Palaeontology, palaeobiology and evolution

Further pounding for ideas on the Ediacaran fauna (*January 2016*)

About 635 Ma ago fossils of large-bodied organisms first appeared in the geological record: some quilt like, others with a crude bilateral symmetry, yet more looking like 'mud-filled bags' and ribbed discs but none that can easily be distinguished as animals, plants or colonial microorganisms. First found abundantly in the Ediacara Hills of South Australia, hence their sack-name the Ediacaran biota, it now seems that they were distributed globally in the late Neoproterozoic Era. Interpreting their metabolism is risky enough – some are reckoned to be animals that absorbed nutrients through their skin, others said to be dependent on photosynthesis – but a controversy has raged for many years over the kind of environment in which they thrived. In a detailed 2012 study of sedimentary structures and petrography in the South Australian sandstones from which they were first described, Gregory Retallack of the University of Oregon inferred that some lived on land (see *The Ediacaran fossils: a big surprise* December 2012) and are now found in palaeosols: they include Spriggina, *Dickinsonia* and *Charnia* that are among the most favoured candidates for being animals or some kind. Others inhabited shallow water. Anticipating fiery disputes a *Nature* editorial appeared in same issue in which Retallack published his paper.

Rich fossil assemblage of the Ediacaran Mistaken Point Formation, Newfoundland. (Credit: Alex Liu, Earth Sciences, University of Bristol)

Retallack has now moved on to the even more fossil-rich Ediacaran sediments of Newfoundland (Retallack, G.J 2016. Ediacaran sedimentology and paleoecology of Newfoundland reconsidered. *Sedimentary Geology*, v. **333**, p. 15-31; DOI: 10.1016/j.sedgeo.2015.12.001). Eye-wateringly detailed sequence stratigraphy of the now famous Mistaken Point locality and others suggests that the ecosystem there was an intertidal salt marsh. In detail it contains evidence for shallow-water graded bedding, signs of regular storms and perhaps tsunamis together with interbedded palaeosols and subaerial volcanic crystal tuffs whose feldspars survive intact. The palaeosols can be subdivided into several pedogenic types akin to those used to classify modern soils. Unlike the arid setting of the South Australian Ediacaran sediments, whose palaeosols show signs of freezing, the Newfoundland package indicates humid, cool-temperature climes

As in Australia, the palaeosols are rich in Ediacaran fossils, including the best known; the leaf-like Charnia and its discoidal support structure that appears in Retallack's reconstruction of the environment in an analogous way to salt-tolerant shrubs in modern tidal flats. They occur together with encrusting fossils that bear some resemblance to modern foliose fungi or lichens. Further chuntering in the palaeontological community seems inevitable, but the sedimentological observations alone knock one hypothesis on the head: it has been said that the graded bedding common to both major Ediacaran assemblages constitutes evidence for deep marine origins from turbidity currents. But there is further compost in which controversy may thrive, in that Retallack ascribes the repeated palaeosols to glacially controlled sea-level fluctuations: the Newfoundland sequence contains two diamictites interpreted as tillite, one dated at ~583 Ma the other undated but at the top of the sequence.

More on early life

Hunting down the Tully Monster (*May 2016*)

The word 'monster' has its origin in the Latin *monere 'to warn'* but has broadened out in its usage. It has even reverted to its origins as a verb: a highly critical, verbal attack. But I prefer 'something about which one needs to be warned', and the Tully Monster encapsulates that meaning. It once lived in Illinois, specifically at just a single location, Mazon Creek, where thousands of them have been seen. But should you be especially fearful of *Tullimonstrum gregarium*? Well, at first sight, no; it's only about 10 cm long and apparently has no proper bones and it's dead. The first specimen was spotted in a coal-mine waste heap by Francis Tully in 1958, a pipefitter with an interest in Carboniferous fossils. Two years after his death in 1987, he and his monster were honoured by a bill that the Illinois State Legislature passed to make it the official State Fossil.

Artist's impression of the Carboniferous Tully Monster (*Tullimonstrum gregarium)* (credit: Sean McMahon, Yale University)

It seems to have become a 'monster' by stumping all previous attempts to categorise it; so much so that it long served as a warning to eager palaeontologists not to tangle with its taxonomy. That's not surprising, because as well as bearing a passing resemblance to Captain Nemo's submarine in Jules Verne's *20 000 leagues Under the Sea*, it has some truly astonishing features. Portholes down its sides are not the weirdest – actually they are gill openings. It has a biting apparatus at the end of an absurdly lengthy forward protuberance, that would not be unexpected if it were one of those fish from the Amazon that, you know, men really ought to be warned about. Most of us would not share a bath with it if we had been. And then, there are the eyes on the ends of a dorsal bar which would give *Tullimonstrum gregarium* superb stereoscopic vision to guide it unerringly to its target, lashing its efficient-looking caudal fin. The fact that it has only a single nostril is merely puzzling by comparison.

Six decades on, Victoria McCoy of Yale University (now at Leicester University, UK) and 15 undeterred colleagues have pored over more than 1200 Tully Monster fossils and seem to have cracked its affinities (McCoy, V.E. *et al*. 2016. The 'Tully monster' is a vertebrate. *Nature*, v. **532**, p. 496-499; DOI: 10.1038/nature16992). In fact, it's surprising that it has remained an enigma for so long, because McCoy and colleagues have documented almost every aspect of its anatomy, available from a huge number of superbly preserved specimens – teeth, fin, muscle traces, gills, nostril, notochord, gut and so on. As well as being a vertebrate, its dreadful proboscis is very like that of the Cambrian oddity *Opabinia* from the Burgess Shale. A separate study by four British palaeontologists and a Texan concentrated on the eyes using electron microscopy and found 'ultrastructural details', including pigment cells (Clements, T. *et al*. 2016. The eyes of Tullimonstrum reveal a vertebrate affinity. *Nature*, v. **532**, p. 500-503; DOI: 10.1038/nature17647) which, according to the authors, unequivocally confirm that it is a vertebrate. It has all the hallmarks of being related to lampreys and hagfishs, which devour rotting, drowned corpses.

But McCoy *et al*. did not escaped the taxonomic curse of the Tully Monster, for there has been a technically detailed rejoinder (Sallan, L. *et al*. 2017. The 'Tully Monster' is not a vertebrate: characters, convergence and taphonomy in Palaeozoic problematic animals. *Palaeontology*, v. **60**, p. 149-157; DOI: 10.1111/pala.12282).

Signs of life in some of the oldest rocks (*September 2016*)

For decades the record of tangible signs of life extended back to around 3.4 billion years ago, in the form of undulose, banded biofilms of calcite known as stromatolites preserved at North Pole in the Pilbara region of Western Australia. There have been attempts to use carbon-isotope data and those of other elements from older, unfossiliferous rocks to seek chemical signs of living processes that extracted carbon from the early seas. Repeatedly, claims have been made for such signatures (see *Pushing back the origin of photosynthesis* February 2013) being extracted from the 3.7 to 3.8 Ga Isua metasediments in West Greenland. But because this famous locality shows evidence of repeated metamorphism abiogenic formation of the chemical patterns cannot be ruled out. Isua has been literally crawled over since Vic McGregor of the Greenland Geological Survey became convinced in the 1960s that the metasediments could be the oldest rocks in the world, a view confirmed eventually by Stephen Moorbath and Noel Gale of Oxford University using Rb-Sr isotopic dating. There are slightly older rocks (the Acasta Gneisses) in Canada, which just break the 4 Ga barrier, but they were metamorphosed at higher pressures and temperatures and are highly deformed. The Isua supracrustals, despite deformation and metamorphism show far more diversity that can be linked geochemically to many kinds of sedimentary and volcanic rock types.

Vic McGregor (left) and Allen Nutman examine metasedimentary strata at Isua, West Greenland (Credit: Getty Images)

Two of the Isua addicts are Allen Nutman of the University of Wollongong, Australia and Clark Friend formerly of Oxford Brookes University, UK, who have worked together on many aspects of the Isua rocks for decades. Finally, thanks to melt-back of old snow pack, they and colleagues have found stromatolites that push the origin of life as far back as it seems possible for geoscientists to reach (Nutman, A.P. *et al*. 2016. Rapid emergence of life shown by discovery of 3,700-million-year-old microbial structures. *Nature*, v. **537**, p. 535-538; DOI: 10.1038/nature). The trace fossils occur in a marble, formerly a limestone that retains intricate sedimentary structures, which show it to have been deposited in shallow water. The carbon and oxygen isotopes have probably been disturbed by metamorphism, and no signs of cell material remain for the same reason, but the shape is sufficiently distinct from those produced by purely sedimentary processes to suspect that they resulted from biofilm build-up. The fact that they are made of carbonates suggests that they may have been produced by cyanobacteria as modern stromatolites are.

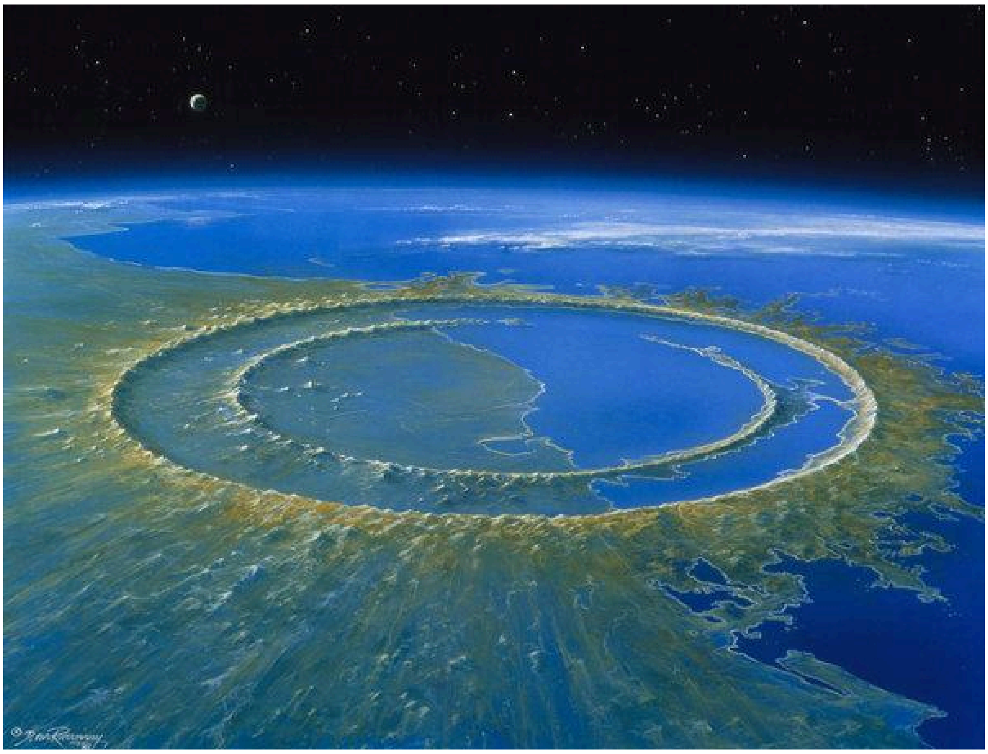
Stromatolite-like structures from an Isua metasediment (Credit: Allen Nutman)

The age of the structures, about 3.7 Ga, is close to the end of the Late Heavy Bombardment (4. 1to 3.8 Ga) of the Solar System by errant asteroids and comets. So, if the physical evidence is what it seems to be, life emerged either very quickly after such an energetic episode or conditions at the end of the Hadean were not inimical to living processes or the prebiotic chemistry that led to them.

You can find more on early life here

Related article: Allwood, A.C. 2016. Evidence of life in Earth's oldest rocks. *Nature*, v. **537**, p. 500-501; DOI: 10.1038/nature19429

K-T (K-Pg) boundary impact probed (*November 2016*)



Artist's depiction of the Chicxulub impact crater shortly after it formed (credit: Wikipedia)

One of the most eagerly followed ocean-floor drilling projects has just released some results. Its target is 46 km from the centre of the geophysical anomaly associated with the Chixculub impact structure just to the north of Mexico's Yucatan Peninsula. In the case of large lunar impact craters the centre is often surrounded by a ring of peaks. Modelling suggests such features are produced by the deep penetration of immense seismic shock waves. In the first minute these excavate and fling out debris to leave a cavity penetrating deep into the crust. Within three minutes the cavity walls collapse inwards creating a rebound superficially similar to the drop flung upwards after an object is dropped in liquid. This, in turn, collapses outwards to emplace smashed and partially melted deep crustal material on top of what were once surface materials, creating a crustal inversion beneath a mountainous ring of Himalayan dimensions that surrounds a by-now shallow crater. That is the story modelled from what is known about well-studied, big craters on the Moon. Chixculub is different because the impact was into the sea and involved debris-charged tsunamis that finally plastered the actual impact scar with sediments. The drilling was funded for several reasons, some palaeontological others relating to the testing of theories of impact processes and their products. Chixculub is probably the only intact impact crater on Earth, and the first reports of findings are in the second category (Morgan, J.V. and 37 others 2016. The formation of peak rings in large impact craters. *Science*, v. **354**, p. 878-882; DOI: 10.1126/science.aah6561).

The drill core, reaching down to about 1.3 km below the sea floor penetrates post-impact Cenozoic sediments into a 100 m thick zone of breccias containing fragments of impact melt rock, probably the infill of the central crater immediately following the first few minutes of impact. Beneath that are coarse grained granites representing the middle continental crust from original depths around 10 km. The granite is intensely fractured and riven by dykes and pods of impact melt, and contains intensely shocked grains that typify impacts that produce a transient pressure of ~60 GPa – around six hundred thousand times atmospheric pressure. From seismic reflection surveys this crustal material overlies as yet un-drilled Mesozoic sedimentary rocks. Its density is significantly less than that of unshocked granite – averaging 2.4 compared with 2.6 g cm^3. So it is probably filled with microfractures and sufficiently permeable for water to have penetrated once the impact site had cooled. This poses the question, yet to be addressed in print, of whether or not this near-surface layer became colonised by microorganisms in the aftermath (Barton, P. 2016. Revealing the dynamics of a large impact. *Science*, v. **354**, p. 836-837; DOI: 10.1126/science.aak9802). That is, was the surrounding ocean sterilised at the time of the K-T (K-Pg) mass extinction?; an issue whose resolution is awaited with bated breath by the palaeobiology audience. OK; so theory about the physical process of cratering has been validated to some extent, but will later results be more interesting, outside the planetary sciences community?