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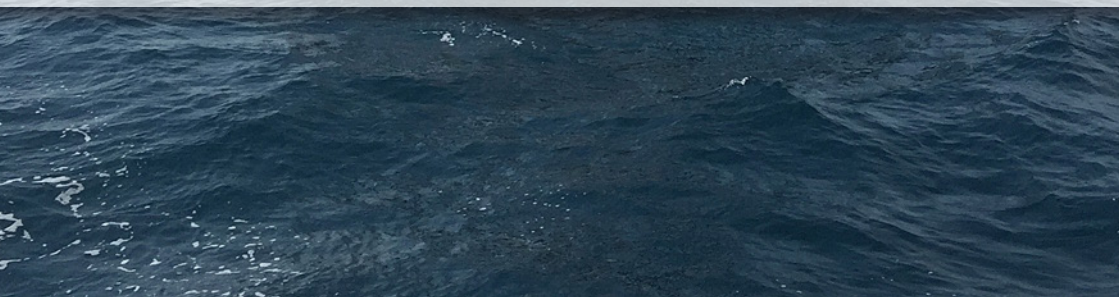

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Cover Illustration

The *L/B Myrtle* on site in the Gulf of Mexico preparing to drill the Chicxulub impact crater. For more on this story see the article by Claire Mellett on page 5. Image: EPM©ECORD_IODP.

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The Crater of Doom, Exhibitions and Endurance

An editorial ramble by Phil Stone

No, the heading is not a cryptic reference back to the EU 'Brexit' referendum but instead plagiarises the title of the book by Walter Alvaraz that chronicles the emergence of the asteroid-impact explanation for the extinction of the dinosaurs. Our first article in this issue of *The Edinburgh Geologist*, by Claire Mellett, prompted me to dig out my copy of *T. Rex and the Crater of Doom* (first published in 1997) and rediscover just what a splendid scientific story it tells. Claire describes the recent and very successful expedition that recovered the first drill core from the offshore sector of what has become widely accepted as the site of that fateful impact—the Chicxulub crater in the Gulf of Mexico.

As Claire writes, the idea that an asteroid impact and its aftermath caused the end-Cretaceous mass extinction is now sufficiently 'mainstream' to be included in school curricula, but when first proposed, in 1980, it was highly controversial. Alvarez and colleagues spent the 1980s scouring the World for data from the Cretaceous-Tertiary (or now more properly Palaeogene) boundary, with the now-famous iridium anomaly one of the key discoveries. But Claire's story focuses on the impact site itself, and that discovery took longer, and is a classic example of disparate threads of geological evidence being productively drawn together.

The first hint came from Texas, where it was realised that an unusual sandy bed at the KT (or should that now be KPg?) boundary was a tsunami deposit that had been emplaced from the south. Then, core records from the Ocean Drilling Project showed that in the Gulf of Mexico the uppermost Cretaceous strata were missing, eroded away, with the resulting gap followed by an unusually cross-bedded, sandy deposit containing an abundance of clay pellets – were these the remains of devitrified impact-melted glass particles? Finally, suspicion fell on a pattern of circular gravity anomalies spanning the north coast of the Yucatán Peninsula, Mexico.

Ironically, that phenomenon had been previously investigated—and interpreted as an impact structure. Back in 1952 the Mexican State

Oil Company, Petróleos Mexicanos (PEMEX), had drilled the gravity anomaly in anticipation of an oil-bearing sedimentary basin. But beneath about a kilometre of Palaeogene beds were discovered dense crystalline rocks of broadly andesitic chemical composition. Understandably, the PEMEX geologists thought they had reached a volcanic basement with no hydrocarbon potential, so they moved on. Much later, in 1981, a PEMEX re-evaluation of the data led to the suggestion that the gravity feature might arise from an impact structure—albeit an improbably large one. Even so, there was no oil potential and so the suggestion remained buried in the company files, with only a brief word to the outside world in a forgotten conference abstract. Finally, in 1991, everything came together[1].

Actually, at first not quite everything came together because the original PEMEX cores from 1952 were thought to have been lost when the warehouse in which they were stored was destroyed in a fire. That proved to be an unfounded fear when the cores were eventually rediscovered safely stored elsewhere, and some did indeed illustrate impact melt-rock features. In her article, Claire Mellett makes nuanced reference to the expedition's recovery of the first offshore core samples, targeting the central part of the crater. There will be much comparative analysis to be done before the full import of the expedition's work is appreciated and another chapter completed in this fascinating story. Of course, not everyone agrees that the dinosaurs were wiped-out by an asteroid impact ... but if we took a vote on it I think the dissenters would lose.

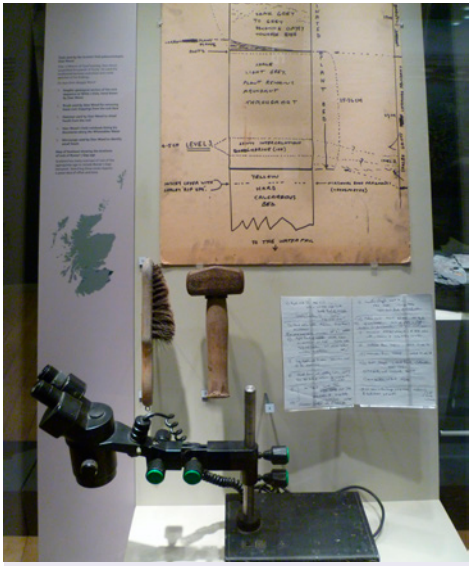
Exhibition reflections

So much for the dinosaurs, but of course there would have been none had tetrapods not made it onto land in the first place. In the second of our articles, Nick Fraser brings us up to date with the latest extraordinary fossil finds from the Scottish Borders, in his account of the latest phase of the TW:eed project. The summer exhibition at the National Museum of Scotland, *Fossil Hunters*, gave us an opportunity to see some of the remarkable discoveries in their full geological context, but an appealing complement to the palaeontology was the inclusion of the personal viewpoints of the scientists involved. Audiovisual presentations allowed most to speak for themselves, but sadly that was not possible for the late Stan Wood whose pioneering work provided the

[1] Hildebrand, A R. *et al*. 1991. Chicxulub crater: a possible Cretaceous/Tertiary boundary impact crater on the Yucatán Peninsula, Mexico. *Geology*, 19, 867–871

starting point for TW:eed. Hence a poignant part of the exhibition was that devoted to Stan, with some of his field and fossil-preparation tools on display alongside notebook pages and his stratigraphical compilation of the section subsequently examined in detail by Nick's team. This is *EG's* third contribution from the TW:eed project and hopefully there is still more to come.

When visiting the National Museum for *Fossil Collectors* I was intrigued by another small, temporary exhibition, this one of Neolithic axeheads; not practical tools made of flint or rhyolite, but exquisite products of polished jadeitite. These were produced about 6000 years ago in the North Italian Alps and traded widely across NW Europe. They can have had no practical use but were clearly very highly valued, revered even. Examples have been found in many parts of Scotland, probably brought into the country by immigrant farmers from northern France shortly after 4000 BC but thought to have been at least 100 years old even then, so they were perhaps family heirlooms. Who said that immigration and a single European market were new phenomena … or the desire for a bit of fashionable bling for that matter?



Stan Wood's field tools and microscope on display at the National Museum of Scotland as part of the* Fossil Collectors *exhibition.

Another new exhibition, but of a more permanent nature, is the subject of our third article, in which Laura Hamlet and colleagues describe the latest developments at the North West Highlands Geopark. *The Rock Stop* is a newly opened visitor centre at Unapool, just to the south of the Kylesku Bridge; it nestles on Lewisian rocks in the shadow of the Moine Thrust Zone. As Laura explains, the ethos of the Geopark is to 'Explore Deep Time, Evoke a Sense of Place and Encourage Stewardship'. It showcases some of Scotland's most renowned geology and deserves every success. I'm

Neolithic jadeitite axeheads found in Scotland, on display at the National Museum of Scotland.

pleased to note that in a small way the Edinburgh Geological Society was able to contribute.

Endurance

Finally, in our fourth article, we have a centenary to celebrate. The survival of Shackleton's Antarctic team after the expedition's ship, *Endurance*, had been crushed by pack ice has become well known as an established icon of polar heroism. Final relief for the men marooned on Elephant Island came on 30 August 1916, and amongst those rescued was a young Scottish geologist, James Wordie. Ironically, having survived Antarctic vicissitudes, Wordie promptly joined the army and was badly injured in April 1918 during the early stages of the Battle of Lys. Happily he recovered and went on to have an illustrious scientific career, eventually bequeathing to the National Library of Scotland an extensive archive of polar, mountaineering and geological material. In the fourth article for this issue of EG, Paula Williams tells us something of the man, his later involvement in Arctic exploration, his influence on British Science policy and the range of his collection. Wordie would undoubtedly have had some 'traveller's tales' to tell. An anthology with a decidedly geological slant is the subject of the book review that completes this issue of EG.

The full title of Shackleton's *Endurance* adventure was the *Imperial Trans-Antarctic Expedition*. In the one hundred years since then we've abandoned such grandiose claims and developed our major scientific ventures into collaborations of equal partners, with much success. A good example is the Chicxulub drilling project described for us by Claire Mellett. Now, post-'Brexit' referendum, it's no great secret that there is widespread concern in the British science community about the future prospects of those collaborations and the funding that made them possible. It will be some time yet before the new rules of engagement are established and in the meantime, like Wordie on Elephant Island, we'll just have to endure the uncertainty.

Drilling the Chicxulub Impact Crater

By Claire Mellett

Schools nowadays teach about a giant asteroid striking the earth and wiping out the dinosaurs 66 million years ago. It is dramatic events such as these that often capture our interest in studying Earth Sciences. However, throughout our time at university we slowly narrow our fields of expertise and often end up working further and further away from the topics that inspired us in the first instance. This was certainly the case for me. I am a marine geologist, I research Quaternary continental shelves and this year I found myself managing a high-profile project to drill the Chicxulub Impact Crater.

The end of the Cretaceous Period is defined by a global mass extinction event whereby three quarters of plant and animal species, including the dinosaurs, became extinct. The extinction event is linked to an asteroid striking the Earth and the Chicxulub Impact Crater is believed to be the remnant of that impact. The crater's geophysical signature was first discovered in the early 1980s and it is preserved beneath 100s of metres of sediment on the Yucatan Peninsula in Mexico, and directly offshore in the Gulf of Mexico (Figure 1). Over the past three decades, efforts have been made to acquire more geophysical data and obtain samples of rocks from the Crater itself. Despite these efforts the offshore portion of the Crater has never been drilled. That is until now.

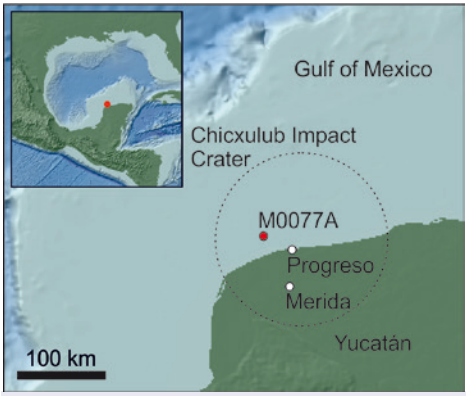


Figure 1 Location of the drill site M0077A showing an outline of the Chicxulub Impact Crater.

The European Consortium for Ocean Drilling (ECORD) operating on behalf of The International Ocean Discovery Program (IODP) funded a project to drill the Chicxulub Impact Crater in April-May this year. A team of 32 international scientists were selected to undertake research on the cores recovered, with support from

engineers, laboratory technicians, data managers and operations specialists. Twelve members of staff from the British Geological Survey (mostly based in Edinburgh) are part of the project team (Figure 2) and it is my role as Expedition Project Manager to connect drilling operations with the scientific objectives and requirements. I act as continuous point of contact for the scientists for the duration of the expedition (which started long before, and continues long after the actual drilling).

Scientifically, why do we want to drill the Chicxulub Impact Crater? Apart from the obvious 'asteroid and extinction of the dinosaurs' motivation, more specifically, Chicxulub is the best-preserved large impact structure

Figure 2 A small subset of the scientific team. Image: Wittmann©ECORD_ IODP.

on earth and it is the only one with an intact peak ring[1]. Our objective was to drill this peak ring and obtain samples that will be analysed to help answer the following key questions:

1. What is the nature of the rocks that form the peak ring?
2. Was there intense hydrothermal activity in the peak ring and did this create habitats for microbial life?
3. After the impact, how long did it take life to recover?

The strategy was to drill a single hole into the peak ring to a minimum depth of 1200 m below the sea floor. To do this we required a drilling rig and a vessel from which to drill. IODP have two large drilling ships but these were unsuitable for this project as the offshore portion of the Chicxulub Impact Crater is located in shallow water depths of <20 m which are inaccessible to the large IODP drill ships. We therefore had to build a Mission Specific Platform (MSP) which means taking a bare vessel and adding everything you need to drill and analyse the rocks recovered.

[1] A peak ring is a roughly circular chain of rugged hills, peaks and massifs that stands above an otherwise flat crater floor in the interior of the crater basin. There is no single model to explain formation of a peak ring and one of the key aims of the project is to recover samples that will test different models for formation

Figure 3 L/B Myrtle on site. Image: PerezCruz©ECORD_IODP.

As we were planning to drill a single site we did not need a ship and could instead use a stationary platform. We used a Liftboat called the *L/B Myrtle* (Figure 3). Liftboats have three large legs that rest on the seabed and they are able to jack themselves out of the water. In our case the *L/B Mytrtle* was elevated about 20 m above the sea surface. Once out of the water the vessel is stable which means there is no need to install a drilling rig with capabilities to compensate for motion in the ocean. The drilling rig fitted to the *L/B Myrtle* was one typically used on land (Figure 4). The advantage of using this drilling rig was that it is optimised to recover high quality

cores which are ideal for scientific analyses as they preserve structures and maximise the amount of core available to work with. Using this rig certainly paid-off as we achieved >99% recovery and the cores are beautiful (Figure 5).

After two months at sea, a total depth of 1335 metres below sea floor was reached. The first 500 m of rock was open-hole drilled. This means no core samples were recovered through

Figure 4 The beginning of the night shift. Image: LeBer©ECORD_IODP.

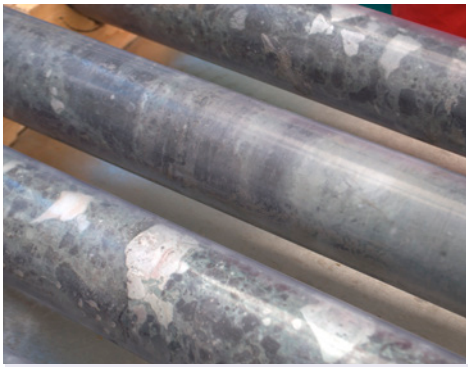


Figure 5 Cores recovered from the Chicxulub Impact Crater (core diameter = 106 mm). Image: Tulloch©ECORD_IODP.

this interval. It may seem wasteful to drill and not recover cores but coring is a slow process so by open-hole drilling the upper sediments that are not related to the impact event, we were able to penetrate the peak ring faster and provide more time to drill deeper into the rocks of interest. Coring began in the post-impact sediments where the rocks are expected to contain a record of the recovery of life after the impact event. Coring then advanced into the peak ring itself and the first ever samples of rocks from an intact peak ring (on Earth and elsewhere) were recovered. To be part of such a ground-breaking expedition is a privilege.

Once the rocks were recovered we needed facilities to analyse them. The

L/B Myrtle does not have any in-built laboratories so we had to supply our own. ESO has a number of modified shipping containers that have been converted into laboratories (Figure 6). It is surprising the amount of scientific equipment that can be fitted in these containers. However, they are not ideal places to carry out a full suite of scientific analyses. We also cannot physically accommodate on the ship all of the staff needed to carry out analyses of the cores. For these reasons, offshore we only analysed ephemeral properties, principally aspects of geochemistry and microbiology (Figure 7). To carry out full analyses, an Onshore Science Party (OSP) was held at the IODP Core Repository in Bremen (Germany) a couple of months after the drilling finished. Here, the entire scientific team worked seven days a week to provide baseline data on core lithology, geochemistry, physical properties and biostratigraphy.

At the end of the offshore phase of the expedition, the vessel pulled up its legs and started a long journey around the Gulf of Mexico arriving in Louisiana where the drill rig and equipment was stripped down leaving a bare platform once again. Here, the cores were offloaded and transported to Houston for state of the art helical CT scanning. The CT data will play a critical role in identifying features such as fractures and bedding planes that will be key to answering questions about crater formation and post-impact history. The CT scanning also ensures the legacy of the expedition by preserving a digital record of the core prior to the main sampling phase.

Figure 6 Analytical work in progress in one of the laboratory containers on* L/B Myrtle. *Image: LeBer©ECORD_ IODP.

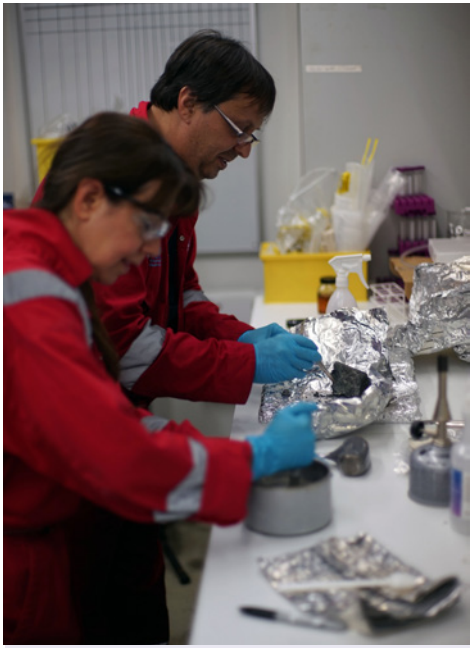


Figure 7 Preparation of microbiology samples. Image: LeBer©ECORD_IODP.

Initial results from the expedition will be published late in 2016. However, results from detailed scientific analysis will only emerge over the next 2–3 years as a large team of scientists begin to unpick the geological history of the impact event using samples from the core. Based on the snapshot of analyses carried out offshore we have high expectations for the outcomes of this project. High quality core along with almost 100% recovery provide an exceptional record in which to study the impact and post-impact processes.

This expedition is one that won't be forgotten in the IODP community for a long while.

For a marine geologist, going to sea is fieldwork. As with all fieldwork in remote places I like to think of it as character building. The *L/B Myrtle* is a platform that is a little over 40 m in length on which up to 45 people eat, work and sleep. The deck is crammed with labs and drilling equipment. You work twelve hours a day, 7 days a week and some people were on the platform for the full two months. One of the toughest parts of working in such a confined environment is finding time for yourself. You share your cabin with 5 other people and the 24 hour operations mean there are always people around. After working offshore I now fully understand the term 'cabin fever'. But despite its challenges, working offshore can be extremely rewarding especially on a project drilling into the Chicxulub Impact Crater. In some ways life is easier offshore as you don't have to cook or clean or do the daily commute, you just disappear to the middle of the sea and concentrate on your work. It's rare to have such an opportunity to focus on a single task.

Claire Mellett
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How to collect fossils in a river bed without getting your feet wet

By Nick Fraser

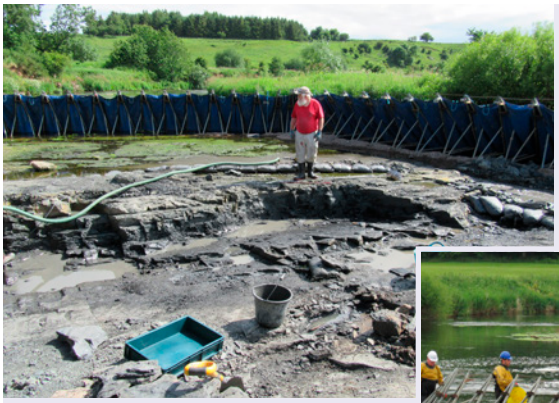
The TW:eed project (see *Edinburgh Geologist* 53 & 56) has been running for almost four years now, and during that time we have flown drones above the beach at Burnmouth (to help us analyse the relationships of the Lower Carboniferous outcrops), drilled 500 metres of core in Northumberland and, with the aid of CT technology, made a 3D print of a tiny new tetrapod that is still completely encased inside sediment. These are just some of the varied approaches we have employed during the course of a very successful NERC-funded research programme that is shedding completely new insights into the environment and the nature of the colonization of land by vertebrates. What was once a missing piece in the fossil record is no more—Romer's Gap has been well and truly filled.

Of course, it all started with Stan Wood's discovery of a remarkable fossiliferous deposit in the bed of the Whiteadder River. Stan always had a grand vision for diverting the river to leave the desired beds exposed so that we could excavate them at leisure! While such a scheme was out of the question, we did have our own challenging plan to bund-off a section of the river for a few weeks. We soon realized how daunting this would be in a river noted for its salmon and trout fishing, and we needed to be meticulous in our planning and timing of the excavation. There is only a short window during the summer months when the waters might be sufficiently low to attempt such an operation, and this was further constrained by the sensitivity of the fishery. However, after a couple of false starts, working closely together with SEPA, SNH and the River Tweed Commission we were able to obtain the necessary permits to erect a temporary dam that would deflect the water away from a significant part of the relevant beds. Importantly, the landowners, Judi, James and Angela Maclean, were also intrigued by our proposition and very graciously permitted us to occupy part of their land adjacent to the river for the duration of the excavation. So last June, coordinated by Andy Ross, the group was able to spend three weeks systematically excavating a portion of the river bed safely behind

a remarkable dam skilfully erected by our contractor *Onsite Portadam*.

The results were quite wonderful and we collected well over 1000 fossils together with some large blocks of unprocessed sediment. Plant remains were abundant and sometimes quite beautifully preserved and rhizodont scales were ubiquitous. The invertebrates included a delicate partial scorpion complete with pincers, but most encouragingly, signs of tetrapods were never too far away. As we split through the sediment the occasional femur or toe bone would be exposed and every now and then a more concentrated association of bones would be exposed. However, these would have to wait until we got back to the lab and potentially months of preparation work and analyses before knowing what we had really collected. The sediment blocks are quite friable and easily disintegrate without stabilizing with water-soluble glues in the field. We had a small 'portakabin' on site where we could sit and have a closer look at the fossils in order to make very general identification. Then, without further ado, each fossil was carefully recorded, wrapped, and transported back to the National Museum.

To keep a permanent record of the excavation, we worked with Digital



Safely behind the dam, Dave Millward surveys progress one week after the start of the excavation.

The first stage of the excavation: erecting the frame for the dam.

With the dam in place, the team was able to conduct a major excavation and stay completely dry.

Taking a closer look at some of the excavated fossil material.

Design Studio from Glasgow to LIDAR-scan the site, firstly at the beginning of the excavation and then again at its conclusion. The result is a 3D visualization of the entire excavation. Moreover, we shall always be able to return back to exactly the same spot should the need ever arise to go back and continue the excavation deeper into the riverbed.

While the elusive tetrapods formed a focus of the excavation, this stunning scorpion fossil (about 4 cm long) was among my favourite specimens.

With so much fresh material collected it will take many months to fully assess and prepare the individual fossils. However, the painstaking task has begun and already two partial tetrapod skulls have come to light. The next steps will be to scan these blocks to determine whether more of the fossils are present deep within the sediment. As well as providing more detail the scans will help guide how we should proceed with the mechanical preparation of the blocks.

Already we can say that there is a significant diversity and disparity of tetrapods and as a consequence we are now asking new questions. For example, just how quickly did terrestrial vertebrates radiate and diversify after the end Devonian? We hope the answers to such questions will lie in some of the material we have collected, but we shall also have to continue our field studies and even venture up the geological column a little further!

With the end of the excavation work in sight, some of the team pose happily behind the dam, from left to right: Andy Ross, Jessica Mason, Sarah Stewart, Jenny Clack (project leader), Rob Clack, Vicen Carrio, Yves Candela, Janet Sherwin, Nick Fraser, Derek the jackhammer operator. Rachel Russell took the photograph.

At 355 million years ago the ponds and rivers around the ancient land surface would have harboured a variety of fishes, including this rather formidable rhizodont. Restoration by Mark Witton.

The terrestrial tetrapods being recovered from Willie's Hole are quite diverse and probably included whatcheerids (far left) and colosteids (centre). Restoration by Mark Witton.

New Exhibition for the North West Highlands Geopark

By Laura Hamlet, Mike Goodwin and Pete Harrison

What is a Geopark anyway?
Although the 'Geopark' concept has been around for more than two decades now, they are only just beginning to register on the public radar. This is almost exclusively due to the hard work of the communities that set them up, working with limited resources but tons of enthusiasm and passion. Their recent inauguration as a new UNESCO programme has been made possible by more than a decade of community-led momentum. Without grass-roots passion for landscape, geology and how it relates to ecological and cultural heritage this would not have been possible.

Geoparks now enjoy the same status as World Heritage Sites, but with some important management differences. Geoparks must be set up and managed by their local communities and go through a rigorous revalidation process every four years to ensure best practice and quality of product. Since every community is different, every Geopark is different but all share a common aim: to tell the story of our landscape and promote it. In turn this helps to bring resources into sensitive areas and encourages families to put down roots. Regions can operate as *de facto* Geoparks, but to gain UNESCO Global Geopark status they must be able to prove that they have unique landscapes, internationally significant geology and a rich cultural heritage.

The North West Highlands Geopark was set up in 2004 by members of the five community councils of Coigach, Assynt, Scourie, Kinlochbervie and Durness with support and encouragement from partner organisations such as the British Geological Survey, Scottish Natural Heritage and the Highland Council. Since then the Geopark has gone from strength to strength, building capacity and forming a development plan to ensure that a three-year program of financial support provided by the Scottish Government in 2013 will lead to a sustainable organisation and stable UNESCO designation into the future.

The North West Highlands Geopark exists to *Explore Deep Time, Evoke a Sense of Place and Encourage Stewardship*. This means encouraging adventures that help people connect with the land and feel responsible for maintaining its beauty, wildlife and resources. The Geopark is currently implementing a five year plan to continue to promote landscape interpretation, adventure activities and educational projects. In 2015 the Geopark opened a new visitor centre—'The Rock Stop'—and ran a program of events that included climbing, kayaking, hikes and rambles. A Climbing Festival and a Geolinks Festival promoted the landscape and geology to groups that wouldn't normally engage with them. Several longer educational trips called Geotours were also offered. In 2016 the organisation achieved charitable status and was able to significantly improve its Earth Science Exhibition at the Rock Stop thanks to assistance from The Edinburgh Geological Society, The Macphail Center in Ullapool, The Curry Fund and Stirling Analyses for Geoarchaeology (StAG). Long term goals are to see a climbing centre built in Lochinver, continue to build momentum with events and assist in the development of a new state-of the-art Geo-centre – the Eden Project of the North West Highlands.

The Rock Stop

In the spring of 2015 the North West Highlands became the first Geopark in Scotland to have a dedicated Earth Science visitor facility. The Rock Stop is sited at Unapool from where, beneath the Assynt Mountains, visitors can enjoy spectacular views over Loch Glencoul and the Glen Coul/Ben More and Moine Thrust zone. Sited on the main north-south road through the Geopark it is perfectly located for those exploring not only the incredibly popular North Coast 500 driving route but also the Rock Route, a driving trail established by Scottish Natural Heritage to link together key geological sites of interest.

The North West Highlands Geopark has teamed up with a local crofting family who have agreed to run a café and craft shop showcasing local produce alongside the Earth Science exhibition which tells the story of the landscape using state of the art educational tools. There is good coffee, an excellent lunch menu, home baking and free wifi.

The centre acts as a hub for businesses in the Geopark who are invited to advertise their products and services free of charge. Situated close to the centre of the Geopark it also supplies information to visitors looking for activities, sites of interest and wet weather activities.

The Rock Stop is ideally situated to take in the NC500 and the Ben More thrust zone.

The Exhibition

The exhibition is still under development but in early 2016, and thanks to financial support from generous sponsors including the Edinburgh Geological Society, a foundational framework of interpretation panels was installed creating a professional, world-class 'look'.

When visitors enter the exhibition room they are offered the opportunity to rest for a moment on a comfy sofa and watch an 8 minute introductory video created by working closely with the British Geological Survey which includes a 3D topographical landscape flythrough visualisation of the landscape with the geological map draped over it. This sets a basic understanding of mountain building theory, Geoparks and what makes the North West Highlands Geopark so special.

At the next stop interpretation is made incredibly accessible through the work of another local family who specialise in graphic design. By this point visitors will understand what

An eight minute video provides visitors with an introduction to the exhibition and a basic understanding of mountain building theory.

An interpretation panel sponsored by the Edinburgh Geological Society.

a Geopark is, why the landscape around them looks the way it does and what the main rock types in the Geopark are as well as a little bit about the historical legacy of pioneering Victorian geologists.

Glaciation and Beaches

The exhibition is designed to be dynamically themed. At present the 'theme' is beaches and glaciation as market research in 2014 revealed that the majority of visitors to the North West Highlands Geopark come for the unique landscape and white sandy beaches. The interpretation panels explain the origins of the inselbergs, caves and straths which characterise the landscape and how geodiversity and coastal processes create sand of different compositions at each beach. Visitors are invited to look at sand under the microscope and to model landscape processes and learn about topography and hydrology using an Augmented Reality Sandbox.

The sandbox was built 'in house' utilising a Microsoft X-box 360 Kinect sensor to scan and feedback the topography of sand in a box which lies beneath it. Software developed at the University of California, Davis, feeds topographic information to a projector which projects a moving colour overlay onto the sand and simulates rainfall and fluid flow across the sandbox topography.

Education and Outreach

The Geopark is currently working with Kinlochbervie High School to develop an outreach program to teach about topography, water-sheds, weathering and erosion on the landscape-scale to help school pupils understand landscape formation

Augmented Reality Sandbox demonstrating state of the art topographical and hydrological modelling software.

and the environmental impacts of flooding and landslip.

The Augmented Reality Sandbox is proving a real draw for both children and adults. The children don't always get a look in as their parents seem to enjoy 'playing' with the box just as much as they do!

Next steps

The exhibition continues to develop and grow. The next ambitious step is to work with partners in industry and Aberdeen University to provide visitors with a visualisation of tectonic processes, thrusts and 3D models. The North West Highlands Geopark is also a partner in the *Drifting Apart* project, a Northern Periphery and Arctic Programme project funded by the European Regional Development Fund. Working with partners across the Northern Hemisphere to tell the geological story of the opening of the North Atlantic, the *Drifting Apart* project aims to reveal and strengthen understanding, appreciation and enjoyment of the fascinating and interconnected geological heritage of the Northern Periphery and Arctic region, and its many links to natural, built and cultural heritage.

The North West Highlands Geopark has enjoyed incredible success over the past decade but takes its responsibility to the sustainable development of the region very

Pupils from Kinlochbervie High School taking part in a workshop using the Augmented Reality Sandbox.

seriously. In order to maintain the top-quality geo-tourism on offer, sponsorship is continually sought. To find out more visit the North West Highlands Geopark website www.nwhgeopark.com, find us on Facebook 'North West Highlands Geopark' or join our friends network by e-mailing info@nwhgeopark.com.

We are also working to provide a Geo-guardians scheme which will allow supporters to back our work through a paid membership scheme in return for a range of benefits.

We wish to extend our sincere thanks to the Edinburgh Geological Society for their support over the past year, without which we would not have been able to achieve the high standards expected of us within our exhibition. This makes a significant contribution to the visitor experience and geological outreach which in turn supports local businesses by bringing more visitors into our area. It will also greatly assist with our next UNESCO revalidation assessment.

Laura Hamlet, Mike Goodwin & Pete Harrison, North West Highlands Geopark

The Rock Stop, Unapool, Kylesku, Sutherland, Scotland IV27 4HW

Now at the National Library

The current exhibition at the National Library of Scotland, George IV Bridge, Edinburgh—**You are Here**—is an eclectic display drawn from the Library's extensive map collection. Just one geological map is included but it is well worth seeing: John Phillips' Geological map of the British Isles and Adjacent Coast of France (Scale 1:1 584 000), corrected to 1862 and published by The Society for Promoting Christian Knowledge, London. You even get the chance to walk up and down it—until 3 April 2017.

Shackleton's Geologist: the works of Sir James Mann Wordie

By Paula Williams

One hundred years ago, at the beginning of September 1916, a young Scottish geologist would have been deliriously happy, and much relieved, to find himself in Punta Arenas, southern Chile. James Mann Wordie was a member of Ernest Shackleton's ill-fated *Endurance* expedition and had just survived the loss of that aptly-named ship, months floating on ice in the Weddell Sea, a perilous open boat journey and four months living under an up-turned boat on the exposed shore of Elephant Island, awaiting an improbable rescue. Shackleton and a few companions had sailed a jury-rigged lifeboat, the *James Caird*, 800 miles to South Georgia, trekked over its previously un-climbed mountains and raised the alarm of the expedition's peril. Three un-successful attempts to rescue the marooned and starving men were thwarted by the ice and weather, but finally, on the 30th August 1916, all were picked up by the Chilean naval vessel *Yelcho* and returned to safety.

James Wordie photographed by Frank Hurley during Shackleton's Imperial Trans-Antarctic Expedition.

A promising student under Professor John Gregory at Glasgow University, the young geologist left his native city to study in Cambridge, becoming demonstrator in petrology and gaining a further degree in geology. An association with fellow geologist and Antarctic veteran Raymond Priestly led to Wordie's recommendation to

Shackleton to join the Imperial Trans-Antarctic Expedition. Shackleton was keen to unlock the extra funding that a full scientific programme would bring, so was only too pleased to recruit the quiet, funny young Scot, predictably nick-named Jock, especially given his useful mountaineering experience. Wordie had climbed more than 50 Scottish peaks by the time he reached his majority, was a member of the Scottish Mountaineering Club and had climbed extensively in the Alps as a teenager. He was also a member of the notorious, secretive night-climbers at Cambridge, with the formidably sheer tower of St John's Chapel being one of his favourite routes.

When *Endurance* sank, Wordie was forced to abandon his geological specimens from the early part of the expedition. The loss of these specimens was a disappointment to the young geologist as the expedition had subsequently failed to reach land, limiting him to the examination of pebbles from the stomachs of penguins and the rock debris on icebergs. Once on Elephant Island he devoted some of his time to the islands geology, trading tobacco with the other men in return for 'exotic' pebbles. That pebble collection was lost in the haste of the rescue, but Wordie did salvage 26 precious '*in situ*' rock fragments. They were described as sheared and silicified mafic phyllites in a paper published in the *Transactions of the Royal Society of Edinburgh* (Wordie 1921) and are now held by Glasgow University's Hunterian Museum. Wordie also used his notes to compare with the findings of other expeditions to the region, taking issue with a recently published interpretation for South Georgia, and writing later on icebergs (Wordie & Kemp 1933).

On return to Britain, Wordie was caught up in the Great War, like many of his expeditionary companions. Injured at Armentières he was invalided home and returned to his work at Cambridge where he would spend the rest of his life. He took up a post as lecturer in geology and, despite having lost much of his evidence, managed to write three papers from his time on Antarctica, including a useful assessment of the ice movement in the Weddell Sea. (Wordie 1921). Joining forces with Raymond Priestly and Frank Debenham, they drew up plans for a polar institute based in Cambridge, originally funded from the Scott Memorial Fund. Wordie was later chairman of the Scott Polar Research Institute (SPRI).

His thoughts now turned northwards, and in the summers of 1919 and 1920 he accompanied William Speirs

***The spectacular folding of Early Cretaceous turbidite strata seen in the 400m-high cliffs of Stromness Bay, South Georgia. Wordie used a sketch of these folds to illustrate his 1921 paper for* Transactions of the Royal Society of Edinburgh.**

Bruce on exploratory expeditions to Svalbard for the Scottish Spitsbergen Syndicate, looking for potentially valuable economic deposits on that island. The bituminous smell of natural gas ('just like Broxburn') had encouraged a belief that oil shale or even free oil was present; Wordie's work disproved the possibility.

Over the next few years, Wordie made six journeys to the Arctic, following Bruce's successful formula for a small, quick, one season expedition. These journeys, to both East and West Greenland, would have clearly defined goals and geographic focus. This is a model that is still followed by university expeditions today. Often though, as well as geological research, he manged to fit in a good climb, including the first ascent of the Beerenberg on Jan Mayen Island, and of the formidable Petermann Peak. He used skippers who were accustomed to the ice and always made sure they carried enough stores to overwinter if they became trapped by the sea ice. The journeys were written up as scientific papers, for the Royal Geographical Society (Wordie 1938) and others, and were accompanied by the all-important lecture tour to raise funds for the next journey.

Of these, his trip in 1934 to West Greenland and Baffin Island was typical (Wordie 1935). Leading a team of researchers, each with their own objective but working together, they successfully collected a number of Inuit artefacts (now in the Museum of Archaeology and Anthropology in Cambridge) as well as written notes and journals (at SPRI), mapping new stretches of coastline, both topographically and geologically. They were beset at times by poor weather but still managed worthy scientific results. At the age of 48, Wordie headed north for his last expedition to Ellesmere and Melville Islands. As usual he was accompanied by a team of young Cambridge scientists, this time including Scots geologists T T Paterson and H I Drever.

During the Second World War, Wordie was recruited to help manage the production of the 'blue books' for the Naval Intelligence Division and later advised Operation Tabarin which saw the establishment of permanent bases on the Antarctic Peninsula. Developing post-war into the Falkland Island Dependencies Survey (FIDS) and ultimately into British Antarctic Survey (BAS), one of the stations was named 'Wordie House', built on Winter Island.

Wordie headed south to Antarctica again in 1946, tasked by the Colonial Office to report on the progress of FIDS. The ship was shared with a film crew from Ealing Studios, making *Scott of the Antarctic.* This must have enlivened the four month trip. The ship laid anchor close to Elephant Island. Wordie elected not to go ashore.

With a steadily rising academic career, steering cannily through labyrinthine college politics, Wordie was elected Master of St John's College in 1952. At this time a number of other honours and responsibilities came his way, including presidencies of the Royal Geographical Society (RGS), and the British Mountaineering Council. He oversaw the successful Everest Expedition in 1953 for RGS and was on the committee for the also successful Commonwealth Trans-Antarctic Expedition led by his student and friend Vivian Fuchs. The Royal Society had made him chairman of its International Geophysical Year committee in 1955. Two years later he was knighted for services to polar exploration.

An avid bibliophile, Sir James collected a large personal library of polar books, including first editions in many languages, and fiction. He conducted correspondence with renowned booksellers around the world, and was often asked for advice

Sir James Mann Wordie, Master of Saint John's College, Cambridge. Picture courtesy of the Wordie family.

on draft works by polar authors. He also actively collected to allow other researchers to use duplicates which could be borrowed from his office. Retiring from St John's in 1959, he donated his collection of more than 4000 volumes to the National Library of Scotland along with his personal papers, including the journals of his Greenland journeys. As the Library is free to readers, this gift enables his prized books to be used by anyone who needs them. Most recently his family have gifted a copy of his Weddell Sea log to the Library, charting that early adventure with Shackleton (Wordie, 2015). Some of his log is usefully reproduced in Michael Smith's biography (Smith, 2004).

Passing away at his home in Cambridge on 16th January 1962, Wordie's ashes were interred in the family plot in the church of Holy-Rood, Stirling. He is remembered in Antarctica, with the Wordie Ice Shelf (now mostly disappeared) and the hut that bear his name, but Wordie's

The bookplate used by Wordie for items in his extensive collection.

The resting place of Wordie's ashes at the Church of Holy-Rood, Stirling.

lasting legacy is in his Collection at the National Library of Scotland and his innovative approach to expedition logistics. Through SPRI, FIDS, BAS and RGS, his influence on polar and mountaineering research has changed our knowledge of the world.

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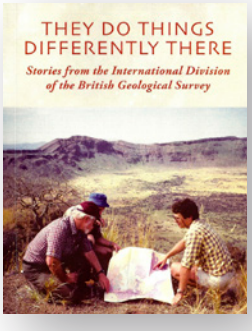
Book review

They do things differently there compiled and edited by A J Reedman and D G Bate. Aspect Design, Malvern. 2016. Paperback, 317 pp. Price £12.99. ISBN 978-1-908832-89-4.



This entertaining anthology is subtitled 'Stories from the International Division of the British Geological Survey'. It is not a book about geology, but instead collects the reminiscences of geologists working in remote and unfamiliar parts of the world over the last fifty years. The clean lines of a geological map and the dry scientific description that accompanies it are satisfying conclusions to a project but they tell only a small part of the real story. This book gives some insight into the trials, tribulations and camaraderie that made it all possible. There are anecdotes from 50 different contributors recounting their experiences in 37 different countries; 38 if you count the allusion in the book's title, taken from a poetical quotation wherein it is preceded by the line 'The past is another country'.

The geographical spread ranges widely across the developing countries of the world with most of the action taking place in Africa, Asia, South America or the Pacific Islands. There is just one European story (apart from a view from 'head office'): the disruption of the 1968 International Geological Congress as Russian tanks suppressed the 'Prague Spring'. Elsewhere in the world, the obstacles thrown up by local bureaucracy were perhaps not quite so dramatic but still required skilful navigation, whilst a lack of infrastructure and invariably unreliable vehicles were accompanied by the common challenges of the natural environment: hostile terrain, extremes of weather, snakes, crocodiles, swarms of biting insects. Some problems, such as being hijacked to Cuba or mistaken for Che Guevara, were more specific to time and place. Somewhat depressing is the seemingly constant backdrop

of local civil wars and banditry, and in some stories the larger-scale conflicts in Vietnam, Cambodia and Afghanistan loom large. Even so, despite their occasionally being shot at, it seems to me that for the geologists featured here, the greatest threat to life came whilst being flown-in to remote field camps. Would you be happy in an aircraft with a large canoe strapped on the outside? Not that the boats were any better …

For many of the contributors it is their first assignment with its culture shock and the enforced life-style readjustments that holds the fondest memories. They were usually thrown in with little or no preparation yet invariably developed a deep affection for the adopted country, the counterpart geologists and the local support staff. Adaptability was certainly at a premium whilst coping with the unpredictable problems of life in strange places called for resilience and ingenuity. The latter talent also helped address the questions of geological interpretation that arose with no recourse to relevant advice in those mostly pre-internet days. Diplomatic skills kept (or got) you and your team members out of trouble, whilst sheer bloody-minded persistence overcame local bureaucracy. Sometimes special skills were required. One contributor felt that his previous military training as a commando had been very helpful. At the other extreme, one of the first women to be involved in overseas field work (in 1977) was surprised to discover that she was allowed to purchase a 'cocktail dress' at UK government expense; one of her successors in more recent times regretted that she had not received training in ballroom dancing. It is notable how many times the adjective 'surreal' appears.

The book will have an obvious appeal to anyone who has been involved in geological fieldwork far from home comforts. There will also be a wider community to whom the contributors or locations are familiar: interesting comparisons can be drawn from accounts of the same country seen decades apart, whilst several contributors keep reappearing in different continents. The book is also a commentary on the history of geology during fifty years of colossal change in political attitudes (think funding of overseas aid programmes) and the technicalities of geological fieldwork (think internet, mobile phones and GPS). Or if you just want some bizarre adventure stories then they are covered too. Finally, some advice from an 'old-hand' to future geological generations—never try to eat a cormorant and don't volunteer for the snake wrestling.

Phil Stone

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