

The Edinburgh Geologist

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Cover Illustration

Middle Devonian fossil fish from Caithness. BGS image number P064452. These examples of *Thursius macrolepidotus* were found at Sandside Bay, Reay. The width of the view shown is about 18 cm. For a history of the genus *Thursius*, established by Ramsay Traquair in 1888, see Newman, M J & den Blaauwen, J L. 2007. The synonymy of the Scottish Devonian osteolepid fish *Thursius macrolepidotus*. *Scottish Journal of Geology*, Vol. 43, 101–106. More on fossil fish—but in the pavements of Edinburgh—can be found in the article by Tom Challands and Ken Shaw in this issue of *The Edinburgh Geologist*.

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Gone fishing, on museums and collections, and down amongst the bears

An editorial ramble by Phil Stone

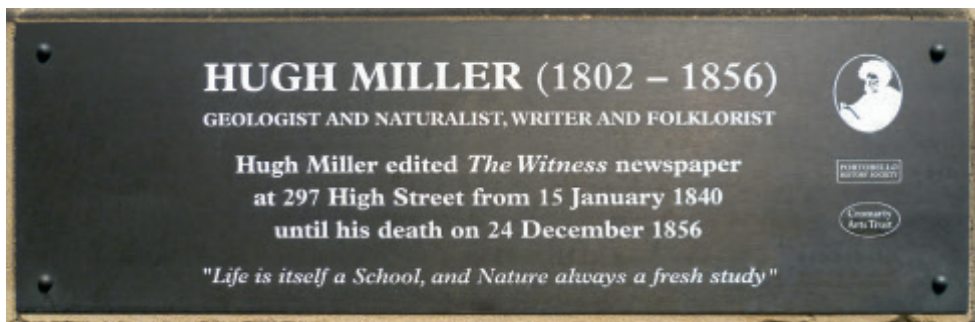
Gone fishing

Just when you thought that the streets of Edinburgh might soon be disencumbered of tram-related obstacles, a new hazard presents itself. In the future we will have to beware tripping over prostrate palaeontologists carefully examining our paving slabs because, as Tom Challands and Ken Shaw explain in this issue of *The Edinburgh Geologist*, some have proved to contain an unexpected fossil bonanza. It seems that the Caithness flagstones that grace much of central Edinburgh are host to Devonian fish, and such is the quality of some specimens that the City Council has been persuaded to finance removal of the requisite slabs to allow for their preservation and further examination. As Tom and Ken describe it, the story is an excellent example of ‘citizen science’ in action that will enliven many future walks around the city—and further afield. Was that one that I saw on the paved terrace area outside the new cafeteria at Rosslyn Chapel? It’s in the far left corner as you go out. So far so positive, but there was some associated bad news early in June when it was announced

that Caithness Stone Industries, operators of Achscrabster Quarry whence came some of the fossiliferous paving, had gone into administration citing “increased competition, heavy investment expenditure and rising operating costs”. Let’s hope that the business can be revived. We need more fish.

On museums and collections

The best of Edinburgh’s pavement fish are destined for display in The Museum of Edinburgh, and as an introduction there are quite a few fossil fish to be seen in one of the books reviewed in this issue of *The Edinburgh Geologist*—Nigel Trewin’s *Scottish Fossils*. Like the Challands & Shaw article it highlights the pioneering work on Scottish Devonian fish faunas by Hugh Miller and Ramsay Traquair. The book’s illustrations also reminds us that Miller, after moving from Cromarty to Edinburgh in 1840 to become editor of *The Witness* newspaper, broadened his palaeontological interests to include Carboniferous plants. Whilst in Edinburgh, Miller stayed at ‘Shrub Mount’, a house behind 76–80 Portobello High Street



where an extension was built to house his growing collection of fossils. It was in his bedroom at 'Shrub Mount' that he shot himself on Christmas Eve, 1856, a tragedy attributed to overwork and an increasing paranoia about the security and future of his prized specimens. He need not have worried. Much of Miller's collection is now held by the National Museum of Scotland in Edinburgh, having originally been acquired by public subscription to an appeal fund. How that all came about was described by Michael Taylor and Martin Gorstwick back in *EG* 40. If you don't still have a copy you can check it out on the EGS website.

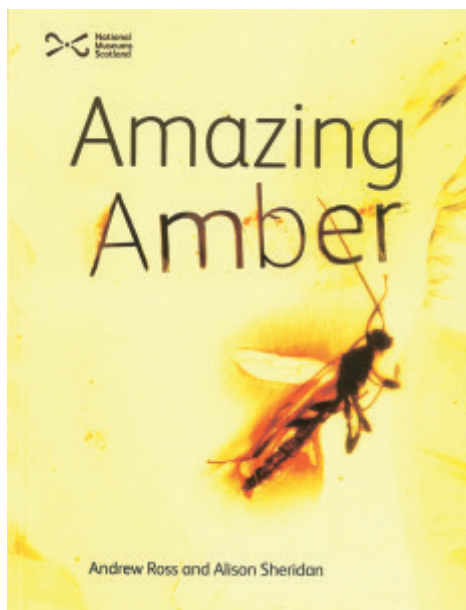
Traquair became Keeper of the Natural History collections in the Edinburgh museum from 1873 to 1906, but in the museum of today, where his specimens reside, is mostly remembered by association with his artistic wife, Phoebe. Quite apart from her more celebrated works she illustrated her husband's palaeontology papers and it is these drawings that the museum now

This plaque commemorating Miller's time in Edinburgh can be seen on the Royal Mile opposite St Giles. I have a very vague memory of there being an earlier, bronze version. Can anyone confirm that?

displays rather the fossils themselves. You can see them on Level 5 of *The Story of Scotland*, though they take a bit of finding in the architectural labyrinth. Ramsay Traquair died in 1912 and he and his wife are buried in Colinton churchyard in south-west Edinburgh. On an EGS excursion that passed that way a couple of years ago, Beverly Bergman pointed out the rather touching adornments carved into their gravestone: two little fish with a distinctly Devonian look for Ramsay, and an artist's palette for Phoebe.

Happily, fossils collected by Miller, Traquair and many others now have a splendid new home, as Andrew Ross describes for us in his article on National Museums Scotland's

recently completed palaeobiology store. With something like 250 000 specimens in the palaeontology collections alone you can imagine the labour involved in sorting, packing and re-establishing the collections as they were moved from the cramped basement in Chambers Street to their state-of-the-art accommodation in Granton. Some readers might recall that a few winters ago Andrew Ross lectured to the Edinburgh Geological Society most entertainingly on one of his specialities—amber. I'm not sure how, but whilst supervising the move across Edinburgh of a quarter of a million fossils, he also found time to master-mind an excellent exhibition of amber at the National Museum of Scotland. Sadly it came to an end in September, so if you missed it—tough luck. But don't despair. The 'book of the show' is still available and is beautifully illustrated: *Amazing Amber* by Andrew Ross and Alison Sheridan. Apart from the geology of amber there is quite a lot about its archaeological appearances in Scotland, artistic uses, some advice on spotting fakes and much on the included insects—and yes, *Jurassic Park* does get a mention. Some of the insects featured previously in an amazing set of photographs published by William Crichton and Vincen Carrió in *Scottish Journal of Geology* back in 2007 (Vol. 43, 89–96)—well worth another look. By coincidence, their paper is in the same



issue as that referred to in our cover picture caption.

Astonishing geological detail from Mars continues to flow from the *Opportunity* rover, but our extra-terrestrial contribution in this issue of *The Edinburgh Geologist*, from Andy Blythe, looks further afield to the asteroid belt, and closer to home at the meteorites sent our way from there. Andy gives a fascinating account with Russian examples ranging from the spectacularly recorded, Chelyabinsk meteorite fall earlier this year, to the famous 'Tunguska Event' of 1908. Though Andy's examples were all comfortably far away, Scotland has not been immune to meteorite strikes. I

came across some nicely personalised references to what was probably our largest one (so far) when searching through the National Museum's catalogue for something completely different. When I found what I was looking for, the following two entries then also caught my attention:

1. Large meteorite which fell at Easter Essendy Farm, Blairgowrie, Perthshire, on Monday, Dec. 3rd, 1917, about 1.15 pm. It was found by Charles Smart, farm servant, who recovered it from a hole 18" deep, made by the stone. Specimen weighed [on] 6.10.21 on large balance at Heriot Watt College. Wt = 9911 gms.
2. Meteorite which fell at Carsie, Blairgowrie, about 1.15 pm. on Monday, Dec. 3rd, 1917. It was observed to fall by Grace Welsh who was standing about 30 yds. from the place where it struck the ground. Wt. = 1085 gm.

I suppose that Grace (the Carsie farmer's wife) could count herself quite fortunate at her near miss. These days, judging from Andy Blythe's article, Charles (other reports give his surname as Small or Steel and describe him as the farm foreman) could have made his fortune via 'certain online auction websites'.

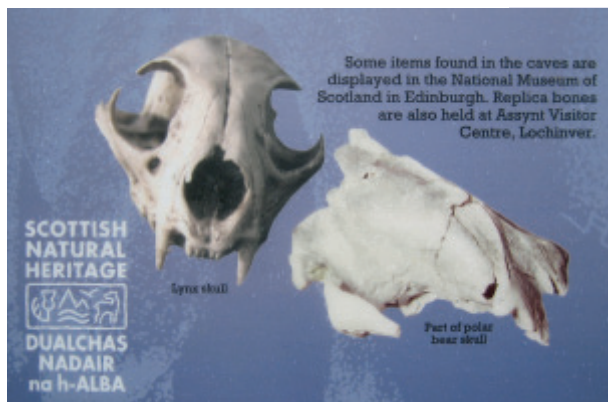
These were two fragments of the 'Strathmore Meteorite', a stony

chondrite. Two other fragments were also recovered (both weighing about 1 kg), one of which crashed through the roof of a house in Keithick just to the south-west of Coupar Angus. The 'Keithick Fragment' is now on display in the National Museum—although the accompanying text rather confuses its history by relating the meteorite to an event in February 1916 when "a large fireball was seen in the skies of northern England and central Scotland". And I could have another rant about the back-lighting of dark rocks in dimly illuminated museum galleries.

One final thought on things extraterrestrial: a letter from Bill Gilmour reminded me of an early association between Mars and the Edinburgh Geological Society, as recorded in *The Edinburgh Geologist* number 40 (Spring 2003) where the late Donald McIntyre described (to Alan Fyfe, then *EG* editor) his involvement with experiments aboard the two Viking landers, launched in 1975. By another odd coincidence, the article immediately precedes the one on the Hugh Miller fossil collection that was mentioned above—*EG* 40 is clearly worth another look.

Down amongst the bears

Rather deeper holes than the one made by Charles Smart's meteorite are the subject of our final article in this issue of *The Edinburgh Geologist*.



A detail of the display board from the Inchnadamph National Nature Reserve. BGS image number P637351.

Holes in the ground always have a fascination for geologists and Alan Jeffries takes us on a tour of some of Scotland's relatively rare cave systems. Alan founded the Grampian Speleological Group in 1961 and has been personally involved in many of the Scottish discoveries. In his article he mentions the recovery of a brown bear skeleton from one of the Assynt caves. This would have been in 2008 (it got quite a lot of media attention) and at about the same time DNA analysis of a bear skull unearthed back in 1927 finally resolved the argument over whether it was a brown bear or a polar bear in favour of the latter. So, polar bear can join brown bear in the long list of 'exotic' species represented in the Assynt bone caves: lynx, arctic fox, wolf, reindeer, lemming etc. Quite a range of ages have been proved by radiocarbon dating, back to about 45 000 years ago, but the polar bear is thought to be about 22 000 years old. Human remains from the cave

have been dated to about 4500 years ago. Of course, the Assynt caves are now a SSSI and a part of the Inchnadamph National Nature Reserve. The polar bear skull can be seen in Edinburgh, at the National Museum, whilst a lynx skull (also held by the museum but not currently on display) is one of the featured fossils in Nigel Trewin's book, mentioned above and reviewed later in this issue of *The Edinburgh Geologist*.

Finally, thinking of books, our second review in this issue of *The Edinburgh Geologist* takes us back to the city streets, or rather steps. *Ardtonish House* by Peter Warren features the 19th century mansion overlooking Loch Aline so at first sight might seem to have little relevance to the capital. But links with Martin Creed's *Work No. 1059*, aka *The Scotsman Steps*, suggest some surprising sources of inspiration for our local, colourful and geologically eclectic landmark. Incidentally, the Steps seem to be standing up to their environment rather more robustly than I had feared. Sometimes it's nice to be proved wrong.

Poissons, Pavements and the Public: tripping over Devonian Fossil Fish in the streets of Edinburgh

By Tom Challands and Ken Shaw

Fossils in building stones are common enough. We are used to seeing beautiful sections of coiled mollusc shells in Portland Limestone buildings or the half bullet silhouette of a belemnite in the floor of Edinburgh's Ocean Terminal shopping centre for instance. Fossils of vertebrate remains in building stones are, however, rare and the opportunity to find, study and let the world know about such discoveries is an exciting one.

One such discovery was made in May of 2012. Ken Shaw, a member of the Edinburgh Geological Society (EGS), was making a trip to Our Dynamic Earth when, much to the chagrin of his children, he noticed an unusual 'inclusion' in the paving slab. In Ken's words, "I was walking along East Market Street to visit Our Dynamic Earth with my children, when I noticed something in one of the paving slabs. On closer examination, a clear fish head and scales could be seen, much like some we had seen the previous summer in the Hugh Miller museum in Cromarty". Not wanting such a fine specimen to be destroyed by a passing stiletto heel or scraped off during snow clearing,

Ken contacted Dr Al McGowan of the University of Glasgow, whom he had met during EGS field excursions, to see if, somehow, its preservation could be arranged. "Little did I know then what had been set in motion! A brief subsequent examination of the length of the East Market Street pavement highlighted several more fish and also plant specimens. Then as more people became involved more fish were spotted in the pavements around Edinburgh, and soon I found myself amongst a team of people watching as some of the slabs were uplifted for further study. I'm looking forward to when sufficient funds have been raised to start on preparation of the fossils, and also to having a go myself—but not on any critical areas!"

The presence of fossil fish in paving slabs around Edinburgh is an interesting story linked intimately with the industrial heritage in the far north east of Scotland and the complex palaeoecology of the Orcadian lake system of 370 million years ago. Some of the great pioneers in 19th century Scottish geology, such as Ramsay Traquair and Hugh Miller,



Figure 1 Ken Shaw on East Market Street pointing out the first specimen of *Dipterus* that he found. This specimen and four others are currently being prepared in Murchison House prior to being displayed in the Museum of Edinburgh.

were familiar with fossil fish from the Devonian sandstones and siltstones of Caithness, Orkney and Shetland and published extensively on them. Such was the abundance of the material that it was frequently brought to the attention of the leading ichthyologists of the time, Louis Agassiz and Achille Valenciennes. Agassiz devoted a significant proportion of his seminal

Recherches sur les Poissons Fossiles to Scottish Devonian material. The fish-bearing beds of the Orcadian basin still produce new and exciting finds with new species, such as the lungfish *Pinnalongus saxoni*, having been discovered as recently as 2007.

In the 19th century the Caithness flagstone industry was in its hey-day. Material was exported throughout the world and it became renowned for its high quality and hard-wearing properties. The extent of its worldwide dominance is still seen in the streets of cities such as Rio de Janeiro, Paris and Boston. Today, only two working quarries remain; Spittal Mains Quarry and Achscrabster Quarry. Spittal Mains Quarry is less than a mile from the famous Achanarras Quarry and is run and owned by A & D Sutherland, whereas Achscrabster is owned and operated by Caithness Stone Industries Ltd. Though this is a small fraction of the number of quarries operating during the turn of the 20th century, the last fifteen years have seen a revival in the use of Caithness flagstones, particularly for paving. The material that paves the streets of Edinburgh today was sourced from both quarries during different phases of redevelopment of the city centre over the last ten to fifteen years. The material around the Scottish Parliament, Holyrood Palace

and Our Dynamic Earth originates from Achscrabster Quarry whereas material on East Market Street and Lothian Road was sourced from Spittal Mains Quarry.

What's the difference between the paving stones from the two quarries? The main ones are the thickness of the flagstones and the type of fish that are found in them. Lithologically the flagstones are very similar since both quarries yield fine-grained organic-rich laminated siltstones with thin sandy horizons. Coarser-grained units show evidence of ripples and dewatering structures. Syneresis cracks are abundant and both dolomitic and pyritic nodules pepper the surfaces of bedding planes. Material shipped from Achscrabster Quarry is typically split to be around 120 mm thick whereas flagstones from Spittal Mains Quarry vary between 70 mm and 80 mm. The reason for the difference in thicknesses is nothing more than the preference of the person who originally ordered the material. The flagstones are, however, unusual given that for the purposes of pedestrian use 30 mm thickness is more than adequate for this type of stone.

Since the initial discovery of three fossil fish specimens on East Market Street by Waverley Station, more

than twenty five flagstones with fish and plant fossils have been located throughout the city of Edinburgh. The majority are not as fine as the original specimens of *Dipterus* sp. discovered by Ken on East Market Street but some of the best include a large predatory fish, *Gyroptychius* sp., and the front portion of an armoured fish *Dickosteus threiplandi* from the Scottish Parliament esplanade. These specimens are from Achscrabster quarry. The quality of many specimens is good enough to warrant further study and justifies preserving them for the public. Furthermore, Spittal Mains Quarry is a SSSI and is the type locality for *Dickosteus threiplandi* Miles and Westoll, 1963 and *Trewinia magnifica* Janvier & Newman, 2005, the only cephalaspid fish from the Middle Devonian and also the only one from the Orcadian Basin. Coupled with the recent discovery of a new fish-bed in this quarry and reports in volume 16 of the Geological Conservation Review (Ch.6, p.2) of "*a probable new, and as yet, undescribed species of Dipterus*", it was deemed appropriate to engage in dialogue with the local authorities to plan the rescue and recovery of the best specimens. This was particularly timely given the imminent construction of the new Scottish Parliament security wing which would have seen some of the specimens being built on.

East Market Street specimen AR 653/3/12
Dipterus sp.

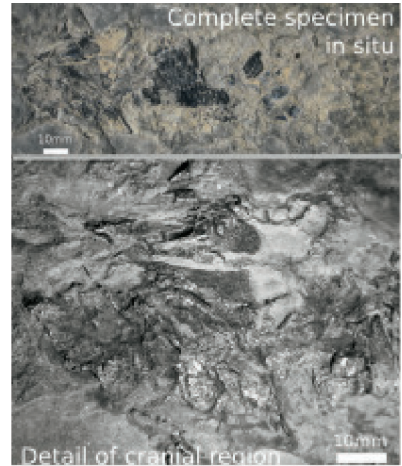
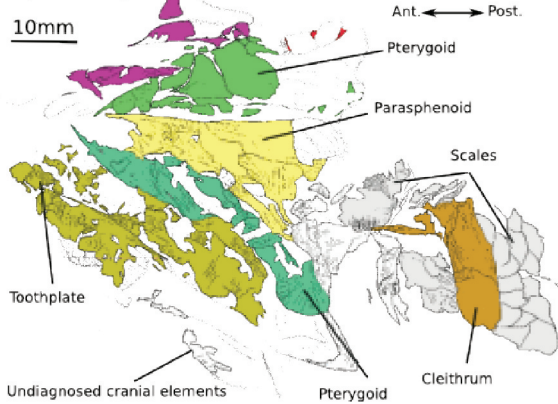


Figure 2 Details of the specimen in Figure 1 showing the arrangement of bones in the head of the specimen. This specimen of *Dipterus*, a fossil lungfish, has been preserved so that the bottom of the head is visible i.e. the images show the lower jaw.

‘Rescue archaeology’ is a term that most people are familiar with but ‘rescue palaeontology’ is a relatively new concept, indeed, even more so on the streets of a capital city. When Dr Al McGowan approached the City of Edinburgh Council they agreed to help and contribute to the project by paying for extraction costs and donating the material for our study. On completion of work the material will be housed in and put on display in the Museum of Edinburgh on the Canongate. The custodians of the Scottish Parliament have been equally receptive to the notion that a small piece of Scotland’s geological and

industrial heritage was lying on their front doorstep. Extraction of two specimens from the Scottish Parliament area was conducted in September 2012 coinciding with the beginning of the building works on the new security wing.

Further contributions made by individuals and institutions has been extraordinary. The British Geological Survey (BGS) at Murchison House have granted storage space for the specimens and have allowed one of their laboratories to be given over to use in preparation of the specimens. The University of Glasgow Chancellor’s Fund,



Figure 3
Removal
operations by
Tarmac Ltd on
East Market
Street.

alongside the BGS, provided the means to equip the lab and develop a 'roaming' museum that can tour various venues to exhibit the material and also demonstrate the preparation techniques used in study of these specimens. Furthermore, A & D Sutherland have been central in the operations allowing continued access to Spittal Mains Quarry to sample the new fish bed and to collect specimens. Two specimens were even CT-scanned at the Edinburgh Royal Hospital for Sick Children following an invitation from a radiographer who saw the specimens at a BGS open day at Murchison House. This process greatly aids the preparation process by providing an image of areas of bone that are still embedded in the rock.

Scientifically, these fossil fish specimens are important in two

ways. Firstly, they raise the possibility of recognizing new taxa of fossil fish from the quarries. Secondly, the palaeoenvironmental importance of the new, fish-bearing horizon in Spittal Mains Quarry is enhanced by its proximity to the unique Achanarras Quarry. Achanarras is unique in that it yields a high diversity of taxa and is slightly more carbonate rich than stone excavated at other localities. Though the new fish bed and Achanarras quarry lie at different stratigraphic horizons their difference in age is close enough to tentatively hypothesize that they were formed by the same or similar processes. An undergraduate student at the University of Edinburgh is currently addressing this question by painstakingly measuring the thicknesses of laminae throughout the Spittal Mains fish bed and comparing the frequency of depositional cycles to those at Achanarras, which have

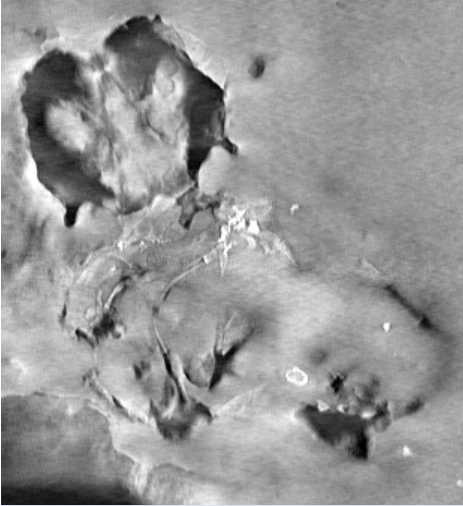


Figure 4 CT-scan of *Dickosteus threiplandi* recovered from Spittal Mains Quarry. The large dark area is the head of the specimen with the main elements of the body being less obvious and lying below the head. *Dickosteus* was a bottom-dwelling placoderm fish superficially resembling a heavily armoured shark.

already been attributed to sunspot activity (Andrews *et al.* 2010).

More and more natural stone material is being used around cities in the UK but there is no definitive geological map of the streets and building of our cities. We simply do not know where else to look for similar specimens. In Scotland there is certainly material in Glasgow,

Aberdeen and Dundee, whilst in England a considerable proportion of Newcastle city centre and parts of London are paved with Caithness flags. With modern quarrying methods bypassing many fossil finds, bringing the stone to the public by putting it quite literally under their noses, is an excellent means of stimulating mass participation in fossil hunting. Moreover, the effect that one interested amateur has had on the generation of a research and scientific outreach project has been profound and will encourage more public participation in geoscience projects. If you see any more fish on the pavements of Edinburgh please let us know.

Acknowledgements

Those involved in what has informally become known as 'The Pavement Fish Project' would like to thank the City of Edinburgh Council, the British Geological Survey, the University of Glasgow, The Museum of Edinburgh, The Scottish Parliament, Tarmac Ltd, A & D Sutherland and Mike Newman.

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Meteorites and the building blocks of the Earth

By Andrew Blythe

Russia has witnessed two remarkable and widely differing falls from space during the previous century, the Tunguska event and the Sikhote-Alin meteorite. On the morning of 15th February 2013, and thanks to unprecedented media coverage, the world witnessed the most remarkable meteorite fall of the twenty-first century to-date. Brighter than the Sun, and followed by a massive shockwave blast minutes later, we all saw the arrival of the Chelyabinsk meteorite over Russia.

For the meteorite enthusiast and collector, this fall near the south-eastern edge of the Ural Mountains has re-invigorated an enormous amount of interest in the subject... and a frenzy of buying activity on certain online auction websites, leading to some astronomical prices! Rarely grabbing attention, the humble meteorite has been elevated from the dusty shelf of the museum or collection back into the spotlight.

Continued from page 11 . . .

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Meteorites however, are a fascinating subject in their own right, as within these rocky time-capsules are preserved the earliest processes of the planetary formation within the Solar System.

The media spotlight on Chelyabinsk has led to many individuals asking the question, *what are meteorites and where do they come from?* Could the extraordinary fall of this 'ordinary chondrite' shed further light on the most mysterious and remarkable fall of the twentieth century, *the Tunguska event of 1908?* This article aims to provide an overview of the former, whilst providing a platform with which to explore the latter, with thought-provoking implications.

Whilst it is well known that meteorites originate from asteroids, it is often assumed that they are the rocky remains of a spectacular planetary collision and break-up. However, the origin of almost all of the estimated 100 000 asteroid bodies is less glamorous, as they are nothing more than piles of planetary building block rubble, with a total mass less than the Moon.

So, let us have a look at the origin of these pieces of space rubble that grab the headlines on the rare occasion they come crashing through the atmospheric window of the Earth.

Meteorite origins and composition

Meteorites originate within the Solar System from the fragmented material released by the collision of asteroids with other asteroids and planetary bodies.

Asteroids formed ~4.56 billion years ago within a disc-like rotating nebula of material, left over from the formation of our Sun. Consisting of interstellar gases and heavier elements of 'cosmic dust', formed from earlier generations of stars, this material condensed out of the solar nebula into solid matter as temperatures reduced, in the following order: metal oxides, metallic grains of nickel-iron alloy, silicates, sulphides and finally organic compounds. Gravitational attraction and collision of this material within the rotating nebula led to the formation of small rocky 'asteroid' bodies, which in turn accreted together to form larger embryonic planetary bodies.

The majority of the 7000 meteorites catalogued originate from the asteroid main-belt located between Mars and Jupiter. With the exception of a handful of dwarf planet-like bodies, the asteroids represent the failed formation of a planet, caused by the gravitational interaction between Mars and the massive 'gas-giant' Jupiter. The disruptive effect of this interaction results in the collision and fragmentation of

asteroid material out of orbit. As a consequence, meteorites provide us with material that has a composition, structure and age identical with the original building blocks of the terrestrial planets including Earth.

The abundance or absence of condensed solar nebula material within a meteorite reflects stages in the process of material accretion within a parent asteroid or planetary body, leading to four meteorite types: chondrite, achondrite, stony-iron and iron. Possible meteorite sources can be determined through the matching and classification of an asteroid by surface reflectance spectra.

Chondrite meteorites

Chondrite meteorites contain the original planetary building block material, relatively unaltered by tectonic/melting processes, though often displaying the effects of impact, accretion or break-up of the parent asteroid body.

Chondrite meteorites are characterized by the presence of 'chondrules', globules of melted material thought to be formed by transient heating processes within the solar nebula during the 'T-Taurid' phase of stellar evolution. The most abundant meteorite type is the 'ordinary chondrite', typically composed of a stony assemblage of

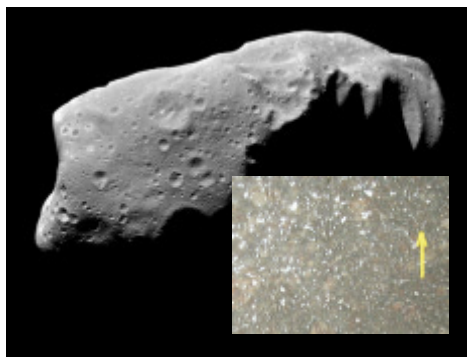


Figure 1 An S-type main belt asteroid '243-Ida' (Image JPL/NASA). At 58km in length and believed to have originated from a larger undifferentiated body, this is a typical source for the ordinary chondrite (inset). Highlighted amongst this 3cm-wide section of pale chondrules and bright metallic flakes is an 'armoured chondrule', formed by the condensation of metals onto the spherical surface.

ferro-magnesium silicate chondrules interspersed with grains of metallic nickel-iron in a cosmic dust matrix.

Ordinary chondrites make up the highest proportion of observed meteorite falls, typically originating from the dominant population of siliceous S-type asteroids orbiting within the inner asteroid main belt. However, the carbonaceous C-type asteroid is the most abundant within the main belt, yet provides the source

for one of the rarest and most studied meteorite types, the carbonaceous chondrite. Not only do carbonaceous chondrites include the first solid material to condense out of the solar nebula in the form of calcium-aluminium-rich inclusions (CAI's), but their primitive structure may also contain amino acids and other carbon-rich organic compounds, which are the building blocks of life on Earth.

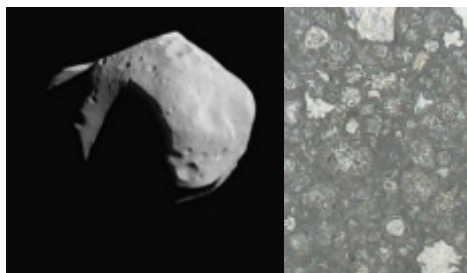


Figure 2 *The C-type asteroid '253-Mathilde' (image JPL/NASA), at 59x47km diameter and formed from loose rubble this is a typical source of the carbonaceous chondrite (inset). Note the white irregular-shaped CAI's and grey-rounded chondrules, set within the dark gray cosmic dust matrix of this 1cm-wide section.*

Iron meteorites

Composed almost entirely of a metallic nickel-iron alloy, these meteorites originate from relatively uncommon metallic 'M-type'

asteroids, and represent fragmented core material of a once larger body that has undergone 'differentiation'. Differentiation is the process of material separation that occurs when a planetary body becomes large enough, through the accretion of stony or carbonaceous asteroids, to generate sufficient heat to allow melting. Dense metallic grains sink to form a core, whilst lighter silicate material rises towards the surface to form a mantle-like layer that we see on terrestrial planets such as Earth.

In contrast to stony chondritic meteorites, the amount of iron meteorite material available to the collector is disproportionately high when compared to their low rate of fall. Iron meteorites are relatively durable; with an increased chance of surviving atmospheric entry and weathering, they are more readily identifiable on the ground. The fall of the Sikhote-Alin meteorite, 12th February 1947, provides the most remarkable example. The descending fireball and thick dust train was observed, some 380 km NNE of Vladivostok, and led to an immediate scientific expedition to the crater site. Understanding of the fall process and break-up of the ~3–4 m diameter, 90–100 tonnes mass, was uniquely aided via the morphology recorded in ~23 tonnes of recovered meteorites, ranging in size from one 1745 kg

individual down to droplet-sized spheres.

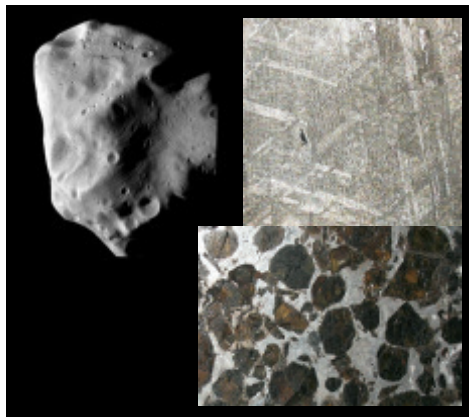


Figure 3 *Originating from a fragmented differentiated body, the M-type asteroid ‘21-Lutetia’ is a 96km-wide rubble pile of stony and metallic fragments (Image JPL/ NASA), and a typical source for the iron meteorite (inset top right, 2cm-wide) and pallasite (inset lower right, 5cm-wide). Iron meteorites commonly feature an interlocking structure of nickel-iron crystals known as the ‘Widmanstätten’ pattern, the coarseness of which is proportional to the rate of cooling of a differentiated asteroid body over millions of years, possibly following catastrophic impact.*

Achondrite meteorites

Achondrites are rare stony meteorites that represent the crustal and magmatic processes

of a differentiated planetary body, and consequently they generally lack primitive chondrule material. Meteorite sources include the Moon, Mars and the only differentiated body within the main asteroid belt ‘Vesta’, of which the latter is a source of the Howardite-Eucrite-Diogenite (HED) sub-class of meteorites. Typically, Howardites originate from the burial and heating of impact fragment ‘soil’ at the surface, Eucrites from the basaltic crustal rocks and Diogenites originate from the slow-cooling igneous rocks deep within the crust.

Unusually within the Asteroid Belt, the dwarf planet ‘Ceres’ is much larger than Vesta, yet is believed to have the core properties of a rocky C-type asteroid overlain with a water-ice mantle.

Stony-iron Meteorites

Composed of a silicate material and nickel-iron mixture, these extremely rare meteorites originate from the break-up of a differentiated asteroid. The ‘Pallasite’ sub-class has a structure of silicate crystals embedded within a metal matrix, and are thought to represent the core-mantle separation boundary prior to disruption by a large impacting body. The ‘Mesosiderite’ sub-class is identified by metallic grains within a silicate matrix, and represents the impact melt of a metal-rich body

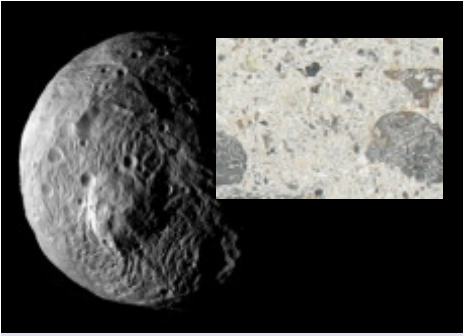


Figure 4 Asteroid '4-Vesta' at 575km-wide is technically large enough to be called a protoplanet, and is the only known intact differentiated body within the main belt, and source of HED-type achondrite. The 1.5cm-wide slice of 'Howardite' (inset) is made up of dark basaltic fragments within a matrix of rocky 'soil'.

into the silicate crustal surface of an asteroid.

The arrival of the Chelyabinsk meteorite parent body, ~17–20 m diameter and ~10,000+ tonnes initial mass, was the largest known meteor to have entered the atmosphere since the Tunguska event, 30th June 1908. However, the source body of the Tunguska event over Russia, with associated destruction of 2000 km² of forest in the Podkamennaya Tunguska River basin, remains controversial within the scientific community.

With only instrumental records and observed atmospheric phenomenon initially reported, Tunguska event research was hampered by the lack of scientific site investigation until nineteen years later, due to political reasons and site remoteness. Based on initial observations and the lack of subsequent crater and substantive material evidence, the Tunguska event was widely regarded to have originated from a comet body as opposed to an asteroid source.

However, the destructive effect of the Tunguska body, originally estimated at ~30–60 m diameter (with 10–15 Mt energy release) has been modeled down more recently, through a more directed air-burst trajectory, to a ~20–30 m diameter body (3–5 Mt energy release). Recent computer modeling of the Tunguska event trajectory, widely believed to have been from a retrograde comet orbit, also favours an 83% probability that the source body may have been a main-belt asteroid.

The airburst and ballistic shockwave near Chelyabinsk released an estimated 440kt of energy (20–30 times greater than the Hiroshima atomic bomb), as a fireball entered along a path some 23 km above the ground, and fortunately at a shallow entry angle! With the likely recovery of less than 500 kg of ordinary

chondrite breccia material, of which the largest specimen recovered to date is less than 2 kg and the vast majority only a few grams, the almost complete disintegration of the Chelyabinsk meteorite may provide more weight towards the meteorite hypothesis for the Tunguska event.

The predicted occurrence of a comet-sourced, Tunguska-sized atmospheric explosion is in the order of every few millennia, whilst the atmospheric entry from an asteroid source body as witnessed near Chelyabinsk is every few centuries. With the possible down-sizing of the Tunguska event source body to within the range of the Chelyabinsk meteorite, coupled with a high atmospheric entry angle, a Tunguska-sized atmospheric explosion may occur every few centuries if from an asteroid source.

Illustrations:

The asteroid images are courtesy of JPL/NASA (Jet Propulsion Laboratory, National Aeronautics and Space Administration). The meteorite images are provided by the author.

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The new Palaeobiology Store at National Museums Scotland

By *Andrew Ross*

The new Palaeobiology Store at the National Museums Scotland is now open for visiting researchers wishing to come and study its collections.

The development has come about thanks to the Royal Museum Project (RMP) whereby the Royal Museum on Edinburgh's Chambers Street (now part of the National Museum of Scotland) was refurbished with new

exhibition galleries, which opened in 2011. As part of this project it was decided that all collections should be housed off-site and that the Museum would be used solely for exhibitions. This meant that all the Palaeontology collections that were in the Royal Museum needed to be moved. The type & figured collection, and parts of the fossil vertebrate and invertebrate collections had already



Figure 1 Before—The overcrowded 'Room 68' at the NMCC where some of the fossil invertebrates and vertebrates were kept.

been moved to the National Museums Collection Centre at Granton (NMCC), but there they were stored in three different buildings. These storage locations were not ideal as they were overcrowded (Figure 1), and one building did not have any environmental control. The remaining collections residing in the Royal Museum in 2008 consisted of some fossil vertebrates, the main part of the fossil invertebrate collection and the fossil plant collection. The fossil plants and remaining vertebrates were wrapped and packed into plastic crates and taken off-site to be stored in a commercial store at Coatbridge, as there was no room for them at NMCC. The main fossil invertebrate collection was housed in wooden cupboards and was kept in the basement of the Museum (Figure 2). There it was to remain for the

time being, though access had to be restricted while building work was going on.

The Palaeobiology curators undertook a survey of the Palaeontology collections, to gauge how much space the thousands of drawers and crates were taking up. Some of the drawers and crates were packed several layers deep with fossils. From this a recommendation for a new store for the Palaeontology collections was submitted, which gained support and was approved. As part of RMP one of the existing stores at NMCC was to be extended and it was decided that the Palaeontology collections would be housed on the ground floor of this extension.

The extension was built in 2010 and compactor storage was installed later that year. In the meantime a plan was produced of where everything would go in the store, providing the opportunity to reunite



**Figure 2 Before—
Part of the main fossil
invertebrate collection
in the Museum
basement at Chambers
Street.**

parts of the Palaeontology collections that had been separated for many years. Moving of the collections commenced late that year but was hindered by the harsh winter, and then delayed by the all-hands-on-deck installation of the new museum galleries in the first half of 2011. However, by the end of that year the existing Palaeontology collections at NMCC had been packed and moved into the new store, along with the crates duly retrieved from

Coatbridge. The final collection to be moved was the main invertebrate collection in the museum basement, which was packed and moved last year. Since then the Palaeobiology team have been busy unpacking the specimens. A batch of new conservation-grade polyester-lidded boxes was delivered in the spring of this year and re-boxing of the type & figured collection is now well underway.



Figure 3 After—one of the banks of mobile racking in the new Palaeobiology Store.

The new store is approximately 400 m squared with good environmental controls (temperature and humidity) and lights with motion sensors. There are two banks of mobile racking—2 metres high, 65 racks in all, with 489 bays—and benching has been installed along one side of the store (Figure 3). The mobile racking bases can take a weight of 2 tonnes per square metre. There are three types of storage:

- 1) The type & figured collection and part of the vertebrate collection are held in 130 new lockable metal cabinets. These contain new metal drawers of four different depths that are lined with plastozote (conservation-grade foam). The drawers can take a weight loading of 50 kg.
- 2) The main racking was designed to take the existing drawers and crates, with runners adjustable every 30 mm that can take a weight loading of 70 kg.
- 3) Part of the racking is heavy duty with large open-span shelves that can each take a weight of one tonne. This part houses some of the larger crates and slabs.

So now the Palaeontology collections at National Museums Scotland (about 250 000 specimens in total)

are housed in excellent conditions to safeguard them for future generations, and are all in one place for the first time in at least 50 years. As one might expect, the collections consists primarily of Scottish material, particularly from the Palaeozoic Era, and include some notable historical collections, for example that of Hugh Miller. However readers may be surprised to learn that there are also specimens from all over the world and of all ages. Most of the specimens were acquired in the 19th Century and it is likely that there are some important discoveries still to be made amongst them. The Museum continues to add to its collections via donations, targeted fieldwork by staff, and by purchase of specimens deemed to be of significant scientific importance and/or required for exhibition purposes.

If any palaeontologists wish to visit to study specific parts of the collection, please e-mail to book an appointment. There is also an amnesty for the return of specimens that were borrowed on loan and that are now well overdue. We also welcome enquiries.

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Geology from the Inside

By Alan L Jeffreys

Efforts to study landforms and their evolution into the landscapes we know today can be frustrated by factors such as weather erosion, earthquakes, frost shattering, even human intervention. There is however, one niche corner of Scotland that has preserved geological evidence in pristine condition—the underworld of caves.

Speleology—the study of caves—is a relatively young science and investigation of Scottish caves didn't really catch on until the very end of the 19th Century. Even then it was driven more by the needs of archaeology than geology. However following the Second World War there was an explosion of activity within Britain's caving community, and English groups began serious explorations in Scotland, particularly in the Cambro-Ordovician dolostones of Assynt. Here many caves have formed along the strike of thrust faults, although 'classic' karst mechanisms are also at work, creating the longest and deepest cave systems known in Scotland.

By the early 1960s, indigenous cavers had begun their own investigations and in 1961 the Grampian

Speleological Group was formed in Edinburgh; it rapidly became, *de facto*, a national association dedicated to cave and pothole exploration. During the following 50 years, members discovered and mapped caves in widely differing landscapes, ranging from the hills of Appin, Argyll, the Isle of Skye, Kishorn, Applecross and around Schiehallion in Perthshire. All these regions have a common aspect—the presence of limestones, although these are divided into several different types, ranging from the Cambro-Ordovician dolostones of Assynt, Durness and Skye, Jurassic limestones in Applecross, and Dalradian dolomitic limestones and marbles of the Appin Group (Blair Atholl Subgroup), principally below Schiehallion mountain but also occurring as metamorphosed limestone/schist/phyllite bands in Appin. Each area houses cave systems with a character uniquely Highland in aspect, some of considerable size, others more accurately classified as 'sporting' (ie tight, wet and uncomfortable!)

Speleology has been defined as a 'sporting science' on account of

the difficult terrain to be traversed in order to carry out scientific study. Researchers are required to be proficient cavers first, scientists second, otherwise even a casual accident could develop into a crisis, owing to difficulties in getting an injured person back to the surface. Having said that, caving is statistically—and actually—far safer a pursuit than many people imagine. Also, it should not be imagined that the sport is all about ‘squirming through rabbit holes’. Tight, low and flat-out passages obviously do exist, but most caves consist of very much larger tunnels and chambers. For example, in Assynt’s Uamh an Claonaite (‘Cave of the Sloping Rock’) there is a void probably twice the size of Edinburgh’s Usher Hall, although a huge pyramid of glacial outwash debris effectively divides the chamber into two sections. It is not generally appreciated, but all of the highest waterfalls in Britain are underground. In the Yorkshire Dales for instance, there are well over a dozen free-fall cascades over 100 metres in height.

Scottish caves provide geologists with superb laboratories where a whole range of subjects may be studied—ice age dating; ancient hydrological processes; palaeo-climates, erosion chemistry, sedimentology and the behaviour

of minerals. Although the basic principles of cave formation have been understood since before the Second World War, details of variable factors give rise to a number of as yet un-answered questions about Scottish caves. When answers do arrive they may be surprising. For example, caves in the dolostones of Assynt have proved to be much older than previously thought. Dating stalagmite samples from Uamh an Claonaite by measuring the amount of thorium-230 in relation to that of uranium-234 typically produced dates between 60 000 and 30 000 years before present, and one exceptional sample dated back 122 000 years ($\pm 12\,000$) years. The samples were sourced from massive lumpy deposits of calcite which in turn would have taken a substantial period of time to be deposited, and of course the passage void would have had to exist before even that.

Indeed, the massive dimensions of these ancient watercourses speak of many years of solutional activity, even though sections have suffered extensive breakdown following land rebound after successive glacier melts. Vast tonnages of reworked till and sandy outwash have been deposited in Assynt caverns by meltwater, and the relatively protected locations have resulted in

well-preserved sedimentary layers, virtual storybooks of clastic activity extending back over thousands of years.

Analysis of calcite formations can also provide information on ancient climate conditions in much the same way as analysis of skeletons can reveal surprising details of use, disease and diet. Scotland as a whole is not rich in flowstone decoration, with a few spectacular exceptions. In the Jurassic limestones of Applecross, two major cave systems have been explored that are possessed of extremely fine formations: Uamh nam Fìor longantais ('Cave of True Wonders') and Uamh nam Breagaire ('Cave of the Liar'). In the former, opened in 2011, calcite formations fill the main passages with a splendour unsurpassed north of Hadrian's Wall, probably due to a change in the levels of magnesium in the limestone.

Another fascinating window into the past has been the finding of brown bear, reindeer and wild horse bones in Assynt's



Figure 1 *Stalactite formations in Uamh nam Fìor longantais, Applecross, showing broken boss embedded in floor debris. Photograph by Ivan Young.*

Uamh an Claonaite, quite the best assemblage of bear remains so far discovered. Carbon dating has produced ages of between 14 000 and 45 000 years before present and future excavations



Figure 2 *Collecting brown bear (Ursus arctos) bones from Uamh an Claonaite, Assynt. Photograph by Ivan Young.*



Figure 3 *Stalagmite being crushed by subsiding bed of limestone, Uamh nam Breagaire, Applecross. Photograph by Ivan Young.*

will probably reveal even more of these faunal remains which can tell us so much about the interglacial environments of western Sutherland.

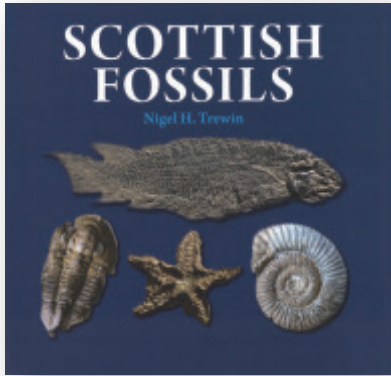
Explorations in Scotland, however interesting, will never equal the phenomenal scale of cave systems in England and Wales, where complexes with literally hundreds of kilometres of passages are almost common place. For example, Ogof Draenen, above Blaenavon in

South Wales, was only entered for the first time in October 1994 after digging out a blocked sinkpoint, but is now known to possess over 75 kilometres of passage, some of them of huge dimensions. Contrast that with Uamh an Claonaite, Scotland's longest cave, currently just over three kilometres in length. Size is not everything, however, and the scientific and archaeological potential of Scottish caves is every bit as fascinating, providing researchers with laboratories for a range of geological subjects and explorers with sufficient adventure to maintain that impetus driven by natural curiosity to find out 'what's round the next corner', which is, and always has been, the fundamental engine of speleology. The lure to set foot on territory as virgin as Mars (but rather cheaper to achieve!) and be the first to see earth processes 'in the raw' is reward enough for many Scottish cavers, but study, research and publication remain at the heart of what the Grampian Speleological Group dedicate themselves to accomplishing. A profusely illustrated history of the Group—*Decades in the Dark*—is available from the author of this article, price £20.

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Book reviews

Scottish Fossils by Nigel H Trewin. Dunedin Academic Press, Edinburgh. 2013. Hardback, x + 118 pp. Price £30. ISBN 978-1-780460-019-2.



Nigel Trewin's latest book is an unashamed celebration of fossils drawing on the rich variety to be found in Scotland—or at least in that minority of the country boasting appropriately sedimentary rocks. There is in truth little focus on geography; no maps are to be seen and the 'fossiliferous' regional geology is covered very briefly in a succinct introduction. What follows is, in Trewin's introductory words, "an armchair museum gallery". In it, we tour from the Cambrian to the Quaternary but, since the 'exhibits' are arranged taxonomically, we actually start with Devonian

cyanobacteria, move on through plants, and then work through the animal kingdom from sponges to mammoths; trace fossils provide the finale.

At £30 this is not a cheap book but the plethora of colour illustrations justifies the cost. It is no mean feat to bring together such a collection of top-quality photographs covering Scotland's fossil record, 104 entries on a 'one of everything' basis, and most of Trewin's selection is splendid. Some examples are quite extraordinary, the Carboniferous scorpion from East Kirkton for example, although a few, the Southern Uplands graptolites and the tiny Ordovician starfish from Girvan are not seen at their best. Many 'celebrity' fossils are included. We have excellent pictures of Charles Peach's gastropod from the Durness Limestone, the 'conodont animal' from Granton, 'MacCulloch's Tree' encased in lava from Mull, plants and fish originally collected by Hugh Miller, and a selection of the 'Elgin Reptiles'. Some of the important tetrapod discoveries made by the late Stan Wood (to whom the book is generously dedicated) are also happily included, and the famous Devonian locality at Rhynie is well represented by its plants, worms and arthropods (a

biological index and gazetteer usefully aid associations). As one might expect from the author, fossil fish are well represented, no less than 15 of them, and one example is accompanied by the only landscape in the book—a view across Achanarras Quarry, Caithness. The author's predilections are perhaps also apparent in the rather uneven distribution of references to background literature. A few entries get four or five citations covering the original description, the lithostratigraphy and an appropriate field guide; the five brachiopods get none between them.

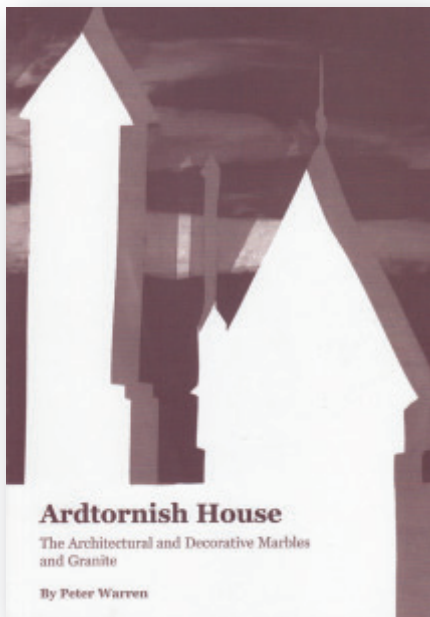
The descriptions accompanying the individual fossil illustrations, and the introduction to each taxonomic grouping, are clear and informative. Information is provided on the life-style of the pictured organism and its mode of preservation; in some cases the details of its discovery and collection are also included. Here and there, relevant anecdotes add to the entertainment. Some are positive—the fortuitous recognition of an important Early Carboniferous amphibian amongst a museum collection of fish material; others less so—the giant eurypterid bombed by the RAF, or the murky past of a dinosaur bone.

Anyone with an interest in Life's extraordinary exuberance through geological time will love this

book—and it is a welcome antidote to the usual 'granite & gneiss' view of Scotland's geology. The ideal Christmas gift for any émigré Scottish geologist.

by Phil Stone

Ardtornish House—The architectural and decorative marbles by Peter Warren. Ardtornish Publishing, Morvern, 2012. Paperback, 84 pp. Price £10. ISBN 978-0-9565893-2-3.



Readers of *The Edinburgh Geologist*, particularly those who have observed Martin Creed's recent

Work No. 1059 (the marbles of the Scotsman Steps, Edinburgh), might be interested to learn of the publication of this illustrated guide. The connection between Ardtornish House and Martin Creed might appear tenuous until we read that his father John created the iron and steel sculptures which stand at the head of the steps to the lower garden, overlooking Loch Aline. But given this link, could it be that Martin Creed first appreciated the use of coloured stone in ornamental architecture at Ardtornish? This book is about the new house which was constructed between 1885–91 by the Inverness Architect Alexander Ross (1834–1925) for Thomas Valentine Smith, son of Octavius Smith (1796–1871). On Thomas's death in 1906 the house was inherited by his sister Gertrude Craig Sellar (1844–1929) and was refurbished and redecorated for her by her son Gerard Craig Sellar, in 1908–10. He employed Edinburgh architect John Kinross (1855–1931), noted for his remodelling (1901–5) of Manderston in Berwickshire and for four outstanding urban villas in Mortonhall Road, Edinburgh (1898).

The book distinguishes the work of Ross and Kinross (much of the marble work is attributed to the

specification of Kinross) and there is a wealth of detail concerning the stones used for columns, chimney pieces, radiator covers, bathrooms and floors. The stones include Ross of Mull Granite, and the following marbles: Belgian Blue, Belgian gris Sainte-Anne, Bianco di mare, Black Marble (including Belgian Black, Kilkenny Black and Ashford), Breccia aurora marina, Breccia di Stazzema, Broccatello di Siena and giallo di Siena, Campan vert, Carrara, Cervelas griotte rouge, Cipollino verde, Crema Valencia, Griotte rouge, Portoro, Rosé de Brignoles, and Sarrancolin. Beautifully illustrated with 63 colour plates of the furnishings and fittings (photographs by Faith Raven, Ian Lamb and Elizabeth Warren) and with an extensive *Selected Further Reading & Works Referenced* list this book is a 'must buy' bargain for architects, historians and anyone interested in marble and its use in Scotland in an age of opulence. Proceeds from the sale of this book go to the Morvern Heritage Society.

Ardtornish House is not open to the public but its rooms are available as apartments for rent and other functions (see www.ardtornish.co.uk).

By Andrew McMillan

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1 Editorial ramble

Gone fishing, on museums and collections, and down amongst the bears

6 Poissons, Pavements and the Public: tripping over Devonian Fossil Fish in the streets of Edinburgh

By Tom Challands and Ken Shaw

12 Meteorites and the building blocks of the Earth

By Andrew Blythe

19 The new Palaeobiology Store at National Museums Scotland

By Andrew Ross

23 Geology from the Inside

By Alan L Jeffreys

27 Book reviews

Scottish Fossils

Ardtornish House — The architectural and decorative marbles