GEOBROWSER

Cosmic trigger for our youngest glaciation?

The Younger Dryas Stadial, lasting from c.12,900 to c.11,700 years BP, was the most recent and longest of several interruptions to the gradual warming of the Earth's climate since the severe Last Glacial Maximum, which started to ameliorate around 20,000 BP. Named after the alpine-tundra wildflower *Dryas octopetala*, the leaves of which are locally abundant in the Late Glacial sediments of Scandinavian lakes, it is known in Britain as the Loch Lomond Stadial, and its influence on landforms has long been recognised in mountainous areas where glaciers temporarily returned. A good example in Scotland is the 'parallel roads' of Glen Roy, which are shorelines caused by the progressive draining of a glacier-dammed lake.

What has really puzzled workers was the dramatically sudden Younger Dryas climatic change, which took place in a matter of decades that saw average global temperatures plunge between 2°C and 6°C. The review by Renssen *et al.* (*2015: Nature Geoscience 8*) notes that the event has traditionally been attributed to a sudden shut-down of the Atlantic meridional overturning circulation by meltwater discharges, possibly from the Great Lakes or the Greenland ice-cap. Other 'natural' explanations include strong, negative, radiative forcing, perhaps caused by a net decrease in greenhouse gases and/or increase in atmospheric aerosols, and drastic shifts in atmospheric circulation. The models of Renssen *et al.* suggest that taken alone, none of these mechanisms would account for the suddenness of the Younger Dryas warm-cold transition, although the change could be simulated by using them in combination.

Against this background, the notion that the Younger Dryas could have been caused by some sort of cosmic impact has steadily gained ground. Initially proposed in a book by Firestone *et al*. (*2006: The Cycle of Cosmic Catastrophes*), the hypothesis is now very much to the fore thanks to discoveries at sites in North America containing Younger Dryas boundary sediments (YDB sites). From these, Kennett *et al*.

Locations of ice cores and Younger Dryas boundary (YDB) sites with peak biomass-burning proxies. Diamonds represent 6 ice records that display chemical proxies in support of anomalously high YDB biomass burning. Taylor Dome and Taylor Glacier are off the map in Antarctica. Circles represent 23 sites with a documented YDB layer containing peaks in biomass-burning proxies. (After Wolbach et al., 2018)

(*2009, doi.org/10.1073/pnas.0906374106*) described shock-synthesized diamonds (known as lonsdaleite). A global perspective was subsequently provided by Bunch et al. (*2012, doi.10.1073/pnas.1204453109*), who focused on charred carbon-rich layers at 18 dated YDB sites across Asia, Europe and the USA. All contained very high-temperature impact material such as nanodiamonds, metallic microspherules, carbon spherules, magnetic spherules, iridium, platinum, charcoal, soot and fullerenes enriched in helium-3, a combination which cannot simply be explained by volcanic, anthropogenic or other natural processes. Of considerable significance is the occurrence of scoria-like debris of the type only found in close proximity to a cosmic impact or airburst. These have now been reported from YDB sites in a total of eight countries on four continents, suggesting that there may have been a widespread shower of extra-terrestrial bodies, rather than a single large one.

Although there have been challenges and complications to the Younger Dryas impact theory, two major papers in the Journal of Geology (*Wolbach et al., 2018, v.126/2*) review compelling, globally-sourced

The lake terraces known as the Parallel Roads of Glen Roy.

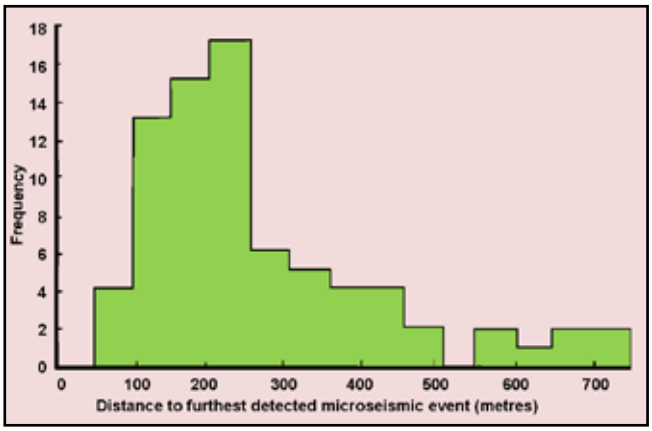
lines of evidence interpreted as showing that the Earth collided with multiple fragments of a 100-km-diameter disintegrating comet at the time of the Younger Dryas cooling. Geochemical signatures in Greenland ice cores, such as anomalously high concentrations of platinum, constrain the event remarkably closely to about 21 years spanning ~12,836–12,815 cal BP. Such a major and protracted impact/airburst event must have generated voluminous dust clouds, and there is evidence for this in four ice-core sequences from Greenland, Antarctica, and Russia, all of which show anomalous peaks in combustion aerosols such as nitrate, oxalate, acetate, and formate. According to Wolbach *et al.*, this reflects one of the largest wildfire episodes in more than 120,000 years, with some 9% of Earth's terrestrial biomass consumed.

Could it be that the cosmic event just happened to coincide with an abrupt climatic change that would have taken place anyway? Wolbach *et al.* think not: they estimate that the impact winter caused by the collision(s) would have been long enough to trigger Arctic sea ice expansion, rerouting of North American continental runoff, and changes to oceanic circulation – precisely the type of multiple climatic feedback considered by Renssen *et al.* to have ushered in the Younger Dryas Stadial. The absence of any obvious impact crater is not a deal-breaker, since, as hinted at by Bunch *et al.* (*op. cit.)*, the attributes of the Younger Dryas event could also be produced by multiple airbursts. Supporting this, Wolbach *et al.* note that the 1908 Tunguska cosmic airburst over Siberia, as well as destroying about 80 million trees and burning 500 km^2 of forest, also created features similar to those recorded in Younger Dryas boundary layers, such as magnetic spherules, meltglass, nanodiamonds and iridium concentrations.

There is a complication though. The Younger Dryas cooling also more or less coincides with the First (or Neolithic) Agricultural Revolution, which involved slash-and-burn techniques to create croplands. But was this sudden and widespread enough to cause the combustion peaks observed in the ice cores?

Problems of fracking-induced earthquakes

Last year's *Geobrowser* gave examples of how hydraulic fracturing could introduce fluids along nearby, critically stressed faults, causing their reactivation: a phenomenon already observed in the seismic activity recorded at Cuadrilla's pilot fracking site at Preese Hall, Lancashire (see *Geobrowser* for 2012). New research into this process was carried out by Durham and Newcastle universities using the microseisms generated during fracking at 109 sites in shale rock, mainly in the USA (*2018, doi.10.1007/s40948-018-0081-y*). Using advanced techniques to estimate how far the hydraulic fractures, and therefore by proxy the introduced fluids, extended horizontally from borehole injection points, they concluded that there is only a 1% chance of these fractures extending horizontally beyond 900 metres from an injection point.



Earthquake frequency plotted against distance away from fracking injection sites (After Wilson et al., 2018)

The implications of this are twofold: keeping within this distance from critically stressed faults would prevent them being reactivated by ingressing fracking fluids; furthermore, there would be a negligible chance for injected fluids or gases to enter a fault and rise upwards to contaminate shallow-level aquifers that may be used for public water supply. However this does not solve the problem of fault movements caused by waste-water injection into deep-lying aquifers, which is a separate process discussed in last year's *Geobrowser*.

This and other studies like it reviewed in previous *Mercian* issues, will feed in to the debate over whether fracking should be permitted in the UK. The research is particularly timely because in February this year the Government's Oil and Gas Authority overruled objections against Ineos Shale accessing land at the 3800-acre Clumber Park estate, near Ollerton, for the purpose of seismic exploration. With the benefits of modern high-resolution technologies the seismic profiles should pinpoint any fault affecting the shale source-rocks, and then model the structure in 3-D, thereby clarifying its stress condition and hence susceptibility for reactivation. Buffer zones could then be constructed to ensure that the fracking lines are at a safe distance from potentially unstable faults, although partitioning the resource area could complicate plans for exploitation.

It's a Square World

In April this year, Birmingham had the privilege of hosting the very first convention of the Flat Earth Society to be held in Britain. No doubt some of the 200 delegates would have found their way to the venue using satnav – which relies on satellites orbiting an essentially *global* Earth. One of the Convention's sponsors is an American organisation known as FECORE. They claim that '… mainstream science is severely hampered by faulty assumptions', the latter abounding on the colourful website describing their various 'projects'.

One convention speaker was David Marsh, a manager at a major NHS Supply Chain head office. He disagrees with the Big Bang theory, which is perhaps fair enough, but goes on to say that his own research '… supports

the idea that gravity doesn't exist and the only true force in nature is electromagnetism'. An impartial observer at the convention (*The Conversation, May 2, 2018*) noted that the speakers touted a multiplicity of competing models that included 'classic' flat Earth, domes, diamonds, puddles with multiple worlds inside, and even the Earth as the inside of a giant cosmic egg. Apparently the after-talk discussions were fairly minimal, and in this community it seems you can come up with all sorts of theories about the Earth's shape, without being seriously challenged. After all, how can a person who ignores or distorts facts, observations and even the fundamental principles of science be taken to task by another who does exactly the same?

In a Jeremy Vine Radio 2 phone-in programme, one of the convention speakers said that at first he thought the whole idea was ridiculous, but after 18 months of research decided that the Earth must indeed be flat. Based on a yacht in Penzance harbour, and therefore being of a nautical inclination, he suggests that the oceans could be confined by a giant wall of ice around the Earth's edges. Quite what happens at the tropical and equatorial regions, which can be rather warm, was not elaborated upon. Another caller neatly sidestepped the ocean spillage problem by suggesting that the Earth is one vast flat plane extending to infinity.

The extreme lengths gone to by some is exemplified by the exploits of a 61-year-old Californian limo driver, 'Mad' Mike Hughes. Mike constructed a steam-powered rocket in his garage, finally blasting off at a site in the Mojave Desert in March this year. Unfortunately he had to bale out at an altitude of about 560 metres, which was not quite high enough for him to prove that the Earth is flat (inews.co.uk, 25 March 2018). Undeterred, upon his discharge from hospital he is now crowd-funding for a more powerful, 2-stage system that will hopefully take him to an altitude of about 110 km. A rocket will be carried upwards by a gas-filled balloon, from which it will separate upon ignition, and one wonders what could possibly go wrong.

Of course the alternative theory, that the Earth is round, has been extant since at least the time of the Greek astronomer Eratosthenes (276–194 BC) and was proved, more prosaically, by Ferdinand Magellan's circumnavigation in 1519–22. But doubts have always persisted; indeed the Flat Earth Society boasts an ever-increasing membership. In explanation, *The Conversation* article noted that the level of discussion at the Birmingham convention mainly revolved around disenchantment towards existing knowledge structures, particularly those scientific institutions that supported and presented current Earth and planetary models. Creationist-type philosophies may play a part (see *Geobrowser* for 2013) in what is an essentially anti-establishment trend, much to do with the current resurgence of populism and 'fake news', and no doubt fuelled by the type of selective research facilitated by the internet.

Mike Hughes and his first rocket.

The cover photographs

Front cover

Image by Keith Ambrose of the Bantycock Quarry, at Balderton, near Newark, Nottinghamshire, of the Mesozoic succession exposed in the walls of the opencast gypsum mine.

The top 3 metres of brown, grey and paler beds are interbedded mudstones and limestones of the Barnstone Member of the Scunthorpe Mudstone Formation within the Lias Group. The lowermost limestone is mapped as the White Lias Formation of the Penarth Group.

Below, about 6 metres of the Cotham Formation appears as three distinct layers. The uppermost greenish grey unit is laminated calcareous mudstone, and the pale grey bed below is calcareous mudstone with siltstone and sandstone laminae. The lowermost, slightly darker bed is blocky calcareous mudstone.

The conspicuously dark grey bed is the Westbury Mudstone Formation, about 5 metres thick, forming the lowest unit of the Penarth Group.

The pale grey unit below, also about 5 metres thick, is the Blue Anchor Formation, the uppermost part of the Mercia Mudstone Group.

The red-brown formation at the base are mudstones of the Branscombe Mudstone Formation of the Mercia Mudstone Group. These are mainly blocky and structureless, but include some thin beds that are laminated. This formation includes thin beds of gypsum, the Newark Gypsum, and at least two gypsum beds are visible near the base of the face. The greenish grey bed near the base is a bed of siltstone.

Back cover

Images of America's red rock country on the Colorado Plateau of Utah and Arizona, from a lecture presentation by Tony Waltham to the Society in 2017.

In sequence from the top:
Monument Valley, seen from the top of Hunt's Mesa.
Antelope Canyon, near Page.
Spider Rock, 220m tall, in Canyon de Chelly.
Turret Arch, in Arches National Park at Moab.
Approach to Angel's Landing, above Zion Canyon.
Colorado River. seen from Dead Horse Point.
Goosenecks of the San Juan River.