

The background of the cover is a photograph of four vertical wooden trays filled with various geological rock samples. To the left of the trays is a vertical scale with markings from 10 to 100 in increments of 5. The rock samples show a variety of colors and textures, including grey, brown, and reddish hues, with some showing distinct layering or fracturing. The trays are arranged side-by-side, and the scale is positioned to the left of the first two trays.

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Cover Illustration

Borehole at West Mains Farm, Norham (scale in centimetres) showing lithologies of the Early Carboniferous Ballagan Formation, as described in the article by David Millward.

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www.edinburghgeolsoc.org

Editors

Phil Stone

Bob McIntosh

psto@bgs.ac.uk

rpm@bgs.ac.uk

British Geological Survey
Murchison House
West Mains Road
Edinburgh EH9 3LA

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Borderlands and back to the future

An editorial ramble by Phil Stone

There's so much packed into this issue of *The Edinburgh Geologist* that there is only space for a short ramble. We go to press at the end of August, so by the time you receive your copy of *EG* you will be either delighted or dismayed by the referendum result. But not to worry, whatever the outcome it will not affect the geology, and geology has little respect for the conceit of national boundaries.

Borderlands

We tend to associate the Anglo-Scottish border with the Iapetus Suture, the large-scale result of an Early Palaeozoic act of union, but the detail of cross-border outcrop is Upper Palaeozoic and Mesozoic. In the west,

Scotland shares the stratigraphy of the Carlisle Basin; in the east it's the Northumberland Trough. No surprise then that in David Millward's article in this issue of *EG*, the lowermost Carboniferous stratigraphy of a critical sequence in Berwickshire was established by sinking a borehole in Northumberland. David provides a progress update on the Tweed project, a multi-collaborative (yes, Scottish and English institutions) investigation of tetrapod evolution based on some remarkable fossil discoveries in the Scottish Borders, as reported in *EG* 53.

Not that long ago, the coastline was as just as geologically irrelevant

Cross-border geology: an anticline in the Penton Limestone (Alston Formation, Yoredale Group) viewed from Scotland but exposed in the English bank of the Liddel Water at Penton Linns. BGS image number P221694.



as the border. Andrew Kitchener's article on mammoth remains from Scotland recalls a time when these recently-extinct beasts could walk here across what is now the North Sea. It's a welcome follow-up to the exhibition at the National Museum of Scotland earlier this year, which has now transferred to The Natural History Museum, London. That might explain why mammoths would seem to be the current celebrity monsters. Even Damian Hirst has got in on the act with "Gone But Not Forgotten", a 3 metre tall, gilded Woolly Mammoth skeleton encased in a huge glass, gold-framed tank. In May the work was auctioned (for Aids charities) at the Cannes Film Festival—it fetched 11 million Euros.

Back to the Future

Whatever the future holds for the British Geological Survey in Scotland, there are going to be major changes to its presence in Edinburgh. Murchison House, since 1976 the BGS base on Edinburgh University's King's Buildings campus, is scheduled to close early in 2016 with the staff moving out to Riccarton, where a new 'Charles Lyell Centre' will be shared with Heriot-Watt University ... more on this as the plans are finalised.

There are also recent changes to report at another of Edinburgh's

geological icons, *Our Dynamic Earth*. Stuart Monro describes the developments there in his article featuring 'Scotland's Time Lords'—one of which was Charles Lyell. I was amused to read in a *Geoscientist* magazine¹, that he was regarded by the ladies as something of a social liability. Emma Darwin thought him a 'dead weight' and wrote to her sister on 2 April 1839, "Mr Lyell is enough to flatten a party, as he never speaks above his breath, so that everybody keeps lowering their tone to his." In the large open-plan offices envisaged for the Charles Lyell Centre that could well be a trait that the occupants will need to emulate.

In the meantime, perhaps we can now move on from constitutional obsession and refocus on the big issues: climate change, resource depletion and natural hazards to name just three with geological connections. Stuart Monro touches on these, as do our book reviews. Sue Loughlin considers the impact of volcanic eruptions in Iceland; Roger Kelly looks at the achievements of 'Paraffin' Young and Scotland's first hydrocarbons boom.

¹ Morgan, N. 2014. Guess who's coming to dinner? *Geoscientist*, **24** (5), 25.

Drilling through Romer's Gap—The TW:eed project borehole near Berwick-upon-Tweed

By David Millward

On the cold sunny morning of 3rd April 2013, heavy rock-drilling equipment began to arrive at West Mains Farm, near the village of Norham, Berwick-upon-Tweed. This was the start of a two-month operation, during which a fully cored borehole was drilled to a depth of 501 m through Lower Carboniferous (Tournaisian) rocks of the Ballagan Formation (Figure 1). For members of the project team, it was a relief that, after months of planning, drilling was finally to get underway.

Obtaining as complete a rock record as possible through the Ballagan Formation and into the underlying Kinnesswood Formation was a key objective for the TW:eed project (TW:eed stands

for Tetrapod World: early evolution and diversification). The project is investigating this interval which



Figure 1 A run of core is recovered at Norham using the Atlas Copco S-Geobor wireline system. On the trestles are a new length of drill stem (left) and a second core barrel with plastic liner fitted (right) ready to be attached. Image: D Millward©NERC

is referred to as Romer's Gap, the period when the aquatic and fish-like limbed vertebrates of late Devonian times emerged on land to diversify into the wide range of fully terrestrial species seen 15 million years later in Viséan times. This was a step change in the evolution of life on Earth that shaped the future of vertebrates, and eventually the appearance of humans.

South-east Scotland is one of only two places in the world where tetrapod fossils from this time interval have been found—the other is Blue Beach in Nova Scotia, Canada. The Ballagan Formation comprises rapidly alternating beds of siltstone and cementstone, with interbedded sandstone and has been interpreted as coastal alluvial plain deposits (Anderton 1985).

TW:eed builds on some remarkable fossil finds made recently in the Scottish Borders by the late Stan Wood, and described by Nick Fraser in his article in the Spring 2013 edition of *The Edinburgh Geologist*. The research is being undertaken by a consortium of organisations led by Professor Jenny Clack at the University of Cambridge, and including the universities of Southampton and Leicester, the National Museums of Scotland and the British Geological Survey, and

funded by the Natural Environment Research Council. The borehole work has been led by BGS.

Why drill a borehole?

A continuous, high-resolution record of the lithology, sedimentology, petrology, stable isotope compositions, palynostratigraphy and biostratigraphy is contained in the cores. Such a record is not possible from outcrop. Significantly greater and higher quality detail is obtainable from cores, though the absence of information on the lateral extent of facies is a drawback. The level of detail is crucial within mudstone intervals which typically crumble to small fragments when exposed and weathered (Figure 2).

This record will enable us to interpret the changing early Carboniferous depositional systems and climate and to infer habitats that hosted the early terrestrial tetrapods. A framework will be established for understanding the environmental factors that may have had an influence on why this evolutionary route was taken and on the preservation of the fossils.

In addition to establishing a stratigraphical framework upon which our tetrapod localities in the region can be pinned, it is hoped that we will be able to 'convert' the rock record data from the borehole into



Figure 2 Comparison of profiles through Ballagan Formation paleosols, left at outcrop (pencil is 150 mm long) and right in core (core width is 102 mm). Images: D Millward (left), BGS (right), both©NERC

however detailed the planning! Indeed, significant problems did arise but these were not insurmountable.

time and hence begin to understand rates of tetrapod evolution. Time-series analysis can be used to test whether the sedimentary cyclicity present through the Ballagan Formation may be related to glacio-eustatic changes in sea level resulting from periodic changes in the Earth's orbit around the Sun. However, we will also need to understand where the time gaps are, for example at unconformities and at fluvial channel bases, as well as the time locked up in the development of the thick paleosols present.

Problems, what problems?

There is an old saying that something will always go wrong during drilling,

Circulating the drilling mud between the rotating drilling head and the surface where the mud can be cleaned of cutting fragments is essential to keep the drill bit moving and the drill stem free, particularly during coring. So, the sudden loss of drilling fluid into cavities or fractures can cause serious problems and potentially abandonment of the borehole.

At Norham we lost circulation repeatedly between 52 m and 103 m from the surface. Core recovered from one of the zones showed a steep, two centimetre-wide open fracture in sandstone. This type of

problem is usually solved by the addition of materials such as mica, or a mixture of shredded materials that resembles the contents of a vacuum cleaner, to the drilling mud, or by grouting the borehole. Frustratingly, one of the zones proved difficult to seal completely, and a small percentage of the circulating fluid continued to be lost at times throughout the operation.

Nevertheless, these problems were overcome with skill and

professionalism by the team of drillers from Drilcorp Ltd in Co. Durham. The 102 mm diameter core was obtained using a triple-tube wireline coring system. In this, a 3 m core barrel latched inside the drill stem behind the drilling bit and the core was taken up into a plastic liner inside the core barrel. The liner gave added protection to the cores which proved high quality throughout. After 3 m had been drilled, the core barrel and its contents were recovered to the surface without the time-



Figure 3 TW:eed team members Tim Kearsey (BGS) and Carys Bennett (University of Leicester) examining the core at the BGS core laboratory in Keyworth. Image: T Kearsey©NERC

consuming need to remove the drill stem.

What has happened to the core?

A summary log was made of the cores on site and then they were shipped to the National Geological Repository at the BGS in Keyworth, Nottingham. There the cores were sliced lengthways, photographed, described in detail and sampled for analysis (Figure 3). One half of the core is archived for reference.

A large number of samples were extracted: 748 for thin section, 586 for palynological studies, 680 mudrocks for carbon isotope determinations; 98 paleosol samples for mineralogy and bulk rock geochemistry; and 24 sandstone samples for heavy mineral provenance analysis. Finally, after logging was completed the working half of the core was broken up and 1016 macrofossil specimens were extracted from almost 600 horizons to provide an indication of the diversity of life present. Many of these specimens are plant fragments, but also present are marine and non-marine bivalves, orthocones, scales and bones of lobe-finned and ray-finned fish, and assorted arthropod fragments.

Currently, the fossils are being identified and the rock samples

analysed and interpreted by specialists in the team. However, the following two examples provide a snapshot of the many notable characteristics of the Ballagan Formation that are being investigated in detail.

Beds of evaporite are rarely seen at outcrop in the Ballagan Formation because of dissolution, but are abundant in the borehole. Twenty-two beds composed of gypsum and/or anhydrite were recorded, most in the basal 80 m of the succession where these beds are clustered in short intervals with a large number of cementstone beds (Figure 4). Their presence indicates intense evaporation of sulphate-bearing water in supratidal sabkhas.

More than 200 fossil soils have been described, providing evidence for emergent land surfaces. Many of these are just rooted horizons at the top of sandstone bodies, indicating the ephemeral presence of vegetation. However, thin, organic-rich wetland soils are also common. In the upper part of the succession there are reddened paleosols up to 1.5 m thick indicative of better drained, seasonally wet soils, interpreted as possibly underlying forests. These most likely took many hundreds to thousands of years to form and represent



Figure 4 Nodular anhydrite in grey siltstone, with pink, secondary veins of gypsum at the contact with overlying siltstone. Image: D Millward©NERC

episodes of established terrestrial environment.

Reflections one year on

The Ballagan Formation proved to be thicker than expected in this region and disappointingly we did not attain our primary goal of coring through Romer's Gap in its entirety into the underlying arid strata of the Kinnesswood Formation. The 500 m depth was the maximum obtainable with our setup. Nevertheless, the cores provide a wealth of detail illustrating the dynamic nature of the environment during early Carboniferous times. As the full picture of this environment emerges we will have a much better understanding of the life and death of these early terrestrial tetrapods.

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Dr David Millward
British Geological Survey, Edinburgh.
Email: dmill@bgs.ac.uk

Website: www.tetrapods.org

More information on the drilling of this borehole, including a short video can be seen at:
<http://britgeopeople.blogspot.co.uk/2013/06/15-million-years-in-56-days-by-tim.html>

The woolly mammoth, *Mammuthus primigenius*, in Scotland

By Andrew C Kitchener

The woolly mammoth, *Mammuthus primigenius*, had one of the widest geographical distributions of any Pleistocene mammal. Its distribution was tied closely to the presence of a unique open habitat, the mammoth steppe, which stretched from North America to western Europe from about 100 000 to 14 000 years ago (Lister and Bahn, 2007; Lister 2014). Four mammoth species have been found in Britain, but only the woolly mammoth has been recorded in Scotland. Mammoths and other terrestrial mammals were able to colonise Britain from continental Europe, because in glacial periods sea levels were much lower than today, so that large areas of what we now call the English Channel and North Sea were exposed land. In this short paper, I will review the known records of woolly mammoth in Scotland since their first confirmed discovery in 1816 (Table 1).

The remains of Devensian and early Holocene mammals and other vertebrates are found comparatively rarely in Scotland compared with those found in the rest of Britain. The effect of almost total glaciation in the last two glacial maxima, a paucity of

limestone caves and prevalence of acidic soils have contributed to this dearth of remains, so that mammoth fossils have been recorded with certainty from only about 10 sites throughout Scotland. The remains have been discovered at varying depths below the surface usually in sandy clay below boulder clay, indicating a late Devensian origin.

It is possible that mammoth remains have been uncovered accidentally throughout history. For example, Geikie (1863; 68) noted that the Scottish philosopher and first Principal of King's College, Aberdeen, Hector Boece 1465–1536, described in 'The History and Chroniklis of Scotland' (translated from Latin to Scots and published in 1536 by John Bellenden) that "In Murrayland is the Kirk of Pette, quhare the banis of Litill Johne remanis, in gret admiratioun of pepill. He hes bene fourtene fut of hicht, with square membris effering thairto." (Bellenden, 1821; xxxiv), which is highly suggestive of a much earlier discovery of mammoth bones.

The first confirmed mammoth remains in Scotland were recorded

Table 1 Woolly mammoth and elephant remains found in Scotland since 1816.

Museum	Register no.	Year	Location	Form	Depth below surface
Woolly mammoth, <i>Mammuthus primigenius</i> , specimens					
NMS	Z.1915.15; Z.1824.68	1816; 1817	Woodhill Quarry, Greenhill, Kilmaurs, Ayrshire	2 tusks	17.5 feet
NMS	Z.1998.66	1820	Cliftonhall Estate, Ratho	2 tusks	15–20 feet
		1825	Woodhill Quarry, Greenhill, Kilmaurs, Ayrshire	Tusk	
GLAHM	V.5120	1829	'Diluvium in the neighbourhood of Kilmarnock' = Woodhill Quarry, Greenhill, Kilmaurs, Ayrshire	Tusk	34 feet
		1831	Woodhill Quarry, Greenhill, Kilmaurs, Ayrshire	Tusk	
		1840	Woodhill Quarry, Greenhill, Kilmaurs, Ayrshire	Tooth (small fragment)	
		1840–41	Chapel Hall, near Airdrie	Bone	
GLAHM	V.5123		'Diluvium in the neighbourhood of Kilmarnock' = Woodhill Quarry	Tusk	
GLAHM	V.5155	<1875	Bishopbriggs	Tooth (right upper)	
		1875	Mainhill Farm, Ballieston	Tooth	33 feet
GUHM	V.5125	1881	Dreghorn, Ayrshire	Tusk	c.90 feet
GLAHM	V.5124	1881	Drummuir Pit, Dreghorn, Ayrshire	Tusk	
GCM	1937.26	1937	Headwood Farm, near Larbert, Stirlingshire	Tooth (right upper)	38 feet
GLAHM	V.5730	1968	Houston's Store, Alloway Street, Ayr	Tooth	
Asian elephant, <i>Elephas maximus</i> , specimens					
		1874	Glenmoidart, Strontian	Tooth	
Specimen lost		c.1884	Springbank near Eyemouth Railway Station	Tooth and part of jaw	
NMS	Z.1926.89	c.1894	Found during laying of Eyemouth and Burnmouth railway line	Tooth	
GLAHM		1902	No.1 Pit, Carfin, near Motherwell	Tooth (lower left)	
ABDMS	012368	1934	30 miles NE of Shetland	Two tusks	seabed
NMS	unreg.	1959	Carse of Stirling, Bridge of Allan	Tooth	

Substrate	Radiocarbon date	Finder	Reference
Brown clay	27 100±200 bp; SUERC-50904	Robert Brown	Bald, 1822; Geikie, 1863; Bryce, 1865
Clay (strong old alluvial earth)			Bald, 1822; Geikie, 1863; Bryce, 1865
			Bryce, 1865
	13700+1300– 1700 bp; GX0634; 46,700	T Fulton	Young & Craig, 1869; Gregory & Currie, 1928; Sissons, 1967; Palkopoulou et al., 2013
			Young & Craig, 1869; Gregory & Currie, 1928
		Dr John Scouler	Geikie, 1863; Bryce, 1865; Young & Craig, 1869; Gregory & Currie, 1928
Laminated sand containing quartz pebbles			Craig, 1842
	45 850±750 bp ; OxA-20051	T Morton	Bryce 1865; Young & Craig, 1869; Gregory & Currie, 1928; Palkopoulou et al., 2013
Sand under boulder clay		Dr Sir D Beveridge	Gregory & Currie, 1928; Macewen, 1876; N Clark, pers. comm.
Laminated sand under boulder clay		Robert Bethune	Kirsop, 1882
Sand and gravel below boulder clay	30080±260 bp.; OxA-10964	T Craig	Bennie, 1885; Gregory & Currie, 1928; Palkopoulou et al., 2013
Upper boulder clay		T Shore	Craig 1888; Gregory & Currie, 1928
Junction between coarse sand/gravel and fine sand below			Absalom & Henderson, 1947; R Sutcliffe, pers. comm.
		Alan Neale	Delair, 1969; N Clark, pers. comm.
			Macewen, 1876
			Hewat Craw, 1919
			Hewat Craw, 1919
			Gregory & Currie, 1928
	255±70 b.p.; OxA-1758		Long, 1992

as being those of fossil elephants, such is the similarity in tooth and tusk form between living elephants and mammoths, both of which belong to the family Elephantidae. The first woolly mammoth remains were found in December 1816 at Greenhill Quarry, near Kilmaurs in Ayrshire (there is some debate about the name and location of the quarry; the early quarry appears to have been called Woodhill Quarry and was later succeeded by Greenhill Quarry; Bryce, 1865). At a depth of 17½ feet (5.33 metres) in brown clay Mr Robert Brown, tacksman at the quarry, discovered two tusks, one of

which was 3 feet 5½ inches (1.05 metres) long, 13½ inches (34.3 cm) in circumference and weighed 20½ lbs (9.3 kg) (Bald, 1822). The other tusk was too decayed to be preserved. The tusk was cut in two; one piece went to the College Museum in Edinburgh, while the other was retained by Lord Eglinton at Eglinton Castle. This latter piece was donated by a later Lord Eglinton to the Royal Scottish Museum (forerunner of the National Museum of Scotland) in 1915, where it is now part of the Vertebrate Biology collection, register no. NMS.Z.1915.15 (Fig. 1). We have recently radiocarbon dated this



Figure 1 a. A fragment of mammoth tusk from Kilmaurs, Ayrshire—the first mammoth remains recorded from Scotland (NMS.Z.1915.15). Length c.362 mm, diameter right-hand cut end 96 mm. b. Detail of label. ©National Museums Scotland.

specimen at $27\,100 \pm 200$ radiocarbon years old. The whereabouts of the other piece is unknown, although it would be expected to have been transferred to the national collections in 1854 when the College Museum was disbanded, under the register no. NMS.Z.1824.68. However, Bennie (1885) noted that this portion of the tusk remained in the possession of Professor Archibald Geikie, who used it in his Geology classes. It is perhaps the same mammoth tusk from Kilmaurs, labelled as having been donated by Professor Geikie, which is now on display in the Beginnings gallery, National Museum of Scotland.

Other mammoth tusk fragments have also been found at Greenhill Quarry, including in 1825 and 1831, and totalling nine specimens all found in sand and clay below boulder clay at depths varying between 17 and 36 feet (5.18–10.97 metres) below the surface (Fig. 2) (Bryce, 1865; Young

and Craig, 1869; Bennie, 1885).

Two of these are in the Hunterian Museum, University of Glasgow, including one found with two reindeer antlers 34 feet (10.4 metres) below the surface by T Fulton on 4th December 1829, which is 32 inches (81.3 cm) long and has a circumference at the narrow end of 11.5 inches (29.2 cm), register no. V.5120 (Table 1) (Young & Craig, 1869; Gregory and Currie, 1928). This was radiocarbon dated in the 1960s at $13\,700 \pm 1\,300$ –1700 bp. (GX0634) (Sissons, 1967), but this date is no longer accepted as reliable. A recent new radiocarbon date for this specimen was $46\,700 \pm 2\,700$ years bp. (Palkopoulou et al., 2013). The second tusk fragment, 26.5 inches (67.3 cm) long, and with circumferences of 11.75 (29.8 cm) and 9 inches circumference (22.9 cm) at each end, was donated by T Morton, register no. V.5123. This has been radiocarbon dated at $45\,850 \pm 750$ years b.p. (N Clark, pers. comm.). Another tusk

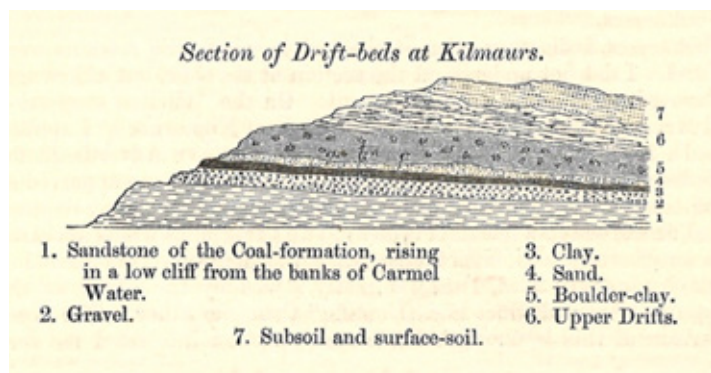


Figure 2
Section showing where mammoth tusks were found at Greenhill Quarry, Kilmaurs (Bryce 1865). a. and b. are where mammoth tusks were found.

was donated to Anderson's College, Glasgow (Bennie, 1885), but its whereabouts are unknown today. A small piece of molar tooth was also found at Greenhill Quarry in 1840 by Dr John Scouler (Bryce, 1865).

The second find of mammoth in Scotland was at Cliftonhall Estate, Newbridge (near Ratho), near Edinburgh, where on 18 July 1821 a piece of mammoth tusk was found during the digging of the Union Canal (Bald, 1822). It was found 15–20 feet below the surface in 'strong, old alluvial earth' or clay. The tusk weighed 25¾ lbs (11.68 kg) and measured 39 inches (99.1 cm) long, and was 13 inches (33 cm) in circumference at the proximal end and the middle and 12 inches (30.5 cm) in circumference at the distal end. The estate owner, Sir

Alexander Gibson Maitland, instructed the workman who found it to take it to Cliftonhall House, but instead he went off to Edinburgh and sold it to an ivory turner for £2. Before it could be recovered, it was cut into three pieces, one of which was being prepared for the lathe to make chessmen. Sir Alexander bought back the remaining pieces. At some point the two remaining pieces of tusk were donated to the Free Church College Museum where they were photographed in the early 20th century by James Ritchie (Fig. 3). In 1966 the Free Church College Museum was disbanded and many of the specimens were donated to the Royal Scottish Museum, but the tusk was not among them. In 1998 Hilary Kirkland of the City of Edinburgh Education Department contacted me about a piece of mammoth tusk,



Figure 3 *The Cliftonhall (above) and Kilmaurs (below) mammoth tusks probably photographed in the 1920s by James Ritchie. The detached distal end of the Cliftonhall tusk is lost and the remaining fragment has been cut in half, so that only the fragment in Figure 4 now survives.*

which had been used as a handling item for education. This was probably part of the Free Church specimen, but the remaining piece of tusk was considerably shorter (Fig. 4) than the original which had apparently been cut into at least two pieces. The surviving piece was donated to the National Museums Scotland, where it is now registered as NMS.Z.1998.66 (Kitchener and Bonsall, 2001). It was radiocarbon dated at $29\,200 \pm 370$ years old.

Mammoth remains have also been found in other localities in Ayrshire and the western Central Belt. Craig (1842) reported a mammoth bone being found at Chapelhall near Airdrie, but no further details are given as to what type of bone it was. Kirsop (1882) reported an upper



Figure 4 *Fragment of mammoth tusk from Cliftonhall, near Edinburgh (NMS.Z.1998.66). Length along outer curve is c.306 mm and diameter of left-hand cut end is c.102mm. ©National Museums Scotland.*

right molar being found by Robert Bethune at Mainhill Farm, Baillieston in about 1875 (700 yards (0.64 km) east of Baillieston, south of the Baillieston to Coatbridge road). It was found 33 feet (10 metres) below the surface in sandy clay overlain by boulder clay. Craig (1888) reported a tusk, 5 feet long (1.52 metres) and 6 inches (15.2 cm) in diameter, which was found in 1881 by T. Shore about 80 feet (24.4 metres) below the surface at No. 5 pit, Warwickhill Colliery, Dummuir Farm, Dregghorn. This specimen is in the Hunterian Museum, register no. V5124, of which only a fragment 9.7 inches (24.6 cm) long survives (Gregory and Currie, 1928). Another fragment from Dregghorn was 6.5 inches (16.5 cm) long and was donated by T Craig in 1881, Hunterian Museum register no. V.5125. It has been radiocarbon dated at $30\,080 \pm 260$ years bp. (Palkopoulou et al., 2013). A right upper molar was found in the upper boulder clay at Bishopbriggs and donated by Miss Margaret Beveridge to the Hunterian Museum, register no. V.5155 (Gregory and Currie, 1928).

The most northerly record for the species in Britain was found in 1947, when a right upper molar tooth was discovered by Headswood Sand and Gravel Company west of Headswood Farm, near Larbert in the Carron Valley, Stirlingshire (Absalom and

Henderson, 1947). This tooth is in the collections of Glasgow Museums, register no. A.1937.26 (R. Sutcliffe, pers. comm.). The most recent find in Scotland appears to be an imperfect molar found at Houston's Store, Alloway Street, Ayr in July 1968, which was donated to the Hunterian Museum by Alan Neale (register no. V.5370) (Delair, 1969; N Clark, pers. comm.). There are also unconfirmed records of mammoth remains from Kimmerghame in Berwickshire and Kinloch, which were listed in Woodward and Sherborn (1890; 344).

However, not all proboscidean teeth and tusks found in Scotland are necessarily from mammoths. Some originate from elephants, but have often mistakenly been identified as mammoth remains. For example, a left lower molar found at No. 1 Pit at Carfin near Motherwell was donated to the Hunterian Museum in 1902 and was identified as that of an Asian elephant, *Elephas maximus* (Gregory and Currie, 1928). Hewat Craw (1919) described two molar teeth found near Eyemouth in Berwickshire. The first attached to a piece of jaw bone was found in c.1885 in a garden at Springbank on the left bank of the Eye and south of Eyemouth railway station. Its current whereabouts are unknown. However, a second tooth was found c.1895 during the laying of the

Eyemouth and Burnmouth Railway and is the specimen in the collection of the National Museums Scotland NMS.Z.1926.89, which is recorded as being from Hilburn, Ayton, Berwickshire. It also is from an Asian elephant. Another Asian elephant tooth was found in the Carse of Stirling, near Bridge of Allan in January 1959 and was misidentified as a mammoth's tooth. It is in the collections of the National Museums Scotland (Fig. 5). Yet another tooth was reported from Glenmoidart, Strontian, Argyll (Macewen, 1876). It is possible that some of these teeth were amongst the ballast on ships from India and the Far East, or tourist curios that were discarded, but they were clearly not native to Scotland.

In 1934 two tusks were reported as being caught in a fishing net on the seabed of the northern North Sea about 30 miles northeast of Shetland (Long, 1992). They were identified by Professor James Ritchie of Aberdeen University as belonging to the woolly mammoth. They are preserved in the Aberdeen Art Gallery and Museums, register no. ABDMS012368.1–2, and are about 1.3 metres long and 15 cm in diameter. However, radiocarbon dating revealed that they were only 255 ± 70 years old (OxA-1758) and it seems that they were part of a consignment of raw elephant



Figure 5 View of crown surface of Asian elephant tooth found in the Carse of Stirling near Bridge of Allan in January 1959. Crown length 125mm and width c.62mm. © Andrew Kitchener, National Museums Scotland.

ivory lost at sea c. AD1650–1750, possibly from one of four Dutch East India Company ships, en route from Batavia (Indonesia) or Ceylon (Sri Lanka), which were lost in a storm off Shetland in 1690 (Long, 1992).

In conclusion, woolly mammoth remains, comprising tusks and teeth, have been found principally in late Devensian deposits in the Midland Valley (Central Belt) and Ayrshire at about ten different locations over the last 200 years. Limited radiocarbon dates range from 27 200 to 46 700 bp., indicating that woolly mammoths do not appear to have survived the Last Glacial Maximum in Scotland.

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- Andrew C Kitchener,
Principal Curator of Vertebrates,
National Museums Scotland,
Chambers Street, Edinburgh EH1 1JF.
Email: a.kitchener@nms.ac.uk

Scotland's Time Lords keep Dynamic Earth Dynamic

By Stuart Monro

It is now 18 years since Dr Sandy Crosbie and I first sat down to write the scientific narrative for *Our Dynamic Earth*, and in the 15 years since it opened its doors it has engaged with around 4 million people. There are a number of significant challenges associated with an enterprise like *Dynamic Earth*. It is essential to keep the story fresh, to maintain the quality of the presentational media and to be completely up to date with the science. This article documents some of the changes that have taken place in *Dynamic Earth* in response to changes in technology and science, ending up with the most recent changes and the introduction of Scotland's Time Lords.

Beginnings

The story told in *Dynamic Earth* was deliberately conceived as a linear one, starting with an overview of the world as a dynamic system in continual change. This was a concept derived from the adage of James Hutton "...no vestige of a beginning, no prospect of an end." Hutton was at the very heart of the concept with a holistic approach to the content and an objective of combining

information and entertainment in its delivery. This was echoed in the final paragraph of Hutton's abstract to his 'Theory of the Earth' in which he writes "*In this manner, there is opened to our view a subject interesting to man who thinks....*"



James Hutton (1726–1797). This plaster bust, now held by the Royal Society of Edinburgh, was sculpted by Patric Park in 1849, based largely on the portrait of Hutton painted in about 1776 (though some authorities claim 1790) by Sir Henry Raeburn. The portrait is now in the collection of the Scottish National Portrait Gallery.



***Earthscapes
Scotland—taking the
exhibition outside.***

made a substantial contribution to the initial capital costs of Dynamic Earth. Accordingly, the Commission established the ReDiscover Fund which was administered by

and one which may afford the human mind both information and entertainment.”

The content progressed through the origins of the Universe and the tectonic, glacial and biological processes that have shaped our planet and the creatures that inhabit it. From there it moved on to explore the environments that had been produced by these processes, from the Oceans to the Polar Regions and through the various biomes to the Tropical Rainforest. The Dome at the end was envisaged as the summing up of what Dynamic Earth was all about. This remains as the fundamental structure of Dynamic Earth.

Funding for redevelopment is always an issue and this was recognized by the Millennium Commission which had

the Wellcome Trust to stimulate re-investment. In the second round of funding, monies were secured to engage with a wider audience. The international market demanded foreign language facilities and these were provided through audioguides. For younger visitors a range of new interactives were introduced and for the very young, a themed soft play area.

Initially, the external space in front of Our Dynamic Earth was largely a grassed area which played no part in communicating the story of Dynamic Earth or giving visitors a feel for what might be experienced inside. The third round of ReDiscover funding introduced new elements into the external environment. One told the story of Scotland's journey from deep in the southern hemisphere to our present comfortable location through

large blocks of rock, demonstrating the key milestones in the journey and the varying environments through which Scotland passed. Other initiatives created a slice through Scotland showing some of the major tectonic features, and produced a geological garden of plants associated with the geological time scale, all set around a glacially striated surface taken from a quarry just outside Edinburgh. The inner structure of the Earth was explored in a 'cave' in the centre of the turning circle and finally, in a very small way, the contribution of James Hutton to geological thought was acknowledged.

Changing the conclusion

In a linear approach to telling the story of Dynamic Earth, it is the beginning and the end that are easiest to change. Many people will have fond memories of lying on the floor of the ShowDome and seeing images projected on to the dome as a summary of the exhibition highlighting the dramatic processes that have shaped the planet. Paradoxically, many of those processes can be regarded as hazards to our every-day way of life even though they are the essential processes of renewal by which the planet operates. But changes in available technology meant that a slide show, even one projected on to a dome surface, did not meet

the expectations of the public. The fourth, and final round of ReDiscover funding gave an opportunity to do something new and innovative.

The FutureDome aimed to look forward and to show visitors that decisions made today would have implications into the future in, for example, the provision of energy and water to an increasing population. The technology employed used rotating floors to simulate transport into the future and used voting mechanisms to determine the outcomes of the various scenarios. This encouraged group interaction and highlighted many of the issues that are current at the present day.

While the FutureDome was very successful and addressed many current issues, there was a need for part of Dynamic Earth which could change more rapidly. To achieve this, and to continually give something new to repeat visitors from Edinburgh and its environs, an emerging technology was utilized which allowed full dome films to be shown. Dynamic Earth joined a consortium to produce a full dome film, 'We are Astronomers', which was part-funded by the Science and Technology Facilities Council to celebrate the 400th anniversary of Galileo first pointing his telescope to the sky. It demonstrates how, in those

400 years, astronomers have worked together to understand the origins and evolution of the universe, culminating in the experiments at CERN.

Reverting to the name 'ShowDome', this gallery is now an ever-changing part of Dynamic Earth showing full dome films that illustrate astronomy, evolution and supervolcanoes.

Responding to Climate Change

With the increasing concern about global climate change it became necessary to respond in the Polar gallery, where the emphasis had simply been on the wonder of the polar environment. These regions now had to be seen as important laboratories of climate change, providing detailed information on changing temperatures and atmospheric gas composition through gas bubbles trapped in ice cores. The redevelopment also provided an opportunity to move from projected still images of the polar regions to a large screen movie incorporating high definition images alongside a mosaic of other footage.

The Journey of Contrasts from the polar regions to the tropical rainforest was a gallery where the scientific message of the diversity of biomes and what causes them was being communicated less than successfully. The response was to substitute this area with the 4DVENTURE. Here

the aim was to create an immersive experience in which visitors would engage with the science behind the various biomes in a 'pre-flight' briefing area before flying across the biomes seeing how plants and animals adapt to different environments.

Recent changes — How it all Started

As time goes by technology can dramatically improve how the story of Dynamic Earth is told. 'How it all Started' was originally conceived as a slide show using many of the spectacular images from the Hubble Space Telescope. However in 2014 it is now possible to use computer generated images to demonstrate contemporary concepts of the origins of the universe. A new film was produced which highlighted more of the fundamental scientific concepts now understood by astronomers and physicists and convey these ideas visually. The end result combines the wonder of the Hubble images with other scientific concepts, from supernova to Earth's bombardment by meteorites, and from the origin of simple elements to their combination in more complex molecules.

Recent changes — the Time Machine

The journey back in time to the singularity just before the Big Bang is important in understanding the origins of the universe. The new



Sir Charles Lyell (1797–1875) at the British Association meeting in Glasgow, 1840. A portrait by Alexander Craig reproduced by permission of the Geological Society of London (archive reference GSL/POR/73).

‘Deep Time Machine’ does just that, touching on the various milestones from the present day back to the mysterious point immediately prior to the beginning of time itself. In the blink of an eye we are back 2 million years, when the first hominids walked the Earth. Between 65 and 230 million years ago our Earth’s inhabitants included the dinosaurs. 380 million years ago organisms began to live on land. An explosion

in the diversity of life took place 580 million years ago. First simple bacterial life appeared 3.5 billion years ago. Earth was bombarded by meteorites between 3.5 and 4.53 billion years ago and formed by accretion of material left over from the formation of the Sun between 4.54 and 4.6 billion years ago. And finally, or rather firstly, galaxies converge to the singularity from which the Big Bang emerged.

Recent changes—Scotland’s Time Lords

At the beginning of this piece, it was noted that the origins of the Dynamic Earth exhibition were strongly embedded in the person of James Hutton, yet little of the exhibition was devoted to celebrating his contribution to Earth science. This has now been remedied by replacing ‘State of the Earth’ with ‘Scotland’s Time Lords’. In this new gallery, funded with help from the heritage Lottery Fund, James Hutton is brought back to life through a ‘Pepper’s ghost’ and he can recount for himself the significance of the observations he made at Siccar Point and on Arthur’s Seat. Scientific progress is a journey made faster in company with other people. The gallery permits Hutton to converse with Charles Lyell, who was the great communicator of his ideas, with Peach and Horne, the Survey geologists who mapped-out the results of mountain

building in Scotland's NW Highlands, and with Arthur Holmes whose appreciation of radioactive decay enabled him to quantify the age of the Earth, something that Hutton could only speculate on.

Global impact of these innovators

There is an international dimension to this story featuring a German polar explorer and meteorologist, Alfred Wegener who, from 1912, championed the theory of continental drift, adding geological evidence to the long-recognised, if puzzling, geometrical fit between South America and Africa. This was a controversial idea which was not widely accepted, mainly because geologists could not agree on a mechanism by which continents could be moved.

The modern approach to the problem started at the Lamont-Doherty Earth Observatory of Columbia University, where Marie Tharp and Bruce Heezen

compiled the first physiographic map of the North Atlantic. It was published in 1957 and was part of the evidence that, in the 1960s, led Harry Hess from Princeton University to the concept of seafloor spreading from a mid-ocean ridge, opening up oceans and moving continents. Further evidence to support this concept came from work on determining the age of the ocean floor and the geomagnetic signature contained within the magnetic minerals. The symmetrical pattern either side of the Mid-Ocean Ridge revealed by Fred Vine and Drummond Matthews working in Cambridge University and Lawrence Morley of the Canadian Geological Survey demonstrated conclusively that magma was rising up along the Mid-Ocean Ridge and moving away from the ridge, providing the mechanism that had eluded Wegener. The corollary of this process, if the Earth were not to be seen as continually expanding, was



A beacon of enlightenment © Our Dynamic Earth

the requirement for crust to be lost, so balancing the generation of new crust in the Mid-Ocean Ridges, this process we now know as subduction. Together these observations built our modern concept of Plate Tectonics the evolution of which provides a scientific culmination for Scotland's Time Lords.

Hutton's ideas revisited

This story moves us a long way from the original ideas of Hutton, but taking the time to reflect might well help make meaningful connections between our modern understanding of how the Earth works and the concepts that emerged from Hutton's work. The following letter, purporting to come from James Hutton and bearing marks of scorching was, according to Gordon Craig's 'A Geological Miscellany', received recently by the editor of *Séance de la terre*. It contains the following lines:

"... We all look forward to meeting some of your young colleagues who have made such spectacular advances in plate tectonics, and I am especially glad to hear that they are using my heat to drive their plates..."

The science has moved on since Hutton's day but his legacy remains as the foundation for our modern understanding of how the Earth works.

The future of Dynamic Earth

As a science centre, Dynamic Earth has a unique role as the only science centre in the UK, and possibly in the world, devoted to engaging people with the processes of how the Earth works. This is increasingly important in an age where many of the issues facing Society, climate change, availability of drinkable water, energy resources, food security, to name but a few, are all underpinned by an understanding of how the Earth works. Equally, the research carried out in universities and elsewhere must connect with those who pay for it, the taxpayers, and science centres have a role in making the impacts of that research widely accessible.

For myself, as I approach retirement from the best job in the world—scientific director of Dynamic Earth—I hand over the baton to the next 'Keeper of the Scrolls' who will further develop this most excellent institution, and will hopefully take note of Hutton's words; *"In this manner, there is opened to our view a subject interesting to man who thinks.... and one which may afford the human mind both information and entertainment."*

Stuart K Monro
Scientific Director of Our Dynamic Earth and Honorary Professor,
University of Edinburgh

Book reviews

Island on Fire by Alexandra Witze and Jeff Kanipe. Profile Books, London. 2014. Hardback, 224 pp. Price £10.99. ISBN 978-1-78125-004-4.



The effects of volcanic eruptions in Iceland can be felt far beyond that island's shores and have the potential to cause serious disruption and economic damage in Britain. Having spent the last four years working with UK scientists and the UK government planning for a potential repeat of a 'Laki eruption' scenario, I picked up this book which, according to its press release is about the 'all-but-forgotten Laki volcano', with some trepidation. In scientific and government circles at least the 1783-4 Icelandic eruption is not forgotten, it is in fact the subject of a number of excellent scientific papers which, coupled with detailed historical records, makes it an ideal eruption for contingency planning. The historical documents, in particular the vivid first-hand accounts of eighteenth century

clergyman Jón Steingrímsson, and the more recent research about the potential impacts of future eruptions combine into a superb story.

It begins in 1773 on the island of Heimaey as advancing lava threatens the town, homes and livelihoods of islanders, leading to a partial evacuation. Nevertheless some stay to mitigate the impacts of the eruption by pumping huge volumes of seawater at the advancing lava in an attempt to divert its flow. This sets the scene well, showing the resilience and innovation of those living and working alongside volcanoes where eruptions may occur at any time.

The tale then moves back to the eighteenth century and Jón Steingrímsson's experiences as the eruption of Grimsvotn volcano at Lakagigar ('Laki eruption') begins. Jón is an interesting character: well-educated, interested in natural history, a farmer, a priest, a self-taught physician and yet also very interested in the supernatural as were others at the time. The book gives a sensitive portrayal of this man and the challenges he faced during and after the eruption as he tried to support his own family and others in the district as the appalling secondary impacts of the eruption set in.

The book weaves the story of the eruption and its impacts between chapters explaining more about volcanism and volcanic eruptions elsewhere in the world. This gives welcome context to the developing story of Laki. Thanks to the growing tendency in the eighteenth century for interested individuals to document their observations of the natural world, the book goes on to draw on the testimonies of Gilbert White, Benjamin Franklin and others as they describe the atmospheric effects and impacts of the Laki eruption beyond Iceland. Later chapters move into modern interpretations of the wider impacts of the Laki eruption as a result of the dispersal of sulphate aerosol by winds in the troposphere. Some of the eruption emissions reached the stratosphere and the possible impacts on climate of such eruptions are discussed. The book gives a good list of resources including scientific papers and this combination of accessible cutting edge science and personal testimony is a great strength of the book. The text is engaging, fast-paced and makes the most of some colourful testimonies.

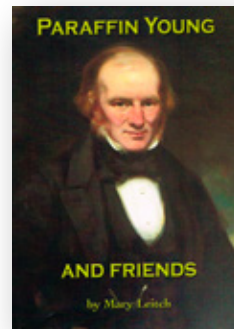
There is an unfortunate use of the term 'Supervolcanoes' to describe major eruptions such as those of Vesuvius 79AD and Krakatau 1883 based on the Volcanic Explosivity Index, but this is not a good way of

measuring and comparing the scales of fissure eruptions like Laki. There are other examples of somewhat erroneous scientific explanation and some important gaps but these should not detract from the excellent storytelling, good descriptions of a wide breadth of scientific and historical topic areas and the fascinating perspectives of both those impacted by eruptions and scientists. The book is very attractively presented and is well-illustrated in black and white.

Sue Loughlin

Volcanologist, British Geological Survey

Paraffin Young and Friends by Mary Leitch, with a foreword by Professor Stuart Monro. Published by Alan Fyfe, Edinburgh. 2012. Paperback, 111 pp. Price £7.50. ISBN 978-0-9548764-3-2



It's a sad fact that in Scotland we know too little about our industrial

and commercial forebears. In her 110 page book, ***Paraffin Young and Friends***, Mary Leitch takes us back to an age of enlightenment (there was a darker side of course) and its practical application, back to the times of Thomas Telford and Michael Faraday. She herself is a great-great-granddaughter of James 'Paraffin' Young (1811–1883). Her book is a good one.

Here we can relive the early years in Glasgow of James Young, the son of a master joiner, He was his father's apprentice. By nineteen, no stranger to the rougher aspects and keener privations of life, James would be getting up at 4am, working through the day, and wrought till 10pm.

"He made coffins, doors, counters for shops, tables and chairs, floors, rollers and frames for maps for sailors and soldiers, window frames, picture mouldings, basin stands, handles, chests, beds, bakehouse drawers, knife boards and vases for bees.

He turned wood, he polished and varnished furniture and snuff boxes and helped with house removals.

James enjoyed his work and liked to do each job to perfection.

Improvements were made and new ideas tried out", including cabinet hinges of his own devising.

At 21 years old he began to take an interest in science. He attended

lectures by Professor Thomas Graham (1805-1869) chemist, and others, and picked up relevant textbooks. His appetite whetted, the uncombed redhead in working clothes enrolled in the Mechanics' Institute to attend the classes at the Andersonian University, earning his keep by making the laboratory apparatus. Outstandingly able, hardworking and inventive, from here Young's progress was fast. He became official assistant to Thomas Graham, giving some of the lectures and demonstrating experiments himself, and when Graham took up a Professorship at University College London, he asked Young to join him as his assistant. In London James Young was soon helping at some of Michael Faraday's public experiments. He was there at the birth of a new age.

Thomas Graham's brother John had been put in charge of the Royal Mint in succession to Herschel, and had developed a new bronze coinage which gave great saving and advantage to the state. James Young was much impressed with John's dedication: "He laboured like Faraday and his work is a monument of patient concentrated thought, and of singleness of purpose that never swerved".

It was an attitude to life that James Young took to heart in his own career as one of the great Scottish

industrial chemists of his generation. The story is ably unfolded in Mary Leitch's book, and earned him his "Paraffin" soubriquet. Fond admiration surrounded Paraffin Young, sometimes tinged with envy for his business acumen, but he was always one of our ain folk. Simple humanity shone through in his affection for his wife and family and support for friends like the explorer David Livingstone and home-loving songwriter James Miller, author of *Wee Willie Winkie* and 'laureate of the nursery'.

Young's singleness of purpose drove him to take an inside track on Archibald Geikie's 1857 geological survey work. He accompanied Geikie in person around the parts of the Lothians where rich bands of shale were likely to be found, and then moved fast to snap up the mineral rights. His enterprise and foresight laid the foundation for future generations of Scottish refining endeavour. His scientific thoroughness and expertise generated prosperity across central Scotland and improved living conditions in his own time through his successful industrial production of safe, clean-burning lamp oils and candles.

Thanks to his early example, those who followed James Paraffin Young like my own ancestor William Young

(no relation) and George Beilby, co-inventors of the Young and Beilby vertical retort, were able to squeeze more light and useful chemicals out of the most unpromising shales. James Young's Scottish oils were used to illuminate the new lighthouses across the far-off Japanese Empire, and their Stevenson-trained engineer Henry Brunton became general manager of Paraffin Young's business at Bathgate and Addiewell on his return from the East.

James Young's work lit up the world. I sense that Scotland's practical enlightenment (getting the most out of science, engineering, communications and social institutions) was as influential worldwide as the earlier philosophical enlightenment had been. The stories of the young men and women of those days have plenty to show us. The motto *Waste Not, Want Not* can be applied to our stewardship of the earth's resources, and also to the way we give back purposeful work to a new generation. James Young was given chances and took them. He helped and kept his friends. Mary Leitch's book shows us something of how it was done.

By Roger Kelly

*Vice-convenor of the Saltire Society
and chairman of the Penicuik Trust*

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