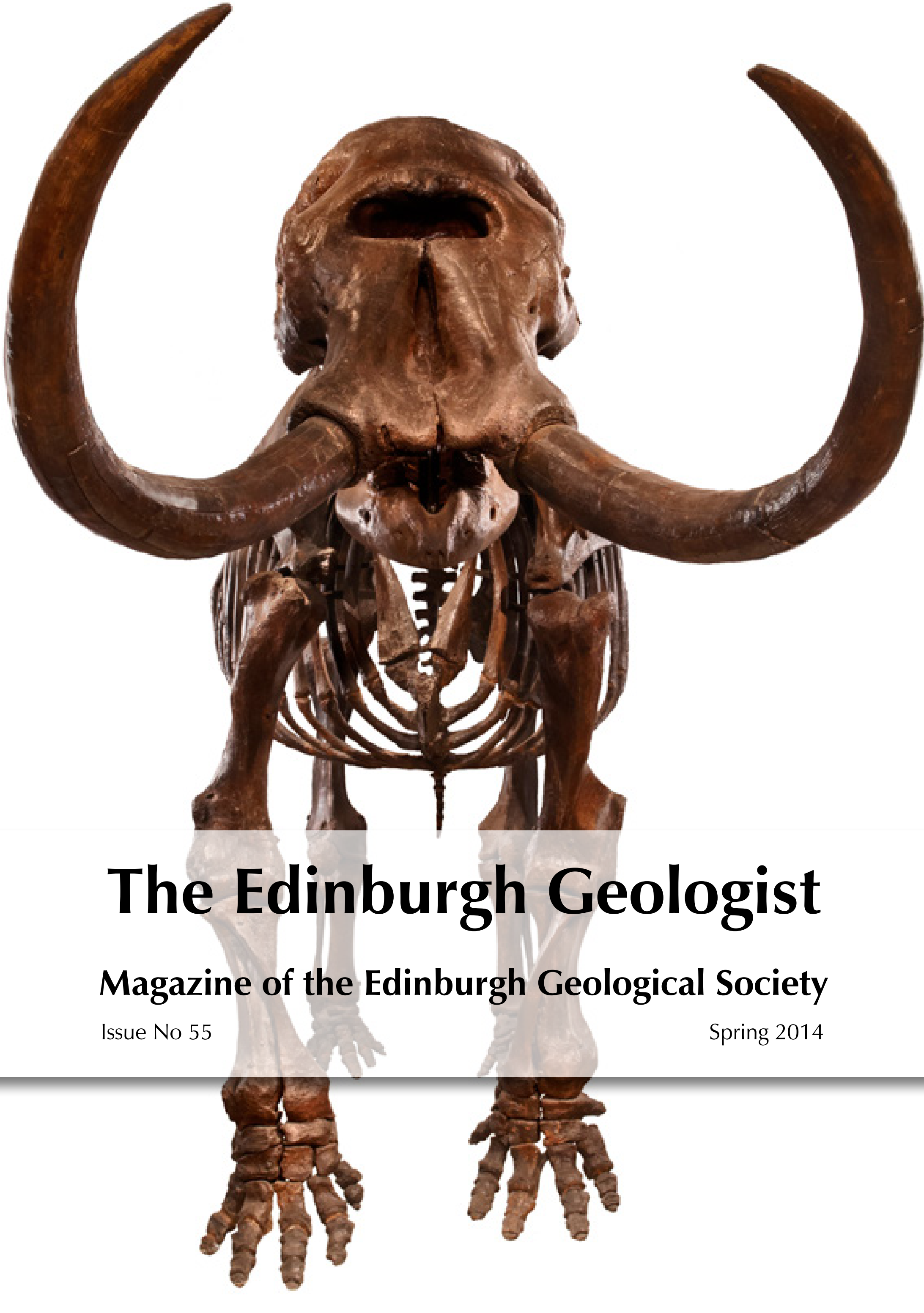

The Edinburgh Geologist

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Cover Illustration

The skeleton of an American Mastodon from the National Museum of Scotland's 'Mammoths' exhibition; part of a touring display from the Field Museum, Chicago. This adult mastodon would have been slightly smaller than a modern, full-grown African Elephant.
Photo by John Weinstein © 2009 The Field Museum.

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Mammoths and models

An editorial ramble by Phil Stone

Have you seen the mammoths at the National Museum of Scotland yet? If not, you have until 20th April to take in this spectacular and fascinating exhibition: *Mammoths of the Ice Age*. It has travelled to Edinburgh from The Field Museum of Natural History in Chicago, and brings together an extraordinary array of material and relics. There is a skeleton of a mastodon (see our Cover Picture) and life-size mammoths and the whole thing is happily interactive with opportunities for the visitor to get up close and personal with skull casts, teeth, tusks, fur and faeces. The exhibition also makes the point that not all mammoths were, well, mammoth, with a huge 4 m tall Columbian mammoth contrasting with its dwarf relative marooned on the Californian Channel Islands. Some mammoths survived on the Arctic Wrangel Island until only about 4000 years ago.

The exhibition also delves into the social behaviour and ecology of mammoths and mastodons, based on both fossil evidence and a comparison with modern-day elephants. Mastodons it seems were shorter and stockier than mammoths, with thicker bones and differently shaped tusks. The two species lived alongside each other

A Woolly Mammoth skull. © http://www.paleoart.com

in North America having adapted to different diets—but if you had to feed an adult of either variety it would require the equivalent of 15 bales of hay every day. Of course the relationship was usually the other way round, with mammoths feeding humans, and that close relationship is illustrated by animal representations in cave paintings, and the early human artwork on display and dating from between 35 000 and 10 000 years ago: models made of bone, stone and mammoth ivory.

A model horse carved from a piece of mammoth ivory. © Rèunion des Musèes Nationaux/Art Resource.

The exhibition is naturally dominated by North American examples so the 'mammoth-hunting kit' on display is a fine assortment of Clovis-type worked-stone spear points. But let's not forget that we had our own 'home-grown' mammoths as well. Most of the Scottish finds have been isolated teeth and tusks recovered from peat or glacial sands and gravels at various locations in the central and southern parts of the country—and of course dredged from 'Doggerland', now submerged beneath the North Sea. Radiocarbon dating suggests that most of the Scottish mammoths lived around 25 000 to 30 000 years ago, accompanied by other Ice Age species such as reindeer and woolly rhinoceros.

A large and very fine mastodon tooth, accompanied by a rather dog-eared mammoth tusk, turned up in another of Edinburgh's winter exhibitions. This one was to be seen

This depiction of a mammoth was painted on the wall of the Rouffignac cave in France somewhere between about 15 000 and 20 000 years ago. © Jean Plassard, Grotte de Rouffignac

at Edinburgh University's George Square Library and was entitled *Collect.ED—Curiosities from the University's Collections*. Curated by Emma Smith it was indeed an eclectic assortment of the bizarre, beguiling and beautiful. Just to give you a flavour: a Tibetan thigh-bone trumpet, Napoleon Bonaparte's death mask, a Babylonian cuniform inscription and a selection of artificial limbs. But there were also many objects of geological interest generally hidden from view in the University's Cockburn Museum collection in the Grant Institute. So, apart from the mastodon tooth, what caught my eye? The ichthyosaur head with grimly staring eye, the rather scary megalodon tooth looming large over all the 'ordinary' sharks' teeth, the beautiful cluster of azurite crystals, the box of shells collected by Charles Darwin on the island of St Helena and passed on to Charles Lyell—there were lots more and it's a great shame that they are not to be seen more often. The inspiration for the exhibition was the Victorian notion of the 'Cabinet of Curiosities' the acquisition of which was an essential accomplishment for any educated gentleman. As Emma describes it, the 'cabinet' was partly intended for scientific study "but also allowed objects to be viewed out of context and on a purely aesthetic level, providing fascinating juxtapositions and new opportunities for interpretation … embodying both the satisfaction of imposed order and the human desire to posses, early collecting focused on the unclassified and unique, aiming as much to instil wonder as to enlighten."

We seem to have returned to that vaguely post-modern philosophy with many recent museum redevelopments. That's a trend to be resisted in my opinion, speaking as one who likes to know what I'm looking at and where it fits into the greater scheme of things. To be fair to Emma Smith, a leaflet accompanying the *Collect.ED* exhibition did identify all of the items on display, though little background information was included; perhaps for some of the earlier-acquired objects it did not exist. But another of Edinburgh University's winter exhibitions, this time at the College of Art, was even less restrained by any lack of information about the geological items on display because its theme was essentially their three-dimensional properties. This exhibition, *The Model*, featured student's work but to provide context and perhaps inspiration it also included a range of teaching-aid models drawn from several of the university departments illustrating aspects of anatomy, geology, music, veterinary science and architecture. For these there was only minimal identification and no attempt at explanation. The objects were there simply as mysterious structures intended to intrigue or perhaps puzzle, ironically the exact reverse of their originally intended purpose.

As with the *Collect.ED* exhibition, the geological items on display for *The Model* were drawn from the Cockburn Museum (further evidence for the wealth of material therein). There were molecular models of diamond and graphite, biotite and garnet, a boxed set of beautiful glass representations of the different crystallographic systems and, particularly appealing to me, seven wooden block 'Sopwith Models' illustrating the interplay of geological structure and topography. These hand-crafted works of art in laminated wood of different colours were originally made by Thomas Sopwith (1803–1879) who had a background in a Newcastle-based, family cabinet-making business, but moved on into mining and railway engineering and so developed an interest in geology. He designed twelve different models that were sold in various sizes and in sets of either twelve or six—so it looks as if the Cockburn Museum has lost some. The surviving models had been discovered, stored in a cardboard box, by Archie Stewart, a painting student at the College of Art, whilst he was researching material for *The Model* exhibition. Saddened by their lack of a proper home, Archie emulated Thomas Sopwith's cabinet making skills and crafted an elegant display box—as illustrated—for the models and the accompanying explanatory booklet.

Another of the geological teaching-aids from the Cockburn Museum on display at the College of Art was a scale-model of Arthur's Seat, with the geological outcrop pattern painted on to the 3D topography. With no scientific explanation offered, the model still retained its aesthetic appeal as a colourful installation and hopefully at least some viewers were stimulated to wonder just what the lines and colours represented. Who was the original model-maker? There may be a clue here in the article by Graham Leslie and Tim Kearsey that appears later in this issue of *Edinburgh Geologist*. Graham and Tim celebrate the geological model of the Assynt district built and painted prior to 1904 under the supervision of the Geological Survey's Chief Draughtsman in Edinburgh, Mr John Dick Bowie. One version of the Assynt model is on display in the Grant Institute's Cockburn Museum, so perhaps its version of Arthur's Seat was also a John Dick Bowie production. Does anyone know for sure? And what about the Ardnamurchan model also to be seen in the Cockburn Museum?

The Cockburn Museum's 'Sopwith Models' as arranged for display by Archie Stewart. Each block is about 10 cm square.

Preceding the Assynt article in this issue of *EG* we have two other interesting contributions. Neil Clark reveals just how scientifically exciting a Society excursion can be, with his account of fossil collecting from the Muirhouse Shrimp Bed at Granton—and in passing he demonstrates the importance of 'old' museum collections. Peter Dryburgh gives us an insight into the life of Sir James Hall—the 'third man' of Siccar Point but an important geological figure in his own right. He also made models. His 1815 paper in the *Transactions of the Royal Society of Edinburgh* records that to complement its original presentation before the RSE he had displayed a model showing the relationship of granite and dykes to the vertical greywacke beds at a site in Galloway overlooking Loch Ken. A duplicate model was presented to the Geological Society of London. I wonder what happened to them. The Galloway site is now densely forested but Hall describes how he had employed labourers and a stonemason to clean up the exposure—and had further 'improved' it using gunpowder. Those were the days. Elsewhere in this *EG*, we have some additional detail of Hugh Miller's time in Edinburgh corresponded by Mike Taylor, and a review by Mike Browne of Con Gillen's recent book describing Scotland's geology and landscapes.

Finally, I can't possibly conclude without congratulating Christine Thompson, our Society's new president. I believe that Christine is the first female president in the Society's long history, which I guess is cause for both celebration and mild embarrassment.

Letter

Mike Taylor writes on Hugh Miller: I noticed the editorial comments (*Edinburgh Geologist* **54**, Autumn 2013) about the plaque on the City Chambers opposite the High Kirk in the High Street, marking Hugh Miller's editorial office, a few days after I had shown it to delegates at the annual Symposium for Vertebrate Palaeontology and Comparative Anatomy, which National Museums Scotland and Edinburgh University hosted last year.

I can't say if there was an earlier plaque, though do not remember seeing any mention. However, during the 2002 bicentenary there was also placed a plaque on Shrub Mount, Miller's last house, in Portobello High Street[1]—or more accurately atop the later close that leads to its front door, Miller's house being sideways-on to the street and having had a tenement block built atop its front garden as well as shop fronts added onto the street facade. The hideously complicated story, including an attempt to sort out the modifications to the main house before and since Miller's time, and the location of his museum in the garden, is admirably told by Ian Campbell and Julian Holder of the Edinburgh College of Art (2005: Hugh Miller's Last House and Museum: the Enigma of Shrub Mount, Portobello. *Architectural Heritage*, **16**, 51–71).

The unexpected conclusion was that Shrub Mount's nucleus is the last of the old 18th century Portobello seaside cottages, so it is of real local architectural interest quite independently of Miller. Remarkably, its survival has largely been a matter of chance, and nothing to do with Miller, in contrast to his birthplace cottage at Cromarty, one of the oldest local cottages.

Miller did have three other houses in and near Edinburgh, not counting short-term lodgings or places where he stayed when a stonemason, but, without tackling the risk of changing street numbering, I can only swear to one being (probably) still standing, in Sylvan Place, opposite the Royal Hospital for Sick Children. A better, or at least alternative, location for another plaque might be Guthrie Street, off Chambers Street. Here were printed his newspaper and some of his books, including the first edition of *The Old Red Sandstone*, as Ralph O'Connor (University of Aberdeen) and I discovered when editing it for a modern reprint.

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[1]. A report of the event can be seen at: http://www.scotsman.com/news/plaque-pays-tribute-to-famed-editor-1-951458

Sir James Hall of Dunglass — a scientific pioneer

By Peter Dryburgh

In issue number 53 of *The Edinburgh Geologist* (Spring, 2013), Bill Gilmour contributed some interesting detailed notes about the relationship of James Hutton with Sir John, Sir James and William Hall. These notes rekindled my interest in the pioneering figure of Sir James Hall and this article has been compiled from material collected over the years. His estate, Dunglass, lies a mile or so north-west of Cockburnspath and was occupied by the Hall family from 1687 until it was sold to the Ushers in 1919. Long before the Halls had the estate, it had been owned by the Home family, ancestors of David Hume.

Early life of Sir James Hall

The founder of the Hall family was Sir John Hall, a wealthy merchant, who was created baronet by James VII and became Lord Provost of Edinburgh from 1689 to 1694. The third baronet was also Sir John Hall (1710–1776) and his first son, James, was born on the 17th January 1761. James was initially educated at home but was sent to Elin's Military Academy in London when he was ten years old. There he was fortunate to be under the care of his great-uncle, the king's physician, Sir John Pringle, a member of a well-known Roxburghshire family whose home was Stitchill House. Pringle had a strong influence on the development of Hall's interest in science, being himself President of the Royal Society from 1772 to 1778. When Sir John died in 1776, James inherited the baronetcy at the age of fifteen and became financially independent. He went to Christ's College, Cambridge, for about eighteen months, left without taking a degree, and then embarked on a visit to France and Geneva. On returning home in 1781, he enrolled at Edinburgh University and attended a number of courses, including some of Joseph Black's lectures on chemistry and Robison's course on natural philosophy. It seems probable that it was during this period that he formed his friendship with James Hutton, who had corresponded with Sir John for some years. His uncle, William Hall, who resided in Berwickshire, had studied chemistry and became a Member of the Royal Society of Edinburgh in 1792. William was one of a group of neighbouring landowners who met periodically to discuss their shared interest in science, and contact with this distinguished group certainly nurtured the scientific interests of the young James.

In 1783 James set off on a grand tour of Europe, which lasted until 1786. Before his departure, he sat for Sir Joshua Reynolds and the resulting portrait, now in the Hall family's collection, shows James as a handsome and rather romantic young man. On returning from his tour, he married Lady Helen Douglas, second daughter of the Earl of Selkirk.

Hall's European tour

Having left London in the summer of 1783, Hall travelled extensively through Europe, lived for some time in Vienna and moved on to Paris. Inspired by the chemical interests of his uncle William, he met the famous chemist Lavoisier and soon adopted his new and revolutionary ideas of chemistry, which were to replace the prevailing orthodoxy of the phlogiston theory. He left Paris and spent the winter of 1783 back in Vienna, where he became convinced of the validity of the work of the naturalist Jean Ingen-Housz, who demonstrated the production of oxygen by illuminated plants, a result which had been questioned by both Priestly and Black. On leaving Vienna in 1784, he travelled to Hungary to visit various mines and became acquainted with the latest developments in chemistry at the Mining Academy and Chemical Laboratory of Schemnitz. He then returned to Vienna and passed on to Italy and Switzerland from where he returned to France and journeyed on to Rome in 1784. During his stay in Rome, he again had his portrait painted, this time by Angelica Kauffman. Kauffman had an impressive reputation as a portrait painter, made more remarkable at the time by her being a woman in a man-dominated profession. This portrait hangs in the Scottish National Portrait Gallery. Early in 1785, his stay in Rome was brought to an end by the news that Vesuvius was erupting and so he hastened to Naples. In studying the lavas, he climbed Vesuvius five times.

In April 1785 he sailed to Sicily and spent two months with the French geologist Dolomieu. He seems to have moved on to Marseilles, Montpellier and Toulouse, absorbing scientific knowledge whenever he could and developing an interest in ballooning.

Hall's thirst for knowledge was always accompanied by a critical and logical approach to ideas; nothing was accepted until all evidence had been rigorously examined. He had a reputation for courtesy but on occasions his scepticism was pungently expressed. When he was introduced to the works of a

Frenchman who claimed to be able to find springs, mines or almost anything else by his divining rod, Hall wrote to his uncle: "indeed what can one think of a man who is the advocate of such a ridiculous piece of witchcraft." In the same letter, he commends Dolomieu for his views on the same mystical diviner: "he is a sound clear headed man and treats all that cursed nonsense with the contempt it deserves."

By March 1786, Hall was back in Paris and thoroughly enjoying eating, dancing and female company. Apologising to his uncle for some delay in writing to him, Hall wrote: "There is no answering for the effects of the dissipation of a great city — one eats a hearty supper sits up late and lies in bed the next morning — This is the true cause of my long silence."

Later that year, he returned to Scotland and was married in November. After his marriage he spent much of his time between Dunglass and his Edinburgh house and in 1788 he accompanied Hutton and Playfair in their celebrated boat trip to Siccar Point. Following Hutton's earlier discovery of angular unconformities at Arran and Jedburgh, this constituted another spectacular confirmation of his theory. Then, in 1791, Hall returned to France for several months where he studied the political situation by attending debates in the national assembly, extended his chemical discussions with Lavoisier, and found time to study French agriculture and the volcanic landscape of the Auvergne.

Experimental geology

Despite Hutton's belief that the heat to which the mineral kingdom was exposed was of such intensity as to lie beyond the reach of imitation, Hall determined to verify geological field observations experimentally. His conjecture that unstratified crystalline rocks — from coarse grained granite to fine-grained basalt — could have been produced from the molten state was encouraged by the observations of James Keir in a Leith glass factory. Keir had observed that molten glass developed crystals if cooled very slowly and Hall quickly grasped the significance of cooling rate. He collected 15 samples of whinstone and lava and, using the furnace of an iron foundry, melted them and subjected them to slow cooling. After much effort, he obtained crystalline masses similar to the starting materials. The results of his experiments were published in his celebrated paper '*Experiments on Whinstone and Lava*', which appeared in the *Transactions of the Royal Society of Edinburgh* in 1805. The results had been communicated initially in 1790 but in the final published version a footnote to the paper records that: "Particular reasons induced me not to publish this paper at full length; but willing to preserve a record of some opinions peculiar to myself which it contained, I introduced a short abstract of it into the History of the Transactions."

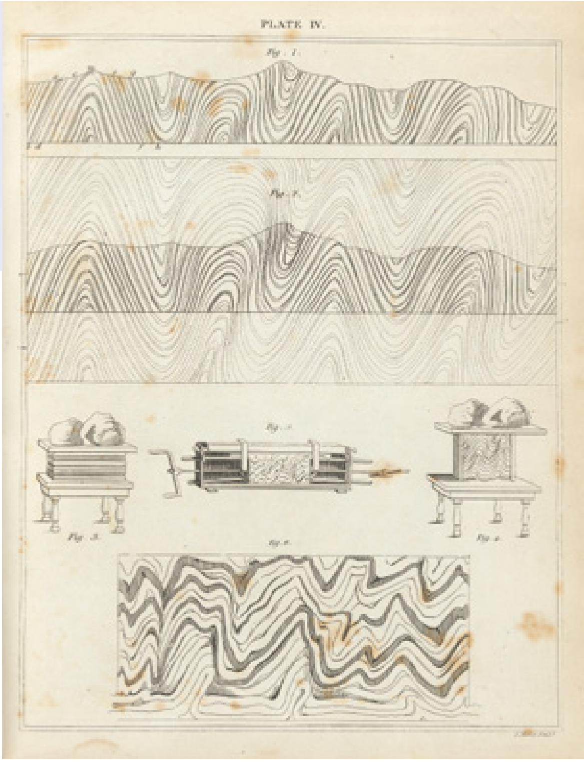
It is fairly clear from other sources that Hall's initial reluctance to publish his work — his "particular reasons" — arose from deference to Hutton who never accepted the experimental approach. After Hutton's death in 1797, Hall felt free to publish his results in full. Although the production of crystalline textures was established, the mineralogy of Hall's specimens was ill-defined and was unconvincing to many sceptics. At this time, he introduced the now familiar term *crystallite* to describe a small, irregular crystal grain.

In 1992, J B Dawson described the examination of some of Sorby's original thin sections of Hall's specimens, held in the Geology Department of Sheffield University, and established their mineralogy. He concluded that Sorby had examined the specimens using the new technique of thin-section microscopy in response to a letter from Alexander Bryson who, as late as 1859, still adhered to the Neptunist version of the origin of granite. As well as confirming the validity of Hall's work, Dawson showed that Sorby's researches established the importance of water and fluxes in the textures of rocks obtained from cooled melts.

The origin of limestone and marble had presented a problem since Black had demonstrated that these rocks decomposed with the evolution of carbon dioxide when heated. Hall realised that pressure was an important variable which had been largely overlooked and embarked upon a series of experiments involving the heating of limestone under pressure. He used gun barrels and other containers, as well-sealed as possible, and subjected a variety of calcareous materials to heating. These materials included common limestone, chalk, 'spar' and sea shells. Between 1798 and 1804, he doggedly pursued his researches, making about 500 experiments. Eventually, he managed to convert the various powdered carbonates into limestones or marbles, depending upon the experimental conditions.

In 1812, Hall published an important paper describing experiments in which he tried to reproduce the various convoluted folds which he had observed in the field, notably on the coast of Berwickshire. He described a machine by means of which pliable

Figure 1 Idealised representations of the folding seen on the Berwickshire coast and Hall's machine for demonstrating folding (Hall, 1815, plate 4).



beds of clay were pressed together to reproduce the observed folds (Figure 1). The folds so produced were convincingly similar to those visible in the cliffs. (Although his machine is remarkably similar to that used by Cadell more than 70 years later, his experiments did not incorporate the brittle layers which Cadell so brilliantly showed were instrumental in causing thrust structures).

Hall had been a Fellow of the Royal Society of Edinburgh (RSE) since 1784 and was elected FRS in 1806, his proposers including Humphrey Davy and William Herschel. He became President of the RSE in 1812, a position he held until 1820. His Presidential portrait (Figure 2) was painted by John Watson Gordon and can be seen at the RSE in George Street.

Political career

Hall was persuaded by his brother-in-law, the 5th Earl of Selkirk, to stand for parliament and was described by one opponent as "a declared democrat and an avowed atheist but clever". He was returned as MP for Mitchell in Cornwall in 1807 and retained the seat until 1812. He was energetic and independently-minded until the onset of the illness in 1810 which troubled him until his death in 1832. He was buried at the Dunglass Collegiate Church, a fifteenth century building now in the care of Historic Scotland. Sometime after his death, his Edinburgh mansion at 128 George Street became the office of the Mercantile Bank of India, London

Figure 2 Portrait of Sir James Hall, President of RSE, by Sir John Watson Gordon, reproduced by permission of the Royal Society of Edinburgh.

and Scotland, an enterprise founded in Bombay in 1853 but which failed in 1893. 128 George Street is now occupied by a pub, *The Alexander Graham Bell*.

Legacy of a polymath

Judged by any standard, Hall was an energetic man of outstanding intellectual ability. He is very properly remembered as the father of experimental geology and, together with John Playfair, played a major part in having Hutton's views generally accepted by geologists. In addition to his geological contributions, he is credited by V A Eyles as having had a most important influence on the whole development of chemistry in Britain. A further example of the breadth of his interests is his 1813 publication *"Essay on the origin, history and principles of Gothic architecture"* which he wrote after studying the interlacing structures of wattle buildings.

His proof that crystals could be grown from molten materials has had an indirect but profound effect on the whole of modern technology. The growth of large single crystals lies at the foundations of the entire electronics industry, much of the optical industry and in the provision of the enormous crystal detectors used in the world's most powerful particle accelerators. Without silicon crystals we would have no computers, mobile phones or other electronic devices; without synthetic rubies and sapphires there would be no high-powered lasers, while calcium tungstate crystals for nuclear detectors are produced by the tonne. All these crystals and many others of industrial importance are grown from melts. Hall could have had no inkling of these applications but his work provided the first observations that led to their development.

Hall lived in an era when personal abuse could be uninhibited but I have come across no unflattering reference to his character or behaviour. One obituary credited him with “unequalled stability and sweetness of disposition.” Despite his most distinguished scientific career, that statement is surely a wonderful epitaph for Sir James Hall of Dunglass.

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Shrimping at Granton—the Muirhouse 'shrimp-bed' revisisted

By Dr Neil Clark

An Edinburgh Geological Society evening field excursion on Wednesday 5th June 2013 added to our knowledge of one of the most famous palaeontological localities in the world: the Muirhouse 'shrimp-bed'. It is exposed on the shores of the Firth of Forth, just to the west of Edinburgh's Granton Harbour [NT 219 772], and is best known for its shrimps, fish and, most significantly, the elusive conodont animal (Figure 1) (Aldridge *et al*. 1993; Knell 2012).

Conodonts have been used extensively since the mid-1800s for everything from very precise relative age dating to defining the thermal maturation of sediments, and have aided environmental

***Figure 1** One of the famous conodont animals (overlain by a shrimp) from the Muirhouse 'shrimp-bed'. This specimen was found by the author in 1984 and is now in the collections of the Hunterian Museum, University of Glasgow (GLAHM Y221), scale bar = 1cm.*

interpretations in rocks from the Precambrian to the Triassic. Despite this huge range, until recently there were few clues as to what organism conodonts derived from. Some speculated that they were parts of plants, snails, worms or fish, but it was not until 1982, when Professor Euan Clarkson was studying the shrimps from Muirhouse in the Edinburgh collections of the British Geological Survey, that the mystery was solved (Briggs *et al*. 1983). He found a complete lamprey-like animal that had conodont teeth in the head region. Subsequently, there were *in situ* discoveries at Muirhouse with ten animals from that locality now adding to our understanding of this most enigmatic of fossils.

The geology of the foreshore at Muirhouse (Figure 2) is complicated by numerous small faults through a series of sandstones and shales of Early Carboniferous age. Nearby Cramond Island and Lauriston House are on an igneous, Carboniferous-Permian olivine-rich intrusion which extends across the Forth to Hawkcraig Point near Aberdour.

The sandstone that is exposed at low-tide at Birnie Rocks is the Wardie Sandstone, which also crops out

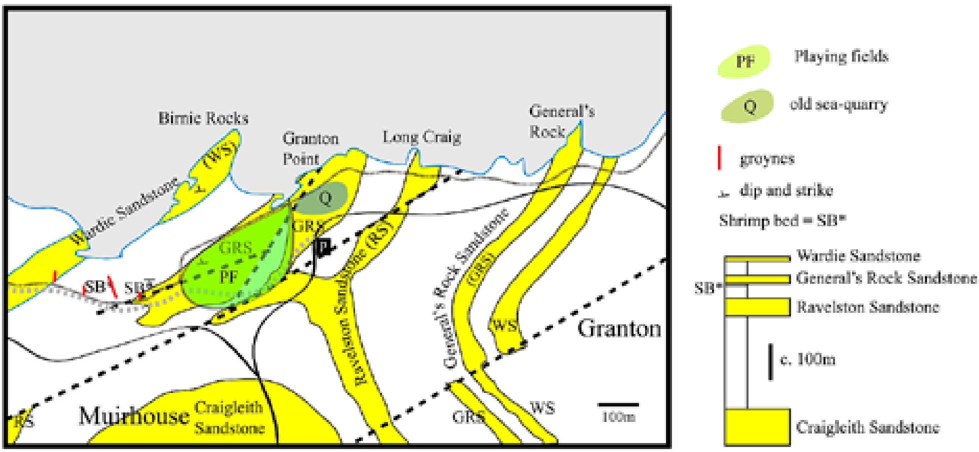

***Figure 2** Geology of the Muirhouse shore based on Edina Digimap. At low tide the shrimp beds can be found below the General's Rock Sandstone at several points to the south west of Granton Point.*

on the western edge of Granton Harbour. The stratigraphically lower General's Rock Sandstone is mostly covered by playing fields but is exposed west of the Wardie Sandstone at the harbour, within the east limb of an open anticline trending northeast-southwest. Immediately to the east of the playing fields is the site of the old sandstone quarry from which the first conodont animal was unknowingly collected in the 1920s.

There are two known shrimp beds exposed immediately below the General's Rock Sandstone, but they are generally referred to jointly as the Muirhouse 'shrimp-bed' (or sometimes as the Granton 'shrimp-bed'). They consist of black, laminated, dolomitic mudstone. Their crustacean fauna (Figure 3) mostly comprises *Waterstonella grantonensis* and *Crangopsis eskdalensis* (Briggs & Clarkson 1983; Clarkson 1985) but a number of other crustaceans, fish, plants and worms are also present (Briggs *et al*. 1991). The environment of deposition of the original sediments varied from low-energy lagoonal muds and shales, to a higher energy environment of deltaic sands and pro-deltaic muds; the

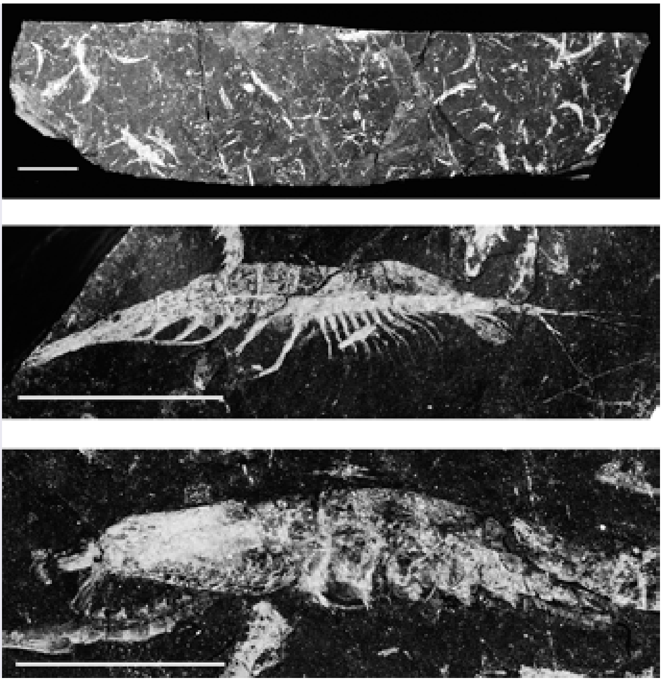

***Figure 3** Some of the more common crustaceans collected on the 5th June, 2013: top = Muirhouse 'shrimp-bed' (Bergman Collection), scale = 2cm; middle =* **Waterstonella** *(GLAHM 152323), scale = 1cm; bottom =* **Crangopsis** *(GLAHM 152337), scale = 1cm).*

Muirhouse 'shrimp-bed' represents a marine incursion across intermittently exposed mud-flats.

NE-SW extensional faulting has disrupted the 'shrimp beds' which are also affected by folding, thrusting and smaller-scale 'pinch and swell' structures caused by the dislocation of less-ductile layers and the thickening of more-ductile layers. Trying to interpret the sequence of lithologies is therefore far from easy, and new exposures seen during the excursion suggest that Cater (1987) got the sequence slightly wrong. It now appears that the lower of the rusty brown sediment layers with the shrimp *Tealliocaris* is slightly above the main black 'shrimp bed' and that both are beneath the General's Rock Sandstone.

Although the shrimp bed is poorly exposed and was largely removed in 1985 by the National Museums of Scotland with the help of the Grant Institute of Edinburgh University and others (McAdam & Clarkson 1986), it is still possible to find the occasional loose block of the black laminated dolomitic mudstone of the main shrimp bed. During the field trip of the 5th June, several such blocks were found and split to reveal the white and blue coloured crustaceans on the dark organic-rich laminae. Despite no examples of the elusive conodont animal being found, two other rarities came to light: a new undescribed crustacean which may be an isopod, and the tomopterid worm *Eotomopteris aldridgei* (Figure 4).

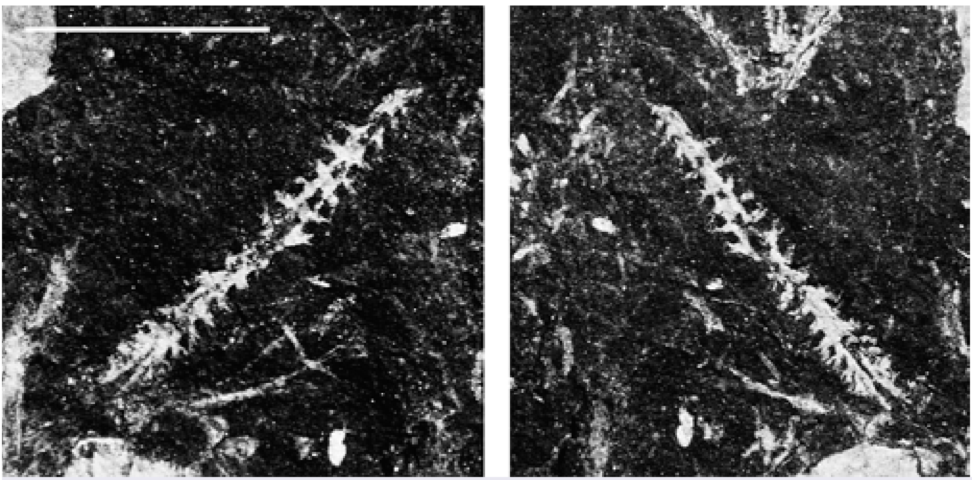

Figure 4 **Eotomopteris*****: one of the rare elements of the fauna collected on the 5th June, 2013 (GLAHM 152324, scale bar = 0.25cm).***

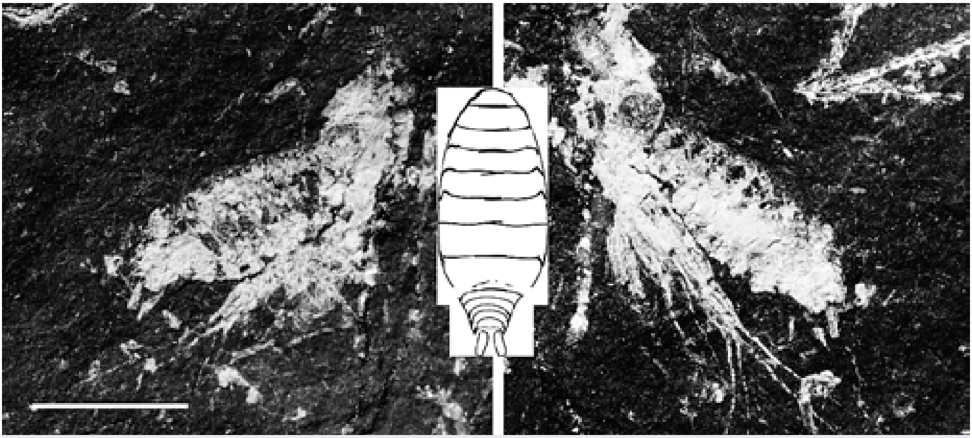

***Figure 5** The unique possible isopod collected on the 5th June, 2013 (GLAHM 152325, scale bar = 0.25cm).*

Of the rarities, the tomopterid polychaete worm is known from only three specimens in the collections of the National Museums of Scotland (Briggs & Clarkson 1987). This fourth example is well preserved and retains the 'limb' structure which has not been observed on the previous examples.

The new crustacean (Figure 5) is a multi-segmented animal with no obvious head-shield and a pair of lobed appendages at one end (probably the tailfan). The body appears to be flattened dorso-ventrally and consists of eight wide segments of the thorax; and six tapering segments of the tail. The basic body-plan is that of an isopod. However, there are no isopods of this nature known from the Carboniferous. There are Carboniferous isopods, but they are elongate laterally-compressed animals. This new animal has more of the appearance of an oniscidian isopod (which includes the terrestrial woodlouse) for which the scant fossil record extends only as far back as the Cretaceous. This could be a highly significant discovery.

The field trip successfully helped to reinterpret the sedimentary environment, the local lithostratigraphy, and the distribution of the Muirhouse 'shrimp-bed' along the foreshore. The discovery of a further tomopterid polychaete and the new crustacean has increased our knowledge and understanding

of the fossil record of these animals. This was certainly the most successful field trip I have had the pleasure of leading and I would like to thank all those members of the Edinburgh Geological Society who spent the evening on the Muirhouse foreshore, and in particular Beverly Bergman for providing specimens to be photographed. I would also like to thank Scottish Natural Heritage and Edinburgh District Council for allowing the collecting of material from the foreshore, without which permission the excursion could not have taken place.

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Assynt in 3D

By Graham Leslie & Tim Kearsey

Assynt, in NW Scotland, has attracted geologists to the Moine Thrust Belt for a century or more (Figure 1). Indeed, Assynt has often provided the 'yard-stick' against which aspiring geologists have tested their ability to see geological relationships in three dimensions. The British Geological Survey published a revised geological map of Assynt in 2007, validating it against a series of new geological cross-sections of the Assynt Culmination (BGS 2007). Exploiting recent advances in digital 3D modelling, BGS geologists can now communicate their visualisation of Assynt's complex geological architecture to a wide audience through a free download at: http://www.bgs.ac.uk/research/ukgeology/assyntCulmination.html

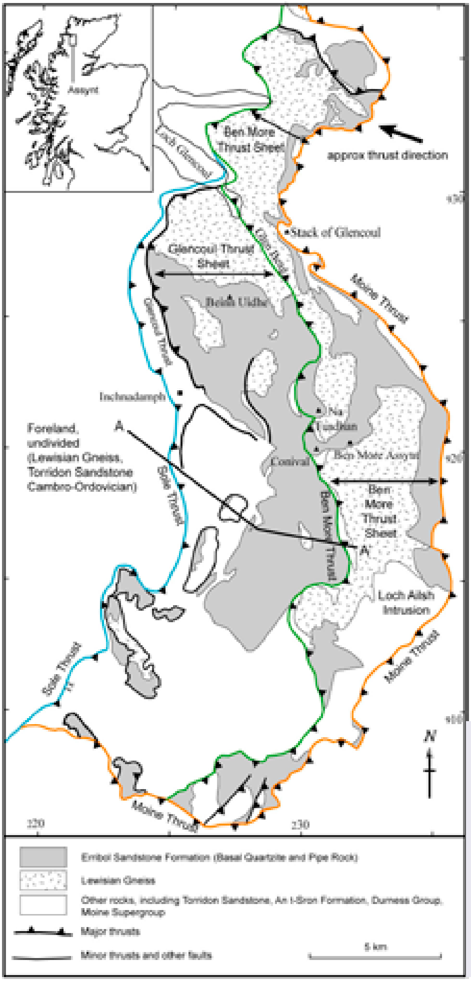

Figure 1 Geological map of the Assynt Culmination, showing the main thrust sheets, colour-coded as per the new BGS Assynt 3D model (see Fig. 3). Section line A – A' is illustrated in Figure 4.

History of geological mapping in Assynt

The late 19th century discoveries by pioneering geologists working in the Northern Highlands of Scotland provided the empirical basis for the recognition of huge sub-horizontal shearing movements in the Earth's crust, and their role in mountain formation. In his seminal 1882–83 examination of the structure of the Moine Thrust Zone in the Eriboll region of the NW Highlands, Professor Charles Lapworth drew inspiration from the Alpine experience of Arnold Escher and Albert Heim, especially the graphic and beautifully illustrated accounts of the structures of the Swiss mountains (Lapworth 1885). Lapworth quickly convinced Survey geologists Benjamin Peach and John Horne of the validity and elegance of his solution involving low-angle fault repetitions. So began a period of hugely productive geological mapping for the Geological Survey of Great Britain, a superb effort that culminated with publication of the classic Geological Survey memoir (Peach *et al.* 1907) and of the 'Assynt Special Sheet' (Geological Survey of Great Britain 1923). Fully a century after publication of that memoir, new revision mapping and structural analysis in the Moine Thrust Belt by BGS has been exploited in order to produce the first digital 3-D visualisations of the beautiful complexity of this iconic geological structure.

This is however not the first 3D geological model of the Assynt Culmination. By 1904 the Geological Survey had constructed a model cast in plaster of Paris from wooden moulds, made under the supervision of the Chief Draughtsman, Mr John Dick Bowie, in the Geological Survey Office in Edinburgh (then located in the Sheriff Court Buildings). This relief model was prepared with no vertical exaggeration, at the scale of six inches to one mile from the Ordnance Survey maps of the time, and represented an area of about 168 sq. miles (c. 435 km^2). The model was orientated N. 33°E–S. 33°W in order to include the whole of the Assynt Culmination within the confines of the four equant blocks constructed in relief (Figure 2). Mr Bowie painted the model, guided by Peach and Horne, adding streams and location names. The design required Peach and Horne to construct sixteen new geological cross sections that would ornament the edges of the four blocks — BGS still retains the original linework of those sections on strips of tracing paper, now brown and rather fragile after more than a century! This first model was destined for exhibit at the 1904 World Fair in St. Louis but on arrival was discovered to have been damaged in transit and hastily, if temporarily, repaired. The model is described in *Guide to the geological model of the Assynt mountains* (Peach & Horne 1914).

***Figure 2** Early 20th Century relief model of Assynt, constructed by the Geological Survey of Great Britain and currently displayed in the Cockburn Museum, Grant Institute, University of Edinburgh. BGS image number P883683.*

Further models were created: one for the 'Edinburgh Museum', one for the Geological Survey's Museum (then in Jermyn Street in London), one for Cambridge University, whilst John Horne wrote (25 Jan. 1906) that "Peach and myself are going to present a copy of the Assynt model to Glasgow University". In the next decade it seems that further models were requested through John Horne from Wisconsin and Harvard Universities, although both were reluctant to pay more than £75. Winnipeg University ordered one through Ben Peach—at any price! Peach was perhaps the better salesman. What of these models now? One remains on display in the exhibition hosted by the Orcadian Stone Company in Golspie, and one more is exhibited on the wall of the Cockburn Museum in the Grant Institute of Geology in Edinburgh University. This latter example is possibly the version originally created for the 'Edinburgh Museum' in 1905 or thereabouts but that remains uncertain.

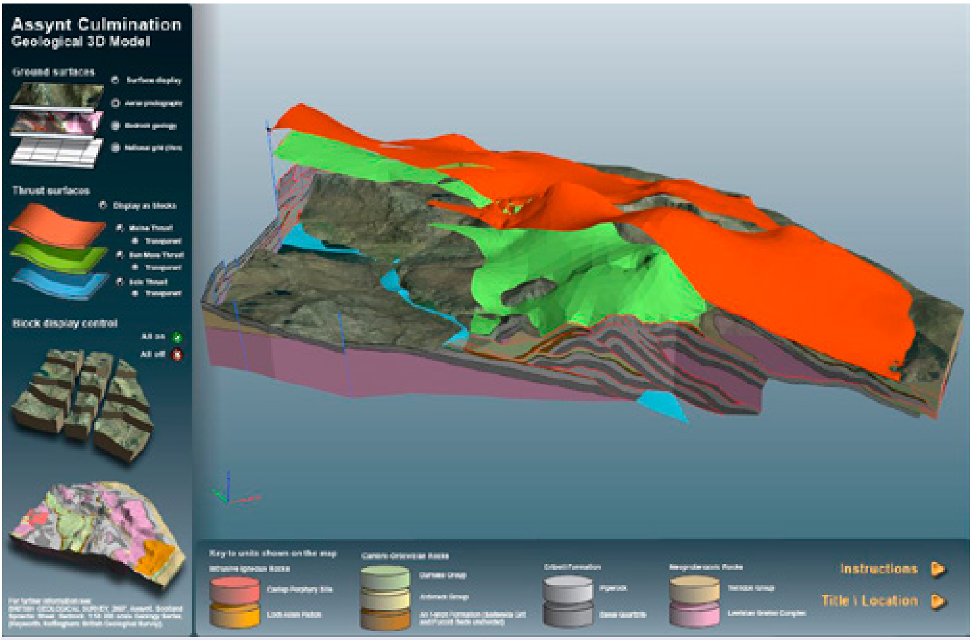

***Figure 3** Interactive digital 3D model of the Assynt Culmination, released by BGS in 2012. Image at … http://www.bgs.ac.uk/research/ukgeology/assyntCulmination.html*

This classic understanding stood until the 1980's, when a raft of new insights and discoveries were made by Dave Elliott and Mike Johnson, Mike Coward and Rob Butler. BGS re-surveyed Assynt in 2002–2004, an effort that allowed publication of the new and revised Assynt Special Sheet (BGS 2007). New discoveries and insights from this most recent phase, which included recognition of transverse structures in the thrust belt, are reported elsewhere (Krabbendam & Leslie 2010). Now, BGS have released a new interactive 3D geological model of the Assynt Culmination in 3Dpdf format (Figure 3). The model is designed to appeal to the widest possible audience, professional and amateur geologists alike, as well as those who perhaps wouldn't consider themselves any kind of geologist—just curious about the nature of the Earth we inhabit.

Unlike the plaster models of Peach and Horne this new visualisation is free to anyone with access to the BGS website. The model aims to provide an informed insight into mountain building processes and the way that individual slabs of rock are stacked up on each other as thrust sheets, each thrust sheet repeating the geology of the sheet below.

Geological architecture of the Assynt Culmination

The geology of the Assynt District is arranged around an upward bulge or culmination in the Moine Thrust plane so that the structure known as the Assynt Culmination is enclosed within the curvilinear map trace of the deformed thrust (Fig. 1, cf. the bulged curviplanar orange-red thrust plane in the model in Fig. 3). Major individual thrust sheets broadly overlap each other within the culmination (and

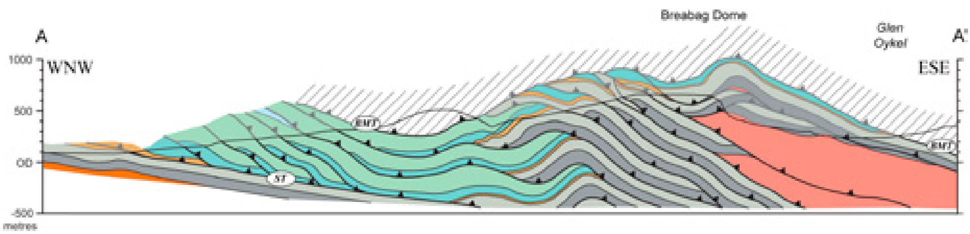

***Figure 4** Cross-section showing thrust architecture in the Assynt Culmination (after British Geological Survey 2007). No vertical exaggeration. Location of section line is indicated on Fig. 1. BMT = Ben More Thrust, ST = Sole Thrust. Ben More Thrust sheet is hatched.*

in the model) in such a way that the more easterly thrust sheets (in general terms) overlie those to the west. Thrust movement overall was to the WNW and most thrusts dip gently to the ESE (Figure 4). The Moine, Ben More and Sole thrusts are visualised as key surfaces in the new digital model. The structurally highest, and also largest, thrust sheet within the culmination is the Ben More Thrust Sheet, with the Ben More Thrust at its base (Fig. 1, green in the model in Fig. 3). The floor thrust in the culmination is regarded as the Sole Thrust (Fig. 1, blue in the model in Fig. 3). Krabbendam & Leslie (2010) demonstrated that elements of the transverse fault system must have been active before, during, and after displacement on the thrusts that built the Assynt Culmination. Thrusting was thus slicing through a geological framework that had already been significantly disrupted by faulting and those pre-existing steeply dipping faults became surfaces able, or more likely forced, to accommodate some of the deformation and horizontal displacements associated with thrusting.

John Dick Bowie. BGS image number P225779

Final Thoughts

Geologists are, in many senses, story tellers. They take a set of discrete geological observations and weave them into a narrative that captures the 3D model and how it evolved through time, a model that is continually being modified and upgraded in their heads as they explore their geological world! They then write that narrative down in papers and memoirs and illustrate it with pictures such as maps, cross sections and block diagrams. The ever present challenge for the story-telling geologist is to create a visualisation that allows their audience/reader/listener to truly appreciate what it is that the geologist has seen in their mind's eye. Of course, there is a limit to what can be shown on a 2D piece of paper and therefore the results can often be confusing to non-geologist and even other geologists may not fully appreciate what the story-telling geologist is trying to convey. The new digital 3D geological model of the Assynt Culmination is designed to address that challenge. As a user, your feedback will guide future developments of the Assynt model. Attempts to create more tangible representations of the geology of Assynt, in either plaster of Paris or in a computer, bracket our evolving understanding of this seminal region of Scottish Geology. The move from paper to pixels continues the development of that understanding.

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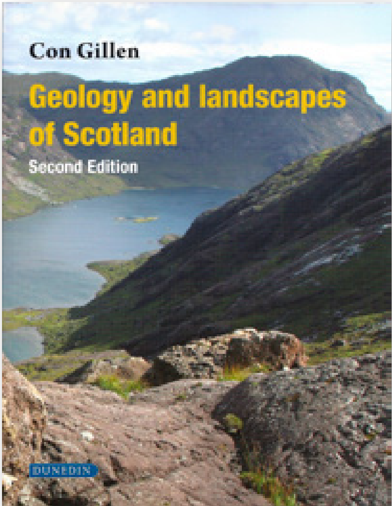
Book review

Geology and landscapes of Scotland by Con Gillen. Dunedin Academic Press, Edinburgh. 2013. Paperback, viii + 260 pp. Price £24.99. ISBN 978-1-78046-009-3.



This is the 2nd edition of the book first published by Terra in 2003. It is partially updated for recent research (e.g. geological time frame and Highland Border Complex debate), in larger page size and with full colour photographs. The book's structure is pleasingly straightforward, with Chapters 1 & 2 providing the basic geological building blocks and an outline of the regional framework. These two chapters set the scene for five regional chapters that describe the essence of Scotland's main geological terranes; *The Ice Age* and *Natural Resources* chapters then nicely 'ice the cake'. This is an economical way of describing Scotland's rich geodiversity generally avoiding repetition of content between chapters, which are complemented by an appendix with suggestions for further study, an extensive glossary of technical terms, translations of Gaelic terms, a bibliography (short), and indexes of place names and general terms. The book is well illustrated with many figures (32 plates, 171 diagrams and 11 tables) none of which is included in the contents list. Was the publisher reluctant to include the extra pages in the contents? I think this would have made the book user-friendlier.

The book is written in lay language for the most part backed up by relevant conceptual diagrams, 'informative green text boxes' and also by the technical glossary. However, I felt that a conceptual sketch of the origins of the Tay Nappe and its associated structures (Chapter 4, p. 83), would have been useful. The generally high quality of the plates should ensure that those with a 'coffee table' type approach would turn the pages. However, there are plates that for a variety of reasons are poorer than the overall standard set by the author (e.g. figs 3.6 Scourie dyke; 4.19 Walls Peninsula folded Old Red Sandstone; and especially 5.4 Ochil Hills from Wallace Monument). This limited selection possibly illustrates some of the problems when authors use only their own photographs with their contents and quality fixed by the circumstances of their visit. Also, some of the captions direct the reader's attention to background features that really are no more than shadows of a distant landscape, or is this my failing eyesight?

There are minor (and repeated) errors in the text such as the erroneous 's' in Uplands in 'Southern Uplands Fault'; Dundee Law is not a plug but a sill; and the Midland Valley is not a simple rift as left and then right lateral strike-slip movements on the bounding and other major faults controlled basin and structural development through time. There is also some avoidable repetition of content. It may be my bias that I dislike the frequent use of such terms as Old Red Sandstone and New Red Sandstone for these lithofacies (this word not in author's glossary); especially since the Torridonian is not referred to as the 'Older Redder Sandstone', a term used by my old professor in the 1960s as a truthful joke. There is also a tendency to switch slightly quirkily between old terms like 'Tertiary' to the modern 'Palaeogene and Neogene'. I prefer 'mudstone' to 'shale' and wacke sandstone is the modern term for greywacke.

However, the above are minor points. A slightly more serious concern is about stratigraphy. There are tables of Divisions (lithostratigraphy and other useful data) in chapters 3 and 4 for the Dalradian to subgroup level (table 4.2) and formation level for the Torridonian (table 3.2) and Moine (table 4.1) but none for the Ordovician and Silurian. All subsequent chapters lack such tables. In a way, I can sympathise with the author especially at formation level within the Devonian and Quaternary (many new names published). The widely spaced Devonian (s.l.) sedimentary basins all have their own and possibly rather dated nomenclatures (e.g. northern Scotland). However, their succinct presentation in tabular form might have provided easily accessible summary information on depositional environment etc.

For the Carboniferous, a divisional table to formation level for the Midland Valley of Scotland (not forgetting the Solway and Northumberland basins; the latter not being mostly limestone, see p. 105) would have contributed to a more coherent account that includes old terms like the 'Ballagan Beds' and also eschews the use of the modern and convenient 'Clyde Plateau Volcanic Formation'. The redundant 'upper limestone group' is also in the text without any mention of a 'lower limestone group' or intervening 'limestone coal group'. The Carboniferous account would also have benefited from a conceptual figure showing the rock types and environments associated with Carboniferous 'cycles' of sedimentation. This might have allowed some tightening up in the text (e.g. p. 119) where limestone, or sandstone and coal are mentioned as if these were the only lithologies in the usually un-named stratigraphical units.

Notwithstanding these and other grumbles that will remain unrecorded, the book is a reasonably comprehensive and generally excellent account of Scotland's geodiversity, explaining and promoting both its rich geology and varied scenery and landforms (but where is the photograph of a drumlin hill?). It is written for and should appeal to a wide audience and, given my previous ignorance of the modern interpretation of the Hebridean Volcanoes (Chapter 7), is easily readable and enjoyable. This is probably not surprising since the author has led or taken part in many field trips across Scotland and the surrounding islands capturing the essence of these in photographs. Much of his career has been focussed on introducing geology to those with little knowledge of the subject. In this book he uses his experiences in life-long-learning and educating tourist guides to show why Scottish landscapes are what they are and why they are so much loved by us residents and our visitors alike. His narrative also makes the reader aware of the historical beginnings of the science of geology in the late 18th century with James Hutton, and other later historic figures such as Ben Peach and John Horne. It also shows how Scotland's geodiversity continues to be at the heart of modern research as it spreads from the detail contained in the basic topics of geology, geomorphology etc into the modern cross-discipline (environmental) themes relating to climate change, changing sea levels and the low carbon economy. I have no hesitation in recommending a trip to the bookshop for this one, or is it to the Amazon these days?

By Mike Browne

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