously at the next meeting on 18th December 1851.



Alexander Rose (1781–1860) in later life. BGS image P228693.

Heddle was to be President till 1853, then Vice-President till October 1862. During the two years of his presidency Heddle gave 8 talks and demonstrated specimens on such topics as titanium, emerald nickel, edingtonite, and the analysis of zeolitic minerals. A talk on metals in the native state was so complex that he was asked to reprise it in sections on later occasions. During Heddle's presidency the Society also discussed

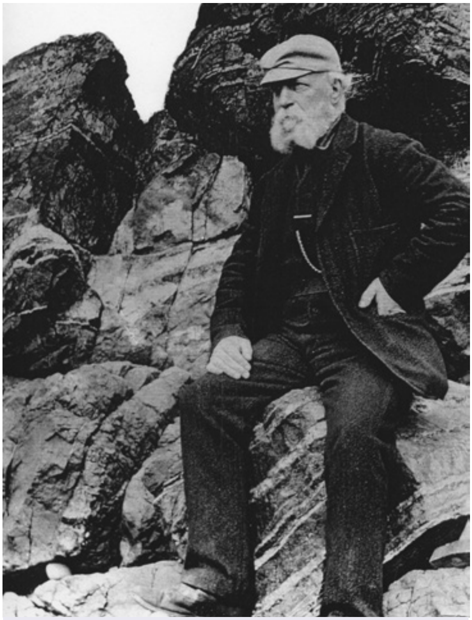


Edinburgh Geological Society's minute book recording Heddle's election as president. By permission of Edinburgh University Library Centre for Research Collections.

other matters. In 1852, and again in 1853, it lobbied government for the replacement of Jameson's College Museum (which was already too small) with a new Natural History Museum in Edinburgh. Heddle's motion that it should be free to the public at all times was seconded by Rose, and the Society agreed to hand over its collection of minerals. Heddle was charged with preparing the case. In due course, with other bodies also urging action, what is now the National Museum of Scotland came into being in the 1860s. In 1854 the Society urged the speeding up of the mapping of Scotland by the Trigonometrical Survey, and in the same year it even lobbied for the introduction of decimal currency!

If Heddle presented innovative papers to the EGS his role as President was less impressive. The Society met on 38 occasions during Heddle's presidency, but he was present at only 17 meetings. A year after he stepped down to Vice-President his attendance and input dropped off to almost nothing. It is clear from the perfunctory minutes that as President Heddle made no progress on Brown's recommendations, and that under him the performance of the Society was little better than before. While Heddle was an expert and enthusiastic mineralogist, he was not a committee man. Also, the EGS needed a reforming leader, and while Heddle may well have had some good ideas, the aged Rose, to whom the Society owed much, was the Secretary, hardly the man to drive change.

One obvious reason for Heddle's absences is that he was a working doctor, but there was another reason. Heddle had learned from Jameson the importance of publishing scientific papers, and he was very keen to share his own discoveries. The EGS did not publish *Transactions*, so Heddle had to look elsewhere. Before he became EGS President in 1851 Heddle had already become a Fellow of the Royal Physical Society of Edinburgh (RPSE — not the same organisation as the Royal Society of Edinburgh). Between December 1854 and April 1856 Heddle read and published 8 papers with the RPSE and in 1856 he was elected a Council member. Also, between 1855 and 1859, 13 Heddle papers were published in David Brewster's *Philosophical Magazine,* then the country's most prestigious scientific journal. Here Heddle was in illustrious company: in March 1855 Heddle's *Analysis of the Mineral 'Edingtonite'* was bracketed by papers from Boole and Bunsen.



Matthew Forster Heddle (1828–1897) in his favourite environment. By permission of National Museums Scotland.

All in all, It is not surprising that the EGS, and indeed medicine, were not top of Heddle's priority list. He was appointed temporary Assistant Professor of Chemistry at St Andrews University in 1856 to cover for the sick Professor Connell, but it was not until 1862, when he became Professor in his own right, that he left the EGS. He then appears to have had little more to do with the Society until much later in his life. The EGS took off in the mid-1860s, not long after Rose's death and Heddle's departure. It found new accommodation, greatly improved its administration, engaged in some clever public relations, improved its membership, and from 1867/8 began to publish *Transactions*. It also started to attract eminent honorary members, although Heddle was not among those invited. In 1884 he was elected to associate (honorary) membership, however, and in March 1897 Heddle read his *On Analcime with New Forms* at the EGS, a few months before his death.

The EGS Long Excursion to Norway 5–12 June 2015

By Beverly P Bergman, Christine L Thompson, Richard A Smith, David Blythe, Stephen Livera, Alison Tymon and Douglas Holliday

The steadily-growing pile of suitcases, rucksacks, sticks and boots at a convenient rendezvous by the atmospheric (in more ways than one) Fisketorget (Fish Market) in a sunny Bergen, Norway, bore witness to the imminent arrival of an intrepid party of geologists, at the start of the Edinburgh Geological Society's first venture into foreign parts. As the afternoon drew on, we embarked on the high-speed (well, relatively speaking) ferry which was to take us northwards through a magical landscape of narrow fjords, mountains, and even, for the sharp-eyed, a glimpse of a spectacular example of retrocharriage on one of the islands in the distance. Eventually we crossed the broad (c. 4.5 km) Sognefjord and reached the area which was to be our home for the next week. Arriving at our destination, Selje (Figure 1), we quickly settled into our hotel and self-catering accommodation and met up with our leader, Simon Cuthbert (University of the West of Scotland and Geological Society of Glasgow). Selje (185 Km north of Bergen) is most conveniently situated for exploring the eastern (Scandinavian) half of the Caledonian collisional belt, the orogen's western counterpart being on the east coast of Greenland.

During our six days at Selje, we began with the orogen's deepest exposed levels and worked our way up through a pile of thrust sheets

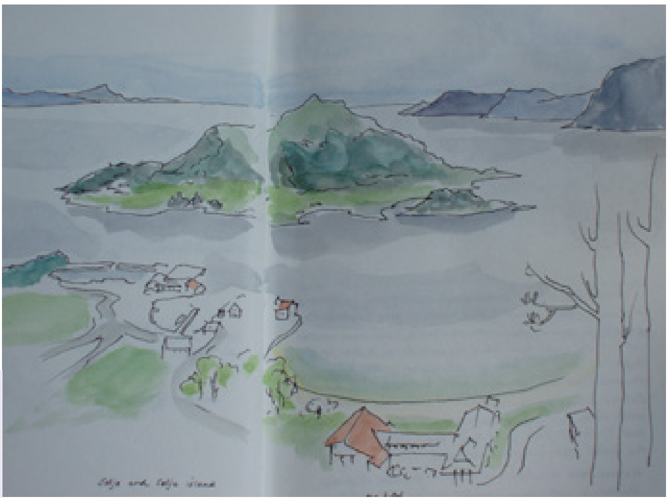


***Figure 1** View from above the hotel at Selje © Alison Kerr*

('allochthons') to the youngest rocks (Devonian) in the area. On the first day Simon introduced us to the Western Gneiss Complex; Proterozoic basement rocks revealed through a 'window' in the overlying thrust-sheet pile. A walk along the shoreline immediately north of the hotel introduced us to the gneisses, typically pink and grey apart from pods of mafic metamorphic rock enclosed within them. We halted at Grytting, where two of these pods are clearly of eclogite. They are now a national scientific monument because it was here in 1921 that the Finnish petrologist, Pentii Eskola (1883–1964), realised that eclogite, being of high density, must have formed under ultra-high load pressures and therefore at great depths. He designated one of the two pods as the type locality of 'eclogite-pegmatite of the Grytting type'.

In 1984 the other pod was found to contain the very high-density form of silica, coesite, an indicator of ultra-high-pressure metamorphism, such as would be experienced at mantle depths of 70 km or more. How did such high-pressure rocks come to be enclosed in apparently lower-grade gneisses? Simon explained that more recent discoveries of microscopic evidence of coesite and even diamond in the gneisses suggested that they too had experienced mantle conditions. Over the rest of our week in Norway, we built up a plate tectonic explanation for the co-existence of the crustal gneisses with mantle-derived eclogites and for their relationship with the overlying thrust sheets.

The following day brought a veritable feast of spectacular eclogites, and developed the theme of the previous day that some eclogites had been in the mantle alongside their country rocks. This concept was reinforced with further evidence of ultra-high-pressure metamorphism in both the eclogites and the surrounding schists and gneisses. The day culminated with a visit to Verpeneset to examine two large eclogite bodies including a stunning bright green omphacite + garnet + kyanite + clinozoisite + quartz eclogite. [see cover picture–Ed]

Day 3 introduced rocks that had escaped such extreme metamorphism and demonstrated characteristics of the old Proterozoic crust of Baltica. The first stop was at Flatraket, a large roadstone quarry which included both deformed and undeformed granulite facies coarse-grained monzonite, known locally as 'mangerite' (Figure 2). In places this spectacular rock contains characteristic large cm-diameter undeformed spherical orthoclase feldspars with locally well developed white plagioclase reaction rims. Original zircon ages of about 1520 Ma are recorded from the intrusion and the granulite facies shows low P-T conditions compared to other rocks seen earlier and surrounding the monzonite body. The quarry also contains dark meta-gabbros containing pink garnets, the first stage of a gabbro to eclogite transition. The meta-gabbros are thought to be basic dykes intruded into the monzonite and their margins were sheared. Further well developed green epidote-lined shear zones are recorded throughout the mangerite.

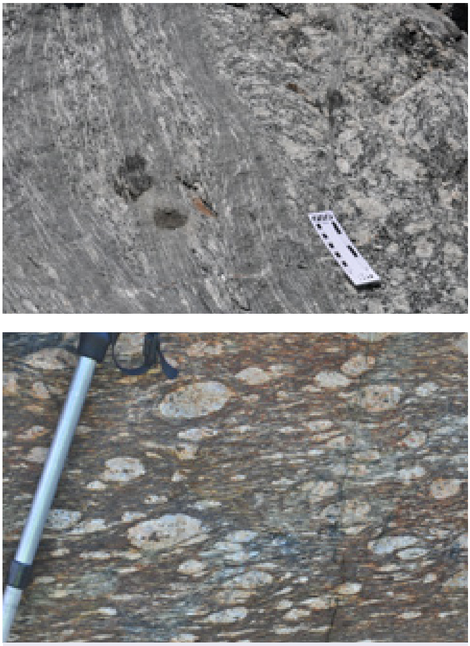


Figure 2 Aspects of the variable deformation in 'mangerite' at Flatracket Quarry. Photographs © Beverly Bergman.

Moving on to Krakenes, the sun shone and there was a beautiful view of the lighthouse and fjord coastline (Figure 3). This headland includes another rapakivi-textured monzonite (Figure 4) with well-exposed, dark mafic enclaves where feldspar had recrystallised in the original basaltic rock. Again, the monzonite is adjacent to dark layered gabbro which shows only partial evolution to eclogite. These bodies are surrounded by migmatitic and non-migmatitic paragneiss which contains coesite. It is not clear why the mangerites demonstrate relatively unmodified conditions, where the plagioclase feldspars have not reacted to form pyroxene and garnet, and it is thought that the rocks may have been too dry to re-crystallise. Eclogite minerals need water as a reaction catalyst and in its absence, reactions are so sluggish that it is possible to get unreacted plagioclase at 10 kbar. The day finished with a visit to the Kannesteinen coastal rock pedestal on Vågsoy Island, which was enthusiastically photographed before attention was diverted back to the beautifully deformed eclogite pods in the adjacent wave cut platform.

Early on Tuesday 9th June we visited the Lien Nature Reserve which

***Figure 3* Coastal section at Krakenes. © Alison Kerr.**

covers part of the Almklovdalen peridotite body, near Åheim. The peridotite body is considered to be a block of sub-Laurentian mantle, which dropped into the Western Gneiss Complex (a subducted part of Baltica) from an over-thrust slab of Laurentia. The reserve was created to protect garnet peridotite masses within the chlorite peridotite and dunite that form most of the body. The mantle block is about 4 km across at outcrop, but the garnet peridotite pods within it are only about 150 m in length. Previous specimen collectors had ravaged the pods so the area has been protected by law against further hammering and collecting. The surrounding hills of the ultramafic massif are distinctly brown-coloured and the vegetation sparse, so we were delighted to get to the top of the hill and find the variegated colours in the excellent garnet peridotite exposures skirted by sparkling purplish-red garnet fragments. The rocks all contain olivine with an extremely high magnesian content indicating that these mantle rocks were depleted after a mafic magma had been extracted from them.

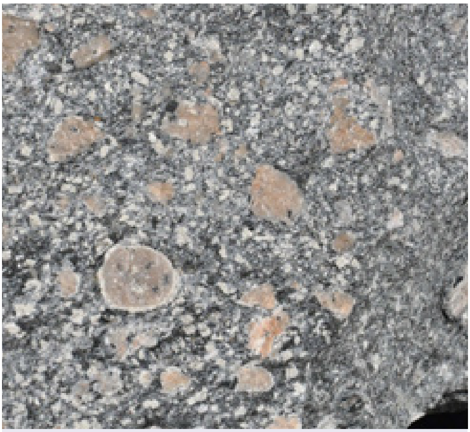


***Figure 4* Rapakivi texture in monzonite (monzogranite s.s.), Krakenes. The largest megacryst is about 2 cm in diameter. Photograph © Beverly Bergman.**

The garnet peridotite contains a metamorphic assemblage of olivine + orthopyroxene + clinopyroxene + garnet, which is regarded as having been formed during mid-Proterozoic times, while the peridotite was still in the mantle. The garnet peridotite and garnet pyroxenite interlayering is considered to reflect dyke intrusion in the mantle. Because of the layering, folds can be seen which predate the pervasive amphibole and chlorite fabric in the main peridotite body. Within the garnetiferous pod, purplish-red chrome-rich garnets are typically surrounded by green 'kelyphytic rims' composed of small radiating grains of amphibole and spinel with some pyroxene in places (Figure 5). This is the result of a decompression reaction between olivine and garnet which occurred during the later Caledonian history.

Our next stop was Gusdal Quarry where a major constituent of the Almklovdalen peridotite body, dunite, is quarried. The fresh, anhydrous olivine is crushed to 3 mm grain size and fed through a tunnel to a deep-water loading facility at Åheim. Most of the olivine is used as a slag conditioner in the iron and steel industry and is exported to countries such as the UK, Brazil and India. With an annual production of 1.8 million

***Figure 5** Garnet peridotite, Lien Nature Reserve. Chrome-rich garnets showing green 'kelyphytic rims'; the largest garnet is about 2 cm long. Photograph © Richard Smith.*

tonnes, the quarry has an estimated life-span of 100 years but could be extended to recover much greater volumes, possibly for up to 300 years.

Finally, beside the road to Raudkleivane olivine quarry, now closed, we examined exposures of chlorite peridotite enclosing boudins of 'internal' eclogites. The chemistry of the eclogites suggests they originated as dykes intruded into the upper mantle during the opening of the Iapetus Ocean. Their mineralogy indicates that subsequently, they and their host peridotite, after dropping into the descending Baltic slab, were carried further down before being exhumed. 'External' eclogite pods are also found in the surrounding gneissose country rocks.

The following day, the overcast conditions of the previous few days gave way to torrential rain, testing both Gore-Tex® and enthusiasm for geology. The programme for the day took us away from the Western Gneiss Complex into the nappes/allochthons above the Nordfjord-Sogn Detachment Zone (NSDZ). We took the ferry across Nordfjord to look at 4 km thick ultra-mylonites which represent up to 100 km of movement of the subducted crust of Baltica. Unsurprisingly, the dark green, highly foliated rocks had strung-out lenses of pink and green minerals, with some shear indicators. Above the NSDZ is a series of nappes which piled up on Baltica as the Iapetus Ocean closed. The Lower Allochthon gneisses were invisible in the mist, but we observed, from the refuge of a convenient bus-shelter, a hillside of very thick Middle Allochthon quartzites, once a psammitic continental cover, now tilted nearly vertically. At Kalvåg, we ate our packed lunches, hunched miserably in the minibuses in a grim, dark and wet graphite schist quarry with pale metacherts, the altered ocean sediments above an obducted ophiolite sequence dated to at least 442 Ma. At the Rylandsvatnet reservoir we braved the rain and wandered over ice-rounded greywackes contained in huge olistoliths in a melange, and thermally metamorphosed to spotted rocks containing lumpy masses of cordierite and sillimanite crystals by granodiorite sheets emanating from a nearby intrusion. But the day ended splendidly with a stop at Bremanger, where the whole group piled into an extravagantly decorated cafe run by an exuberant Thai lady who fed us with tea, coffee and paper bags full of prawn crackers.

The rain continued overnight, contributing to the magnificence of numerous waterfalls which we could admire in addition to the geology. The last day was devoted to an overview of the Middle Devonian Hornelen Basin, which was not, as many of us had suspected, added to the programme simply to appease the soft-rock enthusiasts in the party, but in fact formed the final preserved component of the structural story of the area. Like other Devonian basins in the region, the Hornelen Basin sits on a low-angled normal detachment and is confined to the synformal area seen the previous day containing the allochthonous units overlying the Western Gneiss Complex. Though much less deformed than the older rocks, the Devonian strata have undergone low-grade metamorphism, are commonly steeply dipping and, particularly at the southern margin, exhibit some significant folding, as we saw at Grondalen.

The Devonian rocks dominantly comprise relatively coarse sandstones of braided fluvial origin exhibiting W to WSW palaeocurrents along the basin axis; locally derived alluvial fan breccias formed at the faulted basin margins. Floodplain and lacustrine finer grained siltstones and mudstone occur in some areas. The Western Gneiss Complex seems not to have been exposed during the deposition of the Hornelen sediments whose provenance is largely from the Middle Allochthon and, more locally on the northern margin, from the Upper Allochthon. Perhaps the most characteristic feature of the basin is the spectacular step-topography formed by abundant, <c. 100 m scale, coarsening-upwards cyclothems which are laterally continuous between the alluvial fan and the fluvial domains.

Towards the end of the day, the weather cleared and from the deck of the Isane-Starheim Ferry, Simon was able to demonstrate in the adjacent mountain sides the basal detachment fault under the Hornelen Basin and also revisit some of the geological themes of previous days. Thus the Long Excursion of 2015 ended most appropriately in sunshine amid splendid scenery.

Acknowledgments

With grateful thanks to Anne Burgess for organising the Long Excursion, to Simon Cuthbert for his leadership, for sharing his knowledge, and above all, for his good humour, and to Alison Kerr for contributing some of her sketches to this article.

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Volcano Monitoring in Iceland

By Rachel Whitty and Isla Simmons

Iceland is of such geological interest that, to anyone studying for a degree in Earth Sciences in Edinburgh, the volcanic island just 750 miles to the north is a huge draw. During the summer of 2015, and following our 4th year of university, we were excited to finally get there, with some help from the Edinburgh Geological Society's Clough Fund.

We had arranged for a month's voluntary work with Veðurstofa Íslands (the Icelandic Meteorological Office) which, together with the University of Iceland, is responsible for monitoring Iceland's many active volcanoes. The methods used include studies of gas emissions and seismicity, with results analysed to determine whether or not a volcano shows signs of unrest. We were taken under the wing of Melissa Pfeffer (a gas volcanologist) and our main task was to process gas emission data from Hekla, one of Iceland's most active volcanoes.

Gas Processing

Gas emissions from Hekla are continuously measured by an automatic MultiGAS station located at the summit. This data is sent to the office in Reykjavik, where it is processed to compare the emissions of different gas compositions. Processing the MultiGAS data was achieved using Ratio Calc 2.5, a software system allowing comparison of different gas emissions to find correlations. The Hekla MultiGAS station had a year's worth of data backlog and our first job was to process this data. With two of us working on the task, it took just over two weeks to clear the backlog, and collate the data from July 2014 through to July 2015 into a format that could be used for scientific research.

When we had finished processing the data from Hekla, there was then plenty of other unprocessed data for us to work on, from the numerous other volcanoes around the country. It felt good to know that our work had real scientific value – this wasn't just a course assignment for university, this was real data and processing it was of scientific importance. This was highlighted one afternoon when we were called in to a meeting with three visiting scientists from Italy who wanted to discuss our results. Fortunately for us the scientific language was English, although conversations often slipped into Icelandic or Italian.

Seismic Monitoring

As well as our daily work processing volcanic gas data, we also had the opportunity to be involved with other scientific work being carried out at Veðurstofa Íslands. The seismology department held a weekly meeting to discuss seismic activity in the country over the past week, and we were invited to attend. Most exciting for us was the day that an emergency meeting was called — a seismic swarm had begun off the Reykjanes Peninsula overnight, and there was concern that this indicated a submarine volcanic eruption. We were just silent observers, listening in at the back of the room but it was fascinating to hear the discussions over the implications of what the seismic activity may mean, and what should be done — was the activity purely tectonic? Or was an eruption imminent? Should the Volcanic Aviation Colour Code be upgraded from green to yellow? Should the coastguard be informed? It was interesting to witness first hand that science is not about right and wrong answers – it's about evidence and interpretations, and things can get quite heated when different people have different views on a situation!

Fieldwork

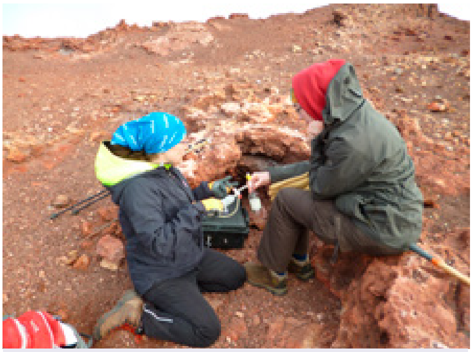
In our second week of working at Veðurstofa Íslands we had the opportunity to help with fieldwork. After driving from Reykjavik to the tiny ferry terminal at Landeyjahöfn, a 30 minute boat trip (complete with killer whale and puffin sightings) brought us to the island of Heimaey, about 5 miles off the south coast of Iceland. At 13.4 km^2, Heimaey is the largest and only populated island of the Vestmannaeyjar, an archipelago of 17 volcanic islands and skerries.

The dramatic silhouette of Heimaey appeared out of the drizzle as we sailed closer, towering cliffs rising vertically from the sea to form a rugged skyline with hundreds of sea birds wheeling overhead. The volcanic cones of Eldfell and Helgafell could be seen dominating the island. Eldfell erupted without warning in 1973, destroying over 400 homes and leading to temporary evacuation of the island. As a fishing community, the islanders depended on the harbour for their livelihood and it was feared that the advancing lava would block it. With a lot of effort, the lava flows were re-directed, saving the harbour.

The purpose of our trip to Heimaey was to measure the gas emissions from Eldfell. Melissa makes the trip every year to collect gas samples with the aim of building up a long term record allowing any trends to be observed. The red cone of Eldfell stands just behind the town of Heimaey, composed of loose scoria, with lava flows extending to the north and east. The climb to the summit took half an hour, scrambling up the path of loose scoria onto the horse-shoe shaped ridge where buttresses of solidified breccia stood out through the rubble. Numerous fumaroles covered the summit, emitting the gases that we were wanting to collect and sample. The high wind and low cloud meant that the only visible signs of the fumaroles were patches of yellow deposits where sulphur had precipitated. Our first task was to find a suitable fumarole to set up the MultiGAS station—it needed to be releasing hot gas, and be sheltered from the wind.

Field work on Heimaey: measuring the temperature of the fumaroles.

After installing the equipment, it was left to run and sample the gas while we retreated back to town for tea and cake, and to warm up. By the end of the afternoon the clouds had cleared and the wind had died-down, giving us the chance to collect gas samples when we returned to remove the MultiGAS station (samples can't be collected in high winds). The second time we reached the summit of Eldfell, the sun was shining, with a beautiful view over the town and harbour. We found a sheltered fumarole with a visible thin plume of gas rising up from between the scoria. Using an electronic probe, we measured the temperature at over 250°C. Collecting the gas involved hammering a hollow metal tube into the scoria, attaching a syringe with which to suck up the gas, and then transferring it into a Gigenbach flask. It was a slow process, but despite the chill in the evening air, it was wonderfully warm sitting on top of the fumaroles!



Field work on Heimaey: collecting gas in a Gigenbach flask.

The following morning, after catching the ferry back to the mainland, we separated to join different fieldwork projects for the day. Rachel went with Melissa to the glacier of Solheimjökull to collect water samples from the glacier melt and take MultiGAS readings at the glacier snout. Meanwhile, Isla went with Baldur Bergsson (from Veðurstofa Íslands) to install equipment for measuring gas concentrations in the groundwater flowing from Hekla. Magma below Hekla releases gases into the groundwater, and it is hoped that changes in these gas concentrations, especially SO_2, will be able to be used as an early warning system for any future eruption. This is a joint project between the Icelandic Meteorological Office and the British Geological Survey.

Hot springs at Hverigerði.

Travels in Iceland:

We spent our weekends exploring more of this fascinating country. We climbed the lava plateau of Mt Esja near Reykjavik, we camped in the steaming geothermal town of Hveragerði, and we explored the rift valley at Þingvellir, the tectonic boundary between the European and North American plates. The field geology was great, but the whole experience of working with real data in an important and dynamic scientific environment was the biggest benefit we gained from our month in Iceland. Helping monitor active volcanoes and making a genuine scientific contribution was well worth the long and sometimes chilly days. We would like to say a huge Thank You to the Clough Fund for helping make it happen.

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Rachel Whitty and Isla Simmons
MEarthSci students at the University of Edinburgh

The rift at Þingvellir: North American Plate and Rachel on the left, European Plate and Isla on the right.

Pahoehoe lava at Þingvellir.

Lava tunnel at Mývatn.

Earthwise — evolution or revolution?

By Bob McIntosh

The British Geological Survey has produced maps and memoirs for a large part of its history. The first maps were published at a scale of 1:63 360 in the 1830s; sheet memoirs or explanations were an innovation by Sir Roderick Murchison who introduced them in 1857, the first being *The geology of the country around Cheltenham*. The maps evolved from the hand-coloured Old Series to the colour printed New Series in about 1900. Another major change came with the introduction of metrication and the scale change to 1:50 000. This brought in a fresh new design for new maps, of which the current paper maps are examples. A major innovation was the design and production of maps by computer, a process driven by the NERC Experimental Cartography Unit — but the output was still a paper map.

To provide a clearer understanding of geological maps for a wider range of users, there has been a revolution over the past 15 years. The first step in this revolution was to produce a purely digital map, still two dimensions but delivered over the Internet. BGS iGeology[1] has been available for some time, followed by iGeology 3D[2], and more recently, Groundhog, the web service that delivers the National Geological Model — a full 3D representation of the geology of the UK. All these products increase our ability to visualise the geology, making it more accessible for non-experts (and experts!). However, there is something missing from all this iGeology, 3D model activity. We have seen that traditionally the paper map and memoir were the basic Geological Survey products. The development of the map has raced ahead and been transformed into digital maps and 3D models, but the memoirs and other BGS publications have stubbornly remained as printed products. All this is about to change with '**Earthwise**', a new web-based platform for delivering text[3], and the Edinburgh Geological Society is part of this text revolution!

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1 http://www.bgs.ac.uk/igeology/

2 http://www.bgs.ac.uk/igeology/3d.html

3 http://earthwise.bgs.ac.uk/index.php/Main_Page

Anyone familiar with Wikipedia, the massive online encyclopaedia, will immediately be at home with **Earthwise**, as it uses the same underlying open-source software called Mediawiki. This provides a ready-made application for the collaborative creation and editing of articles. Anyone with access to a computer and the internet can become involved in providing content for the whole world to consult. From a BGS perspective, a decision was made that scientific content would be delivered through two routes. Traditional peer-reviewed journal articles would be complemented, in most cases, by a PDF copy on NORA[4], the NERC Open Research Archive. For the rest of BGS publishing, its memoirs, sheet descriptions, popular publications and open reports content would be transformed into articles on **Earthwise**, the Mediawiki platform.

Earthwise provides huge benefits over traditional print.

1. It is a fully interactive media-rich environment where articles can include more images and video and where content can be hyperlinked to other sources, both in **Earthwise** and elsewhere on the internet.
2. It is a collaborative authoring environment where BGS staff and users outside BGS can jointly create articles.
3. Users can select articles of interest and either download them or use the 'Create a book' facility to have them custom printed as a traditional paper publication.
4. Access is free through the BGS website.
5. The free access will lead to a huge increase in use of the content for a wide range of purposes and provide much greater impact for the science that is being published.
6. The Open Access scientific publishing method complements and invigorates traditional publishing.
7. It will greatly enhance and promote the earth sciences.
8. From the **Earthwise** platform a much tighter integration will be created between the digital maps and models and related descriptive text, fully replacing the traditional paper 'map and memoir' duo.
9. For any earth science organisation with limited IT expertise, collaboration with **Earthwise** offers a professionally hosted and run platform and an opportunity to be part of a UK-wide initiative. There could easily be some integration with that organisation's own website.

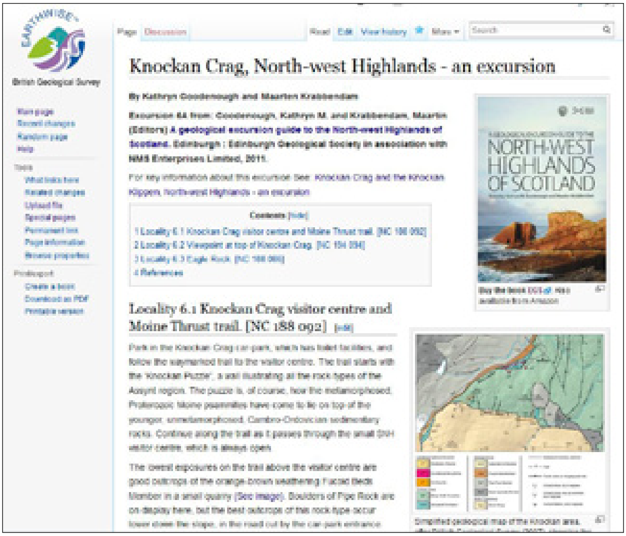
4 https://nora.nerc.ac.uk/

10. The text will be in a format that can be delivered through the semantic web as linked data. In the future, not just articles or web pages will be linked to each other but also data itself in an extension of the Web. This is all rather technical and anyone interested should look it up on Wikipedia![5]

This move from paper publication to a web-based platform is a revolutionary change equal to that revitalising of the paper map as a 3D model. It opens up endless opportunities in the way the text can be delivered and used and in 2016 we are right at the start of this exciting development.

Earlier it was mentioned that the Edinburgh Geological Society was part of this text revolution. The EGS is one of the first organisations to work with the BGS in supplying text-based content for **Earthwise**. The central aim of the Society since it was founded in 1834 has been 'stimulating public interest in geology and the advancement of geological knowledge'. This has largely been achieved by organising regular lectures and field excursions, and by publishing excursion guidebooks. Embracing the new technology **Earthwise** offers, the EGS has been converting content from its guidebooks into individual **Earthwise** articles. Almost 90 excursions have already been 'extracted' from various EGS guidebooks and added as individual articles on **Earthwise**. So far, for most, only the basic text has been added but the Society will create a small team of volunteers to check the current accuracy of the excursions (many were written over 20 years ago) and also enhance the content with additional field photographs and text. Unlike conventional publishing, content can be added and updated immediately. **Earthwise** will provide all sorts of opportunities to be creative, for instance, notes about EGS excursions could quickly be put on **Earthwise** to be shared by all members and the public and then updated after the trip with photos taken on the trip by participants. This would provide an up-to-date and ongoing, rich record of all the Society trips and provide a valuable resource for others who would like to visit the same sites independently. Another initiative to enhance the site which is in the early stage of planning is to georeference all of the individual excursion stops, allowing them to be displayed on web GIS. This may lead to an 'app' for mobile devices so users can read-up excursions in the field. If any EGS members would like to help or have any ideas please contact the author.

5 https://en.wikipedia.org/wiki/Main_Page



The EGS excursions on **Earthwise** fall under the general heading of *Geological walks UK*[6]. This includes articles on individual sites, geological walks or groups of walks formed into excursions. The site currently has about 160 excursions and walks (about 1500 individual stops) extracted from a range of Society excursion guides. There are also descriptions of a number of important geological sites contributed by BGS, initially from the *Cainozoic geology and landscape evolution of north-east Scotland* memoir but with scope to add others, perhaps the 1:25 000 Classic areas guidebooks, especially now that the accompanying maps are all on free access on the BGS Maps Portal. The map/guide pair should prove most appealing. EGS excursions have been converted from *Lothian Geology*, *Scottish Borders Geology*, *Ardnamurchan*, *Ballachullish Igneous Complex* and *Building stones of Edinburgh*; there are also excursions from the joint EGS/BGS *Geology in south-west Scotland*. Other useful sources are unpublished excursion guides provided by excursion leaders for actual EGS trips, such as John Mendum's 2005 Banffshire Coast guide and Nigel Fannin's May 1991 Orkney field excursion guide. There must be more of these that we could use. Most of this content is from older guides, and the real stars from a presentational viewpoint are the recently converted North-west Highlands and Rum guides. With their colourful maps, diagrams and photos they point the way to the standard that can be achieved and show what we are aiming for with all our **Earthwise** articles.

The aim is to extend content coverage from Scotland to other parts of the UK so if there are any other Societies that would like to contribute walks and excursions please get in touch with the author or the **Earthwise** Team at BGS. It

6 http://earthwise.bgs.ac.uk/index.php/Category:Geological_walks_UK

would be a great way of promoting your content and your Society in a modern and free web-based platform that could integrate with your own website.

Footnotes will be hyperlinks in the online version of *EG59*

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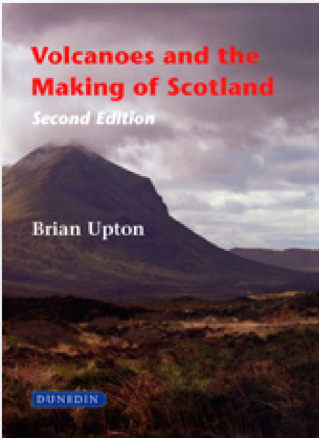
Book review

Volcanoes and the Making of Scotland by Brian Upton**.** Dunedin Academic Press, Edinburgh. Second edition 2015. Hardback, 248 pp. Price £24.99. ISBN 978-1-78046-056-7. Also available as an ebook.



The first edition of Brian Upton's very popular homage to the volcanoes of Scotland, in 2004, was the first fully comprehensive appraisal of Scottish volcanoes since Archibald Geikie's *Ancient Volcanoes of Great Britain* in 1897. This second edition benefits from a rigorously updated text and substantial improvements to both the photos and the figures. It has undoubtedly been a labour of love and, as we would expect from an author who has spent his whole career on igneous rocks in general and those of Scotland in particular, it is both authoritative and comprehensive. Igneous rocks ranging in age from almost 3000 million to 46 million years old and spread across the whole of the Scottish mainland and islands are described and interpreted, either as the products of volcanic eruptions or as the plumbing systems and roots of the volcanoes or as the source of their magmas. Few other books aimed at a non-specialist readership provide such reliable up-to-date accounts.

The first four chapters include sections on deep time, the tectonic history and make up of Scotland, the origin and crystallisation of magmas, the main types of igneous rocks and the main features of volcanoes and their products. All are clearly explained in relatively simple terms and are necessary in order to follow the descriptions and interpretations that constitute the main part of the book. Most of this should be understandable to the target readership, although I have to hope that the highly technical diagram showing isotherms and melting curves on page 10, although beautifully explained on the facing page, doesn't put off anyone from reading any further. I admire the author's bravery for including this explanation of mantle melting.

The chapters dealing with Scotland in particular start with the extensive, very well-exposed Palaeogene lava fields and dissected central complexes and then work backwards in time, through the readily identifiable Permo-Carboniferous, Siluro-Devonian and Ordovician volcanic episodes to less-obvious Proterozoic examples before discussing, tentatively, the possible surface manifestations of various Archaean intrusions. This order might surprise and even unnerve some readers, but that is because we geologists are conditioned to start at the bottom and work upwards in our descriptions. I like Brian's approach, which he does explain and justify early in the 'Introduction'; it is entirely logical for such a 'forensic' investigation. It is, however, quite a challenge for the author and he does tie himself (and me) in knots in several places by attempting to describe the ***complete*** geological history in a continuous backward sequence. It would have been better, and much easier, to expand the introductory 'Brief History of Scotland' (which for some reason ends at the Caledonian Orogeny) to give a full geological history in a conventional, forward sequence and then describe the individual magmatic events as separate entities, from younger to older, without the need to make comprehensive but convolute and hence confusing backward links.

One of Brian Upton's strengths, and charms, has always been his ability to tap into an encyclopaedic worldwide knowledge of volcanoes to find an appropriate modern analogue for any ancient feature and then weave a story around it. I particularly like the linking of the Siluro-Devonian caldera-volcanoes of Ben Nevis and Glen Coe with inferred former calderas above the Etive Pluton to form a volcanic field comparable in size and former destructive power to the current 'sleeping dragon' of Yellowstone. Such comparisons bring life to the descriptions and add considerably to their understanding, especially where they are illustrated by such carefully selected photographs, from the author's own collections, from those of friends and many from other internationally recognised authorities. There are a few interpretations that raise slight doubts in my mind but my attention has been drawn to so many aspects that I had been unaware of previously. Most notably, the updated and comprehensive review of the evolution of the Rum volcano has clarified my understanding of that central complex considerably.

It has to be said that the book does delve quite deeply into some rather technical areas and employs a high level of scientific vocabulary, not all of which is explained. So I fear that the average 'farmer, fisherman, tourist and other ....general public', who are declared to be the target readership in the Preface, will flounder somewhat. A book with that readership would really benefit from a glossary, which is a sad omission. However, it does have a good index, so one can look for a first mention of an unfamiliar term and hope to find an explanation. I spotted very few factual geological errors but there are too many minor glitches and inconsistencies, especially in the figures, their captions and in references that should have been picked up by a scientific edit and/or a good proof check. But hopefully most readers will overlook those.

We will all have our favourite Scottish volcanoes and there really is something in this book for everyone. But it will be welcomed in particular by students at all levels and by amateur geologists such as those who read *The Edinburgh Geologist*. They will learn so much about all the fascinating volcanic relics that we are fortunate to have in Scotland, will clarify their understanding of volcanic and magmatic processes in general and, above all, will thoroughly enjoy reading an undoubted masterpiece.

David Stephenson

Stop Press . . . Fossil Hunters

Whilst *EG* was in proof we learnt of a forthcoming exhibition at the National Museum of Scotland, Edinburgh: *Fossil Hunters — Unearthing the Mystery of Life on Land*. This will feature some of the remarkable Early Carboniferous tetrapod material recovered from the Scottish Borders during the TWeed Project (see *EG* 53 & 56) and will certainly be well worth a visit. The exhibition runs until 14 August and we hope to feature some highlights in the next *Edinburgh Geologist*.

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