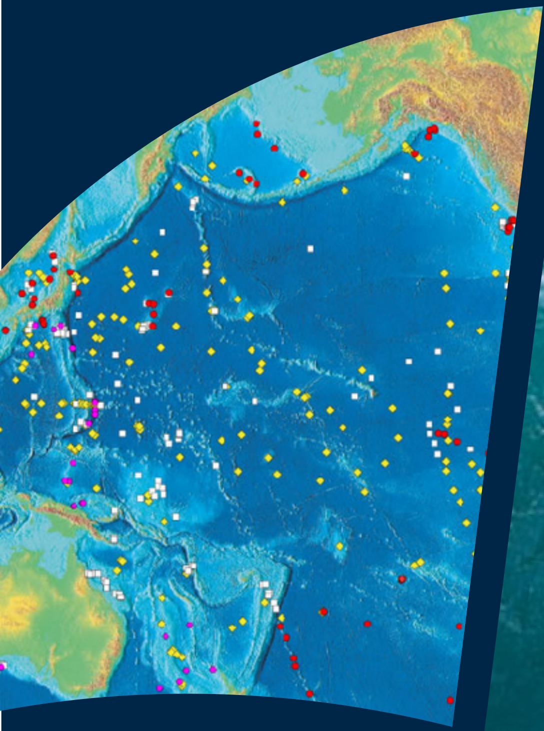
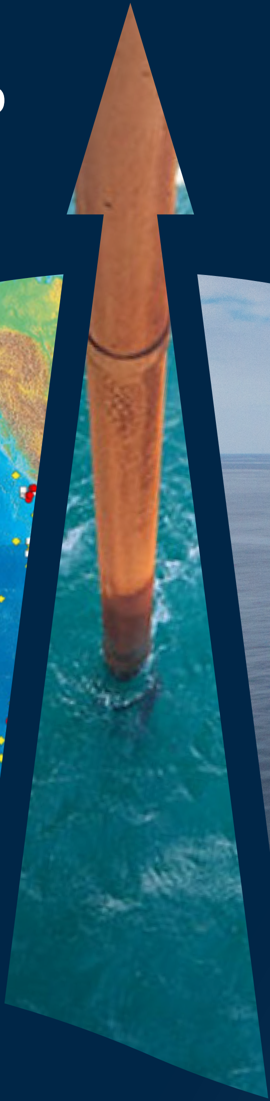
UK IODP
INTERNATIONAL OCEAN DISCOVERY PROGRAM

Newsletter

2020 Issue 1
March





Contents

Cover image credits, clockwise from top: D. Smith & ECORD; IODP JRSO; IODP JRSO; L. Perez-Cruz & ECORD; IODP.

Opportunities & Events

March 2020

Opportunities

Help to shape the future of Scientific Ocean Drilling!
All Members of the IODP community are invited to review and comment on the first version of the NEW 2050 SCIENCE FRAMEWORK.
Submit your feedback by 15th March 23:00 PST

Serve on the IODP Science Evaluation Panel
One position in the Science Subgroup and two positions in the Site Characterisation Subgroup are currently available. Deadline to apply is 27th March. If you plan to apply please inform the UK IODP Knowledge Exchange Coordinator. Find out more

ECORD Summer Schools Scholarships 2020
Scholarships are available to support outstanding Early Career Scientists based in ECORD countries to attend one of the three 2020 ECORD Summer Schools (in Urbino, Italy; B607memn, Germany; or Leicester, UK). Deadline to apply is 30th April. Find out how to apply

ESSAC Chair 2022-2023 - Call for applications
The ECORD Science Support & Advisory Committee is looking for a new Chairperson to serve from January 2022. Deadline to apply is 1st May. Download the full call

ECORD Distinguished Lecturers
If you are interested in hosting an ECORD Distinguished Lecturer at your institution please contact us

Events

UK IODP Annual Meeting, 20th April 2020, Natural History Museum, London
Keynote speakers: Professor Tina van De Flierdt (Imperial College), Dr Ake Fagereng (Cardiff University) & Dr Roz Coggon (University of Southampton).
Registration is free. PhD students and Early Career Researchers are particularly encouraged to submit abstracts. Deadline for abstract submission is 27th March. Visit website

ECORD Virtual Drillship, 20th - 24th April 2020, Bremen, Germany
This training course will provide basic training in IODP coreflow procedures and IODP-style lab exercises, for scientists from academia and industry. Learn more

Joint IODP-ICDP session at EGU 2020, 3rd - 8th May, Vienna, Austria
SSP1.4: Achievements and Perspectives in Scientific Ocean and Continental Drilling
Convenors: Anotony Morris, Jorijntje Henderiks, Thomas Wiersberg. Learn more

ECORD Summer Schools 2020

- Downhole Logging for IODP Science, 4th - 10th July, Leicester, UK. Applications closed. Learn more
- ECORD & NESSC Summer School: (Past) Climates and the Earth System, 13th - 26th July, Urbino, Italy. Deadline for early registration is 31st March. Learn more
- Sea Level, Climate Variability and Coral Reefs, 14th - 25th September, Bremen, Germany. Deadline for applications is 31st March. Learn more

Recent Publications & Media Highlights

March 2020

Recent Publications

Sánchez-Montes et al., 2020. Late Pliocene Cordilleran Ice Sheet development with warm northeast Pacific sea surface temperatures. Climate of the Past, 16, 299-313.

Hull et al., 2020. On impact and volcanism across the Cretaceous-Paleogene boundary. Science, 367, 266-272.
[Featured extensively in the media]

Schaefer et al., 2020. Microbial life in the nascent Chicxulub crater. Geology, 48.

McCaig et al., 2020. Serpentinite in the Earth system. Philosophical Transactions of the Royal Society A, 378.

Expedition 378 Southwest Pacific Paleogene Climate

Dr Flavia Boscolo Galazzo[1], Dr Eleni Anagnostou[2] and Dr Rosie Sheward[3]

On the 4th of January 2020 the JOIDES Resolution (JR) set sail from Lautoka in Fiji with a crew of approximately one hundred people, including 27 scientists. The Expedition 378 team celebrated that ours was not only the first full IODP expedition of the decade, but also the first expedition in the history of IODP to be entirely led by women (both Co-Chiefs, Staff Scientist, and Lab Officer), with a science party comprising more than 70% women. However, one 'first' that cannot be claimed by this expedition is the drill site, for Exp. 378 marked a return to Site 277, previously drilled in 1973 by the Glomar Challenger during Leg 27 of the Deep Sea Drilling Project (DSDP).

We sailed from and to the tropics (the JR arrived in Papeete, Tahiti on the 6th of February), but the destination of Expedition 378 was actually the sub-polar Southern Ocean. We drilled in an area near New Zealand, at about 55° South, called the Campbell Plateau. This is made for one of the longest IODP expedition transits ever; each way we sailed a distance roughly equivalent to that from Lisbon to Moscow! Technical problems with the JR meant that IODP Expedition 378 was shortened to only 1 month and consequently on Site U1553 was occupied The remaining sites have been postponed for now but will hopefully be rescheduled for drilling in a future expedition.

The scientific justification for the expedition was to recover sediments from the subpolar Southern Ocean dating back to the Paleogene (65-23 million years ago). During the Paleogene, Earth's climate was warmer than today, but may have been similar to what we will start to experience by the end of this century if anthropogenic

top: The authors (l-r Rosie Sheward, Flavia Boscolo Galazzo and Eleni Anagnostou.
bottom: Rosie and Flavia at work preparing micropalaeontology samples in the shipboard prep lab (credit: U. Röhl & IODP).

emissions continue unabated. By studying ocean sediments deposited during this period we aim to discover the impact of a warmer climate on high latitude regions (such as the UK, which is at 55º N), in particular on ocean physical, chemical and ecological properties.

We drilled at Site U1553, which spans the early to middle-late Paleogene and is characterized by abundant microfossils in most of the recovered cores. We used Advanced Piston Coring (APC) to drill far less-disturbed, better quality cores than those recovered from the same site 47 years earlier by rotary coring.

The high latitude regions of the oceans are major regulators of Earth climate through ocean currents, deep water formation, and biological productivity. We want to test to what extent these ocean functions were different in a warmer climate to help us make better predictions about our future. The science party includes many early career scientists, and the cores recovered will enable us to push forward our scientific careers.

top: The Expedition 378 Science Team on board the JOIDES Resolution (credit: Tim Fulton & IODP). inset: The Expedition 378 logo.

Author affiliations: 1: Cardiff University, UK 2: GEOMAR, Germany 3: Goethe-Universität Frankfurt am Main, Germany

Our IODP Experience

Have you participated in an IODP expedition before?

Flavia: This was my first time sailing!

Rosie: Also my first time sailing!

Eleni: My first IODP expedition!

How did you learn about the expedition and what made you decide to apply to sail?

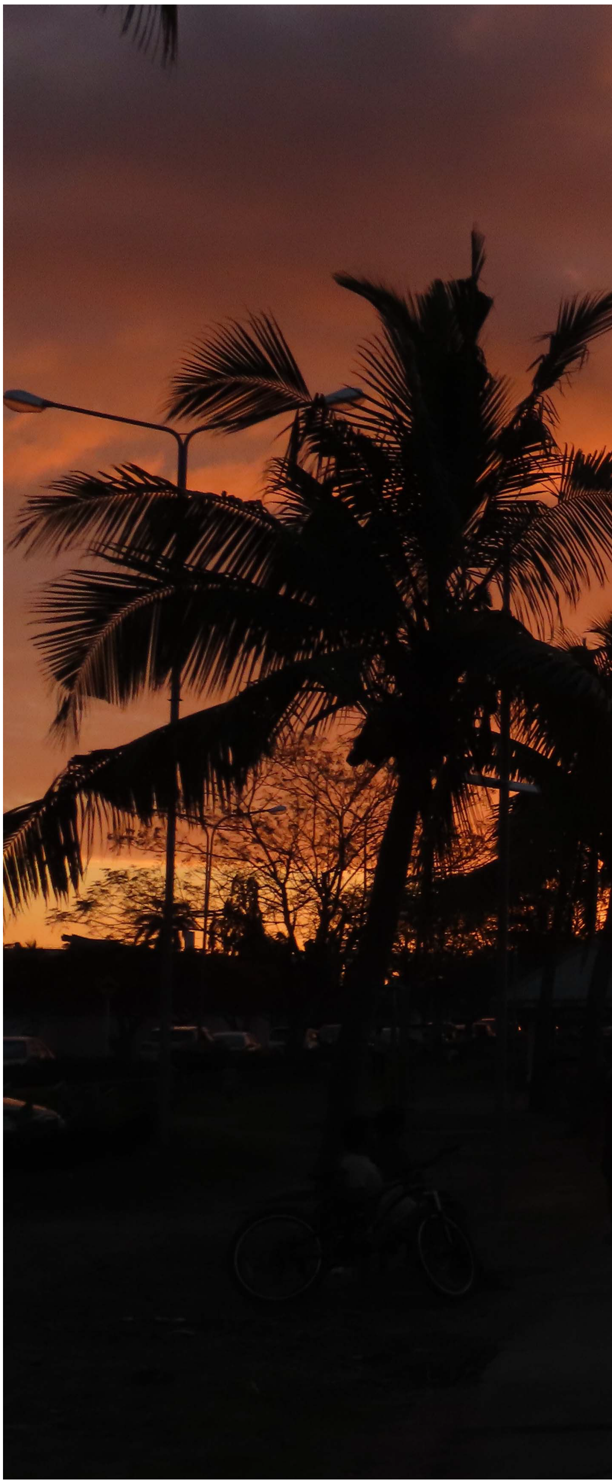
Flavia: I learned about the expedition on the IODP website. I decided to apply because I wanted to experience a scientific expedition. My role in the science party was of biostratigrapher, meaning I was part of the team training to establish live the age of the sediments which are being recovered, based on the microfossil content. This is kind of challenging if you are doing it for the first time, and I wanted to take on the challenge! I also saw this as a chance to establish research independence and start off my own research lines.

Rosie: Having worked on a lot of IODP, ODP and DSDP materials during my PhD research, I've always wanted to sail and see first-hand the excitement of being one of the first people to see a new core from the seafloor on deck and look at the microfossils in it. I decided to apply for this expedition particularly because the time period is really relevant to my research, so I hoped to become involved in lots of exciting research and for the opportunity to lead my own, more challenging research projects afterwards.

Eleni: It was my dream to sail on the JOIDES and collaborate in such a multi-cultural and interdisciplinary environment, expanding my research horizons.

Which science team are you working in on the ship and what does that entail?

Flavia: I'm in the biostratigraphy and micropaleontology team using fossil planktonic foraminifera, calcifying micro-zooplankton, to help constrain the age of our samples.



Rosie: I'm working as a calcareous nannofossil specialist, which means that when a new core comes on deck, I take a very small amount of that sediment and look for the fossil remains of a group of calcified marine phytoplankton under the microscope. Based on the species I can see in each sample, we can estimate how old the sediment is as we bring it up!

Eleni: I'm working as an inorganic geochemist. As part of the geochemistry team, I am responsible for collecting interstitial waters from the sediment cores, and performing analyses on board for major/trace elements, carbonate system parameters, and salinity.

What has been the most exciting part of this science expedition for you?

Flavia: Core on deck!

Rosie: Being one of the first people to see what microfossils were in our first core on deck!

Eleni: When the story comes together, and geochemical observations agree/or not with those from other groups. Also, learning new things.

What have you enjoyed most from your experience of life on a research vessel?

Flavia: Our awesome team of international early career scientists bounding up and working together!

Rosie: I hadn't expected there to be so many small experiences that make each day so fun, like bbqs, band practice, stargazing, movie nights…! And the food has been incredible! It is really hard work to sail, but the incredible sense of community and fun between everyone in the science party make it all worth it!

Eleni: Friendships, laughter, pranks, games, songs, gym and dance buddies, and enjoying sea front coffee :)

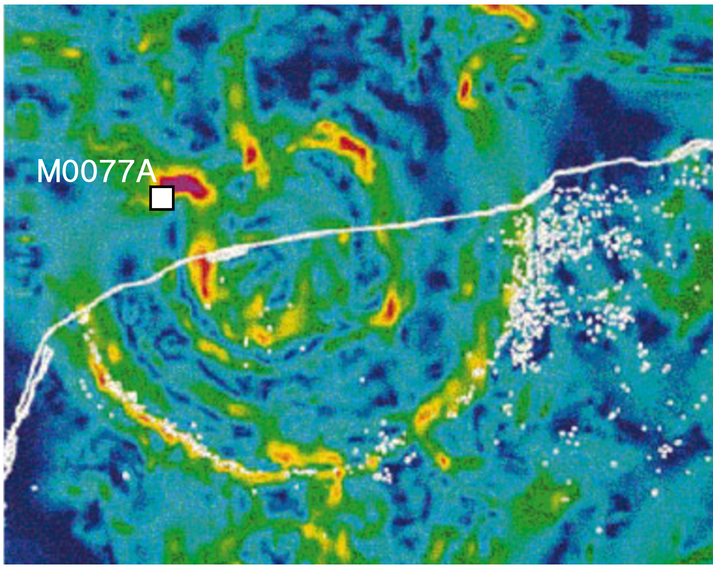
The JOIDES Resolution in port in Fiji (credit: Simon George & IODP).

Drilling Impacts
Discoveries from Chicxulub

Dr Jude Coggon

UK IODP scientists have made it into the prestigious **Science Magazine 2019 Breakthrough of the year Top 10** with findings from Expedition 364 Chicxulub Drilling in the Gulf of Mexico. The project was instigated and co-led by Professor Jo Morgan of Imperial College London, who described to me the journey from her initial idea to pioneering discoveries about the formation of large meteorite impact craters and the surprising response of the biosphere to the catastrophic Chicxulub event.

Professor Morgan first heard about the Chicxulub impact structure at a meeting in 1994, when she witnessed an argument about the size of the crater, with proponents arguing for a diameter of 170 km versus 300 km, based on gravity and magnetic data. At that time, the idea that the Chicxulub impact triggered the mass extinction 66 million years ago at the Cretaceous-Paleogene boundary was contentious. It occurred to Morgan, a Marine Geophysicist, that seismology could be used to answer the question of the Chicxulub crater size and, hence, provide information about the magnitude of impact energy released and the resulting effects on the environment. She and Michael Warner submitted a grant application to the NERC BIRPS (British Institutions Reflection Profiling Syndicate) program and were awarded funding to carry out a seismic experiment on and offshore in October 1996. The experiment was a success and Morgan and colleagues were able to show that the Chicxulub structure is a complex crater ~ 200 km in diameter, with an 80-90 km diameter peak ring. The discovery that Chicxulub is a multi-ring basin, similar to large impact structures elsewhere in our solar system, such as on Venus, was ground-breaking.



top: Chicxulub Bouguer anomaly map (Hildebrand et al., 1995) showing the location of the Expedition 364 borehole M0077A. bottom: The Expedition 364 Science Party at the Bremen Core Repository for the OSP.

A fundamental unknown at that time was the mechanism of complex crater formation, specifically: "How can the strength be removed from the rocks to allow them to rebound to form a wide, flat crater instead of just a big deep bowl? How can rocks temporarily become fluidised?" Morgan and her (then) PhD student, Gareth Collins, used numerical simulations to try to reproduce the Chicxulub crater structure that had been inferred from geophysical data. These simulations, in which the rocks are allowed to temporarily behave like a fluid, led to the so-called dynamic collapse model for peak ring formation. Alternative models were proposed and it became clear to Morgan that direct sampling of an intact peak ring via drilling was necessary to test these hypotheses. Opportunities for such sampling are extremely rare, however. Other than Chicxulub, only two impact structures with diameters ≥200 km are known on Earth: Vredefort (South Africa) and Sudbury (Canada), both of which are approximately two billion years old and have suffered either severe erosion (Vredefort) or tectonic deformation (Sudbury). Chicxulub therefore presents the best opportunity to study multi-ring impact craters on our planet.

Expedition 364 Principal Science Questions

1. What rocks comprise a topographic peak ring and how are peak rings formed?
2. How are rocks weakened during large impacts to allow the formation of relatively wide, flat craters?
3. What insights arise from biologic recovery in the Paleogene (post-impact sediments), within a potentially "toxic" ocean basin, that might be an Early Earth analogue?
4. What effect does a large impact have on the deep subsurface biosphere. Are impact craters (including peak rings) habitats for life?
5. Can we improve constraints on the environmental effects of this impact. What caused the extinctions?

Drilling in shallow waters (credit: D. Smith & ECORD)

Drilling the Chicxulub peak ring onshore would have been challenging because it was not feasible to acquire the necessary seismic data to image the drilling targets, due to the abundance of near-surface caverns in the platform carbonates. In 1998 Morgan and her co-proponents submitted a proposal to IODP to drill Chicxulub offshore. After a constructive review process, successful IODP proposals usually start drilling within three to five years from the original pre-proposal submission. Unfortunately, the shallow water depth of the proposed drill site in the Gulf of Mexico meant that the IODP Drilling Vessel (D/V) JOIDES Resolution could not perform the drilling, so a different platform would be required. In the meantime, the drilling proposal was expanded to include additional objectives with the help of astrobiologist Professor Charles Cockell (University of Edinburgh). Cockell studies terrestrial impact craters as analogues for Martian environments, to investigate which conditions are favourable for the potential emergence of life. Scientific drilling of the Chicxulub crater presented a unique opportunity to investigate the response of the deep biosphere to a newly created environment, and examine the subsequent recovery of life and the colonisation of the crater. It was hypothesised that the highly fractured rocks of the peak ring would be most likely to provide a favourable habitat for microbial life since they are the most porous parts of the crater. The addition of biological aspects to the redrafted proposal significantly strengthened the case for drilling, as it would now address major scientific questions from two different fields.

As the proposal was being developed further, Morgan and Dr Penny Barton (Cambridge University) successfully sought NERC funding for a site survey (a further seismic experiment) and received support also from NSF. The acquired seismic data were inverted to recover a high-resolution velocity model using a technique called full-waveform inversion; this fine-resolution image helped pinpoint the optimal location for drilling. With the introduction of IODP ECORD Mission Specific Platforms (MSPs) in the early 2000s, drilling the Chicxulub peak ring became feasible, and the proposal was approved and scheduled for drilling.

Expedition 364 was carried out as a collaborative operation between IODP and the International Continental Scientific Drilling Program (ICDP), using an MSP: the jack-up platform L/B Myrtle. Offshore operations ran from 5th April to 31st May 2016. Frequent and extreme changes in formation hardness presented a significant technical challenge for the drillers and resulted in numerous bit changes. The drilling mud had to be carefully selected for environmental as well as scientific reasons, and the microbiology team developed special protocols to limit and monitor potential biological contamination of the cores. Together, the drillers and science team overcame these difficulties, and achieved almost 100% core recovery. The 830 m of core from site M0077 includes samples of impact rocks (suevites, impact melt rocks, and shocked granitic basement) of the peak ring down to 1334.7 metres below seafloor, as well as post-impact rocks, including a record of the first few years after the impact event.

Morgan's experience offshore, actively leading drilling operations as Co-Chief Scientist (along with Professor Sean Gulick, University of Texas) on her first ever IODP expedition was "absolutely fabulous"; she recounted being in a state of constant excitement as she and the rest of the science team rushed out to gather around each new core as it arrived on deck, to see what had been drilled. The cores included a veritable geological treasure trove of stunning impact breccias, beautiful but crumbly granites, and the earliest Palaeogene sediments, deposited from seconds to weeks after the impactor struck. Shattercones (structures unique to impact craters, that show the orientation of shock waves produced by the meteorite strike) were found in the core - the first ever discovery of these in the

The L/B Myrtle at site M0077 (credit: L. Perez-Cruz & ECORD).

Chicxulub crater. The structural geologists were over the moon to find preserved cross-cutting relationships of various structures (which are usually lost in craters on land due to erosion, burial and tectonics) that for the first time ever, allowed them to determine the order of deformational events in the crater formation process. Morgan described the experience: "There was a lovely atmosphere; it was hard work but also a wonderful shared experience of scientific discovery - the best moment of my life scientifically". The expedition generated much excitement onshore too, with streams of journalists arriving on the L/B Myrtle every few days and outreach activities organised for local school children. News of the Chicxulub drilling even travelled out of this world to British astronaut Tim Peake, who tweeted about it from the International Space Station.

The drilling was followed by an Onshore Science Party (OSP) at the Bremen Core Repository in Germany, from 21st September to 15th October 2016. The enthusiasm of the science team mounted further as the specialist groups were able to study the cores in more detail and test the hypotheses that the drilling had been designed to address. The location of site M0077 was selected to enable to the Expedition 364 science team to test two competing models for peak ring formation: the Dynamic collapse model (Morgan et al., 2000, 2011; Collins et al., 2002, 2008), which predicted that the Chicxulub peak ring is formed from mid-crustal rocks; and the Nested melt-cavity hypothesis (Head, Baker, 2011, 2015, 2016), which proposed that the peak ring formed from upper-crustal rocks that were uplifted and rotated, making them less shocked and of a shallower depth of origin than in the dynamic collapse model. Furthermore, drilling at "ground zero" would allow the team to investigate the effect of the meteorite impact and subsequent hydrothermal activity on the deep biosphere, and examine the recovery of life after the catastrophic event. In every team there was excitement as the cores began to reveal their secrets and new discoveries were made.

top: The Exp 364 Offshore Science Team on L/B Myrtle (credit: A. Wittmann & ECORD)
inset: The Expedition logo

When the Chicxulub impactor crashed into Earth, it triggered the mass extinction of 76% of species living on the surface of the planet. However, for the deep biosphere it provided a wealth of new subsurface habitats that persist to this day. The impact is estimated to have released energy equivalent to that of 10 billion WWII atomic bombs, geologically instantaneously bringing to the surface rocks from 10 km deep in the Earth's crust. The geological disruption of the subsurface produced vast networks of fractures and juxtaposed lithologies to form new fluid flow pathways and mineralogical interfaces, respectively. These conditions constitute favourable habitats for microbial life, as evidenced by Cockell and colleagues' discovery of increased microbial biomass within the suevite and elevated cell abundances at impact-generated interfaces in the suevite and underlying lithologies. Different geological units within the crater host taxonomically and metabolically distinct microbial communities, depending on the physical alteration of the rocks. These observations demonstrate that large impacts produce subsurface environments with enhanced fluid flow and supply of nutrients and energy, making them key targets in the search for life on Mars and other rocky planets.

Cores from hole M0077A: impact melt (left) and shocked granitoid (right) (credit: M. Mowat & ECORD)

While subsurface Chicxulub microbes flourished, it was widely believed that at "ground zero" the surface biosphere was wiped out, and that global cooling and the reduction in solar energy reaching Earth's surface afterwards slowed recovery. Before the impact event 66 million years ago, it is thought that the sea in the Chicxulub area was approximately 200 m deep. Immediately after the impact, ocean water flooded back into the crater carrying in debris from the surroundings. The Expedition 364 organic geochemists and microbiologists have identified biomarkers in the earliest post-impact sediments that suggest fragments of land plants, cyanobacteria and photosynthetic sulphur bacteria were washed from microbial mats on the adjacent carbonate platform into the crater basin by one or more tsunamis. Surprisingly, the data indicate that within days to months after the crater formed, single celled cyanobacteria were blooming, fuelled by nutrients washed from the coast. Further studies have shown that mammals and trees evolved very quickly to fill the ecological niches left by the mass extinction event.

It is this story of life rapidly re-emerging, phoenix-like, that has captured the attention of the media and public alike, leading to the accolade in Science. But for Morgan, the scientific highlight was finding evidence supporting the Dynamic collapse model, of which she had been an original proponent. The Chicxulub drilling has vastly improved our understanding of how large craters form, providing missing pieces of the puzzle: "The UK's involvement in IODP and ICDP has been absolutely critical to my work. All of my previous research on Chicxulub became so much more important when we drilled; it put everything into context and has been the highlight of my career". Morgan finally has the answers she has been searching for for nearly two decades, but she is quick to stress that hers has been an unusually long journey from pre-proposal to drilling, due to the technical issues associated with the drill site. She never gave up, because she knew that drilling the Chicxulub peak ring was the only way to address these important scientific questions. Her patience and perseverance finally paid off and the spectacular Chicxulub M0077A cores enabled the science team to address all of the objectives put forward in the drilling proposal. Her advice for anyone working on an IODP drilling proposal is to listen to the reviewers and be patient "The review process was very useful and improved the proposal. People are trying to assist you to do the best science you can. Embrace the reviews". While the journey from inception to realisation of the drilling has been long, the legacy of the Chicxulub drilling will last far longer; exciting findings have already been published but the totally unique cores will continue to support and generate scientific research for decades to come.

Useful Contact Details

Dr Jude Coggon
UK IODP Knowledge Exchange Coordinator
jude.coggon@southampton.ac.uk / info@ukiodp.org
+44 (0)2380 596539

Daniel Knight
NERC UK IODP Programme Manager (Research)
iodp@nerc.ukri.org
+44 (0)1793 411672

Professor Damon Teagle
UK IODP Programme Advisory Group Chair
Damon.Teagle@southampton.ac.uk

Jess Surma
NERC UK IODP Senior Programme Manager
jessica.surma@nerc.ukri.org

Dr Mike Webb
Chair of UK IODP Programme Executive Board
michael.webb@nerc.ukri.org

Professor Tony Morris
ESSAC Chair & UK Representative
A.Morris@plymouth.ac.uk