Newsletter No. 287

October 2024

The Black Country Geological Society

www.bcgs.info

Contents:

Copy date for the next Newsletter is Sunday 1 December

To find out more about this photo - read on!

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For enquiries about field and geoconservation meetings please contact the Field Secretary.
Please notify Andy Harrison in advance if you will be attending these events.
To submit items for the Newsletter please contact the Newsletter Editor.
For all other business and enquiries please contact the Honorary Secretary.
For more information see our website: bcgs.info, YouTube, Twitter: @BCGeoSoc and Facebook.

Future Programme

Change of Meeting Venue

The Dudley Archives will no longer be available for our meetings due to Council funding cuts.

We have booked the Lamp Tavern, 116 High St, Dudley, DY1 1QT for all our indoor meetings through the 2024 - 2025 season.

7.30 for 8.00 o'clock start unless stated otherwise.

Visitors are welcome to attend BCGS events but there will be a charge of £1.00.

Monday 21 October *(Indoor Meeting):* **'Volcanic Tsunami Hazards - lessons from Krakatau, Hunga Tonga and beyond'. Speaker: Dr Seb Watt** (University of Birmingham).

Monday 18 November *(Indoor Meeting):* **Dr Duncan Murdoch from Oxford Natural History Museum** will speak on an aspect of his work at the museum (title TBC)**.**

Saturday 14 December *(Geoconservation Day):* **Portway Hill, Rowley.** With the Friends of Rowley Hills and the B&BC Wildlife Trust. To work at the dolerite exposure in the former quarry. Meet at St Brades Close, off Tower Road for 10.00 (Grid ref: SO974893, nearest PC: B69 1NH). Directions: from Birmingham New Road (A4123) turn left on to Tower Road if coming from Birmingham, right if coming from Wolverhampton. Just after Bury Hill park, turn left onto St Brades Close. Wear old clothes, waterproofs and strong footwear. Please bring gloves. Tools provided, or bring your own. Bring a packed lunch, hot drinks provided. Finish around 2.30.

Monday 16 December *(Indoor Meeting, 7.00 for 7.30 start):* Members' Evening and Christmas Social. This is our annual chance for members to share their geological experiences in a sociable atmosphere with a Christmas buffet provided by the Society.

Contributions needed from you!

We need a few of you to volunteer to do a short presentation - on any topic with geological connections; or perhaps bring some of your specimens for admiration, discussion and identification. Please contact Mark Jeffs if you can contribute to this event: honsec@bcgs.info

Other Societies and Events

Geological Society, West Midlands Regional Group

Tuesday 12 November: 'Revealing the Geology of the Lickey Hills - the continuing importance of the amateur geologist'. Speaker: Alan Richardson. Until recently, the geology of the Lickey Hills has been poorly understood, despite their proximity to Birmingham. This talk will explore new evidence of their evolution.

Lectures are being held at Mott MacDonald, 10 Livery St, Birmingham, B3 3NU and by Zoom. They commence at 6.00 for 6.30. For further details please contact the Group Secretary at: geolsoc_wmrg@live.co.uk Click here for website.

Open University Geological Society, West Midlands

Geology Day Schools: The Open University Geological Society offers an annual series of practical geology day schools designed specifically for students new to the earth sciences. The programme comprises five laboratory-based sessions and one field day. Starting in November with the practical identification of minerals, the programme progresses through the analysis and interpretation of igneous, sedimentary and metamorphic rocks, followed by a day devoted to the study of rocks in thin section using the petrological microscope. The workshops are tutored by Alan Richardson, who has 45 years experience of teaching geology.

The sessions take place on Saturdays at the **Lickey Hills Country Park Visitors' Centre (B45 8ER).** Parking is free. The nearest station is Barnt Green (2.2 miles) on a direct line from Birmingham New Street. The field skills day is run in the Bridgnorth area in Shropshire. Non-members are welcome. **A charge of £10 is made for each event.** This covers workbooks, published course guides and the use of all the necessary testing equipment.

For full details of these Day Schools, please visit the West Midlands page of the Open University Geological Society: https://ougs.org/westmidlands/

Lapworth Museum Events

Monday 14 October 5.30 - 7.00: 'How did Large Igneous Provinces change global climate so rapidly?' Speakers: Dr Steve Jones and Dr Manfred Capriolo.

Venue: Lecture Theatre WG12, Ground Floor, Aston Webb Building (R4). There is no admission charge and all are welcome to attend. For more information: https://www.birmingham.ac.uk/facilities/lapworth-museum/events

Woolhope Naturalists' Field Club - Geology Section

Friday 18 October: 'A geological journey through Iceland'. Speaker: James Creswell, Geoworld Travel.

Non-members are welcome and pay £2. More info. at: https://www.woolhopeclub.org.uk/meetings

Shropshire Geological Society

Sunday 13 November: 'The wondrous variety that are mudstones'. Speaker: Prof. Kevin Taylor (University of Manchester).

Meetings commence at 7.15 for 7.30. Lectures are now being held in hybrid form, in person at the Higher Education Centre, Shrewsbury College, as well as by Zoom. If you wish to attend please contact Albert Benghiat: 07710 421 581, email: SGS.chair@hotmail.com
Further information: https://shropshiregeology.org.uk/

Teme Valley Geological Society

Monday 28 October: 'When the Law of Superposition does not work: what Nicolaus Steno and William Smith did not know about some carbonate successions'. Speaker: Dr. Paul Wright.

Monday 25 November: 'The story of flint: a (really) close look at an old friend'. Speaker: Chris Clayton, Rtd. Geochemistry Consultant.

Talks take place in Martley Memorial Hall at 7.30. Non-members £3. For further information email: enquire@geo-village.org or visit: https://geo-village.org/

Mid Wales Geology Club

Wednesday 16 October: 'Walking with trilobites'. Speaker: Roy McGurn.

Further information: Web: http://midwalesgeology.org.uk lectures start at 7.15 and are a hybrid of in person meetings at Plas Dolerw, Newtown, SY16 2EH and via Zoom. Those wishing to join a meeting remotely should contact the secretary, Chris Simpson, at christopher_s@btinternet.com

The Geologists' Association - Festival of Geology

Saturday 2 November: At the Geological Society, Burlington House, Piccadilly, London, W1J 0BG.

- Exhibits by societies, universities and museums, with minerals and fossils for sale
- Talks
- Books
- Activities for children

Sunday 3 November: Field trips to the Crystal Palace dinosaurs, Lesnes Abbey Woods and City of London geology.

For more info: https://geologistsassociation.org.uk/

Warwickshire Geological Conservation Group

Thursday 17 October: 'Carnian Pluvial Event'. Speaker: Mike Simms.

Friday 18 October: 'Urban Geology tour of Warwick'. Led by Dr John Radley.

There is a charge of £2.00 for non-members. For more information visit: https://www.wgcg.co.uk/ or email: WarwickshireGCG@gmail.com.

Editorial

Our first talk of the season took place in The Lamp Tavern, 116 High St, Dudley on Monday 16 September. The talk was by Peter Glews on the subject of H.W. Hughes, 'A Man of Coal'. Peter showed us an amazing sequence of photos taken in the early days of photography capturing the underworld life of miners. For those who missed it, John (webmaster) is preparing it to go with the growing collection of our talks on our YouTube channel. He will let you know when it has been added. For old photos don't forget that we have a growing collection on the BCGS website here: https://bcgs.info/pub/bcgs-photo-archive/ Maybe some of you have some memorable snaps from BCGS events going back to our origins in 1975. It would be good to extend our collection for our 50th anniversary celebrations next year! Please send them to John: webmaster@bcgs.info

Our new venue got the thumbs up from those who attended Peter's talk. It combines the wonderful atmosphere of a friendly, traditional pub with a lift to a comfortable meeting room on the top floor. An unexpected bonus was the picture window providing panoramic views to the Clent, Abberley and Malvern Hills and beyond! The room is now booked for all our indoor meetings for the 2024 - 2025 programme.

In this issue we bring you, as usual, our programme of events to date, and a summary of other societies' activities where we have information for the next two months. Andy reports on our field visit to the Tardebigge area in July led by Mike Allen, and there is more from Mike in part 2 of his Musing 'Gifts from Heaven?' Mike Williams gives us another short item to ponder on - this time telling the intriguing story of the River Loud in Lancashire. Enjoy! ■

Julie Schroder

Field Meeting Report

Sunday 28 July: Field Visit: Tardebigge, Bromsgrove. Led by Mike Allen (BCGS and Warwickshire Geological Conservation Group – WGCG).

It was a fine, sunny, warm day for our July field visit to Tardebigge with WGCG. We met Mike around 1.00pm at St. Bartholomew's Church, Tardebigge, for a gentle circular stroll looking at Triassic mudstones and sandstones and their influence on the local landscape.

Tardebigge village is situated approximately 4km south-east of Bromsgrove, Worcestershire and includes a smattering of houses, a village hall and St Bartholomew's Church, which dates to 1777. The roughly north-east to south-west trending Worcester & Birmingham Canal runs through the village and to the west is a flight of 30 canal locks that raise the canal over 67m (220 feet).

To the east is a roughly north-west to south-east trending ridge that carries the Alcester Road (B4184) and Bromsgrove Highway (A448) from Bromsgrove and past the village. From the ridge, ground elevations fall from roughly 160m Above Ordnance Datum (AOD) in the east, to 80m AOD around Bromsgrove in the west.

Starting from St Bartholomew's Church car park, we initially followed a footpath to the east where, exposed in a small shallow quarry, were examples of Bromsgrove Sandstone, alternatively known as the Helsby Sandstone Formation. A fine to medium-grained, cross-bedded and red-brown sandstone from the middle Triassic, this stratum formed under fluvial and aeolian conditions from rivers flowing across arid floodplains. This stratum underlies the ridge to the east of the village and a broad area underlying Bromsgrove to the north and north-west.

Bromsgrove Sandstone quarry

Returning to St Bartholomew's Church, we headed south, crossing High House Lane, across flat, gently sloping, golden open fields. Underlying this area and extending southwards and towards the west, is the Sidmouth Mudstone Formation (formerly the Eldersfield Mudstone Formation), which belongs to the late Triassic Mercia Mudstone Group. Typical to the Worcestershire and Knowle Basins, this stratum generally comprises reddish-brown mudstone and siltstone with greenish-grey reduction spots and veining.

The Mercia Mudstone Group includes several divisions, represented to different degrees across this stratum's extents. The Sidmouth Mudstone Formation occurs towards the bottom of the Mercia Mudstone Group sequence, which includes:

- Blue Anchor Formation;
- Branscombe Mudstone Formation;
- Arden Sandstone Formation;
- Sidmouth Mudstone Formation; and
- Tarporley Siltstone Formation. ►

View South towards the Malvern Hills and the Worcestershire graben

Like all the Permo-Triassic sedimentary deposits, the Mercia Mudstone Group was deposited within a large intra-continental basinal tectonic setting, resulting from tensional stresses within the Pangaea crust following the Variscan Orogeny. These stresses produced numerous roughly north to south trending rift basins (grabens) across Britain and would eventually lead to the North Atlantic opening around 200Ma. With the area sitting at between roughly 15° and 20° north of the equator, at a similar latitude to the Sahara today, the climate has been interpreted as having a monsoonal nature with prevailing winds from the north-east or east and high rainfall events that led to periodic flash floods.

The Mercia Mudstone Group has been interpreted as forming within subaqueous, hypersaline and evaporitic mudflat environments. Over the mudflats, four main depositional processes prevailed and included: 1) settling out of mud and silt within brackish or hypersaline water bodies; 2) flash floods transporting and rapidly depositing sheets of silt and sand; 3) accumulating wind-blown dust on the wet mudflats; and 4) chemically precipitated salts, mostly halite and gypsum, from marine-sourced hypersaline water bodies and contemporary groundwater.

On our walk, upon reaching the southernmost field boundary, Mike showed us examples of halite pseudomorphs within mudstone/siltstone fragments scattered on the bare soil *(see front cover photo).* Such features provide evidence for the former saline and hot conditions from which salts chemically precipitated.

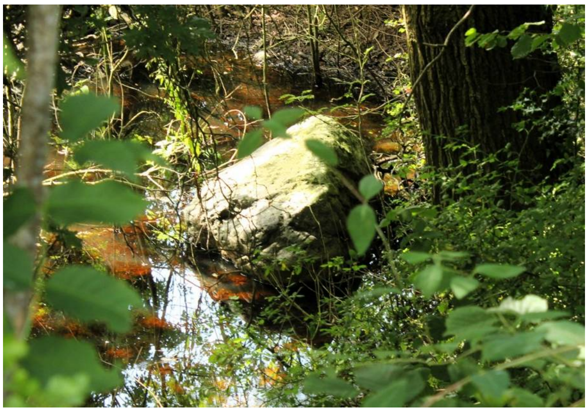
Within the Sidmouth Mudstone Formation, the British Geological Survey (BGS) Map, Sheet 183, dated 1988, for the Tardebigge area, shows numerous blue bands trending roughly east to west. These bands represent thin bluish or greenish grey, often dolomitic, sandstone units known as skerries that sit at various horizons within the Mercia Mudstone Group. In places, skerries are noticeable at surface as distinctive breaks in slope. On the gently sloping ground west of Tardebigge, sudden slope breaks hinted at where skerries may occur *(see photo at the bottom of p8).*

Within the vicinity of Tardebigge, the Permo-Triassic tensional stresses created graben structures such as the Worcestershire and Knowle Basins, through which the Severn Valley and Vale of Evesham pass. Numerous north to south trending faults define these basins and include the Lickey Fault, which is situated close to St Bartholomew's Church. Here, the fault has downthrown the younger Sidmouth Mudstone, to the west, against the older Bromsgrove Sandstone, to the east. ►

Worcestershire and Birmingham Canal

Heading back across the fields to High House Lane, our route continued west to London Lane. Looking south, we had great views towards the Worcestershire Basin and Severn Valley with the Cotswolds to the east and the Malverns in the west.

No superficial deposits cover the bedrock geology immediately around Tardebigge. As our route passed High House Farm and approaching the junction with London Lane, we began to notice a change in the geology and glacial boulders placed along the grass verge either side of the farm entrance. For this stretch, our route coincided with the Birmingham Erratic Boulders Project - Glacial Boulder Trail 6: Around Bromsgrove and Tardebigge. On the BGS map, the high ground west of High House Farm, above Tardebigge Reservoir, is covered with Glacial Till, from which the glacial boulders have been derived.



Large glacial erratic boulder in a hollow below the track towards Patchett's Farm

Crossing London Lane and continuing along a farm track leading to Patchett's Farm, we encountered several more glacial boulders. Along with those at High House Farm these boulders correspond with Localities 4 and 5 on the Glacial Boulder Trail 6. The boulders are predominantly volcanic ash that originated from the Arenig Mountains in North Wales, but also include occasional quartz ones. They were deposited around 450,000 years ago during the Anglian ice advance.

The Tardebigge Reservoir

Before reaching Patchett's Farm, our route struck off northwards, briefly leaving Trail 6 and heading downhill to the Tardebigge Reservoir. This large, man-made lake is bunded along its western edge and was built to feed the Worcester & Birmingham Canal. The lake covers roughly 25 acres (100,000m^2) and is up to 12m (40 feet) deep. It is also home to many mallard ducks and Canada geese.

Following the lake's western and northern edge eastwards, we continued along the Worcester & Birmingham Canal, passing several of the 30 locks back towards Tardebigge. Leaving the canal and entering a field just west of St Bartholomew's Church, Mike pointed out a distinctive break in slope where two tree-choked, disused pits were located. Whether the pits were worked for clay or sandstone is unknown, however, it is thought that they may represent workings within a skerry band that potentially accounts for the slope break seen in the field. ►

Two tree-choked, disused pits and slope change hinting at sandstone skerries.

Crossing the field, we returned to St. Bartholomew's Church, where our walk finished, with a chance to look at the church itself. The church is constructed from Bromsgrove Sandstone, which shows clear evidence of cross-bedding and ripple beds. The source for this sandstone is likely to be from the small quarry we saw at the start of the walk to the east of St Bartholomew's Church.

St. Bartholomew's Church and Bromsgrove Sandstone

Returning to the car park, we completed our walk around 5.20. I would like to thank Mike for a very interesting day out and hope that we can team up with the WGCG again soon. ■

Andy Harrison

References:

British Geological Survey (BGS) Map Sheet 183, 'Redditch', 1:50,000 Series, Solid & Drift, dated 1988.

British Geological Survey, 'Engineering Geology of British Rocks and Soils, Mudstones of the Mercia Mudstone Group', Report RR/01/02, NERC 2022.

'Birmingham's Erratic Boulders: Heritage of the Ice Age', Glacial Boulder trail 6, 'Around Bromsgrove and Tardebigge', 2023.

The Enigmatic River Loud

The River Loud

Think of the Forest of Bowland, and Carboniferous reef knolls, crinoid ossicles - and shales capable of yielding natural gas probably come to mind. However, a recent visit revealed a river system clearly a misfit for the size of its valley and flowing in completely the wrong direction to conform with drainage patterns observed from the West Pennine watershed. Our local guide claimed that the 'Loud' is the longest eastward flowing river in England to eventually discharge into a westerly flowing river system.

The answer to this reversal of drainage in the Vale of Chipping lies in its glacial history. Competing lobes of Irish Sea and Pennine ice, the latter flowing down a proto-Ribble valley, clashed in the Longridge area of Bowland. This effectively blocked the western end of the vale and necessitated a reversal of the drainage pattern eastward to find a new exit to the Irish Sea via the River Hodder which then joins with the Ribble just south of Clitheroe and then hence to the Irish Sea. ►

I think our former field secretary, Andrew Rochelle, would have liked this one! *(Andrew Rochelle was BCGS field secretary until his untimely death in January 2006. He was especially interested in glacial geomorphology. An obituary can be found on our website in Newsletter 175, February 2006. Ed.)* ■

Mike Williams

References

Geolancashire (The Lancashire Group of the Geologist's Association) offer a series of excellent downloadable guides under the title of 'Ribble Valley Geotrails' in particular.

Ribchester Geotrail Section 3 – a detailed discussion on the evolution of the Ribble Valley.

Brockholes Geotrail Section 4 - impact of glaciation in the Brockholes area.
Section 5 - glacial erratics.

Mike's Musings No. 53

Gifts from Heaven? (Part 2)

Fig. 1: Artist's concept of collision
Wikimedia Commons

Following on from a brief round-up of the various celestial bodies with which we share the universe *(Newsletter 286, August 2024)* and in particular that tiny part we call the solar system, we can see from the traces they leave behind them that on occasion the smaller bodies we refer to as **asteroids** have, in the past, collided with our planet. And there is no reason why they won't repeat this performance again in the future, which makes a great subject for the 'disaster-movie' industry. But while we can't see into the future, we can at least examine past situations.

Perhaps the largest impact event to involve our home planet took place around 4½ billion years ago when, it has been suggested, a 'Mars-size' planet (called Theia) collided with the infant Earth resulting in the formation of our Moon: the widely accepted 'giant-impact hypothesis' (Fig.1).

Leaving such a momentous event aside, we are aware of around 35,000 near earth objects (Fig.2); an awareness that has come on in leaps and bounds since the turn of the millenium (Fig.3). These are mainly classed as **near-earth asteroids**, but include some falling under a wider definition of a **meteoroid** as well as a hundred or so **comets**. Of these, some 2,400 are perceived as potentially hazardous, i.e. large and / or close enough to make their presence really felt! They are not necessarily believed to be on a direct collision course as their trajectories have not been well enough established for this to be the case, besides which, gravitational perturbations can alter paths which may otherwise lie just beyond the range of a possible strike. Nonetheless, we now live in an age in which we recognise their threat as real. Agencies exist to track such objects and provide some semblance of an early warning system. Other agencies exist to investigate what, if anything, can actually be done to protect ►

ourselves against this hazard; all very comforting I'm sure!

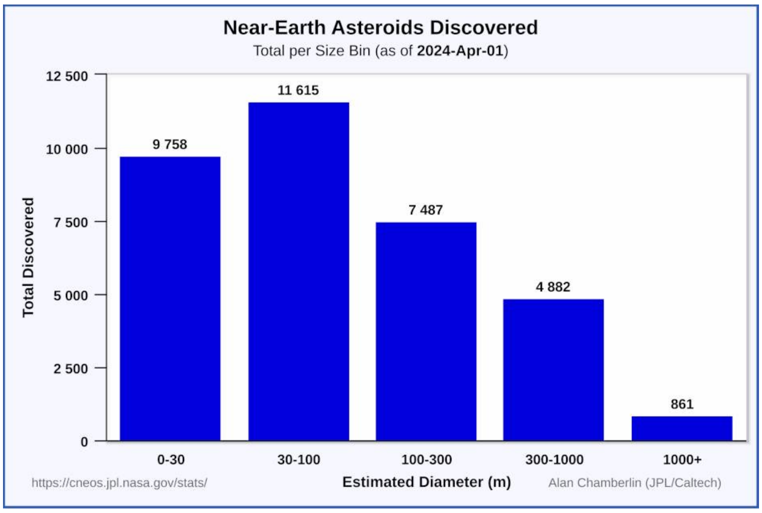


Fig. 2: Known near-Earth asteroids by size
Wikimedia Commons

Perhaps not the 'gifts from heaven' we would wish for, asteroid impacts have certainly left their mark, not just on Earth but on our other close neighbours. Indeed, we recognise a period in the early history of the inner solar system when the intensity of impacts was especially high. This 'Late Heavy Bombardment' period, between around 4.0 to 3.8 billion years ago, left the Moon (and Mars) scarred as we see them today, while most of the damage to the early Earth has been removed by weathering and erosion, due to the presence of our dynamic atmosphere.

Notwithstanding the reshaping effect weathering has on the face of our planet, just under 200 impact craters are generally recognised around the world (Fig.4). They come in all sizes and on all continents, a few even scarring the sea-bed. Tell-tale features associated with impacts (other than an obvious crater, if it still survives) include shock-structures such as high-pressure shatter cones (Fig.5), shock-lamellae induced in quartz or other strong minerals and high-pressure phases of certain minerals, such as coesite or stishovite, which are high-pressure forms of quartz. With large impacts much material is vaporised, often entirely consuming the impactor itself and leaving no evidence as to its nature. In smaller and more recent events fragments of the actual impactor do survive, but ancient impact sites rarely yield such material either because it remains deeply buried, or because it has been lost through erosion.

A broader range of 'impact lithologies' may arise during such a collision, depending on the exact mechanics involved. The celebrated 15 million year old **Ries Crater** in southern Germany illustrates such variations. In this instance fractured crystalline breccias which were formed in situ rather than through ejection, survive in the centre (deepest part) of the crater. These are covered by so-called **'suevite'**, a complex breccia containing much glassy melt-rock and both crystal and lithic rock fragments (Fig.6). Overall it resembles a 'gas-rich, well perforated' volcanic tuff. Some of the suevite was ejected early on during the impact and remained airborne longer than the disrupted sedimentary rocks at the impact site which, being varied, produced another colourful kind of 'ejection-breccia' locally known as the '**bunte trümmermassen'**. This was formed from the 'rain' of material that fell back to Earth before the ejected suevite, both of which survive mainly ►

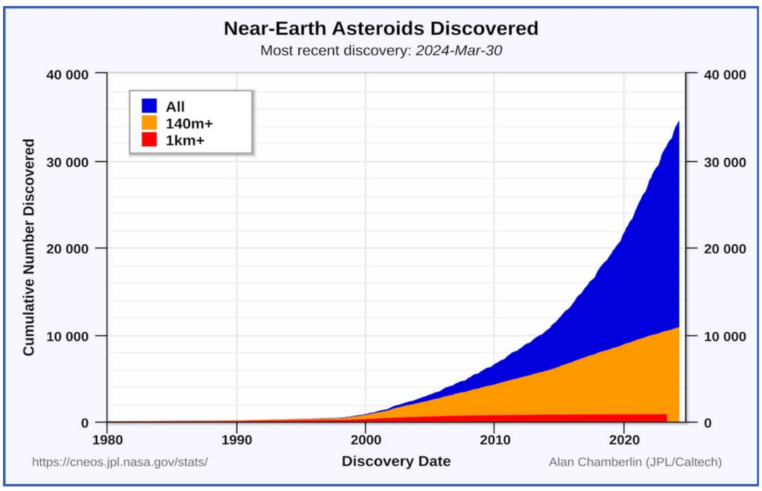


Fig. 3: Cumulative discoveries of near-Earth asteroids over time
Wikimedia Commons

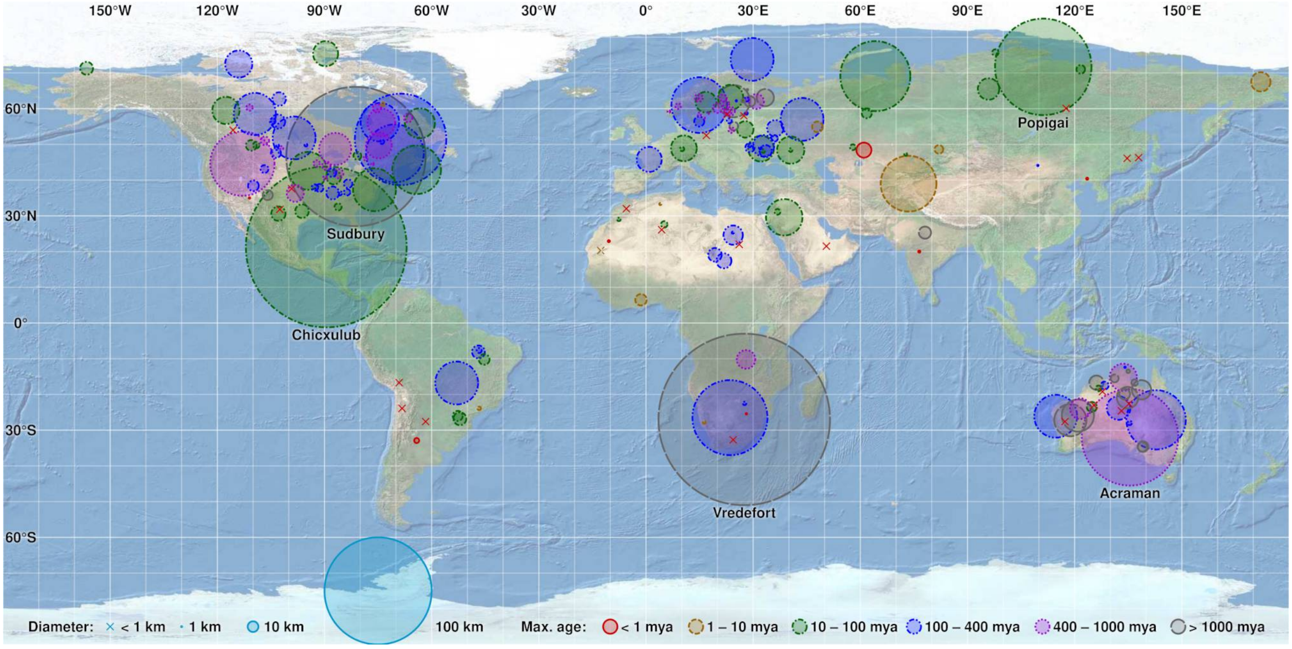


Fig. 4: World map of craters on the Earth Impact Database by CMG Lee - Wikimedia Commons

around the crater margins. A third kind of 'impactite' was produced in the form of larger globules of melt-rock known as a tektite, of which I shall have more to say in my next piece.

The nearby, smaller, **Steinheim Crater** is of the same age and may have been caused by a separate fragment from the same asteroid. Much of the sedimentary target rock in this crater shows clear evidence of shattering and wholesale fracturing (Fig 7). There are several other instances of possible multiple impact events amongst the list of the world's impact sites, but none have been definitely sustained as far as I am aware.

The first impact site to be recognised (at least in the scientific literature) appears to have been the **Barringer (or Meteor) Crater** in Arizona (Fig.8). An extremely obvious 'hole in the ground', at just over a kilometre in diameter, this is just a baby alongside many of the others. However, it does have the honour of having been the first to be universally regarded as resulting from the impact of an extraterrestrial object, and really began all such studies. Meteor Crater has an almost circular rim rising almost uniformly 45 metres above the surrounding Arizona desert, the flatness of which makes the crater stand out particularly clearly. The floor of the crater is also flat and about 100 metres below the level of the desert floor. Its inner slopes are steep and rugged contrasting with its outer ►

Fig. 5: Shatter Cone from Steinheim Impact crater by Johannes Baier, Wikimedia Commons

slopes which are gentle, and the normal horizontal bedding is upturned around the perimeter, in places being overturned producing an inverted sequence of the sedimentary bedding. Overall it has a very 'fresh' appearance due to its desert location and from being just 50,000 years or so old ('yesterday' in geological terms!). Many fragments of the nickel-iron impactor have been recovered: 30 tonnes of 'large' meteorites plus an estimate of around 12,000 tonnes in the form of micro-meteorites ('meteorite dust') in surrounding soils up to a distance of 10 km from the crater edge. Impact glass and shock structures have also helped to prove its impact credentials, and do away with the original notion of the US geological survey that the crater was of volcanic origin. With increased understanding, other craters once attributed to volcanoes have now been re-interpreted as impact structures.

Fig. 6: A sample of Suevite from Ries... the grey, bubbly parts are the melt rock fragments

Better known, thanks to all the publicity of recent decades, is the much mightier **Chicxulub Crater** (Fig.9), even though the crater is very far from obvious, with much of it offshore around the Yucatan peninsula in Mexico. Its fame is largely due to its age (around 66 million years) coinciding with the final demise of the dinosaurs, to which it certainly contributed (if not entirely so). The size of this crater is often quoted as anywhere between 150 and 200km diameter (and 20km deep), making it the second largest crater on Earth generally recognised. Only the very much older (approximately two billion year old) **Vredefort Crater** tops this, at between 160 and 300km diameter according to various sources. There are other contenders, but as with all statistics, some are not fully accepted, and all dimensions are open to interpretation! Two more huge craters with their centres offshore, **Bedout High** (200km) off the north-west coast of Australia and **Shiva** (? 500km!) off the west coast of India, have been reported, but both have been questioned. However, their respective ages (rather better constrained than their size) of 250 and 65 million years are curiously in line with both the end-Permian and end-Cretaceous mass extinction events. Yet another gigantic (c. 500km) crater, possibly of impact origin, has been detected in **Wilkes Land** beneath the ice of Antarctica and also dated at around 250 million years ago.


Fig. 7: Highly fractured 'target rock' (Jurassic limestone) from the rim of the Steinheim Crater

It would be extraordinary indeed if two such climactic events (Chicxulub and Shiva and/or ►

Bedout High and Wilkes Land) had occurred at more or less the same time, and even more amazing if they were actually related to single gigantic asteroids breaking into two… dare I say some things are just too hard to believe!

Only three other structures in excess of 100km diameter are generally accepted: **Sudbury** (in Canada) at around 140km diameter, depending on who you believe, **Manicouagan** (also in Canada) just tipping the 100km mark and **Popigai** (in Siberia), perhaps not quite reaching the mark, between 90-100km diameter. These are dated a little more assuredly at 1849, 216 and 36 million years respectively and have, again respectively, the world's largest copper-nickel deposit, a 100 metre layer of melt rock and a two kilometre layer of suevite sprinkled with tiny diamonds to distinguish them. The two latter events have, however, also been associated with two lesser mass extinctions by some authorities, so Chicxulub may not be at all unique in this respect.

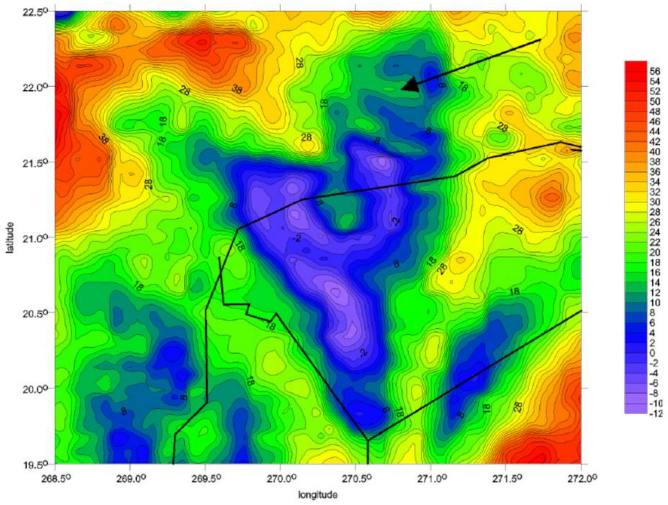


Fig. 9: Chicxulub Free-Air Gravity anomaly from EGM2008 global dataset, from Klokočník at al. 2010 Figure 4 Wikimedia Commons

Indeed, it makes reasonable sense that such impacts occurring from time to time might lie behind all 'significant' extinction events. And, before we dismiss asteroid impacts as being wholly bad things, we should reflect that without Chicxulub (with or without Shiva) it is just possible that the evolutionary trajectory of life on Earth might have taken a very different course, completely by-passing humankind altogether, although some would argue that a 'higher-intelligence' (or human-like entity) was bound to evolve at some stage.

So much, then, for the history of large impact events. Part 3 will focus on the smaller end of the size-spectrum and deal with **meteorites**, as defined in Part 1, and **tektites** as mentioned above. ■

Mike Allen

Fig. 8: Meteor Crater by Tsaiproject - Wikimedia Commons