IODP Proposal Cover Sheet

1004 - APL 3

Nadir K-Pg Impact Crater

Received for: 2022-04-01

Title	Into the Nadir: a new Cretaceous-Paleogene impact structure?
Proponents	Uisdean Nicholson, Sean Gulick, Veronica Bray, Tom Dunkley-Jones, Christian Maerz, Thomas Wagner, Pim Kaskes, Elisabetta Erba, Cherif Diallo, Thomas Davison, Chris Lowery, Cornelia Rasmussen, Daniel Condon
Keywords	impact crater, K-Pg boundary
Area	Guinea Plateau

Proponent Information

Proponent	Uisdean Nicholson
Affiliation	Heriot-Watt University
Country	United Kingdom

☑ Permission is granted to post the coversheet/site table on www.iodp.org

Abstract

The hypervelocity impact of large asteroids and comets represent an important geological hazard and can cause major perturbations of Earth's climate and biological systems. Seismic sections across the 8.5-km wide, 200-m deep Nadir structure offshore Guinea, West Africa, show numerous characteristics consistent with a complex impact crater. The feature is relatively shallow, at only ~300-400 m below the seafloor, and uniquely accessible by riserless drilling. Leveraging planned IODP Expeditions in the Central Atlantic, we request up to 7 days JOIDES Resolution ship time to test the hypothesis that this structure was caused by a hypervelocity impact of Late Cretaceous to Early Paleogene age. Drilling will allow us to test conceptual and numerical models of crater formation based on seismic data. We also seek to determine the age of the impact lithologies and therefore the age of the crater, testing the hypothesis that this impact was coeval with the Chicxulub impact event in Mexico (i.e. Nadir could potentially be a secondary impact site) or part of an impact cluster. If the crater pre-dates or corresponds with the K-Pg boundary then the selected sites will provide a high-resolution archive including K-Pg impact ejecta and the Paleogene recovery of life following the K-Pg mass extinction. It will also provide an important low-latitude record of early Cenozoic oceanographic, climatic and biotic conditions, likely including the Paleocene-Eocene Thermal Maximum (PETM) and Eocene hyperthermal events. This proposal addresses the IODP Science Plan themes on climate and ocean change, as well as discrete elements of the new 2050 Science Framework (Natural Hazards Affecting Society and Terrestrial to Extraterrestrial Enabling Element) and has strong synergies with recently drilled and planned IODP expeditions.

1004 - APL 3

Scientific Objectives

The overarching aim of the proposal is to test the hypothesis that the Nadir structure was caused by a Late Cretaceous / early Paleocene meteorite impact, particularly from the presence of diagnostic shocked mineral phases. The submarine location of this crater also preserves key structural features that are rapidly eroded on land, and that can be sampled with the proposed drilling.

Secondary objectives include:
A. Recovery of samples from the inner crater to test models of crater formation, including central peak exhumation, shock melting and initial crater fill.
B. Recovery of samples from below the crater floor to test the extent of shock metamorphism, thermal alteration and greenhouse gas (GHG) emissions of the target stratigraphy.
C. To determine the precise age of this impact event and establish if this crater is synchronous, and hence potentially co-generic, with the K-Pg boundary Chicxulub impact structure.
D. Recovery of samples from near the potential crater rim to test for the presence and composition of an ejecta blanket and to obtain unshocked samples of the target stratigraphy (alternate site only).
E. Recover a high-resolution post-impact sequence to document ecological recovery locally for comparison with other submarine impact craters
F. Recover an Upper Cretaceous and full Paleogene stratigraphic sequence producing a rare equatorial record of later environmental perturbations (Cretaceous OAEs, PETM, Eocene hyperthermals)
G. Constrain the age of Cretaceous and Cenozoic seismic stratigraphic surfaces above and below the crater to constrain the stratigraphic evolution of the wider plateau, and support a potential full IODP Expedition

Non-standard measurements technology needed to achieve the proposed scientific objectives

Have you contacted the appropriate IODP Science Operator about this proposal to discuss drilling platform capabilities, the feasibility of your proposed drilling plan and strategies, and the required overall timetable for transiting, drilling, coring, logging, and other downhole measurements?

yes

Science Communications Plain Language Summary

Using simple terms, describe in 500 words or less your proposed research and its broader impacts in a way that can be understood by a general audience.

Impacts of asteroids or comets are a very important Earth hazard over geological time scales. A recent IODP drilling expedition showed that collision of a 12 km wide asteroid offshore Mexico (Chicxulub) unequivocally caused the major end Cretaceous extinction event, 65 million years ago, when the dinosaurs and 80 per cent of all other species became extinct. Smaller events are also likely to be a significant local hazard, as shown by the destruction caused by the airblast from the 50 m wide Tunguska asteroid in Russia in the early 20th Century. However, the geological record of these events is scarce, with only 200 confirmed impact craters anywhere on Earth. Very few of these are under water, which should be the most common type of impact, and not many are well preserved or imaged by geophysical techniques.

A new candidate impact crater has recently been discovered offshore West Africa and we propose to drill this to test whether it was caused by a marine impact. Computer models suggest this impact could have been caused by a 400 m wide asteroid, a similar size to the Bennu asteroid in near Earth orbit, considered to be the most hazardous object for an Earth impact in the coming centuries (1 in 1,750 chance of collision). The potential crater is exceptionally well imaged with seismic reflection data, but we require hard data to test our models of crater formation. We propose to drill a single well through this crater, and into the sedimentary rocks beneath it, to understand how it formed and what its consequences were. This will be used to constrain computer models of the impact itself and associated earthquakes, tsunami, ejecta and gas emissions.

One intriguing aspect of this crater is that it appears to be the same age, or very close in age, to the Chicxulub event at the Cretaceous-Tertiary boundary. This suggests that it might have been part of the same impact event, perhaps caused by breakup of a parent asteroid, or a binary asteroid. Alternatively, it may have been part of a cluster of impacts that occurred in close succession, perhaps as a result of an earlier collision in the asteroid belt. Dating impact melts in the crater will help us to test these alternative hypotheses.

Even if the crater turns out not to have been formed by an asteroid impact, this drilling expedition will help us to understand what other process could have formed this (perhaps an underwater volcanic eruption), as well as providing important new records of the Earth's climate and ocean conditions during a 'hothouse' world, when temperatures were significantly higher than at present. This will include new equatorial records of Ocean Anoxic Event 2, which occurred when the Earth's oceans were starved of oxygen around 90 million years ago. It will also include the Paleocene-Eocene Thermal Maximum (PETM), when global temperatures rose rapidly around by 5-6°C, 55 million years ago, often considered to be one of the closest analogues to present day global heating.

Proposal History

Submission Type: Resubmission from previously submitted proposal

Review Response

Alternative hypotheses: The proposal now describes alternative hypotheses for crater formation, and implications for expedition outcomes. We note that the positive (below-crater) velocity anomaly is consistent with that observed at the marine-impact Mjølnir Crater, a better analogue in terms of size and target composition (porous sediments) than Chicxulub– discussed in the accompanying revised manuscript.

Depth of drilling: The SEP review panel requests that we reduce the depth of drilling of the primary site as the deep target "does not address any objectives (not defined by the hypothesis)… recommend…to focus entirely on the target of the crater". We disagree that this doesn't address any objectives. The primary reason for drilling below KU1 is to test Objective B – to constrain target lithologies and assess shock metamorphism, thermal alteration and greenhouse gas (GHG) emissions. The inferred black shale deposits below KU1 are the most important source of GHG emissions as well as a unique archive of global climate perturbation. This is also linked to Objective G – to constrain the age of Cretaceous and Cenozoic seismic reflections. We note that the comment contradicts that from the 1004 APL review, which stated "proposed penetration depth… is 640 m which just reaches the reflector KU3* (* corresponds to KU1 in APL-2/3). Considering (velocity) uncertainty… proponents should consider deepening… by several tens of meters to ensure that this reflector is sampled.". We extended deeper than recommended and acknowledge that the drilling plan in the APL-2 proposal was overly ambitious. However, we reiterate the importance of drilling the target stratigraphy, particularly the black shales, to meet these key objectives. In discussion with WD5, we have reduced this hole to 700 mbsf, reducing drilling time to 6.7 days. We also include an option to drill to 530 mbsf with only APC/XCB coring, still allowing the main hypothesis to be tested.

Proxies: With respect to the selection of geochemical proxies, we do not expect the Cenozoic sequence to consist of pure carbonates. These sediments will almost certainly have a variable siliciclastic and organic component, making them suitable for a range of organic and carbonate-based proxies. This is consistent with analytical techniques planned for Expedition 388 and equivalent Cenozoic lithologies recovered from ODP Leg 207 and 159.

Site data: At the time of writing, we did not have access to the 3D seismic. We have included images of interpreted 3D horizons in the SSDB, which increase our confidence that this is an impact crater but, due to commercial sensitivity, cannot share these in the proposal itself. Likewise, we do not have permission to show all crossing lines (with detailed CDP data, etc.) on site forms. We will have access to the 3D in the coming months and anticipate that this data, or crossing line at a minimum, will be available prior to drilling. We note that this data would strengthen the proposal, but that SEP consider that the data already submitted are adequate for drilling.

We have addressed other site and operational issues in the proposal and site summary forms.

Proposed Sites (Total proposed sites: 4; pri: 2; alt: 2; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
GC-01A (Primary)	9.393794 -17.08129	903	700	0	700	Primary site (GC-1A) is located near the centre of the crater, to allow maximum recovery of crater fill sediments and calibration of seismic facies (objective A), to obtain material suitable for dating (objective C) and to penetrate the central peak below the crater floor to a depth of 700 m below seabed to sample target lithologies (objective B) and constrain the age of seismic horizons and the lithology of Cretaceous sequences (G). The site will also recover core from the Paleogene sequence documenting recovery of life (E) and paleoclimate/ocean archives (F).
GC-02A (Alternate)	9.389207 -17.06619	903	600	0	600	Alternate site GC-2A is located at a crossing line location within the crater, to allow recovery of some crater fill sediments and calibration of seismic facies (objective A), to obtain material suitable for dating (objective C) and to penetrate the deformed sediment below the crater floor (objective B). The site will also recover core from the Paleogene sequence documenting recovery of life (E) and paleoclimate/ocean archives (F).
GC-03A (Alternate)	9.406276 -17.12273	907	600	0	600	Alternate site GC-03a is intended to penetrate the crater rim (including proposed ejecta blanket deposits; objective D) and to penetrate the subsurface, to document the extent of shock metamorphism and deformation on the margins of the crater (objective B) and to recover core across the main seismic reflections in the Upper Cretaceous (Objective G) that represent the target rock. The site will also recover core from the Paleogene sequence documenting recovery of life (E) and paleoclimate/ocean archives (F).
GC-04A (Primary)	9.378413 -17.02969	904	600	0	600	Primary site GC-04a is intended to penetrate the crater rim (including proposed ejecta blanket deposits; objective D) and to penetrate the subsurface, to document the extent of shock metamorphism and deformation on the margins of the crater (objective B) and to recover core across the main seismic reflections in the Upper Cretaceous (Objective G) that represent the target rock. The site will also recover core from the Paleogene sequence documenting recovery of life (E) and paleoclimate/ocean archives (F).