IODP Proposal Cover Sheet

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Chicxulub K-T Impact Crater

Title	Chicxulub: Drilling the K-Pg Impact Crater
Proponents	J. Morgan, S. Gulick, L. Alegret, I. Arenillas, J. Arz, P. Barton, G. Christeson, P. Claeys, C. Cockell, G. Collins, K. Goto, R. Grieve, C. Koeberl, D. Kring, T. Matsui, J. Melosh, K. Miller, C. Neal, R. Norris, M. Rebolledo, U. Reimold, U. Riller, J. Urrutia, M. Whalen,
Keywords	Chicxulub, cratering, K-Pg impact
Area	Gulf Of Mexico

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Abstract

The Chicxulub impact crater, Mexico, is unique. It is the only known terrestrial impact structure that has been directly linked to a mass extinction event. It is the only one of the three largest impact structures on Earth that is well-preserved. It is the only terrestrial crater with a global ejecta layer. It is the only known terrestrial impact structure with an unequivocal topographic "peak ring." Chicxulub's role in the K-Pg mass extinction and its exceptional state of preservation make it an important natural laboratory for the study of both large impact crater formation on Earth and other planets, and the effects of large impacts on the Earth's environment and ecology. We propose to drill Chicxulub to address several questions, including: 1) what is the nature of a peak ring, 2) how are rocks weakened during large impacts to allow them to collapse and form relatively wide, flat craters, and 3) what caused the environmental changes that led to a mass extinction? Our understanding of the impact process is far from complete, and the first two questions represent fundamental gaps in our knowledge. Despite over 30 years of intense debate, we are still striving to answer the third question.

A principal objective of the proposed drilling is to understand the fundamental impact process of peak ring formation, and two holes were originally planned: one into the peak ring (Chicx-03A) and the other into the flanks of the peak ring (Chicx-04A). In view of the limited budget available for drilling, we have proposed to the ECORD FB that they drill only the highest priority hole (Chicx-03a), which will sample the rocks that form a topographic peak ring, and drill to a TD of 1200 m instead of 1500 m.

The purpose of this addendum is to advise SEP of the modified drilling plan. The objectives of drilling Chicx-03A remain unchanged from the original proposal reviewed by the SPC in 2010, which was ranked third of all proposals under review at the time, was the highest ranked of the MSP proposals, and was thus forwarded to ECORD for scheduling. The proposed drilling directly contributes to IODP goals in the: Deep Biosphere and the Subseafloor Ocean and Environmental Change, Processes and Effects, in particular the environmental and biological perturbations caused by Chicxulub.

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Scientific Objectives

Hole Chicx-03A Chicx-03A will sample material that forms a topographic peak ring, and reveal the lithological and physical state of these rocks, including porosity, fracturing and extent of shock effects. Chicx-03A will test the working hypotheses that peak rings are formed from: 1) overturned and uplifted basement rocks, 2) megabreccias, or 3) some other material. If the peak ring is formed from uplifted basement rocks as predicted by several independent numerical simulations of crater formation, we can distinguish whether the rocks have been uplifted from the upper crust or deeper, and thus constrain the kinematics of peak ring formation. The data acquired will be used to discriminate between models of peak ring formation; for example, predicted shock levels within the peak ring are quite different in alternative models. The recovered samples have implications for our understanding of regional to global effects on the biosphere; we will document the re-habitation of the deep biosphere following a large impact and investigate whether peak rings and impact breccias generally are an ecological niche for chemosynthetic life potentially important to early Earth habitats, through documentation of microbiology and hydrothermal circulation within the peak ring and earliest Paleogene.

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

Proposed Sites

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
Chicx-03A	21.45141, -87.95108	17	670	530	1200	1: Constrain the formational processes and lithology of peak ring 2: Investigate the deep biosphere 3: Investigate post-impact recovery 4: Sample the PETM

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Addendum to IODP 548-Full – a proposal to drill the Chicxulub impact crater

Submitted 1st April 2014 by co-chief Scientists: Joanna Morgan and Sean Gulick

The ECORD FB have advised us to re-consider our options for drilling the Chicxulub impact crater that take into account the budgetary constraints of the current program.

In the original proposal we asked for two drill holes, Chicx-03A and Chicx-04a (Figure 1). A principal objective of the proposed drilling is to understand the fundamental impact process of peak ring formation, but the specific objectives of these two holes are distinct and independent (Table 1). In view of the limited budget available for drilling, we have proposed to the ECORD FB that they drill only one hole, the highest priority hole (Chicx-03a), and drill to a TD of 1200 m instead of 1500 m. The objectives of drilling Chicx-03A remain unchanged from the original proposal reviewed by the SPC in 2010. In 2010, this proposal was ranked third of all proposals under review at the time, was the highest ranked of the MSP proposals, and was thus forwarded to ECORD for scheduling.

The ECORD FB have asked us to submit this addendum as they wish to seek advice from the SEP on the modified drilling plan.

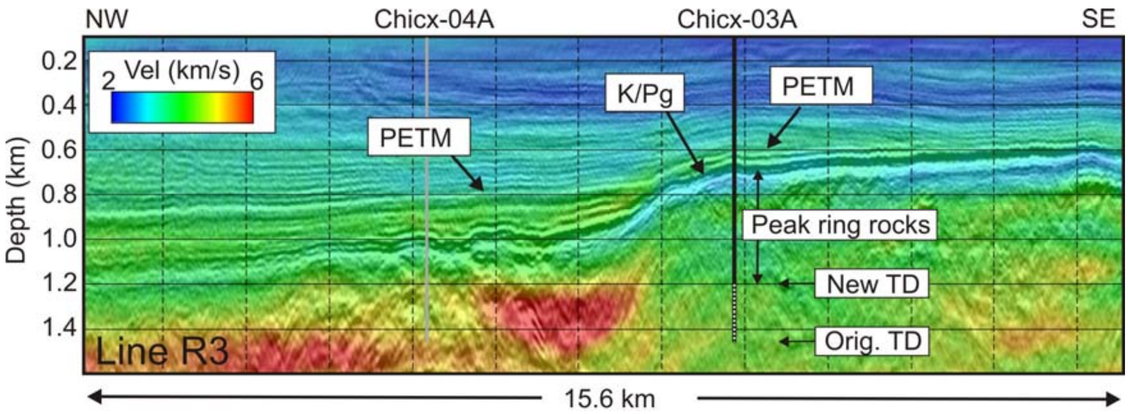

Figure 1. Location of the proposed drill hole, Chicx-03A, on seismic reflection profile R3. Background color is p-wave velocity, obtained from inverting the full seismic waveform (Morgan et al. 2011). The hole depth has been reduced from 1500 to 1200 m, but Chicx-03A will still recover, for the first time, over 500 m of rocks that form the topographic peak ring, as well as sample the PETM (at ~600 m), earliest Tertiary, and K-Pg transition (at ~670 m).

Chicx-03A: Drilling Objectives

A large international group of scientists at a joint IODP-ICDP workshop in Potsdam in 2006 identified sampling the peak ring lithologies as the principal and most important goal for understanding impact crater formation generally, and Chicxulub specifically (Morgan et al. 2007). Peak rings are a ubiquitous feature in large craters on all silicate planetary bodies and hold the key to testing models of large crater formation, with implications for energy and volatile release critical to potential kill mechanisms, the role of melt in planetary resurfacing during large impacts, and the generation of hydrothermal systems by impacts with their potential chemosynthetic habitats.

Chicx-03A will sample material that forms a topographic peak ring (Figure 1), and reveal the lithological and physical state of these rocks, including porosity, fracturing and extent of shock effects. Chicx-03A will test the working hypotheses that peak rings are formed from: *1) overturned and uplifted basement rocks, 2) megabreccias, or 3) some other material.* If the peak ring is formed from uplifted basement rocks (see Figure 2), as predicted by several independent numerical simulations of crater formation (e.g. Collins et al. 2002; 2008; Ivanov 2005; Senft and Stewart, 2009), we can distinguish whether the rocks have been uplifted from the upper crust or deeper, and thus constrain the kinematics of peak ring formation. The data acquired will be used to discriminate between models of peak ring formation; for example, predicted shock levels within the peak ring are much higher (close to melting) in the models by Head (2010) and Baker et al. (2011), than in the model of Collins et al. (2002) and Morgan et al. (2011) – see Figure 2. The recovered samples have implications for our understanding of regional to global effects on the biosphere; we will document the re-habitation of the deep biosphere following a large impact and investigate whether peak rings and impact breccias generally are an ecological niche for chemosynthetic life potentially important to early Earth habitats, through documentation of microbiology and hydrothermal circulation within the peak ring and earliest Paleogene.

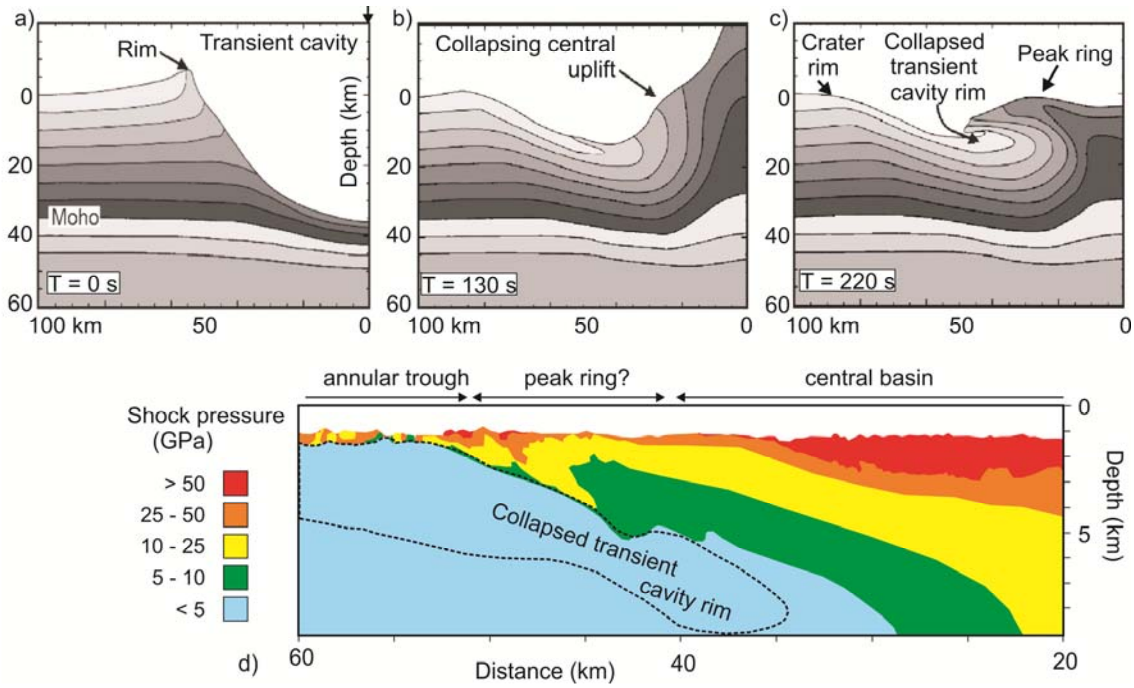

Figure 2.. Hydrocode simulation of the formation of the Chicxulub crater (Collins et al., 2002; Morgan et al., 2011). Layering shows stratigraphy; impact point and center of crater are at a horizontal distance of zero kilometers. Sediments that form the transient cavity rim (a) collapsed inwards and downwards, while material in the central crater collapsed upwards (b). In this model, the stratigraphically uplifted material (central uplift) collapses outwards across the downthrown rim material to form a peak ring (c). d) Cross section through the final crater. Color shows maximum shock pressures that rocks have been subjected to during crater formation. Dashed line shows the location of sediments that originally formed the transient cavity rim, see (a).

Original objectives

Proposal 548-Full3

Prioritization of proposed operations/objectives

Rank	Site name	Depth range (mbsf)	Objective(s) addressed at site	Essential*
1	Chicx-03A	650-1500	Understanding a fundamental cratering process - peak ring formation, through documentation of lithology and physical state of peak ring forming material. Re-habitation of deep biosphere and investigation of whether peak rings are an ecological niche for early life, through documentation of microbiology and hydrothermal circulation within peak ring and earliest Paleogene. Results from these will have implications for our understanding of regional to global effects on the biosphere.	Yes
2	Chicx-04A	850-1500	Recovery of the biosphere in response to extreme environmental change through documentation of microbiology and geochemistry in impact breccias and earliest Paleogene. Understanding a fundamental cratering process - peak ring formation through determining the nature of the dipping reflectors that run beneath the peak ring – are they structural, lithological, hydrothermal conduits, or some combination of these?	Yes
3	Chicx-04A	400-850	Expanded section of Paleocene-Eocene, calibration of marine seismic data	No
4	Chicx-03A	400-650	Paleocene-Eocene boundary, calibration of marine seismic data	No

Table 1. Ranking and prioritization of objectives for holes Chicx03A and Chicx-04A, from Addendum reviewed by the SPC in March 2010 and forwarded for scheduling.

Summary of changes to original objectives

The original objectives of Chicx-03A are unchanged, although the change in total depth drilled means that we will recover ~530 m of peak ring rocks instead of ~830 m. Our new high resolution velocity model (Figure 1) suggests that we will recover two distinct lithologies: 1) rocks from 670-800 m depth that form uppermost peak ring and have low velocities (2.8-3.0 km/s; colored light blue in Figure 1), and 2) slightly higher velocity rocks (4-4.5 km/s, colored green) from 800-1200 m. There is no strong change in velocity within the peak ring rocks below

1200 m, which suggests they are lithogically similar. Hence, we believe that our proposed drilling will recover material that is truly representative of the peak ring and is thus able to fully address our objectives.

Although Chicx-04a may not be drilled during this expedition, we do expect to recover samples of the PETM and earliest Paleogene when we drill Chicx-03A, although they unlikely to be as expanded as in Chicx-04A (see Figure 1). So our objectives of documenting the recovery of the biosphere in the earliest Paleogene, as well as sampling the PETM and calibrating our seismic data (see Table 1) may be partially or even fully achieved in drilling a single hole.

The single high-priority objective that will be lost if we do not drill Chicx-04A is the sampling of the dipping reflectors. The implications of this are difficult to assess. If these reflectors represent a change in rock type (for example from crustal material to sediment, as shown in Figure 2d), this would provide strong constraints on the kinematics of crater formation.

In summary, some of the original objectives will not be achieved through drilling a single hole – but the costs to the program will be halved (see Tables 2 and 3). Should the ECORD FB agree to fund drilling of the single hole we will continue to endeavor to raise additional funds from elsewhere to drill to deeper depths in Chicx-03A and/or drill Chicx-04A, either at the same time or in a future expedition. Currently we have a co-funding proposal in front of ICDP for $1.5M and a positive response from SEP could be instrumental in the goal of a joint IODP-ICDP funded expedition.

Chicx-03A	Scenario 1 (days)	Scenario 2 (days)
Open hole interval 0–550 m	11	13.75
Coring interval 500–1200 m	21.7	32.5
Total expedition days (including transit and logging)	40	53.5

Table 2 Estimated expedition duration using minimum and maximum open hole and coring drill rates (scenarios 1 and 2 in ESO cost estimate, Table 3). Note that the total days are slightly less than in the ESO estimate as we propose to start coring at 550 m instead of 400 m. Hence the cost should be slightly less than the $7.5 – 13.3 million shown in Table 3. The duration of the original two-hole expedition was estimated to be over 100 days and cost between $14.9 and 25.8 million.

Level of investment in drilling Chicxulub to-date

Two seismic reflection and refraction experiments were funded by NSF and NERC in 1996 and 2005, at a cost of ~$2 million each (Morgan et al., 1997; Gulick et al., 2008; 2013; Christeson et al., 2010; Morgan et al., 2011), and include the site survey data used to locate the drill holes.

A successful seabed hazard survey for safe placement of liftboat feet and identification of any shallow marine risks was carried out in March 2013 and observed no major impediments to drilling; this survey was funded through ESO at a cost of $680 K.

In accordance with directions and encouragement from ECORD, we submitted a full proposal to ICDP requesting co-funding from ICDP – this proposal will be considered by the SAG on 2-4th April, 2014.

Sean Gulick and Joanna Morgan have had several meetings within Mexico and elsewhere to facilitate the permitting of the drilling. Along with Mario Rebolledo (our Mexican co-proponent in the Yucatán) they had a critical meeting with Dr. Raul Godoy (the Secretary for Education in the Yucatán) in Merida in May 2013 where he suggested a 3-way Memorandum of Understanding (MOU) between ESO, UNAM and a consortium of Yucatán academic and government research entities. Such an MOU will enable Godoy to bring resources to the drilling and enable ESO to work through UNAM for permitting. A draft MOU, constructed by ESO, is currently with the Dean of Research at UNAM and we are following up on getting it signed and arranging key meetings with officials in Mexico City.

In liaison with ESO a workshop in Merida was arranged for May 7-9th 2014, to introduce the project to the Yucatán science community and public. Dr. Godoy agreed to fund the workshop, which was to be hosted at the Greater Maya Museum that has a wing dedicated to Chicxulub. The Governor of the Yucatán made plans to attend the associated workshop banquet at the museum, but we have postponed the event following the ECORD FB board's decision not to schedule the drilling of 2 holes at Chicxulub in the near future. This workshop was designed to facilitate the permitting process but also as a great public relations and educational opportunity for Chicxulub drilling in specific and IODP in general. Member nation funding for US and Japanese scientists' travel is now in place for attendance to a Merida workshop. We stand ready to reschedule this workshop and associated press releases.

Summary

We have asked the ECORD FB to consider a de-scoped option for drilling Chicxulub in which one single hole (Chicx-03A) is drilled instead of two. ESO have constructed a budget for a single hole with a TD of 1200 m (Table 3). With this commitment, we can seek co-funding from ICDP (our ICDP proposal for $1.5 M is pending and will be considered at their meeting on 2-4 April), as well as the Yucatán government and elsewhere, and use the extra funds to either deepen the single hole and/or drill both holes. We realize that renewal is a key part of programmatic decisions. We are confident that drilling the site of the impact responsible for the death of the dinosaurs (Schulte et al. 2010) will attract enormous international publicity with a major potential for K-12 education as well as scientific advances. Perhaps no single geologic event is as well known as the K-Pg impact and we would be engaged in assisting IODP and ECORD in leveraging this high profile expedition for the benefit of continuing mission specific drilling expeditions to accomplish transformative objectives into the future.

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Table 3. 548 Chicxulub Impact Crater (descoped project - 1.2km penetration, one hole)

Proposal / Expedition details	
Number of holes to be cored	1
Number of holes to be logged	1
Departure port	Progresso
Total Expedition transit distance (km)	75
Total open hole interval (m)	400
Total coring interval (m)	800
Total penetration (m)	1200
Total logging interval (m)	1200
Number of scientists	16
Number of ESO staff	16
Total number of staff	32

Technical capabilities / rates	Scenario 1	Scenario 2
Ship transit speed (knots)	6	6
Open hole rate (m/day)	50	40
Coring rate (m/day)	30	20

Times	Scenario 1	Scenario 2
Transit (days)	0.3	0.3
Open hole time (days)	8	10
Coring time (days)	26.66666667	40
Logging time (days)	7	7
Expedition duration (days)	41.9	57.3
OSP duration (days)	15	15

Platform & logging costs	**Rates ($/day)**		**Total ($)**	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Mob / demob			2,500,000	4,500,000
Day rate	50,000	90,000	2,083,333	5,130,000
Sailing rate	50,000	90,000	14,061	25,310
Victualling (per person)	100	100	134,233	183,300
Consumables			500,000	500,000
Logging contract			600,000	600,000
Contingeny = ~10% of drilling contract			473,163	983,861
Platform & logging subtotal			6,304,791	11,922,471

ESO costs (excludes ESO base costs)	**Additional expedition costs ($)**	
	Scenario 1	Scenario 2
Salaries	678,264	865,331
Travel and subsistence	55,000	55,000
Supplies	200,000	200,000
Shipping	20,000	20,000
Equipment	60,000	60,000
Servicing, maintainance & upkeep		
Drilling consultancy	20,000	20,000
Database development contract	45,000	45,000
Publications	150,000	150,000
ESO subtotals	1,228,264	1,415,331
GRAND TOTALS	7,533,055	13,337,802

IODP Site Summary Forms:

Form 1 – General Site Information

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Section A: Proposal Information

Title of Proposal:	Chicxulub: Drilling the K-Pg Impact Crater
Date Form Submitted:	2014-04-02 22:12:27
Site Specific Objectives with Priority (Must include general objectives in proposal)	1: Constrain the formational processes and lithology of peak ring 2: Investigate the deep biosphere 3: Investigate post-impact recovery 4: Sample the PETM
List Previous Drilling in Area:	ICDP drilling site Yaxcopoil-1 located at edge of inner basin on land. No drilling of peak ring has occurred anywhere.

Section B: General Site Information

Site Name:	Chicx-03A	Area or Location:	Peak Ring Chicxulub
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 21.45141	Jurisdiction:	Mexico
Longitude:	Deg: -87.95108	Distance to Land: (km)	25
Coordinate System:	WGS 84		
Priority of Site:	Primary: yes Alt:	Water Depth (m):	17

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	670	530
	Total Sediment Thickness (m) 670	
		Total Penetration (m): 1200
General Lithologies:	Carbonates	Impact breccias, impact melt rocks, fractured basement

Coring Plan: (Specify or check)

APC [x] XCB [x] MDCB [ ] PCS [ ] RCB [ ] Re-entry [ ]

Wireline Logging Plan:

Standard Measurements		Special Tools			
WL	[ ]	Magnetic Susceptibility	[x]		
LWD	[ ]	Magnetic Field	[ ]	Formation Image (Acoustic)	[x]
Porosity	[x]	Borehole Temperature	[ ]	Formation Fluid Sampling	[x]
Density	[x]	Nuclear Magnetic Resonance	[ ]	Formation Temperature & Pressure	[ ]
Gamma Ray	[x]	Geochemical	[ ]	VSP	[x]
Resistivity	[x]	Side-Wall Core Sampling	[ ]	Others:	
Sonic (Δt)	[x]				
Formation Image (Res)	[x]				
Check-shot (upon request)	[x]				

Max. Borehole Temp.: °C

Mud Logging: (Riser Holes Only)

Cuttings Sampling Intervals

from m to m m intervals

from m to m m intervals

Basic Sampling Intervals: 5m

Estimated Days: Drilling/Coring: 43 Logging: 7 Total On-site:

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	[ ]	Complicated Seabed Condition	[ ]	Hydrothermal Activity	[ ]	Avoid hurricane season (July - October)
Hydrocarbon	[ ]	Soft Seabed	[ ]	Landslide and Turbidity Current	[ ]	
Shallow Water Flow	[ ]	Currents	[ ]	Gas Hydrate	[ ]	
Abnormal Pressure	[x]	Fracture Zone	[x]	Diapir and Mud Volcano	[ ]	
Man-made Objects (e.g., sea-floor cables, dump sites)	[ ]	Fault	[ ]	High Temperature	[ ]	
H_2S	[ ]	High Dip Angle	[ ]	Ice Conditions	[ ]	
CO_2	[ ]	Sensitive marine habitat (e.g., reefs, vents)				
Other:						

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IODP Site Summary Forms:

Form 2 - Site Survey Detail

Proposal #: 548	Site #: Chicx-03A	Date Form Submitted: 2014-04-02 22:12:27

*** Key to SSP Requirements**

X=required; X=may be required for specific sites; Y=recommended; Y*=may be recommended for specific sites; R=required for re-entry sites; T=required for high temperature environments; † Accurate velocity information is required for holes deeper than 400m.*

Data Type	In SSDB	SSP Req.	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)			Location:
1b High resolution seismic reflection (crossing)			Location:
2a Deep penetration seismic reflection (primary)			Location:
2b Deep penetration seismic reflection (crossing)			Location:
3 Seismic Velocity			
4 Seismic Grid			
5a Refraction (surface)			
5b Refraction (bottom)			
6 3.5 kHz			
7 Swath bathymetry			
8a Side looking sonar (surface)			
8b Side looking sonar (bottom)			
9 Photography or video			
10 Heat Flow			
11a Magnetics			
11b Gravity			
12 Sediment cores			
13 Rock sampling			
14a Water current data			
14b Ice Conditions			
15 OBS microseismicity			
16 Navigation			
17 Other			

IODP Site Summary Forms:

Form 3 – Detailed Logging and Downhole Measurement Plan

Proposal #:	548	Site #:	Chicx-03A	Date Form Submitted:	2014-04-02
Water Depth (m):	17	Sed. Penetration (m):	670	Basement Penetration (m):	530

Are high temperatures or other special requirements (e.g., unstable formations), anticipated for logging at this site?

Estimated total logging time for this site: 7

Measurement Type	Scientific Objective	Relevance (1=high, 3=low)
Check Shot Survey	Tie to 3D seismic survey	3
Nuclear Magnetic Resonance		0
Geochemical		0
Side-wall Core Sample		0
Formation Fluid Sampling	Deep biosphere studies	3
Borehole Temperature		0
Magnetic Susceptibility	Tie to magnetic data to improve models of impact melts	2
Magnetic Field		0
VSP	Tie to 3D seismic data	2
Formation Image (Acoustic)	To identify fractures in breccias	1
Formation Pressure & Temperature		0
Other (SET, SETP, ...)	Deep biosphere sampling	3

IODP Site Summary Forms:

Form 4 – Environmental Protection

Proposal #:	548	Site #:	Chicx-03A	Date Form Submitted:	2014-04-02 22:12:27

Pollution & Safety Hazard	Comment
1. Summary of Operations at site.	APC, followed by XCB, and other techniques as necessary. Expect easy drilling in Cenozoic basin and difficulties with underpressuring due to macroporosity in peak ring lithology. Dipping reflector lithology is either melts or extinct hydrothermal system along a fault. Underlying material is likely to be fractured basement or lithic breccia. Exact drilling and logging program will be dependent on the MSP chosen.
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling.	
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows.	Hydrocarbon show observed in slumped block at outer edge of crater impact basin during drilling of ICDP Yaxcopoil-1. Expected to be because of Cretaceous downthrown blocks originating from outside the transient cavity.
4. Indications of gas hydrates at this location.	
5. Are there reasons to expect hydrocarbon accumulations at this site?	No
6. What "special" precautions will be taken during drilling?	Need to deal with problem of underpressuring in breccia drilling.
7. What abandonment procedures need to be followed?	
8. Natural or manmade hazards which may effect ship's operations.	
9. Summary: What do you consider the major risks in drilling at this site?	

IODP Site Summary Forms:

Form 5 – Lithologies

Proposal #:	548 - Add 4	Site #:	Chicx-03A	Date Form Subm.:	2014-04-01 23:38:43

Subbottom depth (m)	Key reflectors, Unconformities, faults, etc	Age	Assumed velocity (km/sec)	Lithology	Paleo-environment	Avg. rate of sed. accum. (m/My)	Comments
600m	PETM	55		Carbonate			
670m	K-Pg Boundary	65		Impact breccia/carbonate			
top = 670 m bottom = 1200m	Peak Ring Rocks	65		Impact breccias and melts, fractured basement			

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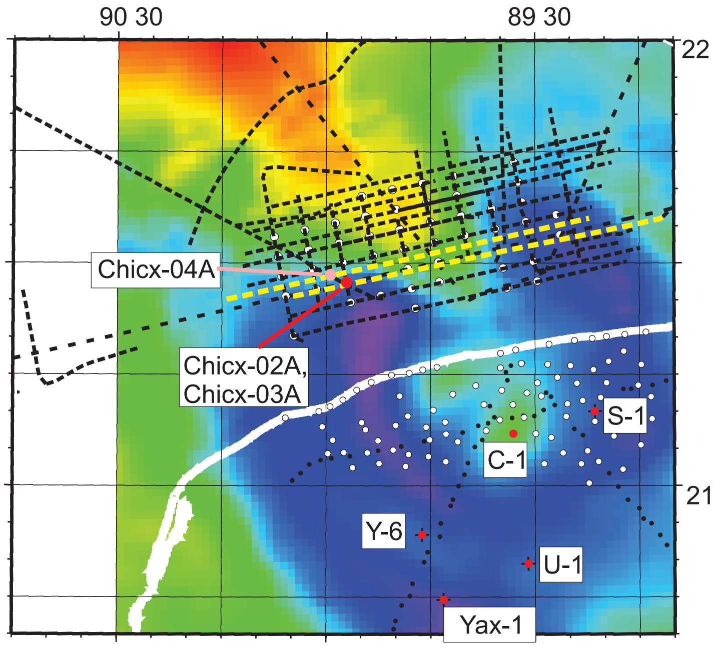
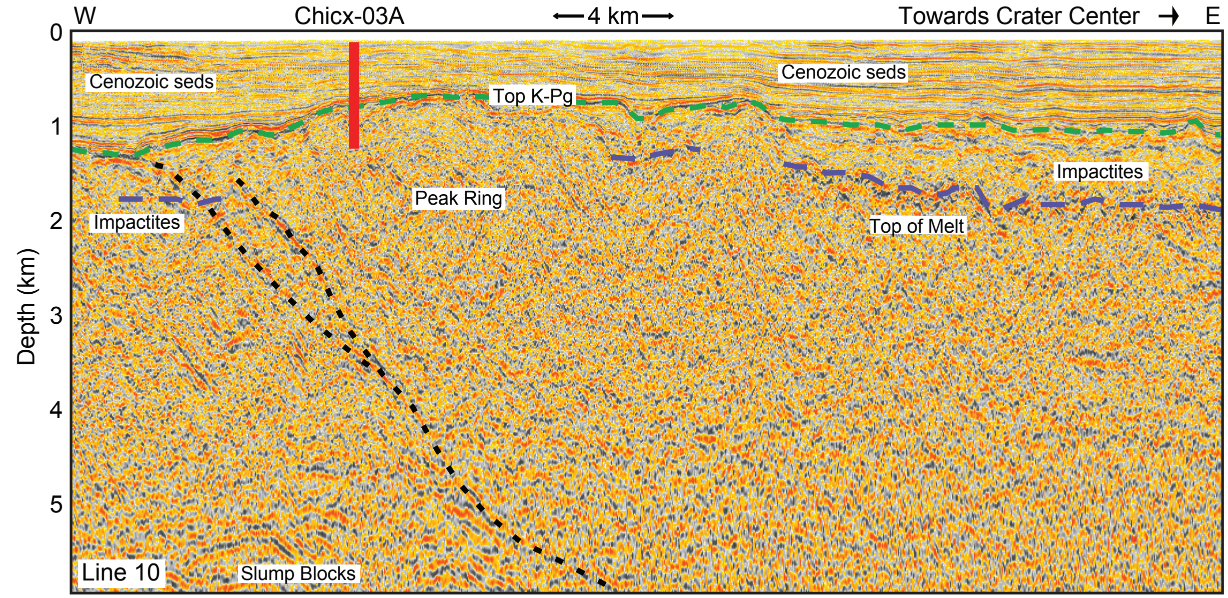
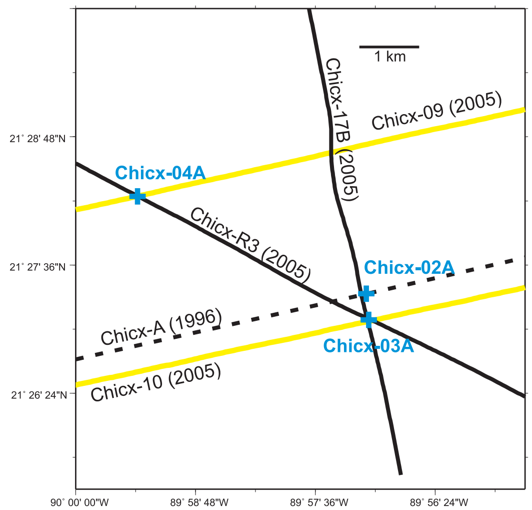
Proposal #:	548 - Add 4	Site #:	Chicx-03A	Date Form Subm.:	2014-04-01 23:38:43

Site Summary Figure Comment	

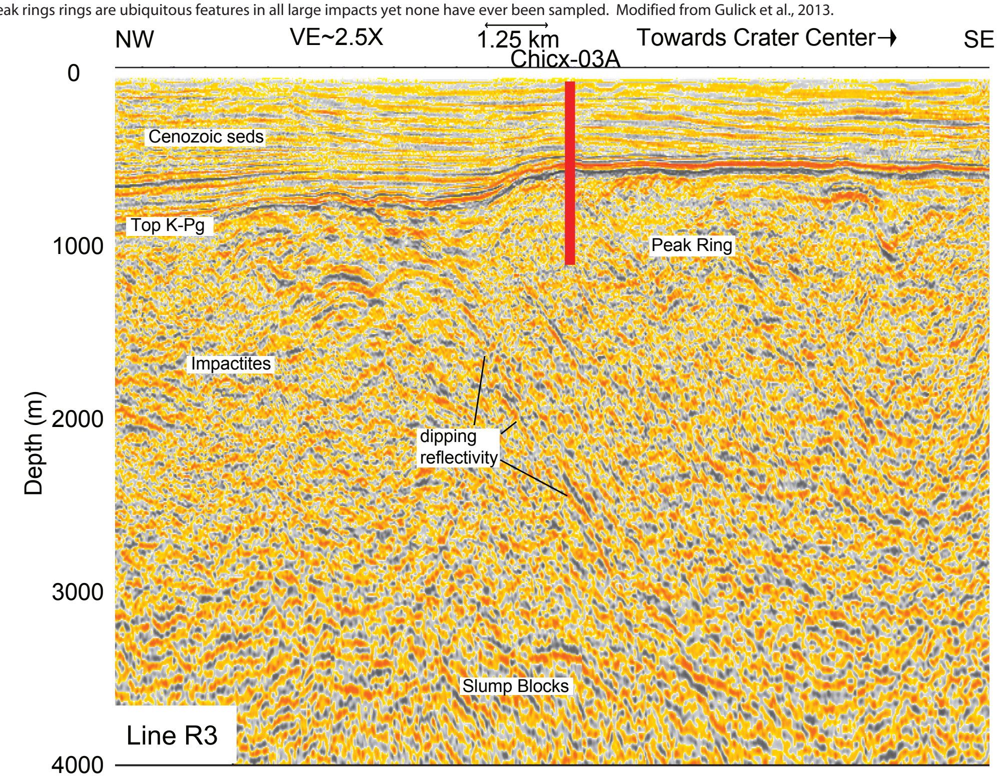




Line 10 from our 2005 R/V Maurice Ewing cruise that crosses our Lines 17b and R3 at the position of the proposed borehole, Chicx-03A. Borehole is shown to a depth of 1200 m. Proposed to be drilled with a liftboat due to 17 m water depth. A seabed hazard survey was completed in 2013. Imaged geology includes Cenozoic carbonate basin overlying the K-Pg boundary sequence and the topographic peak ring with impactites and evidence of melt present inward and outward from the peak ring dipping reflectivity beneath it. Peak rings rings are ubiquitous features in all large impacts yet none have ever been sampled. Modified from Gulick et al., 2013.



Primary site 03A: Located at line crossing of Chicx-10 (CDP 1721), Chicx-17b (CDP 3085), and Chicx-R3 (CDP 1017) SSDB files: Gravity= 1996_2005_boreholes_rev.pdf Mag=comp-mag_rev.jpg Location= chicxmap_ssdb_rev.jpg & loc_site_grav_labelled.jpg Bathy= Basemap_Jan14_Chart.pdf MCS data= chix17bmigspeq_agc.segy & chixR3migspeq_agc.segy & chix17Bmigspqdpthagc.segy & chixR3migspeq dpthagc.segy & chix10migspeqtvf_agc.segy & chix10migspeqdpthagc.segy MCS images=chicx17b_site2and3.tif & chicx17b_site2and3_depth.tif & chicxr3_site3_depth_rev.tif & chicxR3_site3_revised.tif & chicx10_site3_revised.tif & chicx10_site3_depth_rev.tif



Line R3 (uninterpreted) from our 2005 R/V Maurice Ewing cruise that crosses our Lines 17b and 10 at the position of the proposed borehole, Chicx-03A. Borehole is shown to a depth of 1200 m. Proposed to be drilled with a liftboat due to 17 m water depth. A seabed hazard survey was completed in 2013. Imaged geology includes Cenozoic carbonate basin overlying the K-Pg boundary sequence and the topographic peak ring with impactites and dipping reflectivity present away from the crater center. Slump blocks from the crater rim can be seen beneath the peak ring. By drilling the overlying sediments en route to the peak ring the Paleocene-Eocene Thermal Maximum as well as earliest Paleogene sediments will be sampled. Modified from Gulick et al., 2013.