Geodigest

Mediaview

Dippy move?

In 1905, the Scottish philanthropist Andrew Carnegie donated plaster casts of the dinosaur *Diplodocus carnegii*, named after him and discovered in 1898, to leading natural history museums across the world. One of them was the British Museum (Natural History)—now simply the Natural History Museum—and since its installation in the main atrium of the museum in the early twentieth century, 'Dippy' has become a much loved part of the museum (Fig. 1). But a new philanthropic bequest, this time £5 million from Sir Michael Hintze 'to improve galleries and aid research' has led to concerns that the dinosaur might have to be moved (Sarah Knapton, *The Daily Telegraph*, 8 May 2014). Though detailed plans have yet to be unveiled, the newly named 'Hintze Hall' is to be fully refurbished over the next three years—with the possibility of a move for the dinosaur not ruled out by the museum's director, Michael Dixon, a possibility that has been met with alarm in some quarters.

Fig. 1. 'Dippy', will the London *Diplodocus* have to move? (Image: Drow Male, CC-A-SA 3.0).

San Francisco quake history

A cluster of closely timed earthquakes over 100 years in the seventeenth and eighteenth centuries released as much accumulated stress on San Francisco Bay Area's major faults as the great 1906 San Francisco earthquake (Figs 2, 3), suggesting two possible scenarios for the next 'Big One' for the region, according to new research published by the *Bulletin of the Seismological Society of America* (*BSSA*). (*ScienceDaily*, 19 May 2014) 'The plates are moving,' said David Schwartz, a geologist with the US Geological Survey and co-author of the study. 'The stress is re-accumulating, and all of these faults have to catch up. How are they going to catch up?'

The San Francisco Bay Region (SFBR) is considered within the boundary between the Pacific and North American plates. Energy released during its earthquake cycle occurs along the region's principal faults: the San Andreas, San Gregorio, Calaveras, Hayward-Rodgers Creek, Greenville, and Concord-Green Valley faults. 'The 1906 quake happened when there were fewer people, and the area was much less developed,' said Schwartz. 'The earthquake had the beneficial effect of releasing the plate boundary stress and relaxing the crust, ushering in a period of low level earthquake activity.'

The earthquake cycle reflects the accumulation of stress, its release as slip on a fault or a set of faults, and its re-accumulation and re-release. A full earthquake cycle has never been recorded by the people of the San Francisco Bay Area, though the Mission Dolores and the Presidio in San Francisco, founded in 1776, has kept records of felt earthquakes and earthquake damage. 'We are looking back at the past to get a more reasonable view of what's going to happen decades down the road,' said Schwartz. 'The only

Fig. 2. The smoking remains of San Francisco in the wake of the 1906 earthquake, of 8.25 intensity on the Richter Scale, which struck on 18 April 1906. The city burned for three days.

way to get a long history is to do palaeoseismic studies, which can help construct the rupture histories of the faults and the region. We are trying to see what went on and understand the uncertainties for the Bay Area.' To complete these studies, the team excavated trenches across faults, to observe past surface ruptures from the most recent earthquakes on the major faults in the area. Radiocarbon dating of detrital charcoal and the presence of non-native pollen established the dates of palaeoearthquakes, expanding the span of information of large events back to 1600.

The trenching studies suggest that between 1690 and the founding of the Mission Dolores and Presidio in 1776, a cluster of earthquakes ranging from magnitude 6.6 to 7.8 occurred on the Hayward fault (north and south segments), San Andreas fault (North Coast and San Juan Bautista segments), northern Calaveras fault, Rodgers Creek fault, and San Gregorio fault. There are no palaeoearthquake data for the Greenville fault or northern extension of the Concord-Green Valley fault during this time interval. 'What the cluster of earthquakes did in our calculations was to release an amount of energy somewhat comparable to the amount released in the crust by the 1906 quake,' said Schwartz.

As stress on the region accumulates, the authors see at least two modes of energy release—one is a great earthquake and the other is a cluster of large earthquakes. The probability for how the system will rupture is spread out over all faults in the region, making a cluster of large earthquakes more likely than a single great earthquake. 'Everybody is still thinking about a repeat of the 1906 quake,' said Schwartz. 'It's one thing to have a 1906-like earthquake where seismic activity is shut off, and we slide through the next 110 years in relative quiet. But what happens if every five years we get a magnitude 6.8 or 7.2? That's not outside the realm of possibility.'

Fig. 3. San Francisco, looking down Fourth Street, with soldiers patrolling the devastation following the 1906 earthquake, which destroyed 490 city blocks and 25 000 buildings, leaving 250 000 homeless and killing between 450 and 700. Estimated damages added up to over $350 million.

Dino-giant

Scientists have uncovered huge bones in Argentina that could be from the largest dinosaur yet found (*The Boston Globe*, 20 May 2014). Specialists agree the bones are from a previously undiscovered species of sauropod that is at least as big as a previously-discovered specimen of *Argentinosaurus*. This species is known for its huge legs, long neck and tail, and arguably has so far set the record for dinosaur size. But what is known about the anatomy of *Argentinosaurus* is sketchy, as it is based mostly on an incomplete thigh-bone found in 1991, in Argentina's fossil-rich Patagonia region. The new bones were spotted years ago by a worker at a ranch outside the town of Las Plumas, in Patagonia's Rio Chubut valley. With this new discovery, palaeontologists think they will be able to unearth a much more complete fossil. Already, the complete thigh bone they've uncovered is at 2.4 metres (Fig. 4), the longest of any vertebrate yet found, said palaeontologist Jose Luis Carballido, who is leading the research team. He estimates that the dinosaur reached 20 metres tall, 40 metres long and weighed the equivalent of 14 or 15 adult African elephants.

Carballido said a volumetric estimate based on the femur and humerus they've uncovered suggests the animal weighed around 80 tonnes. 'Based on what is known of the animal, it was certainly very, very large,' said palaeontologist John Whitlock of Mount Aloysius College in Pennsylvania. 'Just how large may have to wait for more fossils and will probably depend on the method used to estimate its total size—we've seen how much estimates of mass can change for fragmentary animals like *Argentinosaurus*—but right now it would certainly seem to be a strong contender for largest known sauropod,' Whitlock said.

Palaeobiologist Paul Upchurch of University College London believes size estimates are more reliable when extrapolated from the circumference of bones. He said this femur is a whopping 1.1 metres around, about the same as the thigh bone of *Argentinosaurus*. 'Whether or not the new animal really will be the largest sauropod we know remains to be seen,' said

Fig. 4. Jose Luis Carballido lies next to the gigantic thigh bone of a sauropod from Argentina (Image: *Boston Globe*)

Upchurch, who was not involved in this discovery but has seen the bones first-hand. 'Certainly the new animal appears to be at least as large as *Argentinosaurus* and is a new species,' Upchurch added. 'Its real scientific value comes from the fact that it looks like this new form will be more complete than *Argentinosaurus*, so we'll get a better look at the anatomy of one of these super-giants.'

New English shale oil

A new study by the British Geological Survey (BGS) suggests there are several billion barrels of oil in shale rocks under large parts of southern England, including Sussex, Hampshire, Surrey and Kent (*Water Briefing*, 23 May 2014).

The British Geological Survey, in association with the Department of Energy and Climate Change (DECC) has completed an estimate for the amount of shale oil and shale gas in the Weald Basin (Fig. 5) in south-east England. The range of shale oil in place is estimated to be between 2.20 and 8.57 billion barrels (bbl) or 293 and 1143 million tonnes, but the central estimate for the resource is 4.4 billion bbl or 591 million tonnes.

No significant gas resource is recognized using the current geological model—mainly because the shale is not thought to have reached the geological maturity required to generate gas. The figure for oil represents the total amount of oil present in the rocks. At present it is not known what percentage of the oil present in the shale could be commercially extracted.

The Weald Basin has a long history of oil and gas exploration; there are 13 producing sites in the basin, some almost 30 years old. Hydrocarbons were first produced in the nineteenth century. The results of the study are based upon detailed seismic mapping of some 12 200 km and from 248 existing oil and gas wells. The BGS says that in order to estimate the shale oil reserve, drilling and testing of new wells will be required to give a better idea of oil production rates. Non-geological factors such as oil price, operating costs and the scale of development agreed by the local planning system would also affect the amount of oil produced.

This is the second detailed BGS report summarizing the background geological knowledge and resource assessment of the UK's shale gas basins. These are creating preliminary in-place resource calculations for three study areas in Britain. The first study, published in June, reviewed the Bowland–Hodder shales across Northern England, which covers 11 counties in the North of England. The central scenario estimates there are likely to be some 40 trillion cubic metres of shale gas in the ground. The third study, which covers the Midland Valley of Scotland, is now underway and will be completed in the summer—estimates will be made for both the oil and gas 'in-place resources' of the Carboniferous strata of central Scotland.

Fig. 5. Wealden sandstones crop out in East Sussex, England. The Weald might yet yield a large reserve of shale oil, according to a new BGS study. (Image: Roger Haworth, CC-A-SA 2.0).

Continent origins

An undistinguished lump of rock may hold clues about how Earth's continents first formed (Bryan Alary, *ScienceDaily*, 29 May 2014). The rock is actually a four-billion-year-old piece of an ancient protocontinent, collected by University of Alberta PhD student Jesse Reimink from the Acasta Gneiss Complex in the Northwest Territories of Canada. According to Remink 'The timing and mode of continental crust formation throughout Earth's history is a controversial topic in early Earth sciences.' 'Continents today form during subduction. But it is unclear whether plate tectonics existed 2.5 billion to four billion years ago, or if another process was at play', says Reimink, who believes that Iceland could represent a solid comparison for how the earliest continents formed.

One theory is that the first continents formed in the ocean as liquid magma rose from Earth's mantle before cooling and solidifying into a crust. Iceland's crust formed when magma from the mantle rose to shallow levels, incorporating previously formed volcanic rocks. For this reason, Reimink says Iceland is considered a theoretical analogue of early Earth continental crust formation. Working with Tom Chacko, Reimink spent his summers in the field collecting rock samples from the Acasta Gneiss Complex, which was discovered in the 1980s and found to contain some of Earth's oldest rocks (Fig. 6), between 3.6 and 4 billion years old. Due to their extreme age, the rocks have undergone multiple metamorphic events, making it difficult to understand their geochemistry, Reimink

Fig. 6. A fragment of Acasta Gneiss, Northwest Territories, amongst the oldest rocks known on Earth (Image: Pedroalexandrade, CC-A-SA 3.0).

says. Fortunately, a few rocks were better preserved. This provided a 'window' to see the samples' geochemical characteristics, which Reimink says showed crust-forming processes that are very similar to those occurring in present-day Iceland.

'This provides the first physical evidence that a setting similar to modern Iceland was present on the early Earth.' These ancient rocks are among the oldest samples of protocontinental crust that we have, he adds, and may have helped jump-start the formation of the rest of the continental crust.

A round up of media opinion; the views expressed do not necessarily reflect those of the editorial board of *Geology Today*. With thanks to Alan Holiday, David Nowell and Peter Perkins. If you spot a news item worthy of inclusion send it to the *Geology Today* editorial office, or e-mail to geologytoday@btinternet.com.

News

Charles Swithinbank 1926–2014

Peter Doyle writes Charles Swithinbank was a leading glaciologist whose experience in polar regions was perhaps unsurpassed in its diversity, serving with Canadian, US, Soviet, British and Chilean expeditions. His first experience was in the Antarctic, visiting the Norwegian-claimed Antarctic territory of Dronning Maud Land in 1949–52, where he assisted with measurement of ice thickness and cover—with special emphasis on the rate of nourishment of floating ice. For this work, Swithinbank was awarded the Polar Medal—and its results would figure in his DPhil from Oxford. His continued engagement with sea ice saw him consider its development and distribution in the Canadian Arctic as a fellow of the Scott Polar Research Institute (SPRI), before moving to Michigan University in 1959, and with whom he completed three seasons in the Antarctic, examining the Ross Ice Shelf. His involvement with Soviet Antarctic Science, as a British representative, followed his reappointment with SPRI. Moving to the British Antarctic Survey (BAS), he became head of Earth Sciences in 1976—where he continued to examine ice thickness, this time over the rocky Antarctic Peninsula, the main focus of effort for the survey (Fig. 7). He retired some 10 years later. I came across him as a junior researcher with BAS in 1984; his careful attention to detail meant my early papers were corrected and edited by him—helping to shape my approach to writing. After retirement, Charles Swithinbank remained extremely active in the Polar regions, as lecturer and accomplished scientist. He died on 27 May 2014, aged 87.

Fig. 7. Sea ice in the Antarctic Peninsula, a familiar sight to glaciologist Charles Swithinbank, who died earlier this year. (Image: Peter Doyle).

Olivine mining

John Heathcote writes With regard to the piece on the use of mined olivine to remove carbon dioxide by weathering (Geology Today, 2014, v.30, n.2), I feel that the idea of mining a geological product to try to make good the harm from the excessive use of another geological product is missing the point—in the end we need to learn not to burn hydrocarbons and coal.

In any case, the reaction is not unique to olivine—it happens with all silicates formed from monovalent or divalent metals. It doesn't happen with aluminium silicates since aluminium carbonate solid is not stable. Olivine may be the most reactive, but pyroxenes will work too, and therefore this provides the option of bulk extraction of ophiolites. The Lizard Peninsula will not last long at 7 km3/y, but it will take a while to use up the Oman ophiolite. A particularly important group of silicates reacting in this way is cement hydrates—i.e. concrete demolition waste. This material is rather more readily available than olivine!

Fig. 8. Silica sand being worked in 'pocket deposits' in the White Peak, Derbyshire.

Bunter pebbles story

Trevor Ford writes There is another chapter to the feature on Bunter Pebbles in the recent Geology Today (2014, v.30, n.3, pp.93–97), which the authors seem to have overlooked. Quartzite pebbles derived from the Trent Valley outcrops of these lower Triassic beds were re-deposited in the Miocene Brassington Formation now known only from collapse structures in the Carboniferous Limestone of the southern part of the White Peak of Derbyshire. Locally known as 'Pocket Deposits', these have been worked for silica sand for at least a century (Fig. 8). Both pebbles and sand are also found in several old lead mines around Brassington (see Ford, T.D. & Jones, J.A. 2007. The Geological Setting of the Mineral Deposits at Brassington and Carsington, Derbyshire. Mining History, v.16, pp.1–23). Since the limestone plateau is now much higher than the Trent Valley outcrops, there is an obvious deduction that the plateau was much lower in the Miocene, and its uplift was in Pliocene to early Pleistocene times. Furthermore, pebbles derived from the Brassington Formation were later transported via an early Pleistocene drainage system and were deposited yet again in East Anglian gravels.

Kiwi ancestry

Philip Andrews writes from New Zealand A ratite is a bird with a flat, unkeeled sternum, a feature associated with flightless birds. New Zealand has two groups of ratite birds, until recently thought only to date back to the Pleistocene: the kiwi *Apteryx* (Fig. 9) and the extinct moa. Last year a Miocene forerunner of the kiwi (based on two bones found in sediments of a former ancient lake, Manuherikia, in central Otago) was identified and named as *Proapteryx*. This slender-legged bird was smaller than any living species of kiwi and its existence suggests that the kiwi may have evolved from a small flying ancestor.

The relationship of New Zealand's iconic kiwi to ratites elsewhere in the world has long been problematic, until phylogenetic analysis made in the 1990s suggested that—contrary to long-held expectation—its closest relationship was not to the moa, but actually to ratites from Australia—the emu and cassowary—and to the African ostrich. The country had, it seemed, been colonized twice by ancestral ratites.

Now, a study published in *Science* rejects the notion that the kiwi's closest ancestor was Australian, a conclusion possibly welcomed by New Zealanders, whose rivalry with their neighbours is well-known. A team from Adelaide University's Australian Centre for Ancient DNA, led by Professor Alan Cooper (a New Zealander), has found from its investigation of the DNA of the giant extinct elephant bird of Madagascar, *Aepyornis maximus*, that *it*, not the emu or cassowary, is the kiwi's closest relative. What is more, the only readable sequences of elephant bird DNA have been taken from specimens in New Zealand's own national museum, Te Papa in Wellington.

The vast distance between Madagascar and the islands of New Zealand implies that the two related ratites derived from a flying ancestor, which rather leaves things up in the air, as it were.

Fig. 9. An artist's conception of *Apteryx*, the kiwi of New Zealand, from an illustration in the Reverend Richard Taylor's *Te Ika a Maui or New Zealand and its Inhabitants*, published in 1855.

Searching for alien grains—unique new laboratory opened in Sweden

Matts E. Eriksson (Lund University) writes On 31 October last year, a new laboratory and research environment, coined the Astrogeobiology (AGB) Laboratory, had its grand opening ceremony in Lund, Sweden (Fig. 10). This world-class facility is part of Lund University, and is situated in the modern housing complex at Medicon Village in the eastern part of Lund. Spawned from the mind of Professor Birger Schmitz, and funded through the European Research Council, the Swedish Research Council and the University itself, the research facility works as a melting pot for cross-disciplinary research with the aim of studying and understanding the interrelationship between astronomy, geology and biology.

Given the devastating effects of ancient bombardments of extraterrestrial bodies on Earth through deep time—with the end-Cretaceous mass extinction as a bright and shiny example—we get constant reminders that what goes on in the universe affects

Fig. 10. Professor Birger Schmitz, Vice-Chancellor of Lund University, Per Eriksson, and research engineer, Dr. Fredrik Terfelt, during the opening ceremony 31 October 2013. (Image: Annika Persson).

life on Earth. However, most meteorites that have fallen to Earth end up disappearing without becoming fossilized or leaving an impact crater for researchers to discover. That has made it exceedingly difficult for scientists to recover enough evidence in order to back theories about how astronomical events have tied into Earth's history.

There are, however, some important remnants that can be found in the rock record even if the actual impactor and/or the scars, in the shape of craters, are nowhere to be seen. When a meteorite decomposes, which usually happens rapidly geologically speaking (today in the order of 20 000–30 000 years or even faster), there are some tiny minerals that get left behind (Fig. 11). These are different types of spinels, including very resistant chromium or alumina oxides. This means that strata laden with these kinds of mineral grains can be used as a proxy for times of increased influx of extra-terrestrial matter to Earth, with the added benefit that the grains possess unique chemical and isotopic fingerprints of the types of meteorites they originate from (Figs 12, 13). But how are they discovered? Simply dissolve the ancient lithified sea floors and check the acid resistant residues!

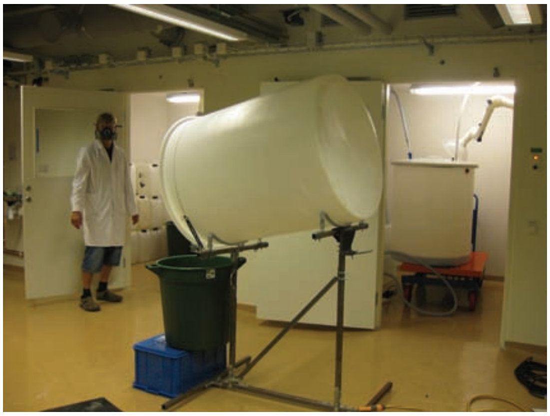

Fig. 11. Dr. Fredrik Terfelt processing samples at the AGB Laboratory in search for extraterrestrial mineral grains. (Image: Birger Schmitz).

Schmitz's hunt for these tiny grains from different parts of the world and of sediments ranging in age from the Precambrian through the Phanerozoic is with the aim of finding the ties between asteroid breakup events in space and climatic or biological events on Earth. As Schmitz himself ponders 'I think it would be very interesting if our spinel approach in the long run could provide empirical evidence, for example, of how asteroid or comet showers correlate with major astronomical events, such as when the solar system travels through interstellar gas clouds during its orbit around the galaxy's centre'.

The AGB Laboratory is specially designed for processing huge amounts of limestone, approximately 5 to 10 tons per year, for the recovery of these exciting spinels. Up to 20 000 litres of hydrochloric acid is used to recover the grains. The facility also houses a remodelled version of Nobel Prize Laureate Luis W. Alvarez' Iridium-Coincidence-Spectrometer that was used for the search for iridium associated with the end-Cretaceous mass extinction, an event that wiped out the non-avian dinosaurs.

The AGB Laboratory welcomes collaborations and visitors. Anyone who is interested in the work be-

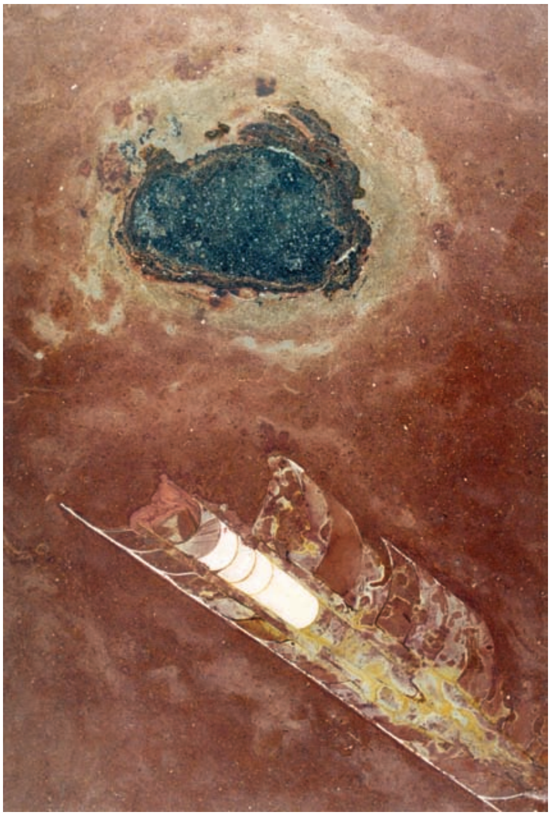

Fig. 12. A polished slab of the Middle Ordovician 'orthoceratite limestone' of Sweden with a nicely preserved fossil meteorite—remnants of the largest documented break-up of a body in the asteroid belt—next to a nautiloid shell. (Image: Birger Schmitz & Mario Tassinari)

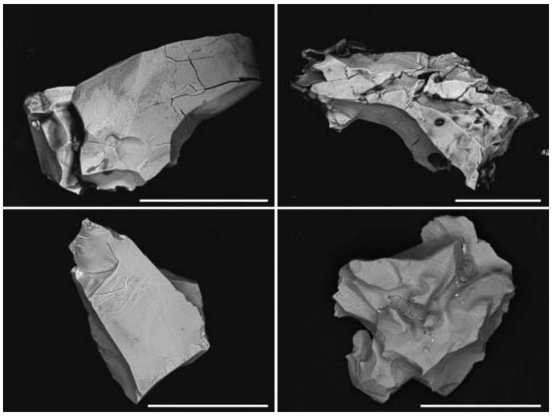

Fig. 13. Even though fossil meteorites are exceptionally rare in the geological record, traces of decomposed meteorites can be found as very resistant microscopic mineral grains. Here are SEM-micrographs of four typical extraterrestrial chromite grains from the Middle Ordovician of Sweden. All scale bars = 100 μm.

ing done at the AGB Laboratory is warmly welcome to contact Birger Schmitz at birger.schmitz@nuclear.lu.se.

For further information, see also: http://www.sciencedirect.com/science/article/pii/S0009281913000354 and http://www.mediconvillage.se/en

Research

Cretaceous beetle diversity

There are some 57 000 described species of living and extinct rove beetles (family Staphylinidae) making them the largest coleopteran family, and perhaps the largest family of any living phylum. The geological record of these beetles has been tracked back to the late Triassic, with nearly 100 fossil species recorded from northern Virginia, USA. That was until a review of the group in 2012 added a further 30 new species. The number of described fossil species has, however, increased further with the discovery of 20 specimens in early Cretaceous amber deposits from Spain (Peris *et al*., 2014, *Cretaceous Research*, v.48, pp.85–95). David Peris and his colleagues collected amber samples from Penacerrada 1 and El Soplao, in the Basque–Cantabrian basin, northern Spain.

Fig. 14. New genera and species of rove beetle have been described from early Albian amber deposits from Spain. (Image courtesy of David Peris, Universitat de Barcelona).

The early Albian El Saplao amber-bearing deposit is included in the Las Peñosas Formation, a unit of heterolithic sandstones, siltstones and carbonaceous mudstones that were deposited in a delta-estuary setting. The Pencarrada 1 amber-bearing deposit belongs to the Escucha Formation, which is characterized by sandstones and conglomerates deposited in inter-distributary deltaic bays. Some 68 beetle specimens are known from Pencarrada 1, with 51 from El Saplao—although when compared with the total number of biological inclusions within the ambers, beetles are relatively more common at El Saplao. Based on this new material, Peris and his colleagues have identified two new genera and four new species (Fig. 14). The new taxa show that the beetles in the Spanish amber are comparable with other Cretaceous ambers from the Lebanon and Burma, despite their different ages. This may be being controlled by the botany, in that all three deposits share a conifer origin for the resin, probably resulting from araucariaceans or cheirolepidiaceans in forests that developed in a tropical or sub-tropical climate. It is not surprising, then that similar insect communities lived under the same palaeobotanical assemblages and palaeoclimates. Beetles assigned to the subfamily Pselaphinae are the most common rove beetles preserved in amber world-wide. This is perhaps due to their small size and leaf litter dwelling habitat, making them susceptible to being trapped in amber and preserved. If Cretaceous beetle diversity was in any way similar to the present day, then many more beetle taxa are still to be described from the geological record.

Cool water carbonates

Over the last 30 years, research on temperate/cool water carbonate depositional environments has significantly improved our understanding of these systems. One area of research has been the understanding of outer-ramp, slope and basin-transition environments, and the processes resulting in offshore sediment transport. This is especially important in low energy areas, such as the Mediterranean Sea. The present-day Mediterranean is a microtidal wave dominated sea, with a tidal range of about 0.3 m, a fairweather wave base (the depth to which surface waves can lead to sediment transport) of 3–5 m and a storm wave base of 20–25 m, and in exceptionally severe storms 40 m (this is the depth to which storm waves can cause sediment transport).

Recently, Ángel Puga-Bernabéu and colleagues have reviewed the controls and mechanisms of offshore sediment transport in Mediterranean low energy temperate water carbonate ramp systems (Puga-Bernabéu *et al*., 2014, *Sedimentary Geology*, v.304, pp.11–27). Their review focuses on the Neogene basins of the Betic Cordillera in SE Spain.

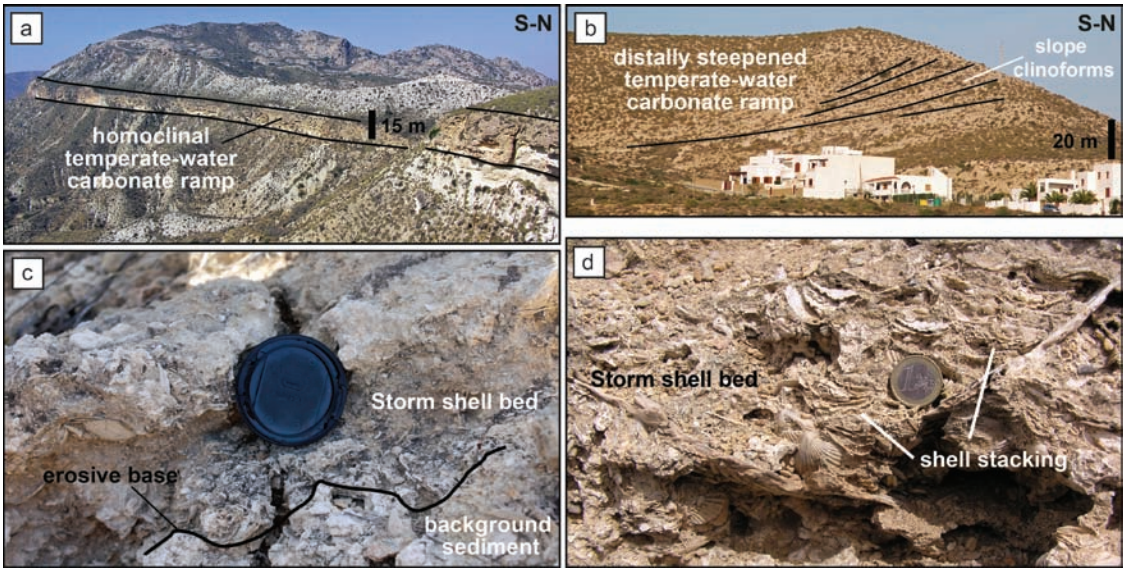

Fig. 15. Cool and temperate water carbonate sediments from the Neogene basins of SE Spain. Carbonate ramps from the **A.** Sorbas and **B.** Carboneras basins. Shell beds from the **C.** Carboneras and **D.** Sorbas basins. (Image courtesy of Ángel Puga-Bernabéu, Universidad de Granada).

The characteristic model for temperate-water carbonate deposition is to have a shallow water coastal belt and shoal area landward of a carbonate factory zone, and deeper water outer ramp (Fig. 15), slope and basin settings below the storm wave base. Within the deeper water settings, deposits include storm shell beds, sediment gravity flows (debris flows and turbidity currents), packages of beds with hummocky/swaley cross-stratification (HCS/SCS), slope sandwaves and channel/lobe deposits. Which of these develop is controlled by local basinal factors such as the slope gradients, hydrodynamic energy levels and basin circulation patterns. For example, storm shell beds developed in low energy protected basins, regardless of the ramp profile, whilst sediment gravity flow deposits characterise the seaward ends of moderately steep ramps in moderately energetic hydrodynamic areas. With the work carried out in recent years these cool and temperate water carbonates are starting to be as well understood as tropical warm water carbonate systems.

Accidental fumaroles

There are always some inherent risks associated with both excavations and site investigation. But in some areas of the world these risks are greater than in others. In August 2013, a shallow site investigation borehole was drilled at a roundabout near Fiumicino International Airport in Rome, Italy. Just hours later at the site of the borehole a fumarole developed, producing emissions of gas (mainly CO_2), cold water (*c.* 20°C) and mud (Fig. 16). The fumarole remained active for months, at times forming a small mud volcano. This wasn't however, the first time that such events had been triggered by site investigations in the Fiumicino Airport area.

So what is the underlying cause? Pio Sella, Andrea Billi and colleagues have examined the causes of these accidental fumaroles and the potential risk that they might pose (Sella *et al.*, 2014, *Journal of Volcanology and Geothermal Research*, v.280, pp.53–66). To understand the causes of the fumarole, Sella and colleagues had to drill a series of boreholes to examine the stratigraphy, but this time, with sensible planning in place, these were drilled with appropriate anti-gas measures. This was a good thing as two of the boreholes intercepted pressurized gases within an interval of permeable gravels at a depth of 40–50 m. The data from the boreholes was combined with a 2D seismic survey and the chemical and isotopic analysis of water samples to understand the cause of the fumarole.

The study showed that the gases were trapped within a mid-Pleistocene gravel. This unit is a con-

Fig. 16. An accidental fumarole caused during site investigation on a roundabout near the Fiumicino International Airport in Rome, Italy. (Image courtesy of Andrea Billi, CNR-IGAG, Dipartimento Scienze della Terra, Università Sapienza).

fined aquifer in which the upwelling gases are stored, and the gravel is sandwiched between two units of silty clay. The lower unit is over-consolidated and very hard, but consequently prone to fracturing, allowing ascending gases to permeate the gravel and dissolve into the aquifer. In contrast, the upper unit is impermeable and seals the gas-pressurized aquifer. Geochemical studies showed that source of the gas is deep-seated, with the isotope chemistry of the CO_2 being consistent with the nearby Sabatini and Colli Albani volcanic districts (Fig. 17).

Widespread entrapment of gas is likely throughout the area, and poses a risk when either accidentally intercepted during site investigations or excavations, or when naturally released during earthquakes or fault movements. The gases released may pose a risk—during a similar event in 2005, seven people living close to the location where an accidental fumarole developed were admitted to hospital suffering a range of symptoms after exposure to the CO_2. The pre-site investigation desk study and risk assessment in this area of Italy clearly needs to understand the high probability of intercepting pressurised gas at shallow levels.

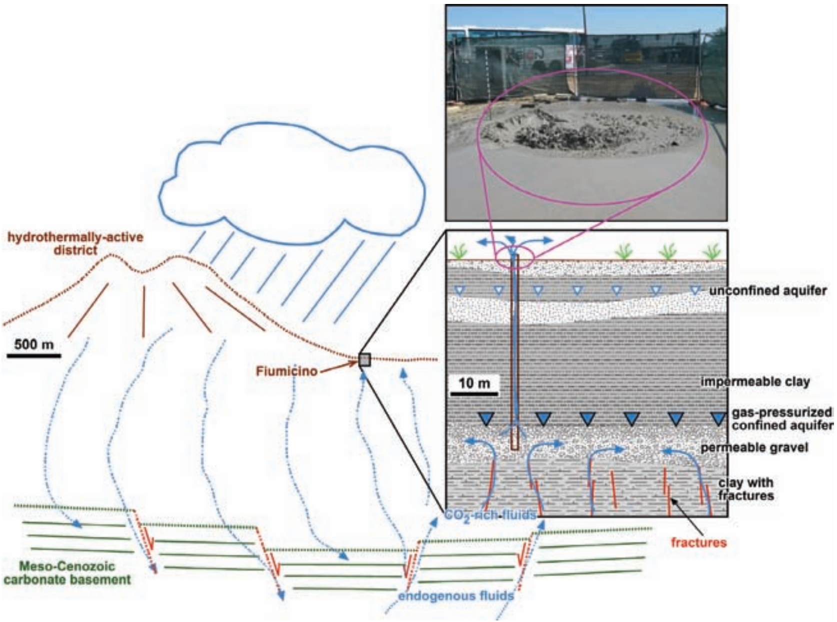

Fig. 17. Model showing the source of the fumarole gas. Deep seated CO_2 migrates into a shallow confined gravel aquifer where it becomes pressurised. Drilling during site investigation can penetrate the aquifer seal causing the fumarole to release water, CO_2 and mud. (Image courtesy of Andrea Billi, CNR-IGAG, Dipartimento Scienze della Terra, Università Sapienza).

On the trail of the swimming hippopotami

Trackways left in terrestrial sediments provide very valuable data with regard to how extinct animals moved. Aquatic or semi-aquatic animals can also leave tracks behind, but they are often less complete, due partially to the fact that the animals will be at least in part supported by the water. Fossil swimming tracks are reported for turtles and crocodiles, but there are also a significant number of scientific papers published which report what are thought to be swim tracks made by dinosaurs. These are, however, potentially controversial as it is difficult to explore the swimming capabilities of extinct animals which do not have any living analogues. Surprisingly there are no records of swimming tracks produced by mammals. Some large mammals, including hippopotami, are known to 'bottom walk', where the animals push off from the bed of a water body with their limbs in order to maintain forward motion; a style of locomotion referred to as punting (Fig. 18).

A paper just published has, however, documented what are thought to be hippopotamus tracks in Plio-Pleistocene sediments in the Kenyan rift valley (Bennett *et al.*, 2014, *Palaeogeography, Palaeoclimatology, Palaeoecology*, v.409, pp.9–23). Matthew Bennett and colleagues have been examining traces left on a series of bedding planes in the Okote Member of the Koobi Fora Formation. These sediments represent the silting-up of a former lake within the Kenyan rift valley between 2.0 and 1.5 Ma ago. One surface dated at 1.4 Ma has hominin tracks, along with tracks from large animals. A separate area examined 70 m away from the hominin tracks, displayed a diverse range of animal tracks, most of which appear to have been made by a four-legged animal moving via 'punting' or bottom walking in a shallow water body (Fig. 19). Based on track morphologies and the associated fossil record, the non-hominin tracks are interpreted to have been made by hippopotami, potentially includ-

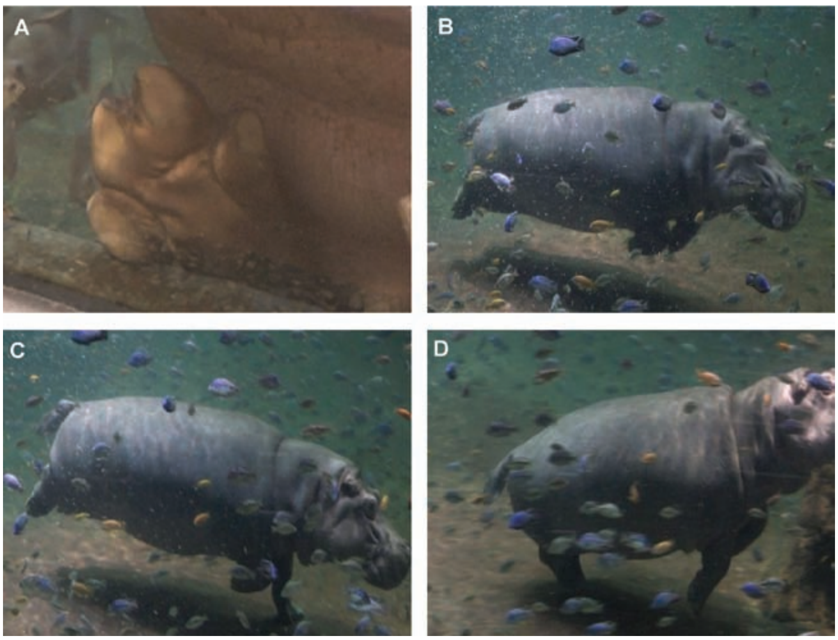

Fig. 18. Photographs of two Nile *Hippopotamus amphibus* taken through the sidewall of their tank at the Adventure Aquarium, Philadelphia showing both the anatomy of the foot and punting behaviour. (Image courtesy of Matthew Bennett, Bournemouth University).

ing juveniles and pygmy species. The tracks record a range of behaviours with in some cases a flat under-surface of the foot being in direct contact with the sediment surface, whilst others consist of prod marks reflecting punting behaviour. Whether the tracks were left over a long period of time by a small number of individuals living in the area or during a short period of time by many individuals is not clear. The close spatial and temporal association between the hominin footprints and the hippopotamus tracks is however, intriguing.

Granitoids and pegmatites of western Nigeria

A Pan-African orogenic belt extends along the margin of the West African craton from Algeria southwards through Nigeria, Benin and Ghana and into the Borborema Province of Brazil. This belt is characterized by post-collisional granitoid plutons well-exposed around the city of Minna. This area is a lush and well-vegetated part of Nigeria, with low rolling hills with rockier whalebacks forming on the granitoids (Fig. 20). Kathryn Goodenough and colleagues have examined the granitoids and present new data on their petrography, geochemistry and age (Goodenough *et al.*, 2014, *Lithos*, v.200-201, pp.22–34).

The Pan-African plutons around Minna can be divided into two main groups: a group of peraluminous biotite-muscovite granites that show varying degrees of deformation in late Pan-African shear zones (Fig. 20), and a younger group of relatively undeformed predominantly metaluminous hornblende granitoids. Pegmatites, some of which host rare metals, occur at the margins of some of the plutons and are the youngest intrusions in the area (Fig. 20). The granitoids in the area show a number of petrological features. They are relatively coarse-grained and primary magmatic crystal shapes are rare. Textures typically range from granoblastic and equigranular to strongly foliated with aligned mafic minerals and quartz ribbons. However, each named pluton has a slightly different mineralogy and petrology with leucogranites, biotite granite, granodiorite, diorite, biotite-amphibole granitoids and pegmatitic granite sheets all present in the area and showing variable degrees of deformation (Fig. 21).

U/Pb zircon dating shows that there was an early phase of magmatism at *c*. 790–760 Ma in the Minna area. This magmatism may relate to either continental rifting or subduction at the margin of an existing continent. The peraluminous biotite–muscovite granites were intruded at *c*. 650–600 Ma during regional shearing in the orogenic belt, and are likely to have formed largely by crustal melting. Subsequent emplacement of the metaluminous granitoids at *c*. 590 Ma indicate the onset of post-orogenic extension with a contribution from mantle derived magmas. The rare-metal pegmatites represent the youngest intrusions in this area and are likely to have formed

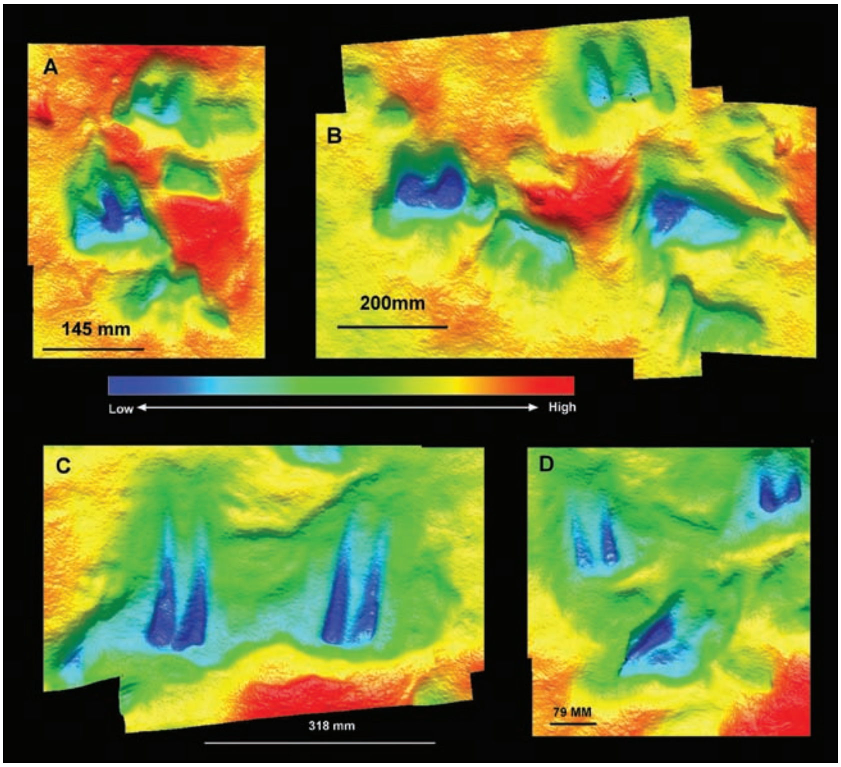

Fig. 19. Optical laser scans of track complexes from the Koobi Fora Formation, Kenya. Warm colours represent areas of elevation. (Image courtesy of Matthew Bennett, Bournemouth University).

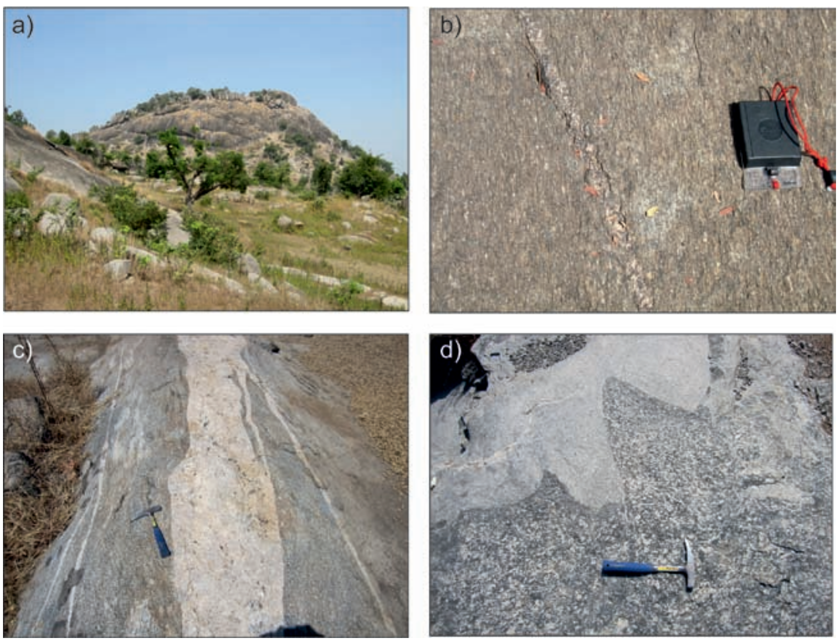

Fig. 20. **a.** The typical scenery of the field area in western Nigeria has whaleback hills of granite. **b.** The granitoids are variable and may be intensely foliated, **c.** coarse-grained and cross-cut by late granite pegmatites or **d.** show evidence of mingling and mixing of dioritic and granitic magmas. (Image courtesy of Kathyrn Goodenough, British Geological Survey, NERC).

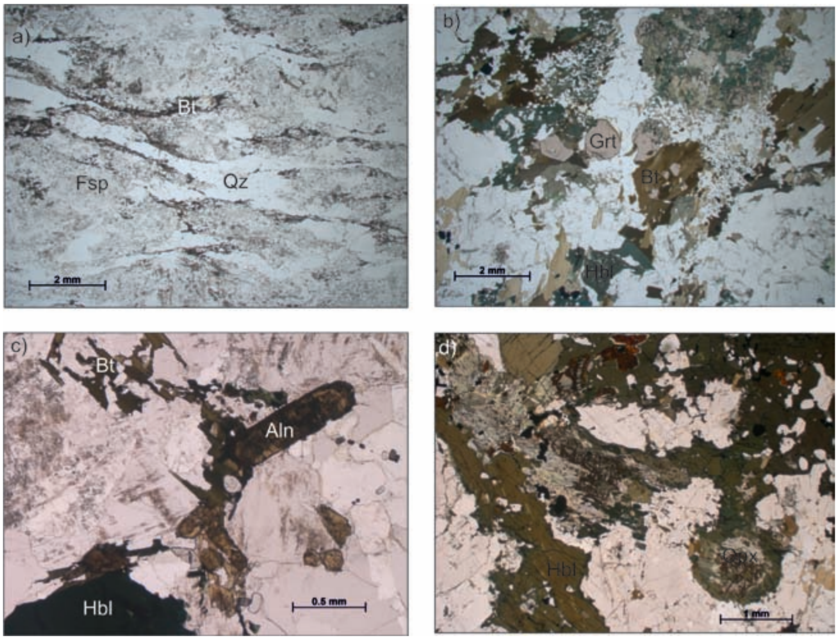

Fig. 21. Petrography of the western Nigeria granitoids. **a.** Sheared granitoid from the Minna batholith with foliation defined by biotite (Bt) and recrystalized quartz ribbons (Qt); **b.** Tegina pluton granodiorite with biotite (Bt), hornblende (Hbl) and garnet (Grt); **c.** Late stage hornblende (Hbl) - biotite (Bt) granite sheet from the Sarkin Pawa area with large allanite crystals (Aln). **d.** Monzonite from the Abuja batholith. (Image courtesy of Kathyrn Goodenough, British Geological Survey, NERC).

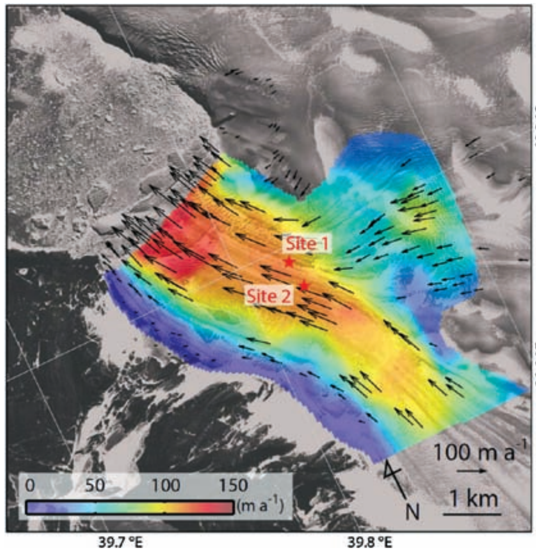

Fig. 22. The Langhovde Glacier showing the rate of glacier flow. (Image courtesy of Shin Suguyama, Hokkaido University, Japan).

during a separate magmatic episode post-dating the granite intrusion.

Life near the grounding line

Around 74 percent of the Antarctic coastline is made up of floating ice shelves and outlet glaciers. Here the flowing ice separates from the underlying bed at the grounding line, entering the grounding zone, a transition zone between the grounded ice and the freely floating ice shelf. This complex zone is poorly known. Research by Shin Sugiyama and colleagues has examined the movement of water and extent of life in this area (Sugiyama *et al.*, 2014, *Earth and Planetary Science Letters*. v.399, pp.52–60). To investigate this complex zone, Sugiyama and colleagues drilled a series of holes through the ice near the grounding line of Langhovde Glacier, an Antarctic outlet glacier in the Lützow-Holm Bay in East Antarctica (Fig. 22).

Boreholes were drilled using hot water through the glaciers' 400 m-thick grounding zone. Beneath the grounding zone there was a 10–24 m deep-water layer of uniform temperature and salinity, with values comparable to those in the ocean in front of the glacier. Organisms live within this sub-glacial water layer. These observations showed that active transport of water and nutrients occurs from the adjacent ocean to the grounding line of the glacier (Fig. 23). A significant implication of these findings is that the subshelf glacial environment interacts directly and rapidly with the adjacent ocean. Climate change may therefore affect these regions very rapidly.

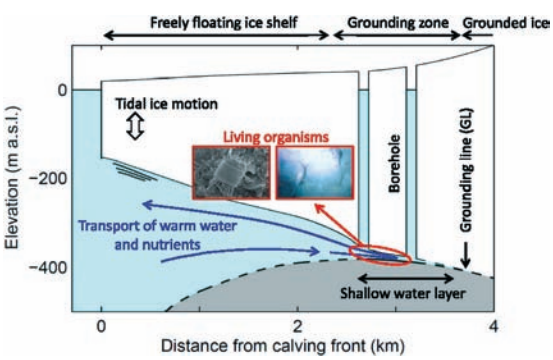

Fig. 23. Cross-section through the Langhovde Glacier showing the processes operating. (Image courtesy of Shin Suguyama, Hokkaido University, Japan).

Texan Tyrannosaurus

Evidence for the presence of tyrannosaurid dinosaurs from Big Bend National Park, Texas, USA is very limited. Apart from isolated teeth, this group of dinosaurs is only represented by an isolated left maxilla (upper part of the jaw) with incomplete dentition (Fig. 24). A partial right lower leg and foot has been collected but is yet to be described. The rarity of *Tyrannosaurus* fossils in the latest Cretaceous (Maastrichtian) of North America makes the discovery of a relatively complete tyrannosaurus vertebrae important. Steven Wicks reports on the discovery in a paper published in *Cretaceous Research* (Wicks, 2014, *Cretaceous Research*, v.50, pp.52–58).

The very large caudal (tail) vertebrae was collected from the Javelina Formation in Big Bend National Park. This formation represents a series of river channels along with their associated floodplains. Based on the size and morphology of the vertebrae, which is approximately 173 mm long and 140 mm wide, Wick suggests that it was almost certainly from an adult *Tyrannosaurus rex*. But *T. rex* wasn't alone. Remains of a titanosaurid dinosaur, probably *Alamosaurus*, occurs at, or very near, every locality in Big Bend

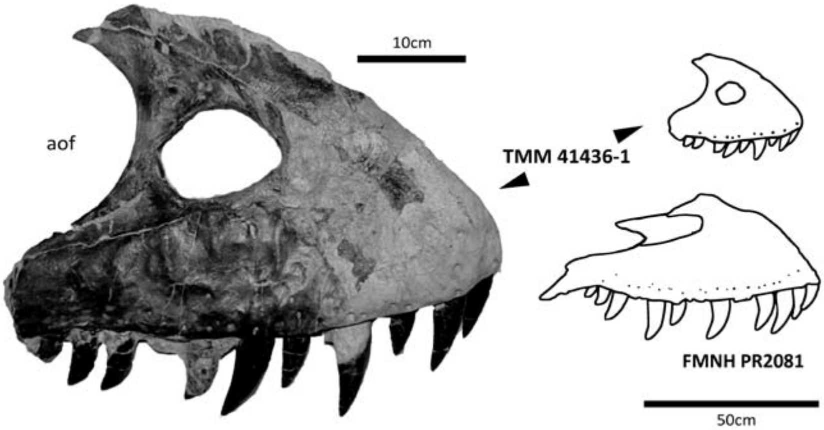

Fig. 24. Photograph of the maxilla of *T. rex* (specimen TMM 41436-1 (cast with restored teeth)) from Big Bend National Park, Texas, and general comparative proportions with mature *Tyrannosaurus rex* maxilla specimen FMNH PR2081. (Image courtesy of Steven Wicks, Big Bend National Park).

National Park where tyrannosaurid fossils have been collected. Together these giants roomed around the floodplains in Texas in the latest Cretaceous.

Carbon storage and loss in the peatlands of Indonesia

Peatlands can be important sinks for carbon over long time periods, but little is known about the role of tropical peatlands in the global carbon cycle. René Dommain and colleagues have determined the past rates of carbon storage and release over the last 20 000 years from the Indonesian Peatlands of Kalimantan and Sumatra, which represent the Worlds largest concentration of tropical peatlands (Dommain *et al.*, 2014, *Quaternary Science Reviews*, v.97, pp.1–32). Dommain and colleagues have mapped the spatial distribution of peatland in this area through time (Fig. 25). Sea level change is the most important factor for peatland formation and expansion in western Indonesia, as it controls atmospheric moisture supply and the hydrological gradient. The formation of inland peatlands in Kalimantan was linked to periods of rapid deglacial sea level rise. However, falling sea level after 5000 years ago led to rapid coastal peatland expansion and a doubling of the total peatland area in western Indonesia to 131 500 km^2 between 2300 years ago and the present day. During this time period annual carbon storage increased to 7.2 Tg C yr^{-1} (where Tg = teragram which is 10^{12} g which equals one megatonne). With this growth in carbon storage the peat carbon pool increased to 23.2 Pg C at the present day (where Pg = petagram which is 10^{15} g which equals one gigatonne), with 70% of the carbon stored in coastal peatlands.

The peatlands of western Indonesia have been a persistent carbon store over the last 15 000 and became a globally important carbon store over the last 2000 years. However, things are starting to change and current annual losses of carbon caused by rapid deforestation, peat drainage and repeated fires are greater than the rate of carbon storage. Thus the carbon storage in the peatlands of western Indonesia has changed from being a carbon sink to a significant source of atmospheric carbon.

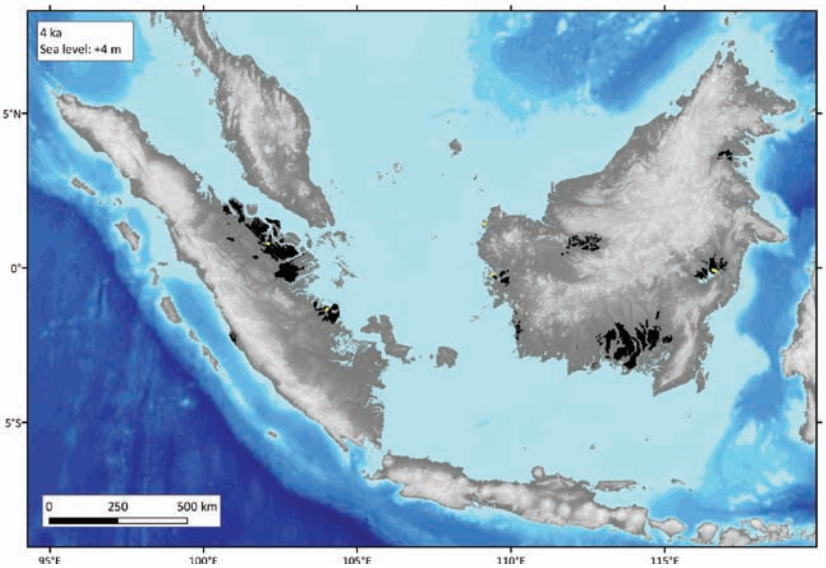

Fig. 25. Palaeogeographical map showing the distribution of peatlands (shown in black) in western Indonesia 4000 years ago, with sea level estimated to be 4 m higher than the present day. Yellow dots represent dated peats. (Image courtesy of René Dommain, University of Greifswald).

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