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East Midlands Geological Society

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Front cover: Triassic sandstone forming the cliff on the southeastern corner of Castle Rock, Nottingham, with Mortimer's Hole behind the left door; see p. 37. Photo: Tony Waltham.

Back cover: A geological map of Nottingham from the 19th century; see p. 51.

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GEOBROWSER

When did the Earth first chill out?

There seems little doubt that soon after its accretion the Earth was a highly energetic body, but are the theories that it began with a prolonged Hadean or 'hell-like' episode extending from 4400 to 4000 million years (Ma) ago correct? Unfortunately, no rocks go back farther than about 4000 Ma (*Contributions to Mineralogy and Petrology, 1999, p.69)*, but older *minerals* are known, in the form of 4404 Ma zircon crystals found in Archaean rocks at Jack Hills, Western Australia. This find is fortunate, because zircons provide reliable Oxygen 18 measurements, and the occurrence of this particular isotope in relative abundance is believed to be an indicator of magmas formed from the melting of rocks that had been in contact with low-temperature hydrous fluids – in other words these precursor rocks had experienced significant alteration or weathering. The high ^{18}O values (c.7.5%) in the Jack Hills zircons could be due to a number of other factors, but the only theory to survive rigorous examination is the crystallization of these zircons under conditions more appropriate to the 'cooler' Earth system that existed much later in the Archaean, 3800-2600 Ma ago (*Geology, 2002, p.351)*. If this is the correct interpretation, it follows that water may have existed on an Earth that had stabilized well before about 4000 Ma. Furthermore, there could not have been a prolonged 'high energy' period of meteorite bombardment between 4450 and 3900 Ma, as some have suggested; instead there may have been a single, relatively short-lived meteorite 'spike' at about 4000-3800 Ma, followed by reversion to quieter conditions.

Ever - changing climates

The current debate about human involvement in triggering climate change is increasingly being balanced by research into the many natural causes of such fluctuations. The time-scales at which these factors could have operated are equally varied, as three recent articles show.

• On a geological time-scale, it has been proposed that since the Precambrian (543 Ma ago) at least 66% of the variance in palaeotemperatures may be due to the galactic cosmic ray flux (CRF), caused by our solar system passing through the spiral arms of the galaxy *(GSA Today, 2003, p.4)*. This hitherto unperceived astronomical factor might mean that we are today overestimating the influence of the long-term global CO_2 greenhouse effect.

• On a much shorter time-scale, one of the most important predictions is that Arctic ice sheet melting could very rapidly cut off the supply of warm tropical water to the North Atlantic, triggering the onset of more 'continental' climatic conditions in the UK. This is now supported by studies of clay minerals recovered from Atlantic drill cores *(Quaternary Research, 2003, 243),* which demonstrate the operation of this process at least twice in the recent geological past. The oldest recorded Atlantic meltwater pulse, at about 130,000 years ago, probably resulted from ice sheet collapse. The younger event, 77,000 years ago, was of shorter duration and may have been caused by the sudden discharge of water from Siberian ice-dammed lakes.

• An added complication to short-term global temperature change, at least during the Holocene epoch, was the periodic release of large quantities of methane that is otherwise locked up in seafloor sediments – the 'clathrate gun hypothesis' (see also, Geobrowser in Mercian 2003). Methane release is a consequence of sediment instability caused by continental-slope failures, and studies of methane contents in ice cores have shown that over the past 45,000 years there have been two main episodes – 15,000 to 13,000 years and 11,000 to 8000 years ago (*Geology, 2003, p.53)*. These are both glacial-interglacial transition periods, but the underlying causes of the slope failure were rather different. The older event followed a deglaciation and occurred at low latitudes; it resulted either from warming of the ocean or from enhanced rainfall causing vast loads of sediment to be conveyed to the continental slope, which then became unstable. The younger slope failures were high latitude ones, and were probably caused by the destabilizing effect of isostatic rebound following retreat of the ice sheets.

K-T extinction: more complications

Previous Geobrowsers (*Mercian, 2000, 2001)* have reviewed the development of ideas about what really caused the end-Cretaceous (K-T boundary) event that wiped out the dinosaurs, and many other types of animal. Since those issues, further detailed examinations of bolide ejecta layers, iridium layers and faunal changes have been carried out across the critical Cretaceous/Tertiary transition strata, and a multicausal scenario now looks very appealing. One of the most recent contributions *(Earth-Science Reviews, 2003, p.327)* favours the following event sequence in the Central American and Caribbean regions:

1. At the very end of the Cretaceous (but before the actual K-T boundary) the first impact occurred, at 65.27 Ma. This was the Chicxulub meteorite. In association with on-going voluminous Deccan volcanism, which lasted from 68.1 to 61 Ma, it contributed to rapid global warming and the consequent terminal decline of planktonic foram populations.
2. The actual K-T boundary impact, at 65 Ma, is not well represented in many sections, due to intraformational erosion; it marks a major drop in primary productivity and the extinction of all tropical and subtropical foram species.

3. A third meteorite impact occurred in the earliest Tertiary, and is tentatively dated at about 64.9 Ma; it contributed to the marked delay in recovery of productivity and evolutionary diversity.

Some of the more doom-laden prophecies about what might happen to the human race under such a bombardment may, to some extent, be erroneous. Calculations based on the composition of the Chicxulub ejecta layer (*Geology, 2002, p. 99)* do not bear out the original scenarios that featured the shutdown of photosynthesis during a succession of 'impact winters' caused by volcanic dust. In fact, more than two orders of magnitude more fine dust than was kicked up by that meteorite would have been necessary to do this. So if not dust, then what caused plants to cease growing? One of the two most likely theories is that this resulted from soot caused by global fires *(GSA Special Paper, 1990, p.391)*. Research soon to be published, however, will suggest that there is a remarkably low amount of charred plant remains in strata at the K-T boundary. If correct, this would leave only the second theory as viable – that widespread plant death, and consequent destruction of the whole terrestrial ecosystem, was due to acid rains produced from sulphate aerosols released from gypsum deposits that happened to be present in the Chicxulub target rock *(Journal of Geophysical Research, 1997, p. 21645)*, a unique combination of circumstances that was unlucky for the dinosaurs but is perhaps unlikely to be repeated.

Silverpit update – controversy

The 20 km-wide Silverpit 'crater' could be considered England's own Chicxulub, buried as it is beneath younger strata in the North Sea about 150 km off the Humber Estuary. This impressive circular feature, detected on the basis of oil company seismic reflection profiles, was attributed to deformation that occurred about 60 million years ago as a result of the impact of an extraterrestrial body (*Nature, 2002, p.520)*. This suggestion is now challenged, however, by another explanation - that it could be the result of tectonic deformation within a complex fault zone *(Journal of the Geological Society, 2004, p.593)*. In essence, this argument suggests that torsional stresses caused by strike-slip faulting may have been transmitted upwards into a 1100 m-thick Permian evaporite deposit which then thinned in response, causing a circular salt-withdrawal syncline to develop at the base of the overlying Triassic strata. The latter subsided, and overlying Jurassic mudstones 'flowed' into the void created, at the same time deforming around a radial thrust-fault system. The effect of all this on overlying Cretaceous rocks was to cause subsidence around a complex system of circular, 'caldera' faults, with Jurassic material forced up into the centre, causing a diapir-like structure that mimics the central upheaval of a meteorite impact crater. The tectonic theory seems complicated, but is attractive in that it could also explain the origin of similar circular structures, such as the Upheaval Dome of Utah and the Compton Valence structure of West Dorset, both featuring highly deformable evaporitic sequences associated with strike-slip fault systems.

MERCIAN NEWS

Cave art at Creswell Crags

Long known for the archaeological material in its sediments, Church Cave, in the Permian limestones of Creswell Crags, has now been found to have artists' impressions of about 90 animals etched into its roof. Partially covered with stalactite, they are genuinely old, and are thought to date from 13,000 years ago, even though the caves were also occupied long before then. The eroded bas-relief images have only just been found, because they are only visible in the strong sidelight reflected into the cave from the morning sun. Details are in *Antiquity* v77, pp227-231, or on their website http://antiquity.ac.uk/ProjGall/bahn/

Mam Tor still on the move

The East Midlands home-grown landslide at Mam Tor continues to creep downwards (see *Mercian Geologist* v15, pp54-55). Prof Ernie Rutter, Christine Arkwright and colleagues at Manchester University have taken the research another step forward with further monitoring and with their analysis of strain fields within the slide debris; they also relate rates of movement to climates past and present. Read the full story in the *Journal of the Geological Society* v160, no5, pp735-744, or an excellent summary in *Geology Today* v19, no2, pp59-64, both published in 2003.

Geopark for Derbyshire?

With the new Geopark in the Abberley and Malvern Hills featured in this issue of *Mercian Geologist*, it is timely to consider the potential for a Geopark in the White Peak. There have already been informal thoughts and discussions on this, and the limestone area around Matlock and Wirksworth can certainly be justified in terms of both its natural geology and its mining heritage. Designation could raise the profile of the Peak District National Park, and could provide a welcome boost to conservation measures.

Editorial

Readers will have seen that our Geobrowser column remains uncredited, so it is up to the Editor to thank John Carney for continuing to produce these fascinating extracts from the geological literature.

And apologies to Ben Le Bas, warden of the Lathkill Dale NNR, whose name had a phonetic and incorrect spelling in the last issue of *Mercian Geologist*.

FROM THE ARCHIVES

An archive photograph of East Midlands geology from the British Geological Survey collection

Greetwell Ironstone Mines

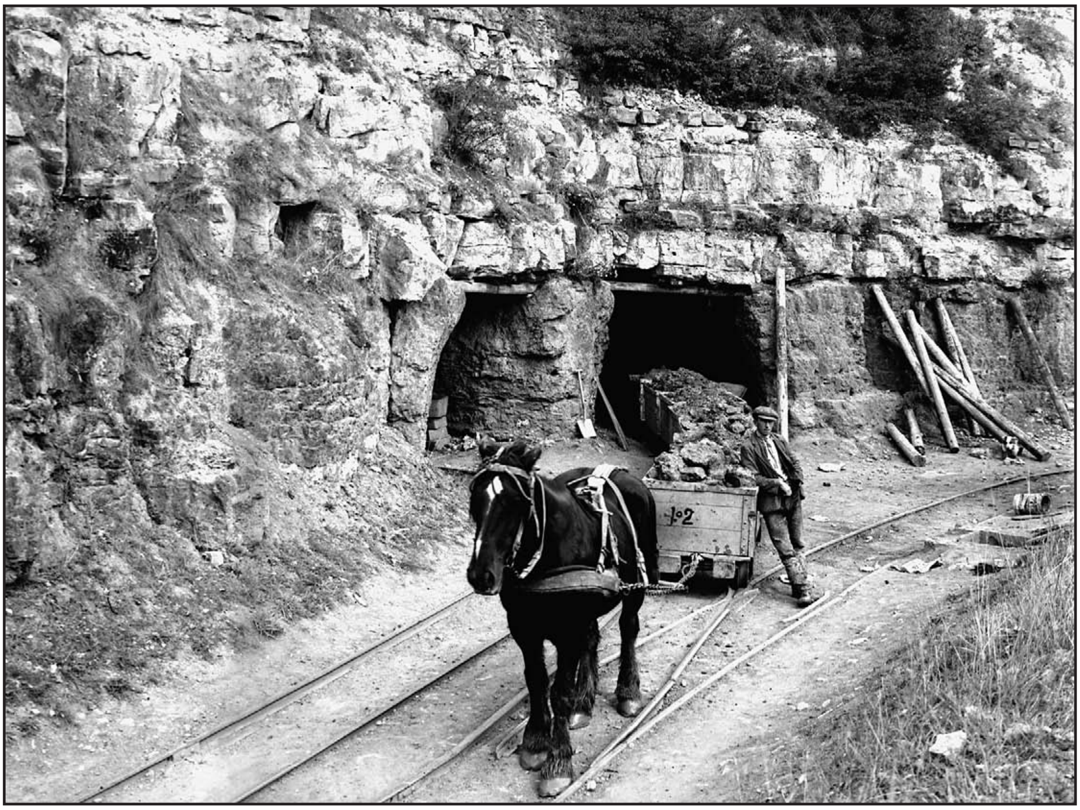
From the far east of the East Midlands region, the ironstone mines in the Greetwell area, east of Lincoln, feature in one of a series of BGS photos taken in 1933 by the Survey photographer, Jack Rhodes.

Ironstone was worked in the Greetwell district for at least 60 years, using both underground pillar-and-stall and opencast methods. Mining commenced around 1878 and ended just before World War II, although the opencast mines remained in operation throughout the war as a source of 'hard core' and 'pitching stone', which was obtained from the Lincolnshire Limestone overburden and was used for roads and aerodrome runways.

Geologically, the ironstone was worked from the Northampton Sand Formation of Aalenian age (in the early Mid Jurassic). The entire formation is about 3.5 m thick, with workable ores occurring as sideritic ironstones with berthierine ('chamosite') ooids, interbedded with sideritic and calcareous sandstone. In the Greetwell area, the Lincolnshire Limestone unconformably overlies the Northampton Sand Formation in most places. The Grantham Formation (formerly Lower Estuarine Series), which separates these formations farther south, is mostly absent, though is represented locally by about 0.3 m of iron-stained sandstone with plant remains. At shallow depth, the ironstone weathers into a limonitic, 'boxstone' structure, and was obtained in this form from the opencast workings. This ore was blended with the less oxidised, blue-green ores won from the underground mines, and was sent to the ironworks at Scunthorpe, where it was usually mixed with the Frodingham ores before smelting. The overlying Lincolnshire Limestone was also worked for use as a flux in the smelting process.

The photograph shows ore-laden trucks emerging from the Long Harry Mine, which was entered by several adits dug into the sides of the opencast workings. The contrast between the darker coloured ores of the Northampton Sand Formation and the paler coloured, well-bedded Lincolnshire Limestone can be clearly seen. The working face was about 2.5 m high, leaving a bed of ironstone 0.3 m thick to form the roof. The main roadway was excavated in a northwest direction from the adit mouth, with pillar and stall workings extending underground for about 2km north-east from the roadway. A substantial fault, which throws down to the northeast, formed the boundary of the workings. Faulting, together with facies change along strike to the north, effectively constrained the extent of workable resources at Greetwell, with all viable reserves exhausted by the late 1930s, despite the imminent demands of World War II.

Andy Howard, British Geological Survey



Long Harry Mine, Greetwell, Lincoln, in September 1933 (BGS photograph # A00733, © NERC).