GEOBROWSER

William Buckland: genius or 'buffoon'?

If anyone deserves the epithet of 'eccentric genius' it would have to be Professor William Buckland (1784-1856). The son of a parson, and himself deeply religious, he was nevertheless a free-thinker who acknowledged that the Earth supported life long before the existence of humans, let alone Adam and Eve. Among his many scientific achievements was the world's first formal naming of a recognized non-avian dinosaur, *Megalosaurus*, in 1824, as well as the discovery of mammal-like representatives among the same fossiliferous assemblage in Oxfordshire. He pioneered the study of coprolites, and suspected that those containing small bones in Kirkdale Cave (Vale of Pickering) were fossilized dog droppings. He confirmed this by taking into his house a pet hyaena, feeding it on live guinea pigs, and studying what was passed out (e.g. *Strange Science*, *2015*).

With his presidency of the Royal Geographical Society Buckland's reputation grew, as did his eccentricity. As recounted by Fraser Lewry *(The man who ate everything: Guardian, Feb 25, 2008)*, his role at the Society for the Acclimatization of Animals allowed him to import a virtual menagerie into Britain, fulfilling a lifelong personal ambition to eat an example of every animal in existence. No living creature was spared: mice on toast were a favourite, and guests were also treated to bluebottles, porpoise, puppy, panther and mole; although even Buckland's palate was offended by the last, which he described as being horrible' (*Augustus Hare*: *Story of My Life, vol 5, 1900*). His unique talents nevertheless enabled him to debunk the legend that a stain on the floor of St Paul's Cathedral was caused by the spillage of fresh saint's blood. Upon licking the stained flagstones, Buckland immediately identified the mystery liquid as bat urine.

Perhaps his most extraordinary exploit came on a visit to Lord Harcourt, the Archbishop of York, at Nuneham Courtenay, just outside Oxford. His host's most treasured possession was a silver casket which contained what was claimed to be the heart of the 'sun king' Louis XIV, apparently looted by activists during the French Revolution. The shrivelled item was passed around the dinner table; that is, until it reached Buckland, who promptly ate it (albeit washed down with port), observing that he had "never eaten the heart of a king before".

Realising that natural science bored many of his contemporaries, Buckland always injected humour into his talks, prompting Charles Darwin to churlishly claim that he "… was incited more by a craving for notoriety, which sometimes made him act like a buffoon, than by a love of science". Buckland has the last laugh though, when a sketch he published in 1836 was included in the Geological Society of America's 2015 session on 'The Great Images in Geology' *(Timothy Oleson; www.earthmagazine.org/article/illustrating-geology-great-images)*. There it stands alongside such icons as William Smith's 1815 geological map of Britain and the 'Duria Antiquior' of De la Beche *(see also, Mercian 2010)*. Buckland's watercolour combined an idealized cross section of European geology drawn by Scottish geologist Thomas Webster with 120 sketches of animals and plants from the different ages represented, many probably the work of Buckland's wife, Mary. Unlike the 'Duria Antiquior', which is essentially a single snapshot in time, Buckland's depiction embodied a growing perception that rock strata contained the record of life that must have evolved over a very long period of Earth history.

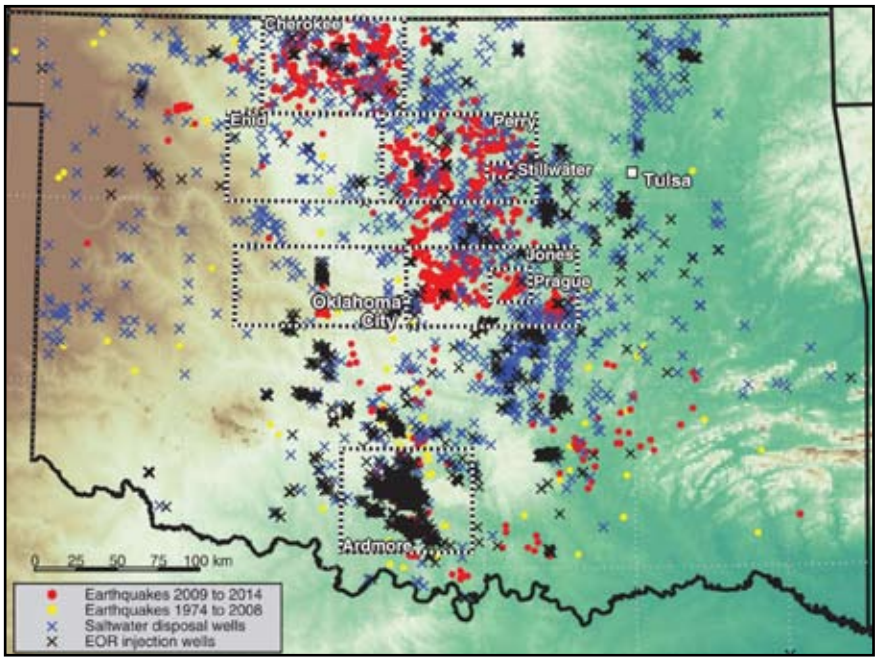
Ancient Egyptians 'mined' meteorites

At a time when 'futurists' are seriously considering mining asteroids for rare minerals and diamonds, it is worth noting that extra-terrestrial objects were greatly valued more than five thousand years ago. One of the puzzles uncovered by the famous archaeologist Howard Carter in 1925 was a dagger found within the wrapping of the teenage king Tutankhamun, dating back more than 3300 years ago. The dagger had a gold handle and was clearly a prized possession; but more than this, ironwork was extremely rare at this time in ancient Egypt, which was still in the later stages of the Bronze Age.

To investigate the source of this iron, Italian and Egyptian researchers studied its chemical composition, and found high levels of nickel and cobalt that strongly suggest an extra-terrestrial origin. They then compared the composition with known meteorites within 2000 km of the Red Sea coast of Egypt, and found similar levels in one meteorite (*Comelli et al., Meteoritics & Planetary Science, 2016: DOI: 10.1111/maps.12664)*. This meteorite, named Kharga, was discovered 240 km west of Alexandria, at the seaport city of Mersa Matruh. The researchers concluded that "…ancient Egyptians attributed great value to meteoritic iron for the production of fine ornamental or ceremonial objects". They also advanced an hypothesis that great importance was placed on rocks falling from the sky (*see also Geobrowser, 2014)*, and went further in suggesting that this finding of a meteorite-made dagger adds meaning to the use of the term "iron" in ancient texts, noting that around the 13th century BC, a term "literally translated as 'iron of the sky' came into use … to describe all types of iron". The high quality of the blade suggests that Tutankhamun was served by workers skilled in iron-working who, despite the relative rarity of the material, anticipated Western culture by more than two millennia.

This discovery also confirms what had previously been argued, for example in 2013 by Egyptologist Joyce Tyldesley of the University of Manchester, who excavated nine decorative iron beads from a cemetery near the Nile in northern Egypt. Analysis proved that they too were fashioned from meteorite fragments *(www.nature.com/news/iron-in-egyptian-relics-came-from-space-1.13091)*.

Egyptian dagger with its blade made from meteoritic iron (photo: Astronomy Magazine).



Locations in Oklahoma of the recent earthquakes (2009–2014), historical earthquakes (1974–2008) and of wells, used either forenhanced oil recovery (EOR) or for saltwater disposal, where injection exceeded 30,000 barrels (~4800 m^3) in any month within the most recent three years of data (from Walsh & Zoback, 2015).

Fracking and earthquakes

Last year's *Geobrowser* discussed issues over groundwater contamination associated with high-volume hydraulic fracturing ('fracking'), or rather the wells drilled for that purpose. However, the magnitude 2.3 and 1.5 earthquakes recorded at Cuadrilla's experimental shale gas site in Lancashire (*see Geobrowser, 2012*) highlighted another concern that will become prominent in the lead-up to fracking, should the government of the day push ahead with it. There are indeed some extreme examples of earthquake swarms directly related to exploitation of the major shale oil and gas producing regions of North America, and fluid injection at depth is the main culprit. The problem is complex, however, and in case studies from Oklahoma and Alberta, two different modes of fluid injection are implicated.

In Oklahoma, researchers have found that the underground disposal of 'waste' fluid (flowback fluid) left over from fracking was the main cause of a startling increase in seismicity (*Walsh & Zoback, 2015, doi: 10.1126/sciadv.1500195)*. In this process waste fluids are injected into dedicated saltwater disposal (SWD) wells that intersect sedimentary formations with high porosity and permeability. Unexpectedly however, this caused an increase in pore pressures throughout the aquifers, resulting in slippage along already-stressed fault planes. The result is that earthquake frequency has greatly accelerated in a state where, prior to 2008, there were only a few 'historical' events distributed over a relatively wider area. In 2015 for example, some 900 earthquakes of magnitude 3 or greater were recorded (*Associated Press; March 08, 2016*). Moreover, Walsh and Zoback found that far more damaging events could not be ruled out in the future; the prediction was soon fulfilled by the magnitude 5.8 Pawnee earthquake of 2016. The strongest ever recorded in the state's history, it caused damage up to 300 miles away and precipitated the immediate closure of 69 fracking wells around the epicentre.

In our second example, from the Alberta Province of Canada, hundreds of quakes have been recorded in a major fracking region (*huffingtonpost.ca/2016/11/17/fracking-earthquakes*). There, researchers have found that underground fluid disposal was not the primary cause of this induced seismicity. Instead, it seems that certain faults were preferentially reactivated by increased pore pressures initiated during the hydraulic fracturing process itself - a conclusion also reached for the Lancashire seismicity.

Although fracking will never be carried out on such a vast scale in Britain, where prospective areas (as opposed to the licence blocks) are much smaller, the North American (and indeed Lancashire) examples show that some induced seismicity can be expected. On the plus side, copious amounts of research in the USA are suggesting that whatever the cause, the problem can be controlled and mitigated by better regulation involving a combination of strict seismic monitoring along with geological and hydrological modelling of the fracking prospects. This responsible approach is embodied in the UK Environment Agency's most recent guidelines (*EA Onshore Oil & Gas Sector Guidance, Version 1 August 2016*), which state that: '*Operators must carry out prior geological analysis to identify natural faulting, background monitoring of seismicity before operations start and on-going monitoring during operations. Operators must also submit a Hydraulic Fracturing Plan to the Oil & Gas Authority for approval. Operators must use the 'traffic-light system' to ensure that operations can be stopped quickly and reviewed if seismic activity is detected. If the magnitude increases the operation may need to be reconsidered or stopped altogether*.' These regulations indicate an intention to deal with the problem but are unlikely to satisfy the most hard-line anti-fracking groups, some of whom oppose borehole drilling, even for monitoring purposes.