REPORT

Charnia masoni - 50th Birthday Party

In 1957 Roger Mason and his two climbing friends, Richard Allen and Richard Blachford, found the original specimen of *Charnia* in the north quarry on the Charnwood Golf Course – 50 years ago.

The same fossil had had been seen by a local schoolgirl, Tina Negus, a year earlier, but her teachers had refused to accept that there could be fossils in Precambrian rocks, and nothing therefore came of her find. As the quarry had been disused at least since the 1860s, it makes one wonder how many others had seen *Charnia* before Tina and had done nothing about it. To make matters more uncertain, a person unknown had hammered the rock alongside the specimen between the writer's first and second visits. Indeed, in the 1860s it was known as the "Ring Quarry" from the enigmatic circular markings not then regarded as fossils. Roger Mason and his father took Trevor Ford out to see it, and a year later a short paper was published naming two frond-like impressions *Charnia masoni* and *Charniodiscus concentricus* and, in the absence of anything comparable in geological literature, it was tentatively suggested that they might be impressions of soft-bodied algae.

With the aid of two quarrymen the type specimens were extracted and taken to Leicester Museum, on a block weighing about 200 kg. Later this was split down to a block weighing a more reasonable 30 kg, which is still on display in the Museum (Fig. 1).

To celebrate the 50th birthday of what turned out to be one of the most important fossil finds in Britain, the Geology Section of the Leicester Literary and Philosophical Society in conjunction with the Geology Department of the University of Leicester organized a seminar at the University on Saturday, March 10th 2007, under the "local heroes" theme sponsored by the Geological Society London, whose bi-centenary is also in 2007. The local hero in this context is *Charnia*. Abstracts of the lectures are available on the website of the Philosophical Society's Geology Section at www.Charnia.org.uk .

With twelve speakers from around the world and about 150 delegates present, the seminar presented an opportunity for a re-assessment of views as to what sort of organisms the Charnian impressions (variously listed as Charniomorphs, Rangeomorphs or Petalonamae) were, their ecology and environment, their chronological range within the Late Precambrian (Neoproterozoic), and whether they were direct ancestors of the Phanerozoic Phyla or not. Most of these questions have been asked several times before, and one important outcome of the seminar was that we still do not know all the answers, though we are perhaps getting a little closer.

Discovery of the Charnian fossils

The seminar started with three short talks on the discovery (Roger Mason), naming and potential interpretation as "algae" (Trevor Ford), and the later discovery of further Charnian fossils at other localities (Helen Boynton). Roger was able to pin-point the discovery from his father's diaries as April 19th 1957. Trevor took photographs to his former palaeontology lecturer Peter Sylvester-Bradley at Sheffield University and that is how it came to be published in the *Proceedings of the Yorkshire Geological Society*, as Sylvester-Bradley was the editor then (subsequently he became the first Professor of Geology at the University of Leicester).

Australian fossils

Within a few months, Professor Martin Glaessner of Adelaide University in South Australia published a note in *Nature,* drawing comparison between *Charnia* and a frond found in the Pound Quartzite (now Rawnsley Formation) of the Flinders Ranges, some 400 km north of Adelaide. He interpreted the fronds as fossil sea-pens (Pennatulids). Whilst Glaessner and his associate Mary Wade regarded the abundant discoid impressions in the Flinders Ranges and many other localities, including Charnwood Forest, as jellyfish (medusoids), others have seen them as holdfasts for frondose organisms. Current opinion is that there may be a mixture of the two, but there is still no consensus of views. Both fronds and discs are impressions of moderately soft-bodied, perhaps of leathery consistency, organisms with no hard parts.

Figure 1*. The original* Charnia masoni.

More Charnian fossils

A few years later, Trevor Ford reported the discovery of a disc on a loose block in the Outwoods (NE Charnwood) and this led to the finding of several discs on a bedding plane there at a stratigraphic horizon comparable with that bearing *Charnia* (Fig 2). A student whose attention wandered away from a field class in cleavage/bedding relationships in Bradgate Park found more discoid impressions on a bedding plane in Bradgate Park, later leading to the discovery of *Bradgatia* and a variety of other impressions on the same surface. Helen Boynton and Trevor Ford described both these and the discs found in Cliffe Hill Quarry at Markfield, and the assemblage of older fossil impressions of uncertain biological affinity in the considerably lower strata of Ives Head, notably *Ivesheadia, Shepshedia* and *Blackbrookia*, which occur 2000 m below the *Charnia* horizon.

The Charnian environment

John Carney (British Geological Survey) outlined the geology of Charnwood Forest, of which a new map has just been produced by BGS. In particular he compared the sedimentary environment with the recent volcanic eruptions on Montserrat in the West Indies (Fig. 3). The Atlantic floor adjacent to that island is now mantled with debris flows and turbidites comparable with the so-called Bomb Rocks and volcaniclastic turbidites of the Charnian succession. *Charnia* and the other Precambrian fossils were laid down on bedding planes showing little sign of shallow-water features such as ripple-marks, and are thus generally regarded as having been deposited below wave-base at depths perhaps as great as 500 to 1000 m in sediments derived from Charnian volcanoes. Later in the seminar Professor Guy Narbonne (Queens University, Kingston, Ontario) reported that the sedimentary environment of the Newfoundland biota was much the same. This was not surprising as both Charnwood and the Avalon peninsula of Newfoundland were parts of the ancient land mass of Avalonia, and their rock sequences of volcanics and turbidites represent parts of the same volcanic arc, then some 30º south of the equator.

Note that the term *biota* is used in preference to *fauna* while there is doubt on whether the Charniomorphs were animals or not. Also the term Metazoa may not be applicable if they are not animals.

Figure 2. Cyclomedusa davidi *from the Outwoods.*

Dating the Charnian biota

Assigning dates to the Charnian biota was discussed by Steve Noble (BGS). Ongoing research places the *Charnia*-bearing strata at 562 Ma on the basis of U-Pb dates derived from zircon crystals in adjacent ash-beds. This is close to dates for the Newfoundland strata, but the fossil-bearing strata in Namibia and South Australia lack sufficient ash-beds with zircons and the dates are less constrained at around 540-575 Ma. The Charnian date of 562 Ma is an appropriate mean. A recent discovery is the date of 606 Ma for the Ives Head biota. The Ives Head Formation is 2000 m stratigraphically below the *Charnia* horizon, and this would make the fossils there the oldest macro-fossils in the world. The gap of 40 Ma raises the question of the possibility of a major hiatus in deposition of the Charnian sequence, perhaps between the Blackbrook and Maplewell Groups. In Newfoundland, the Gaskiers Tillite (at about 580 Ma) would have been emplaced during that gap. It represents the last of a series of "Snowball Earth" glaciations in Neoproterozoic times, but with no equivalent of the tillite known in Charnwood, either it was never deposited or was eroded during the hiatus.

Dating the Ediacarian

In more on-going research, Dan Condon (NIGL, Keyworth) discussed zircon dating and other potentially applicable methods in more detail with the varied constraints on how data may be interpreted. He made particular reference to dating the beginning of the Ediacaran Period recently established by the International Stratigraphic Commission (see *Mercian Geologist*, 2005, p75). This new geological period is regarded as starting immediately after the Marinoan glaciation ended at 635 Ma with a Global Stratotype Section showing the base of the Ediacaran period defined at the top of a glacial tillite in the Flinders Ranges National Park, in South Australia. Thus Charnian strata are clearly of Ediacaran age and entirely post Marinoan glaciation.

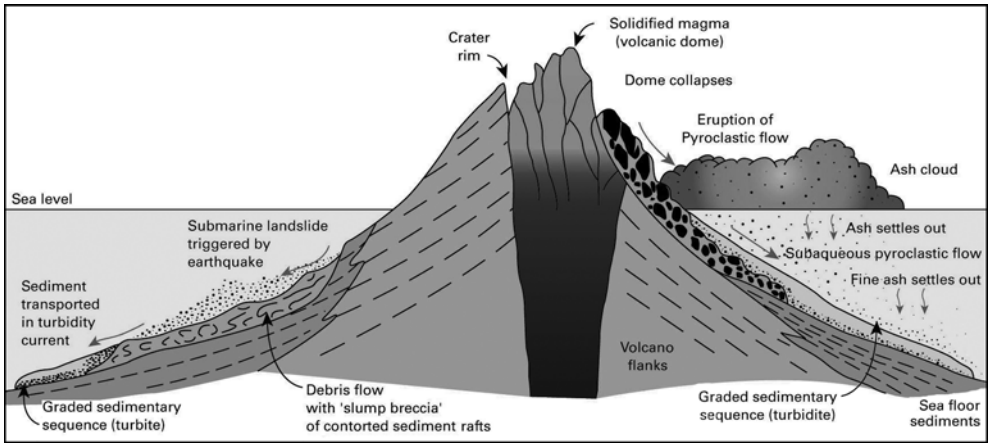

***Figure 3**. A Caribbean (Montserrat) model for Charnwood's volcanoes, with debris flows and turbidite sedimentation around a volcano (courtesy John Carney, BGS).*

The status of the Ediacaran biota within the Earth's history of macro-evolution, mass extinctions, adaptive radiation and uniformitarianism was discussed by Dr Nick Butterfield (Cambridge University). The 3000 Ma before the Ediacaran period was one of very limited evolution with life represented almost entirely by unicellular algae and bacteria which showed little evolutionary change. However, after Snowball Earth, the Ediacaran period was a phase of much increased oxygen levels with the appearance of diploblastic and triploblastic Metazoa, with early bio-mineralization demonstrated by the impression fossils such as the Ediacaran and Charnian biotas (the possibility of bio-mineralization would be disputed by some researchers). The Phanerozoic "explosion" of life forms followed little more than 20 million years later.

More Australian fossils and dates

Dr James Gehling (South Australian Museum, Adelaide) took up the story with a review of the chronological ranges of some 20 of the key genera now known in the Ediacaran biota. Most of them have a global distribution in strata of Namibia, Newfoundland, Western Canada, USA, South Australia, England (Charnwood Forest), Russia and China. He opined that the lower half of the newly defined Ediacaran was characterized only by microfossils (acritarchs) but that from 575 Ma there were also abundant trace and impression macro-fossils as well as a few body fossils such as the segmented *Spriggina*. While Sprigg had found discs interpreted as jellyfish as far back as 1947, the Pound Quartzite was then regarded as basal Cambrian because it had fossils – a circular argument which meant that they did not hit the headlines as Precambrian! With more intensive searches of the appropriate strata in the Flinders Ranges, many more fossils were found and new finds are still being made. At a new locality on the western flank of the Flinders Ranges many fossils had been found on a succession of bedding planes. Sedimentary environment interpretations showed that some fossils seemed to be restricted to certain facies, and an alternation from shallow to mid-depth littoral-marine conditions had been deduced. Dr Gehling concluded with comments on conservation and security (one choice specimen had been stolen and re-appeared in a Japanese dealer's list with an exorbitant price tag, but it had later been returned to Australia). A large part of the Flinders Ranges is now a World Heritage Site and this assignation was marked by a visit from the Prime Minister of South Australia.

The Newfoundland biota

Although a Precambrian fossil, the possible medusoid *Aspidella*, had been found in Newfoundland in 1872, it was written off as inorganic by the American palaeontologist, C. D. Walcott. A century later, and ten years after the discovery of *Charnia*, Misra and Anderson, of Memorial University, St Johns, Newfoundland, found abundant fossils in the Late Precambrian Conception Group rocks at Mistaken Point and many other localities on the coast of the Avalon Peninsula of southeast Newfoundland. Professor Guy Narbonne described the biota as very similar to that in Charnwood Forest but with thousands more specimens and several extra genera, notably the "spindle-shaped organism" (Fig. 4). On the cliffs of the Avalon Peninsula, single bedding plane exposures can have more than a thousand fossils. With many such bedding planes over a length of some 200 km of coast, there was a wealth of material, some still awaiting formal naming and description. Almost all the fossil-bearing beds occur above the Gaskiers Tillite on turbidite bedding planes covered with thin layers of volcanic ash, but a few were also found in the much older Drook Formation, one being *Charnia wardi*, a frond more than 2 m long. Prof. Narbonne quoted geochemical work by D. Canfield and others which indicated that the post-glacial sediments were much more oxygenated and this might be because the release of nutrients from the weathering of periglacial sediments encouraged blooms of photosynthesising micro-organisms. In turn these could provide food for the Ediacaran biota, but the lack of evidence of mouths or alimentary tracts could be taken to suggest that nutrition was absorbed directly from the sea. In short, were the macro-organisms absorbing nutrients instead of eating microbes? The recently discovered three-

***Figure 4**. A compound spindle-shaped colony, from Mistaken Point, Newfoundland.*

dimensional fronds in the rocks of Spaniard's Bay supported the absorbtion concept, and suggested that there was evidence of a fractal growth pattern, whereby the same frondose structure is repeated on a decreasing scale down to a fourth order. Professor Narbonne reported that the Mistaken Point area was now a World Heritage Site, and that some of the local people had been enlisted as guardians. A Visitor Centre was a boost to the local economy.

One of the most abundant Newfoundland fossils is the spindle-shaped form, as yet un-named. A speaker from the audience suggested that as they occurred in the Conception Group at Mistaken Point, there was an opportunity to have a latinized biological name based on Mistaken Conception!

The White Sea biota from Russia

The White Sea coasts and an adjacent river section in Arctic Russia provided a wealth of specimens which were briefly described by Dr Dima Grazhdankin (University College, Dublin). The metamorphism seen in Charnwood and Newfoundland was lacking and the fossils were in soft sediments, some still with carbonaceous traces. Following Seilacher's concept of a failed evolutionary experiment, Dr Grazhdankin regarded many as having a quilted body structure where growth was by inflation. There were now over 100 named genera and species in the Ediacaran biota. He reported that there appeared to be several environmentally-controlled communities, notably the Nama-type characteristic of distributary bar shoals, i.e. shallow water, the Ediacara community characteristic of pro-delta environments (shallow to medium depths), and the Avalon-type biota characteristic of low-energy shelf environments. Although there was some overlap of these biotas, the fossils of Charnwood Forest were within the Avalon community. However, the inferred water depths there, below wave base, were too great to permit photosynthesis, though it was possible that the fossils drifted from moderate into deeper waters. More than 40 years ago Professor Martin Glaessner had invoked a beach environment to explain the Ediacaran fossils preserved in a sandstone in South Australia.

As with several other speakers, Dr Grazhdankin was of the opinion that the Ediacaran fronds were not related to Pennatulids (sea-pens); nor were the discoid fossils jellyfish as proposed by Glaessner and Wade. There was some feeling at the meeting that the Ediacaran fossils were neither plant nor animal but somewhere between. So the biota could not be direct ancestors of the Phyla which arose in the Cambrian "explosion" of life forms. Dr Grazhdankin thought that some of the various alleged medusoids bore a resemblance to circular bacterial colonies.

New techniques

As several speakers referred to the Ediacaran biota as a "failed experiment" in the evolution of life, it leaves us with two questions - "where did the Phanerozoic Phyla come from", and "how did pre-Ediacaran microbes evolve into multi-cellular fronds?".

As part of a research project on Animal Ancestors Professor Martin Brasier and Jonathan Antcliffe (of Oxford University, together with associates in Newfoundland) have started using laser scanning techniques to extract as much information as possible from the Charnwood and Mistaken Point fossils. In particular they have been able to show that *Charnia* had fourth order subdivisions of the "cells" on the frond branches and that *Charniodiscus concentricus* may have had three fronds growing from a central disc. No evidence of polyps such as might be expected on Pennatulids had been found so far and the growth pattern was unlike Pennatulids. They confirmed that *Bradgatia* was a bush-like form of many fronds. Other details of ontogeny and phylogeny were also emerging from on-going research, in particular using the technique of morphometric analysis whereby one fossil image can be changed into another by a simple geometric process of rotation on a computer screen.

Concluding remarks

To return to the questions asked at the beginning of this report, it seems that the jury is still out on what sort of organisms the Ediacaran fossils were – plant, animal or somewhere between, and whether they were a failed experiment in evolution. To a large extent we still have little idea of how they fed and grew, or how they reproduced. No evidence that the Ediacaran fossils represented ancestors of the Cambrian phyla was put

forward. Their age range is post-Gaskiers tillite at 580 Ma to the very end of the Precambrian at 542 Ma. However, the Ives Head fossils at 606 Ma pre-date this and *Charnia wardi* from the Drook Formation in Newfoundland seems to be of comparable age. While it might be expected that the earliest Ediacarans would be small, one fossil in the Drook Formation was 4 m long! There is some evidence of differentiation of assemblages in environments ranging from river-mouth shoals, through pro-delta shallows to low-energy shelf below wave base. There had also been a suggestion that many of the organisms were floaters which were punctured by hot volcanic ash and then sank into the deep water environment.

Surprisingly some aspects of the Ediacaran story were overlooked. What were the few "worm-trails" in the Charnia horizon? The presence of apparently segmented body fossils such as *Spriggina* amongst the Ediacaran biota in South Australia was only briefly mentioned and its possible significance as either annelid worm or arthropod was not discussed. The alleged flat-worm *Dickinsonia* and the putative coral *Tribrachidium* found in Ediacaran assemblages were barely mentioned. The late Ediacaran frondose fossils from Namibia *Pteridinium* and *Swartpuntia* are surely part of the Ediacaran fossil story too. The cup-shaped *Arumberia* found in Australian and Longmyndian rocks was not discussed. The miniature conical fossil Cloudina found in very late Ediacaran limestones in California may have been an ancestor of corals. Was the intensively burrowed and bioturbated Swithland Slate at the top of the Charnwood stratigraphic sequence now confirmed as Cambrian and thus no longer part of the Charnian/Ediacaran story, or did the burrowing organism which produced the *Teichichnus* borings evolve in the latest Ediacaran?

Two days later, the annual Bennett Lecture in Leicester University was given by Professor Stefan Bengtson of the Swedish Museum of Natural History in Stockholm. Among other matters he drew attention to trail-like markings on rippled quartzites aged 1.0 to 1.6 billion years. If these were to be interpreted as trails made by mobile animals it puts the whole evolutionary story back much earlier than the Ediacaran, but if they were not of biologic origin, what were they?

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Selected Reading

Anderson, M.M. & Misra, S.B. 1968. Fossils found in the Precambrian Conception Group of southeastern Newfoundland. *Nature*, **220**, 680-681.

Antcliffe, J.B. & Brasier, M. D. 2007. Charnia and seapens are poles apart. *Journal of Geological Society London*, **164**, 49-51.

Brasier, M. D. 1992. Background to the Cambrian explosion. *Journal of Geological Society London*. **149**, 585-587.

Boynton, H.E. & Ford, T.D. 1979. *Pseudovendia charnwoodensis* – a new Precambrian arthropod from Charnwood Foresty, Leicestershire. *Mercian Geologist*, **7**, 175-177.

Boynton, H.E. & Ford, T.D. 1995. Ediacaran fossils from the Precambrian (Charnian Supergroup) of Charnwood Forest, Leicestershire, England. *Mercian Geologist*, **13**(4), 165-182.

Canfield, D.E., Poulton, S.W. & Narbonne, G. 2006. Late Neo-Proterozoic deep ocean oxygenation and the rise of animal life. *Science*, **315**, 92-95.

Carney, J.N. 1999. Revisiting the Charnian Supergroup: new advances in understanding old rocks. *Geology Today*, **15**, 221-229.

Droser, M.L., Gehling, J.G. & Jensen, S.R. 2006. Assemblge palaeoecology of the Ediacaran biota: the unabridged edition? *Palaeogeography, Palaeoclimatology & Palaeoecology*, **232**, 131-147.

Ford, T.D. 1958. Precambrian fossils from Charnwood Forest. *Proceedings Yorkshire Geological Society*, **31**, 211-217.

Ford, T.D. 1980. The Ediacaran fossils of Charnwood Forest, Leicestershire. *Proceedings Geologists' Association*, **91**, 81-84.

Glaessner, M.F. 1959. Precambrian Coelenterata from Australia, Africa and England. *Nature*, **183**, 1472-1473.

Glaessner, M.F. 1966. Precambrian palaeontology. *Earth Science Reviews*, **1**, 29-50.

Glaessner, M.F. 1984. *The Dawn of Animal Life: a Biohistorical Study*. Cambridge University Press. 244pp.

Jenkins, R.F. & Gehling, J.G. 1978. A review of the frond-like fossils of the Ediacara assemblage. *Records South Australian Museum*, **17**, 347-359.

Jensen, S.R., Droser, M.L.& Gehling, J.R. 2005. Trace fossil preservation and the early evolution of life. *Palaeogeography, Palaeoclimatology & Palaeoiecology*, **220**, 19-26.

Knoll, A.H., Walter, M.R., Narbonne, G. & Christie-Blick, N. 2006. The Ediacaran Period: a new addition to the Geological Time Scale. *Lethaia*, **39**, 13-30.

Narbonne, G. 2005. The Ediacara Biota: Neoproterozoic origin of animals and their ecosystems. *Annual Reviews of Earth and Planetary Sciences*, **33**, 13.1-13.22.

Runnegar, B. N. 1992. Proterozoic fossils of soft-bodied Metazoa: Ediacaran faunas. 369-395 in *The Proterozoic Biosphere*. Edited by J.W.Schopf & C. Klein, Cambridge University Press.

Seilacher A. 1992. Vendobionta and Psammocorallia: lost constructions of Precambrian evolution. *Journal Geological Society London.* **149**, 607-613.

Sprigg, R.C. 1947. Early Cambrian jellyfishes of the Flinders Ranges. *Transactions Royal Society South Australia*, **71**, 212-224.

Wade, M. 1972. Hydropoa and Scyphozoa and othr medusoids from the Precambrian Ediacara fauna, South Australia. *Palaeontology,* **15**, 197-225.

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