IODP Proposal Cover Sheet

1004 - APL 2

Nadir K-Pg Impact Crater

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Title	Into the Nadir: a new Cretaceous-Paleogene impact structure?
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Area	Guinea Plateau

Proponent Information

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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 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 9 days JOIDES Resolution ship time to test the hypothesis that this structure was caused by a marine-target 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 determine 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 and climatic 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.

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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 central peak and crater rim 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 and rim to constrain target lithologies, and assess the extent of shock metamorphism, thermal alteration and greenhouse gas (GHG) emissions.
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.
E. Recovery of a high-resolution post-impact sequence to document ecological recovery locally for comparison with other submarine impact craters
F. Recovery of a full stratigraphic Paleogene sequence producing a rare equatorial record of later environmental perturbations (PETM, Eocene hyperthermals)
G. Constrain the age of Cretaceous and Cenozoic seismic stratigraphic surfaces overlying 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

In the previous review, the SEP was ‘excited by the potential of the APL’ and the fit to IODP Science Plan/Framework but highlighted a number of issues that would have to be addressed to strengthen the proposal. In particular, the SEP asked for a stronger justification of the impact crater hypothesis and the potential relationship of Nadir with Chicxulub and the K-Pg extinction. SEP also asked us to consider reducing the drilling plan to a single site, to further develop the scientific objectives and provide additional information on lithologies.

We have strengthened the scientific justification for drilling, addressing both the evidence for an impact crater and the significance of the age of the crater and its relationship to the K-Pg event. The former is done exclusively in the submitted paper, which we provide as a preprint in the SSDB. We have also discussed alternative hypotheses in the paper and made more explicit mention in the proposal of the benefits of drilling even if this is not an impact crater. By reducing the text justifying the crater hypothesis, we have been able to expand on the scientific objectives (and reduce the length of Table 1) in the proposal.

The proposal also adds new details on expected lithologies (including in Figure 3) and we have added some more details on paleoclimate proxies if lithologies are dominated by carbonates.

In terms of the operational plan, we have followed SEP advice and reduced the plan to a single borehole (GC-01a) and extended the depth of the borehole by ~200 m to increase recovery of Upper Cretaceous black shale deposits. The total time on site is estimated at 8 days, allowing more time (1 day) for transit and remaining within the 9-day limit for an APL. We also provide an option for a full 9 days drilling, allowing full penetration of the Upper Cretaceous sequence and 'Albian' unconformity.

In terms of the Site Survey Data, we have addressed reviewer concerns by adding navigation data, additional seismic images (and more consistent interpretation) to the SSDB and acquisition and processing parameters for all lines/surveys. The SEP also requested additional velocity data – this has been added where available and more data has been requested from industry partners. We note, however, that we have PSDM (depth) seismic for the main M17_9101 line.

In terms of bathymetry, we recognize that the GEBCO 15-arc second data (~450 m resolution) is not ideal but no other data was available at the time of preparing the proposal. We have identified a newly acquired commercial 3D seismic survey across the sites and are in discussion with the commercial company about accessing the data, at least the shallow data, under a confidentiality agreement. This will be included at a later stage if we manage to access the data. However, we believe that this will not be entirely necessary for drilling given that the seabed is almost completely flat on all seismic lines around the site. Other Site Panel concerns have also been addressed.

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	850	0	850	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 850 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).