MAY 2025

GSS Geoscience

Informal article: "The Silverpit Crater – Evidence of a Dinosaur Killer?"

By Mike Bidgood

DINOSAUR EXTINCTION

Hands up who *doesn't* know about dinosaurs and what made them go extinct? Very few of you! If you were a child (or indeed an adult!) after 1993 when the movie "Jurassic Park" came out, and TV series like "Walking with Dinosaurs", then you probably know all about the Asteroid that wiped them… and over half of Earth's other species… out [2].

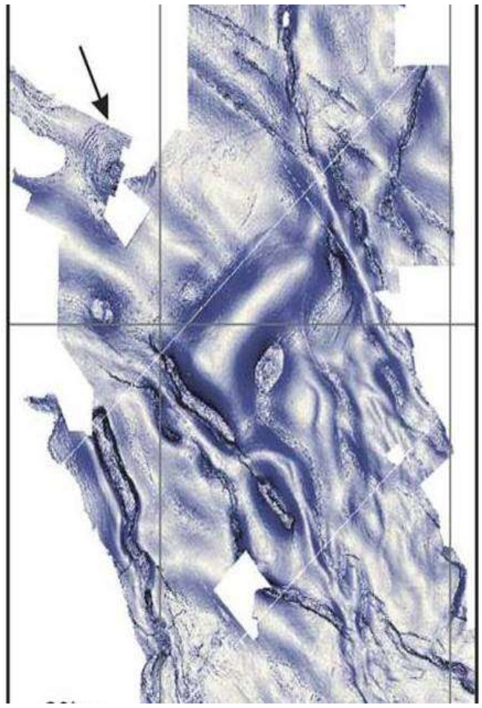
Weirdly, we have never given that asteroid an official name, but simply know that it caused the extinction of the dinosaurs and many other animal & plant groups about 66 million years ago, and that it also left hints of its location in what is known as the **Chicxulub Crater** on the Yucatan Peninsula of Mexico. The size of that crater suggests that the "Chicxulub asteroid" was about 10 kilometres across.

But what if it were not the *only* asteroid that hit Earth at that time? Could there have been more than one, as yet undiscovered?

Let's find out…

The Silverpit Crater – Dinosaur Killer?

In the early 2000s, a consultant geologist called Phil Allen was working for BP on their North Sea prospects. Using a well-known technique called Seismic Imaging, geologists can use sound wave reflections to "see" what structures look like beneath the surface of the Earth. Whilst looking for potential new North Sea oil and gas fields, Phil noticed something unusual tucked away in the corner of one of his seismic images. Pinning a copy of the image to a notice board, he added a Post-It note asking his colleagues if anyone had ever seen something like this before? The answer he got back – to say the least – surprised him…



The image that started it all – the partial concentric ring structure is shown arrowed near the top left.

Normally geologists look at seismic images "from the side" – that is, they see a "cross section" of rocks with older layers at the bottom and younger layers near the surface. Phil however, was looking at the seismic data from above, like a map, albeit with many hundreds of metres of overlying sediment removed. What Phil had seen was a partial image of what looked like a series of more or less concentric rings. The whole structure of the circular part was not present – the seismic imaging only covered the north and west quadrants of the rings. However, it seemed to look like some kind of "bullet hole" was present beneath the Earth's surface. And it was only 150 km from the coast of Yorkshire.

Phil was intrigued but hoping to find a definitive answer he asked his colleagues if anyone had seen anything like this before, by way of a Post-It note attached to the seismic map pinned to the wall. A few days later, someone wrote back…

"Not on this planet!"

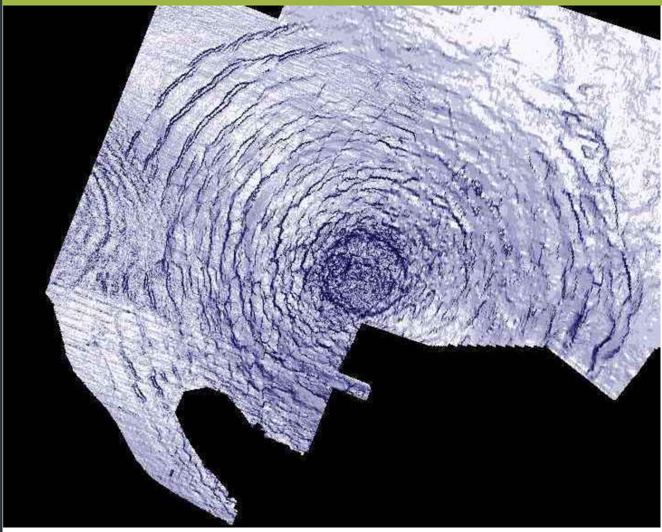
SEISMIC IMAGING

Sound travels very well through solid objects like rocks. If you send a bunch of soundwaves down into the ground, some of them will be reflected back at the boundaries between different rock types and by surfaces like fault planes.

The returning signals ("echoes") can be collected and processed and turned into artificial images of what the rock layers underground look like. It is not cheap to do and – especially if you are surveying under water – can be very expensive. The seismic imaging technique that discovered the Silverpit Crater is known as "3D" because the generated image can be viewed in a 3-dimentional "volume" and looked at from all angles, from side-on (a "cross section") to directly downwards from above (like a map).

Seismic images are good for seeing the gross structure of subsurface rocks, but are not so good at zooming-in on the fine detail, such as knowing the precise ages or depth-below-surface of the rocks they are displaying.

The global resources exploration industries spend billions of pounds on seismic surveys. Analysis of seismic events in real-time can also help in earthquake prediction.



"What do you mean '*Not on this planet!*'"???

Structures like the Silverpit Crater have been observed on Jupiter's moons.

Further discussions and studies, particularly with BP staff geophysicist Simon Stewart, suggested that the rings Allen had observed were similar to those caused by impact craters elsewhere in the Solar System, particularly on Jupiter's moons Europa and Callisto, visible at the surface. Stewart & Allen announced their find of this 20km-diameter crater in the journal Nature in 2002 [13]. They called it the "*Silverpit Crater*", named after a local North Sea fishing ground.

More data was acquired from other seismic surveys and a better image of the crater was produced (see above), together with a cross section. More papers were published [1, 14].

From the start of the project, Allen and Stewart were convinced the Silverpit Crater was indeed a crater – it had been formed by an impact of an extra-terrestrial object. To be fair, other geologists proposed alternative explanations for the crater's origins which did not involve an impact [12, 15, 16]. For example, even deeper below the North Sea lay thick layers of salt deposits. When buried, and under pressure, salt can behave like a thick and very viscous liquid.

This extremely thick salt liquid – less dense than the surrounding rocks – can "migrate" upwards through overlying rocks and push those rocks up into domes. They can also later withdraw from those domes in the same way, leading to the overlying rocks collapsing in a way that would result in structures very similar to Silverpit. Without direct evidence (a "smoking gun") the origins of Silverpit are, and remain, difficult to prove.

"How old is this thing?"

One thing that was essential to establish was the age of the crater. If it *was* an impact, when did it take place? How can we find out? The crater is, after all, around a kilometre below the sea-bed, under the North Sea; not an easy place to get to!

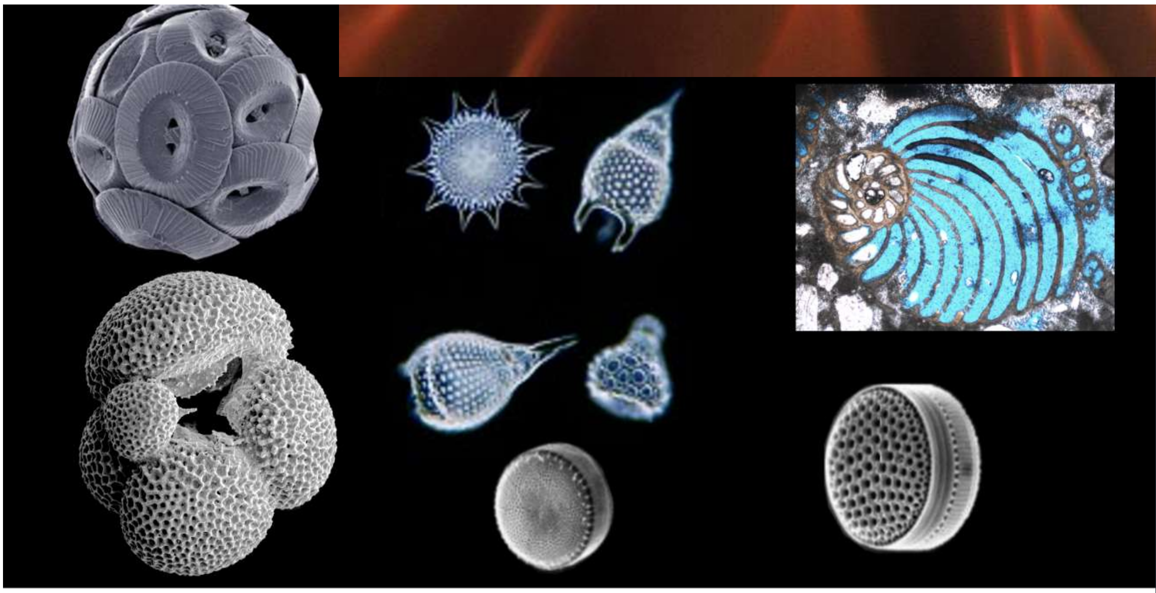
Fortunately, in the search for oil and gas in the North Sea in the 1980s and 1990s, one or two decades before Silverpit was even discovered, two wells were drilled by commercial companies looking to exploit gas reserves in rocks much older and deeper than those in which the Silverpit crater are preserved. In fact, the younger rocks were viewed as an "inconvenience", to be drilled though as quickly as possible, but the wells themselves were located just where the crater was.

Fortunately, rock samples were taken during drilling of these wells and although the samples were not particularly close together, they covered the interval of rocks above and below the crater.

These samples were, however, very small – about 20-30 grams, and comprised fragments that are only 1-2mm across. How can we possibly get any useful information from them?

Despite the advent of amazing techniques such as analysis of different elemental isotopes to yield an age, such techniques may not always be possible. The popular "Carbon Dating" method only really works on samples that are thousands of years old, not rocks that are between 50-70 *million* years old like these. Other methods to determine older ages using isotopes (the heavier radiometric elements) only work in rocks of a certain kind – again, not these rocks.

For answers we need to look for other signs: signs of life. In other words… fossils.



Fossils have been used to indirectly "date" rocks for over two centuries. While most people envisage fossils as objects that can be held in the hand or displayed in museums, fossils obtained from boreholes are generally badly broken up by the actions of the drill-bit. Any visible fossils will have been destroyed by the drilling process and the sample fragments themselves are only very small.

Fortunately so are a lot of fossils.

By using microfossils – fossils so small that only a microscope will reveal them – paleontologists can identify many different species which, together, can often determine the geological age of a sample or series of samples.

Mike Bidgood of GSS and two colleagues – Dave Jutson and Ben Johnson – processed the Silverpit samples and analysed the microfossils within[6]. Studying different groups of microfossils they discovered something interesting… a time gap.

The time-period at the end of the Cretaceous is called Maastrichtian by geologists (after rocks characteristic of this period outcropping near the city of Maastricht in The Netherlands). It ranges between 72-66 mybp (millions of years before present). The time period after that is called the Paleocene (66-56 mybp) and the one after that the Eocene (56-34 mybp).

Mike, Dave and Ben found lots of microfossils from the Maastrichtian and Eocene periods, but not many at all from the Paleocene and even then they were a curious mixture of forms, mainly from the latest part of the Paleocene.

Also, those fossils from the latest part of the Maastrichtian were also missing.

What does this mean for the hypothesis that the Silverpit Crater was made at the same time as the Chicxulub Crater in Mexico?

"Forams, Nannos, Rads and Diatoms"

Fossil Jargon

In a science where multisyllabic words are common-place but "inconvenient" (the Latin species name *Voloshinovella aequisgranensis* does not exactly trip easily off the tongue), jargon is frequently used.

"Forams" are short for Foraminifera – a class of single-celled animals, similar to modern-day Amoeba, but which build shells. "Nannos" are Nannofossils, or more correctly Calcareous Nannoplankton – single-celled green algae (i.e. plants) which also build shells. "Rads" are Radiolaria. Single-celled animals like Forams, but which secrete a shell of a delicate silica mesh. "Diatoms" are… well… Diatoms. They are also single-celled plants in a silica "pillbox"-like or triangular shell.

All of these fossil groups live at the surface or at the bottom of the sea and were found in the Silverpit Crater samples. This shows that at the time the asteroid hit the area it was still under water, but probably quite a bit deeper than it is today. The image here shows the shell of a Foram that lived on the sea floor. It is less than 0.5mm in size. Diatoms and Radiolaria are about the same size but Nannofossils are about 100 times smaller! We use Electron Microscopes to photograph them all.

MICROFOSSILS

A world within a world

Frequently overlooked because of their small size, microfossils are the hard remains of tiny organisms vital to Earth's capability to sustain life. Most microfossils groups are still living today – we just don't see them – and they form the basis of food webs vital to we "larger" organisms. Moreover, some contribute around half of our atmospheric oxygen.

FOSSILS & TIME

Biostratigraphy

The evolution of different fossil species gives us a kind of geological clock that we can use to determine geological time scales. By recording which fossil species are found in samples, and comparing them with dated reference sections elsewhere, we can establish a time scale for our rocks. Fossils that are particularly useful time-markers can be used to establish relatively small units of time called "*Biozones*". These Biozones – if found in other rock sections elsewhere – can be "*correlated*" (i.e., joined together) and a picture of the subsurface rock structure can be constructed. The Biozones also allow geologists to demonstrate that certain geological processes occurred simultaneously.

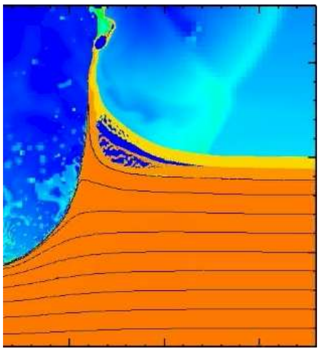
WILLIAM SMITH, CANALS & A MAP

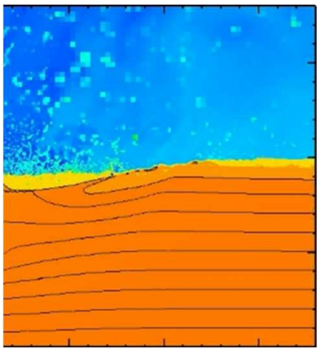
The person who first recognised the link between fossils and geological age was a canal surveyor from Oxfordshire called **William Smith** (1769-1839).

He travelled around England and southern Scotland, mostly on the back of a donkey, surveying the land in preparation for building canals that would provide vital transport arteries for the Industrial Revolution. Noticing the rocks he was surveying often contained similar fossils to those in rocks elsewhere, he was able to "join the dots" based on the fossils (we now call this process *biostratigraphic correlation*) which in turn allowed him to produce geological maps – the first such maps in history.

Sadly, his modest family origins and education (although he was an intelligent and observant man) did not allow him to mix easily in "learned society" and his maps were overlooked by the scientific community. Financially ruined, he was also imprisoned for debt.

He achieved his long-deserved recognition later in life by the Geological Society of London, and is now known as the "Father of Stratigraphy".





Time gaps – where did the rocks go?

What's *not* there can often be as interesting as what *is* there.

Thanks to hydrocarbons exploration we perhaps know more about the subsurface geology under the North Sea than we do about the subsurface under many parts of mainland UK.

Through extensive studies of North Sea geology over the past 50 years, we have a good idea of what kinds of rocks to expect to see when we drill through them. Moreover, we also have a pretty good idea of which microfossil species we can expect to see if we analyse those rocks.

Mike, Dave and Ben saw many fossils they were expecting to see… but not all of them. Rocks (i.e., fossils) from the latest part of the Maastrichtian to the late part of the Paleocene (representing a time-gap between 68-59 million years ago) appeared to be missing. *Where were they?*

Although there could be several explanations for their absence, studies from many nearby boreholes showed that rocks of this age were normally present.

Now we cross the Atlantic to the Sandia National Laboratory in New Mexico, USA where Dr David Crawford was working on understanding what actually happens when an asteroid hits the Earth, especially if it hits water rather than land.

Dr Crawford's simulation (from which he kindly allowed us to use extracts for our paper [6]) had assumed the size of the impacting body was about 1km across – bigger than estimates for the Silverpit impactor (which was estimated to be about 170 metres in diameter) but still within reasonable limits.

The picture above left shows what was happening 12 seconds after the impact, which in the simulation occurs at the left-hand edge of the image.

The 1km impactor has disrupted and "blown away" about 5 kms of sediment beneath the water. The yellow and pale-orange coloured layers (still not quite hardened into solid rock) were behaving more like a splashing liquid than rocks.

The image on the right shows the situation just over 6 minutes after the impact. Although the orange rocks have been badly disrupted or blown away, the yellow, softer rocks had flowed back into the impact zone as a mixed-up mass.

This provided an explanation for why the rocks in the Silverpit area were missing – *but when exactly did the asteroid strike?*

In one or two samples Mike, Dave and Ben had noticed they contained a mixture of fossils from various ages within the Late Paleocene.

Could these mixed fossils have come from mixed up rocks flowing back into the crater just after the impact (i.e. like the yellow layers in the simulation)?

Above these samples, Mike, Dave and Ben found fossils that were Early Eocene in age which appeared to be "normal" and occurring in the right order. They showed that these upper sediments were the result of normal deposition with no evidence for mixing. They proposed a sequence of events that would account for what the fossils were telling them…

1. **72-66 mybp**: Rocks of Maastrichtian (Cretaceous) age were deposited normally.

2. **66-c.59 mybp**: Rocks of Paleocene age were deposited normally.

3. **One day, between c.59-56 mybp**: *The asteroid hits!* Rocks of late Maastrichtian and Paleocene age are blown away but soft sediments of late Paleocene age flow back in to crater area and are mixed up.

4. **57/56 mybp onward**: Normal deposition resumes in the very latest Paleocene and continues into the Eocene and beyond.

So… what do we now know?

The fossils we found, and the ages that they represent, enabled us to establish a sequence of events which closely fit with those predicted by David Crawford's impact simulation model.

We showed that the Silverpit impact did not take place at the same time as the end-Cretaceous mass extinction, but probably some 8-10 million years afterwards. This was worked out by knowing what fossils were present in the rocks… *and* which were not.

But… was the Silverpit Crater caused by an impact at all?

Although we appear to have dated the Silverpit "event", do we know for sure it was caused by an asteroid impact, or one or other of the alternative mechanisms like salt withdrawal?

There are signs… but very subtle ones. Perhaps one of the subtlest – but also perhaps the most significant – is that some of the very smallest fossils (the nannofossils) are broken or "fractured". Such fracturing has been observed in nannofossils from a major impact crater in Chesapeake Bay, USA and other impact craters and is believed to be caused by micro-impact forces [7, 11].

The images below right show a nannofossil (called *Biscutum*) which has been fractured across its middle.

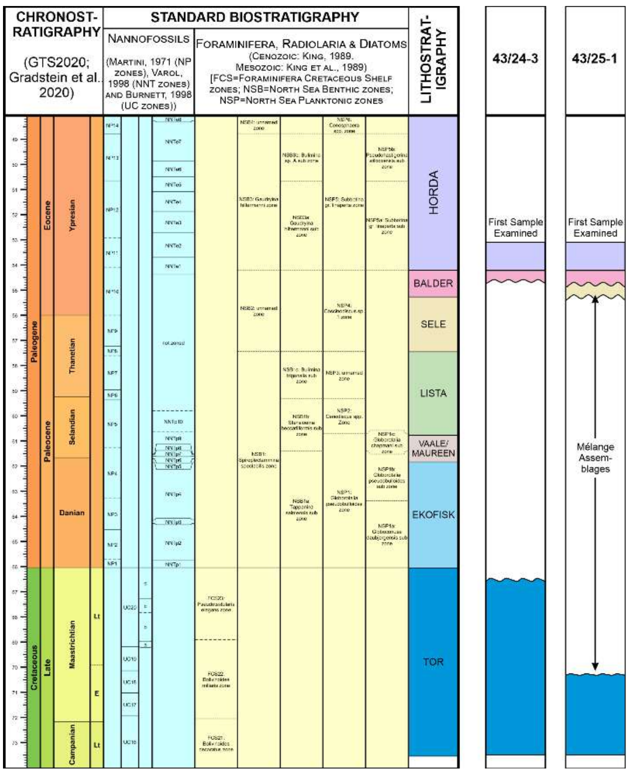
Other signs include the presence of the "mixed" layer of sediments and the absence of large chunks of geologic time represented by the rocks that are no longer there (see the "gaps" in the diagram below) [6, 8].

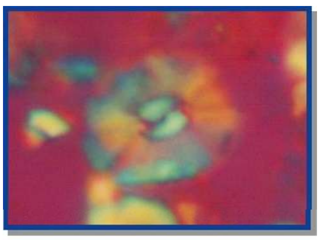
Further afield, in boreholes from East Anglia, there is some evidence for a "Tsunami-like" event at or around the same time as the Silverpit event [3].

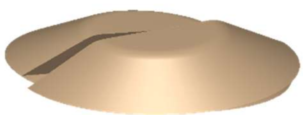
There are other, secondary signs, that indicate a *possible* impact origin. For example, there is a strange, characteristically purple-coloured layer of rock found extending over most of the North Sea at about the same time. This rock is rich in the element manganese. Other than in the very deep oceans (and the North Sea in this area was a lot shallower than that), manganese is only generated on the sea-bed in the presence of *fresh* water. It would have been as if, after the impact, the whole of the North Sea had suddenly turned to fresh water! How could *that* be possible? See right →

In conclusion, we think that "an event" occurred in this part of the North Sea between 56-59 million years ago that caused significant disruption to the sea-bed and for several kilometres beneath. We also think it was *probably* caused by an asteroid or cometary impact (although we cannot be absolutely sure).

There were also interesting "side effects" (such as Tsunami and the release of fresh water from methane hydrates).







METHANE HYDRATES

A hidden energy source?

Molecules of the gas methane are released underground over millions of years by the decomposition of organic matter, or by bacterial action. These can be "trapped" by molecules of water in a crystalline-like structure within buried sediments, the stability of which can be very delicate.

Disrupt that delicate balance – by, say, an asteroid impact – and in seconds massive amounts of methane gas could be released.

This chemical process (technically known as a "methane hydrate dissociation event") also produces, as a major side-effect, large volumes of… *fresh water*. It is estimated that buried methane hydrates today hold 8 times more fresh water than all of Earth's rivers [10].

This sudden release of fresh-water could have precipitated the formation of manganese, found in the purple rock layer.

It could also have caused widespread environmental disruption in the North Sea during the late Paleocene, causing many organisms, large and small, to become locally extinct.

For now, this remains rather speculative, but it is a possibility.

Dr Mike Bidgood

… is a consultant geologist who has worked characterising the subsurface in the energy industry for 40 years. He specialises in "Biostratigraphy" – the understanding of the subsurface by means of fossil distribution and their calibration to the geologic time scale.

Wrapping up…

- **The Silverpit event took place about 56-59 million years ago in the Late Paleocene, or possibly Early Eocene.**

  So it was not related to the end-Cretaceous mass extinction event caused by the much larger "Chicxulub asteroid", but occurred several million years later.

- **It was *probably* caused by an asteroidal or cometary impact.**

  Estimates and simulation models suggest the Silverpit asteroid was about 170 metres across, compared with the Chicxulub asteroid of 10 kilometres.

- **Secondary effects were significant over a large area.**

  We cannot say for sure how widespread an area exactly but certainly over this northwest part of the European continent. The impact (and its secondary effects) may have been responsible for the extinction of many large and small organisms in the region, and probably caused a Tsunami.

To read the peer-reviewed technical article behind this story, please visit the Carnets Géologie website:
http://paleopolis.rediris.es/cg/25/07/index.html

REFERENCES

1. Allen, P.J. & Stewart, S.A. (2003).- Silverpit: The morphology of a terrestrial multi-ringed impact structure. *Lunar & Planetary Science*, vol. XXXIV, 1351.
2. Alvarez, L.W., Alvarez, W., Asaro, F. & Michel, H.V. (1980).- Extraterrestrial causes for the Cretaceous-Tertiary extinction. *Science,* vol. 208, p. 1095-1108.
3. Bidgood, M.D. (1995).- The Microbiostratigraphy of the Palaeocene of the Northwest European Continental Shelf. *Unpublished Ph.D. thesis*, University of Plymouth, 370pp.
4. Bidgood, M.D. (in preparation).- Evidence of a possible 'tsunami-like' microfossil event in Latest Paleocene (Woolwich & Reading Beds) of southeast England.
5. Conway, Z.K. & Haszeldine, R.S. (2005).- The Silverpit North Sea Structure, unique or ubiquitous? In: Evans, K.R., Horton J.W. Jr., Thompson, M.F., & Warme, J.E. (eds.) SEPM Research Conference: *The Sedimentary Record of Meteorite Impacts*, Springfield, Missouri, May 21-23, 2005, p.11.
6. Jutson, D.J, Bidgood, M.D. & Johnson, B. (2025). Microfossil & Nannofossil Analysis of the Late Cretaceous to Early Paleogene interval from two wells in the locality of the U.K. North Sea 'Silverpit Crater'. *Carnets Geologie*, 25 (7): 155-167 http://paleopolis.rediris.es/cg/25/07/index.html
7. Jutson, D.J. & Self-Trail, J.M., (in preparation).- Impact shock induced damage to nannofossils: a comparison of nannofossils damaged in the Chesapeake Bay and Silverpit structures.
8. Jutson, D.J., Bidgood, M.D. & Johnson, B., (in preparation).- Comparative stratigraphy of the 43/24-3 and 43/25-1 wells (Silverpit Structure) with neighbouring wells, British and Dutch sectors, Southern North Sea.
9. Keller, G. (2003).- Chicxulub – the non-smoking gun? *Geoscientist*, 13, 11: 8-11.
10. Lovell, M., Jackson, P., Long, D. & Rees, J. (2003).- Frozen Carbon Stores: environmental hazard or resource? *Planet Earth summer 2003*, www.nerc.ac.uk
11. Self-Trail, J.M. (2003).- Shockwave-induced fracturing of calcareous nannofossils from the Chesapeake Bay impact crater. *Geology*, 31, 8: 697-700.
12. Smith, K. (2004).- The North Sea Silverpit Crater: impact structure or pull-apart basin? *Journal of the Geological Society*, London, 161, 593–602.
13. Stewart, S.A. & Allen, P.J. (2002).- A 20-km-diameter multi-ringed impact structure in the North Sea. *Nature* 418, 520-523.
14. Stewart, S.A. & Allen, P.J. (2005).- 3D seismic reflection mapping of the Silverpit multi-ringed crater, North Sea. *Geological Society of America Bulletin*: 117, 3, 354–368.
15. Underhill, J.R. (2004).- An alternative origin for the 'Silverpit crater'. *Nature*, March 2004, Gallery Number 1671, doi:10.1038/nature02476
16. Underhill, J.R. (2009).- Role of Intrusion-induced salt mobility in controlling the formation of the enigmatic "Silverpit Crater", UK Southern North Sea. *Petroleum Geoscience*, 15, 197-216, doi 10.1144/1354-079309-843
17. Wall, M.L.T., Cartwright, J. & Davies R.J. (2008).- An Eocene age for the proposed Silverpit Impact Crater*, Journal of the Geological Society* of London, 165, 781-794.

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