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548-Full3

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☐ **New** ☑ **Revised** ☐ **Addendum**

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Title:	Chicxulub: Drilling the K-T Impact Crater
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Area:	Gulf of Mexico

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Permission to post abstract on IODP-MI Web site: ☐ X Yes ☐ No

Abstract: (*400 words or less)*

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-T 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 nearly 30 years of intense debate, we are still striving to answer the third question.

This revised full proposal updates 548-Full2, which was submitted to ODP in Fall 2000. Since the last submission, we have acquired new site survey data as part of a $2 million seismic reflection and refraction experiment, progressed in our numerical modeling efforts of the Chicxulub impact, expanded our proponent group in terms of expertise and international representation, and held a community workshop in Potsdam Germany in September 2006 to reach a consensus on scientific objectives achievable by drilling at the Chicxulub impact crater. We have devised a logistical plan of drilling two 1500-m-deep holes into the peak ring that will meet our scientific objectives but at a significant cost savings in comparison to our originally proposed single 3000-m-deep peak ring hole. The proposed drilling transect 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: (*250 words or less*)

Hole Chicx-03A will sample the material that forms a topographic peak ring, and reveal the lithological and physical state of the peak-forming material, including porosity, fracturing and degree of shock. We will, thus, be able to 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, we will be able to distinguish whether the rocks have been uplifted from the upper crust or deeper and whether the rocks are highly fractured, porous, and/or contain thick zones of pseudotachylitic breccia, as seen in outcrops and drill core at Vredefort and Sudbury**.**

Hole Chicx-04A will penetrate the enigmatic dipping reflectors that run from the outer edge of the peak ring and dip inwards. We suggest three working hypotheses for the cause of the dipping reflectivity: *1) The dipping reflectivity beneath the peak ring at Chicxulub is a lithologic boundary between uplifted basement lithologies and younger Mesozoic sediments; 2) the dipping reflectivity is a thrust fault formed during peak ring emplacement; 3) the dipping events are the result of vigorous hydrothermal circulation in the wake of peak ring emplacement that deposited hydrothermal minerals with this reflectivity marking a former hydrothermal conduit.* The origin of this reflectivity could well be some combination of these origins, such as a fault formed during peak ring emplacement that then served as a conduit for fluids post-impact.

Please describe below any non-standard measurements technology needed to achieve the proposed scientific objectives.

Proposed Sites:

Site Name	Position	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
Chicx-04A	21 28.6578 N 89 57.4404 W	17 m	1500 m			Peak ring formation processes. Origin of dipping reflectivity. Size of transient cavity (energy of impact)
Chicx-03A	21 27.0846 N 89 57.0648 W	17 m	1500 m			Peak ring formation processes. Document lithology and physical state of peak ring forming material. Document microbiology and hydrothermal processes.
Chicx-02A	21 27.33 N 89 57.09 W	17 m	1500 m			Contingency site for Chicx-04A

IODP 548-Full3 CHICXULUB: DRILLING THE K-T IMPACT CRATER

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1. INTRODUCTION

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-T 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 nearly 30 years of intense debate, we are still striving to answer the third question.

Peak rings are a ring of hills that protrude through the crater floor within large impact basins on the terrestrial planets (Fig. 1), and there is no consensual agreement on either their formational mechanism or the nature of the rocks that form them. Geophysical data indicate that the peak ring at Chicxulub is formed from rocks that have a low velocity and density, and one explanation for this is that they are highly fractured and porous. Immediately after impact the peak ring was submerged under water, and located adjacent to a thick pool of hot melt rocks. Hence, we would expect intense hydrothermal activity within the peak ring. This activity may have provided a niche for exotic life forms, in a similar way that hydrothermal vent systems do in the oceans. Drilling the peak ring will determine the origin, lithology and shock state of the rocks that form it, allow us to distinguish between competing models of peak ring formation, as well as document the hydrothermal activity and microbiology.

Numerical modeling of large impacts indicate that the rocks must behave in a fluid-like manner for a short period after impact, to allow the dramatic collapse of a large bowl-shaped transient cavity to form a broad, flat final crater (Fig. 2). The material that forms the peak ring has travelled the greatest distance during crater formation, and should have undergone the most mechanical weakening. Recent geological investigations at Sudbury and Vredefort have provided clues to the weakening mechanism (Lieger et al., 2008), but erosion at these two craters means that we are viewing the rocks at depths of several kilometers below the peak ring. Sampling the material that forms the peak ring at Chicxulub will allow us to examine the mechanically weakened rocks close to surface, and help us better understand large crater formation.

Although some paleontologists initially argued that the K-T mass extinction was gradual and dismissed the idea that the extinction was caused by a meteorite impact, one of their most prolific dissenters has changed her mind on both counts (Keller et al., 2007; Keller, 2008). Initial models of the environmental effects of impact were hindered by the inability to quantify the 3D distribution, chemical constitution and physical state of the global ejecta and its interaction with the Earth's atmosphere. The rapid development of 3D hydrocodes and computer models has led to much improved models of the ejection of materials from the impact site (Artemieva and Morgan, 2008) and thermodynamic calculations for condensation within the plume (Ebel and Grossman, 2005). Thus, we are now in a better position to characterize the impact produces that may have affected the post-impact climate. Drilling the central crater at Chicxulub will help us improve constraints on the energy of impact and the materials ejected from the impact site, and these are fundamental input parameters for climate models.

This revised full proposal updates 548-Full2, which was submitted to ODP in Fall 2000. Since the last submission, we have acquired new site survey data as part of a $2 million seismic reflection and refraction experiment, progressed in our numerical modeling efforts of the Chicxulub impact, expanded our proponent group in terms of expertise and international representation, and held a community workshop in Potsdam Germany in September 2006 to reach consensus on scientific objectives achievable by drilling at the Chicxulub impact crater. We have devised a logistical plan of drilling two 1500-m-deep holes into the peak ring that will meet our scientific objectives but at a significant cost savings in comparison to our originally proposed single 3000-m-deep peak ring hole. The proposed drilling transect 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* (page 44 in the Initial Science Plan).

2. BACKGROUND

2.1. K-T Impact

Initially a circular gravity low was recognized in the Yucatán by Cornejo-Toledo and Hernandez-Osuna (1950), prompting an exploratory drilling program by Petróleos Mexicanos (Pemex) in the early 1950s. At a Society of Exploration Geophysicists meeting, Penfield and Camargo (1981) used the strong magnetic and gravity signature across Chicxulub to suggest that it was either a volcano or a large impact structure. Coincidentally, Alvarez et al. (1980) reported that there had been a large impact at the end of the Cretaceous, using as evidence the high proportions of meteoritic material detected in K-T boundary clay layers. Controversially, Alvarez et al. (1980) also concluded that the impact caused the K-T boundary mass extinction, generating tremendous scientific and public interest. Researchers searched for the impact site but, because the Chicxulub impact structure is buried and has little surface expression, it took nearly 10 years to rediscover and identify Chicxulub as the K-T impact site (Hildebrand et al., 1991; Pope et al., 1991). Cores from the 1950s Pemex wells provided the crucial samples that proved that Chicxulub was a large impact structure (Hildebrand et al., 1991; Siwsher et al., 1992). It is now accepted that Chicxulub is a large impact crater and in fact one of the three largest known impact craters on Earth, and that material ejected from the impact site produced the global K-T boundary layer (e.g., Koeberl et al., 1994; Sharpton et al., 1996; Schulte et al., 2006, and papers in Koeberl and MacLeod, 2002). It is generally also accepted that this impact ended the Mesozoic Era (e.g., Swisher et al., 1992; Blum et al., 1993; Krogh et al., 1993; Smit, 1999). However, a minority of the scientific community does question whether the impact was the dominant force driving the K-T mass extinction (Keller, 1989; Hurlbert and Archibald, 1995; Jablonski, 1997; Keller, 2005). For a recent summary of this debate see Keller et al. (2007) and reply by Schulte et al. (2008).

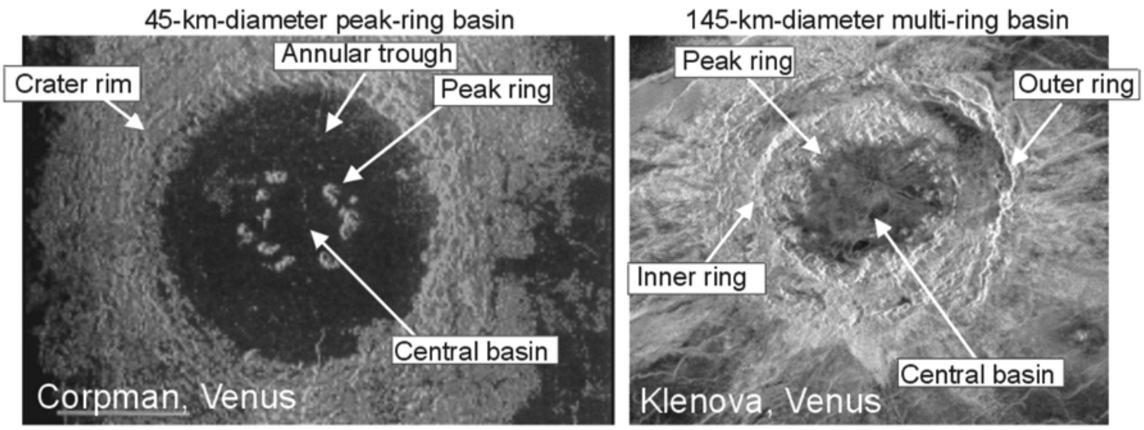

Fig. 1. Peak rings are roughly circular rings of rugged hills and massifs that stand above the otherwise flat crater floor. In peak ring basins, the crater rim is the outer edge of a terrace zone. In multi-ring basins, two or more rings (inward-facing asymmetric scarps) lie outboard of the central basin.

2.2 Character of large impact craters

Impact is a ubiquitous geologic process in the solar system and was a dominant process in early planetary history. While remote sensed images of other planets and moons (e.g., Fig. 1) provide important information on the morphology and morphometry of impact craters, most notably their enigmatic ringed topography, such images do not provide information on the subsurface structure and lithology associated with specific morphometric features. Currently only the study of terrestrial impact craters can supply this information. Unfortunately, the Earth is the most endogenically active of all the terrestrial planets, and consequently has preserved only a small fraction of the population of impact craters (~170) that it acquired over geologic time. In addition, the steep size-frequency distribution of planetary crater populations results in much fewer large craters than small craters. Sudbury (Canada) and Vredefort (South Africa) are the only other craters on Earth of comparable size to Chicxulub (Grieve et al., 2008) and both are significantly older (~2 Ga).

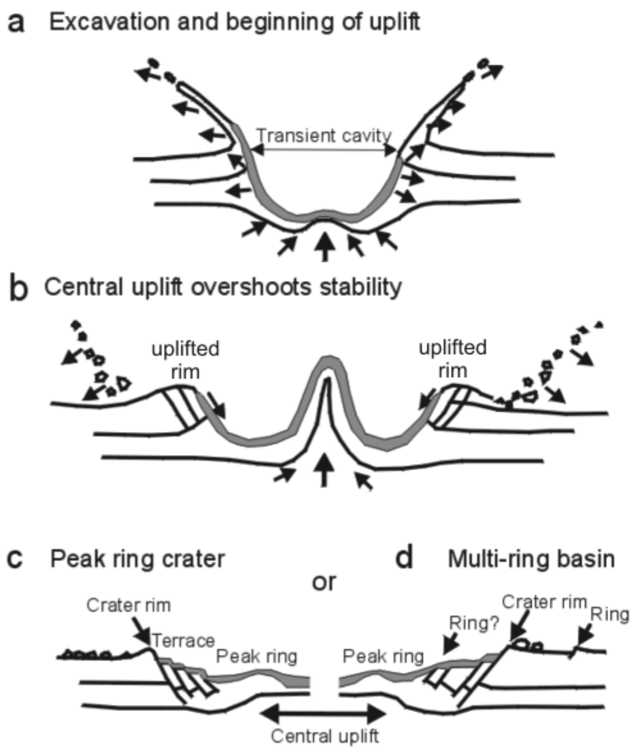

Fig. 2. Generic model for the formation of a large impact crater, adapted from Melosh (1989).

The formation of small craters (<2-4 km) is fairly well understood from terrestrial field studies, laboratory tests and nuclear craters, but the formation of large craters is not easily extrapolated from these observations. This is because the cratering process changes with size: as crater diameter increases, simple bowl-shaped craters evolve to central-peak craters, then to peak ring craters, and finally to multi-ring basins. Fig. 2 shows a generic model for the formation of a large impact crater. According to this model, the center of the transient cavity rebounds upwards to form a central uplift (Fig. 2b), and the uplifted rim collapses inwards and downwards to form a terrace zone of slumped blocks. In large craters, the central uplift is itself gravitationally unstable, and it subsequently collapses to form a peak ring (Fig. 2c). However, there is no single quantitative consensual model for the formation of topographic peak rings, as a result of the current lack of quality ground-truth data (Grieve and Cintala, 1999).

One present challenge is how to use observed crater morphologies to infer the course of events during crater collapse (Melosh and Ivanov, 1999; O’Keefe and Ahrens, 1999). The final crater form is sensitive to conditions of the target planet, including planetary gravity, and density and rheology of the target materials. If we can understand the large-scale cratering process on Earth, we can use this knowledge on other planetary bodies to predict their subsurface character. Numerical modeling of the collapse of the transient cavity has been successful in producing final craters with more-or-less the expected topographic features (Ivanov and Deutsch, 1999; O'Keefe and Ahrens, 1999; Collins et al., 2002; Ivanov, 2005). To enable the transient cavities to collapse, localized transient mechanical weakening of the target rock is necessary, possibly by some combination of frictional melting, thermal softening, and acoustic fluidization.

Recent field work at the Sudbury and Vredefort impact structures has shown that thick zones of pseudotachylite were formed as tensional fracture zones, and this indicates overall dilation of target rocks during crater modification (Riller and Lieger 2008; Lieger et al., 2008) as predicted by the acoustic fluidization model (Melosh, 1979). Vredefort has been eroded 8 - 11 km below the parautochthonous crater floor[1], and rocks outside the melt sheet (SIC) at Sudbury, where the peak would have been located, have been eroded by up to 5 km. Hence, whereas these two craters provide us with observational data on rock weakening at depth, drilling the peak ring at Chicxulub will offer us an insight into the weakening of the rocks in the near surface. Numerical models suggest that the peak ring material has travelled farthest during crater formation (Figs. 2 and 11) and should be the most weakened. Sampling these displaced and shock-modified rocks will be invaluable in improving our understanding of large-crater collapse.

Chicxulub is the only large terrestrial structure where the complete range of ejecta deposits remains. Distal ejecta is observed around the world (the famous mm-thick K-T clay layer), and thicker ejecta beds, up to several meters, are found in the Gulf of Mexico region, Cuba and Belize (see Smit, 1999 for a summary). Several crucial K-T boundary sections were drilled in DSDP and ODP holes (e.g., legs 86, 165, 171). Chicxulub offers our only opportunity to document the transport and deposition processes of the ejecta (solid, melt and vapor), the mixing of debris originating from different depth within the target rock, the incorporation of meteoritic components, the interactions between this ejecta and the atmosphere (including condensation, solidification reactions, etc.), as well as variation in trends in melt and impact debris composition with distance and direction from the site of a large impact crater (Claeys et al. 2002). Recent 3D numerical models of the Chicxulub impact and expanding vapor plume have, for the first time, re-produced the observed volume and general composition of the world-wide ejecta layer (Artemieva and Morgan, 2008), while thermodynamic models have provided some insight into condensation in the plume (Ebel and Grossman, 2005) and new detailed studies of ejecta re-entry and interactions with the atmosphere are re-evaluating

[1] Parautochthonous crater floor: shocked basement rocks that form the crater floor in large craters, and have moved as a block, or series of blocks.

the importance of the heat pulse at the surface (Goldin and Melosh, 2008). This represents a significant advancement in determining the global effect of this impact, and is a fundamental first step in testing mechanisms for extinction.

2.3. What is a Peak Ring?

The term "peak ring" was first used to describe the often discontinuous, mountainous ring that rises above the floor of large craters on the moon. Peak rings are internal to the main topographic crater rim (Fig. 1). Since they were first identified on the moon, peak rings have been observed in large craters on all large silicate planetary bodies. *Notably, peak rings do not appear to occur on the icy satellites of Jupiter and Saturn.* Importantly, the peak ring is a topographic feature - it protrudes through the melt and breccia lining the floor of the crater and stands above the surrounding terrain. As a result, the unequivocal identification of a peak ring at terrestrial craters is compromised by inevitable erosion and/or tectonism. Therefore, apart from at Chicxulub, there is no widely accepted exemplar of a terrestrial peak ring, and consequently there is no consensus as to either the geologic nature of the peak ring (what material does it comprise, from what stratigraphic location does this material derive) or the mode of formation of a peak ring.

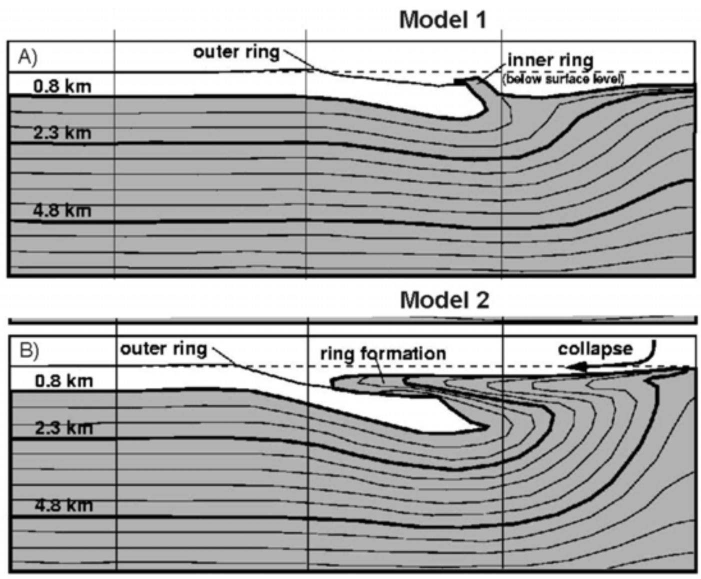

Fig. 3. Two examples of numerical models of crater collapse (Wünnemann et al., 2005). In a) the uppermost target has a high strength, and the target undergoes moderate weakening for a relatively long period. In b) the uppermost target has a lower strength, and a wide area of target is strongly weakened by the impact for a short period.

Most models of peak ring formation suppose that it is generated during the collapse of a deep bowl-shaped "transient crater" formed during the initial stages of cratering (Grieve et al., 1981; Melosh, 1989). During this collapse, structural uplift of the crater floor produces a central uplift, which is over-heightened and unstable under gravity (Fig. 2b). The subsequent outward collapse of the central uplift in some way leads to the formation of a ring of peaks between the crater center and the crater rim. However, this is a highly generic model and the precise kinematics and details of the mechanics of cavity modification remain unclear. Moreover, that such emphatic collapse of the transient crater occurs at all requires substantial weakening of target rocks around the crater relative to their static laboratory-measured strength; the mechanism for weakening the target rocks is also poorly understood. Recent numerical models (Fig. 3) show that the precise form of crater collapse and peak ring formation is dependent on near-surface rheology, as well as the spatial extent, nature and timing of the weakening of the target rocks (e.g., Wünnemann et al., 2005).

On Venus (Fig. 1) peak rings show an increase in peak-ring/crater diameter ratio with increasing crater size (Alexopoulos and McKinnon, 1994), suggesting that outward collapse of the central uplift increases with impact size, and that perhaps only one mechanism is required to explain the formation of all peak rings. However, interior remnant topographic rings within terrestrial impact basins are interpreted to show different lithological and structural character (Fig. 4). Internal remnant topographic rings within terrestrial craters correspond to one of three different morphological elements: overturned transient cavity rim (Ries crater, Fig. 4a), stratigraphic uplift (Popigai crater, Fig. 4b), and megabreccia (Popigai crater, Fig. 4b). In each case, it is unclear whether the morphological element represents a topographic feature in the pristine crater and hence, whether or not the element is analogous to extra-terrestrial peak rings. This diversity in interpretation, as well as a lack of common understanding as to what constitutes the planetary equivalent of a peak ring (Pike, 1985; Grieve and Therriault, 2000), has led to contradictory interpretations of the nature of the peak ring at Chicxulub (e.g., Pilkington et al., 1994; Sharpton et al., 1996; Morgan et al., 2000).

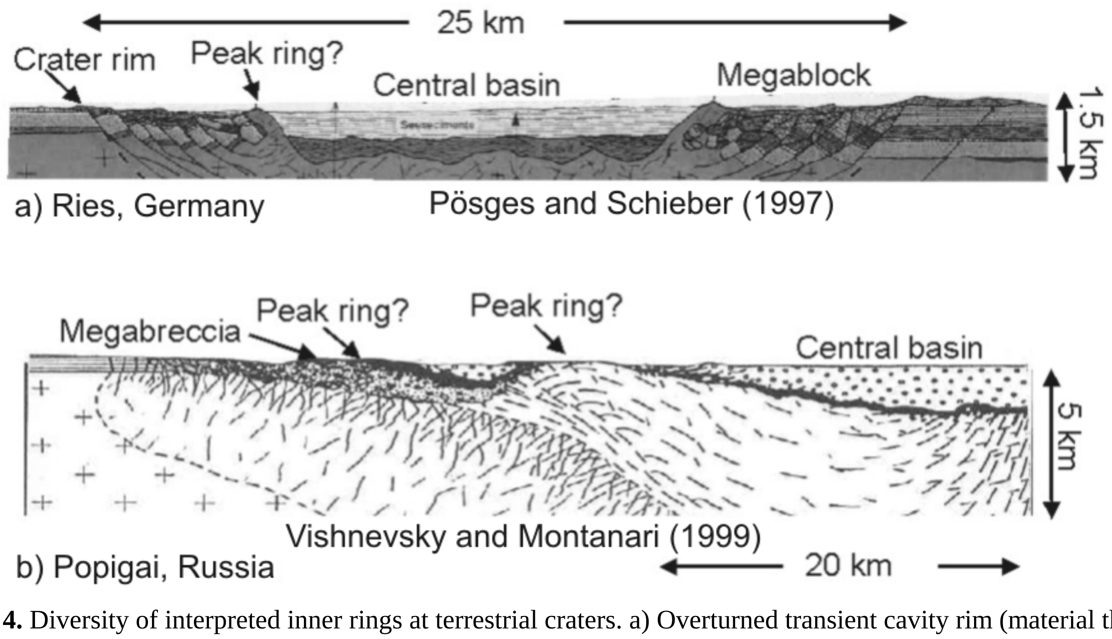

Fig. 4. Diversity of interpreted inner rings at terrestrial craters. a) Overturned transient cavity rim (material that is pushed outwards and upwards during the excavation stage to form the rim of the transient cavity, and then collapses inwards and downwards during the formation of the final crater). b) Stratigraphic uplift (material that is initially below the target surface in the center of the crater, is pushed downwards during the compressional stage of impact, and then moves upwards during the formation of the final crater) or megabreccia (material that has moved along the wall of the transient cavity during the formation of the final crater).

3. CHICXULUB IMPACT STRUCTURE

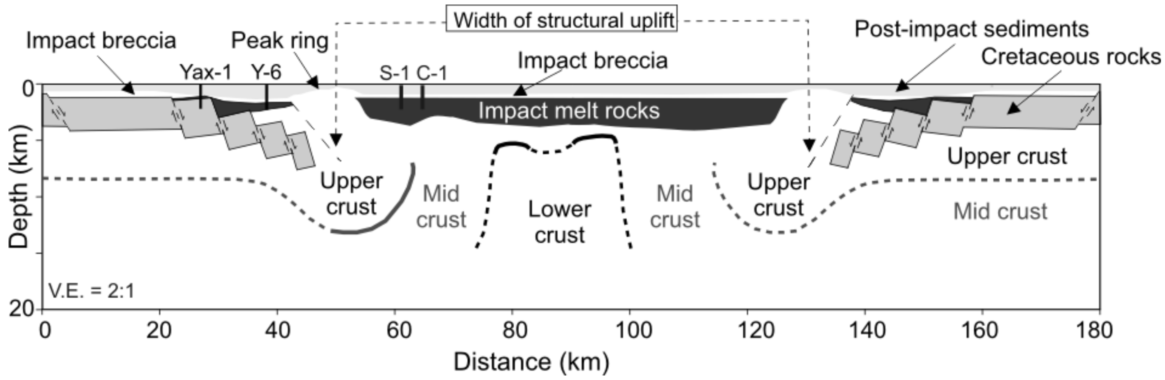

Fig. 5. Geological interpretation of the Chicxulub crater from Vermeesch and Morgan (2008).

3.1 Character of Chicxulub

A geological interpretation of the Chicxulub structure has been built through comparison with other large impact craters and integration of seismic, gravity, magnetics, and drilling data (Fig. 5). From the exterior inward, the crater structure includes a series of extensional ring faults, a terrace zone made up of downdropped slump blocks of Cretaceous carbonates and evaporites, a topographic peak ring, and a central structure that includes impact melt rocks overlying a central uplift (e.g., Morgan et al., 1997; Gulick et al., 2008; Vermeesch and Morgan, 2008). The central crater is now buried ~1 km beneath the surface.

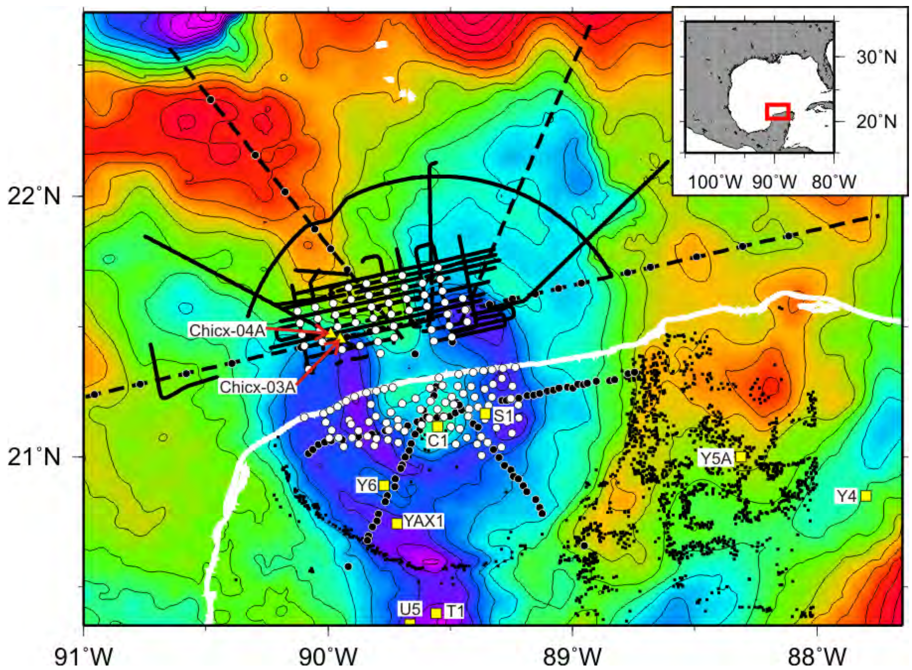

Fig. 6. Location of site survey data overlain on the gravity field. Coastline is in white. Black dots are cenotés. Marine seismic profiles acquired in 1996 and 2005 are shown in black dashed and solid lines respectively. Offshore and onshore seismometer locations in the 1996 and 2005 surveys are shown with black and white circles, respectively. Existing deep well locations are shown with yellow squares; wells U6 and U7 discussed in the text are located WSW of U5. Proposed IODP sites Chicx-03A and Chicx-04A are shown with yellow triangles.

3.2 Past onshore drilling

Pemex drilled several deep (~1.6 km) holes into or close to the Chicxulub crater (Fig. 6), completing their drilling in the mid-1970s. Unfortunately, the amount of coring was limited and their interest in the area waned after they intercepted Paleozoic basement and impact melt rocks without any sign of hydrocarbons. Very few samples of the impact lithologies found in these wells are now available for examination. The Universidad Nacional Autónoma de México (UNAM) conducted a shallow drilling program in the 1990s, during which impact lithologies were penetrated at 3 sites, U5, U6 and U7. ICDP borehole Yax-1 was drilled ~60 km to the SSW of the crater center, within the impact basin and inside the cenote ring (Fig. 6). The stratigraphy of the Chicxulub crater has been constructed using the limited core available and the original Pemex logs (Fig. 7).

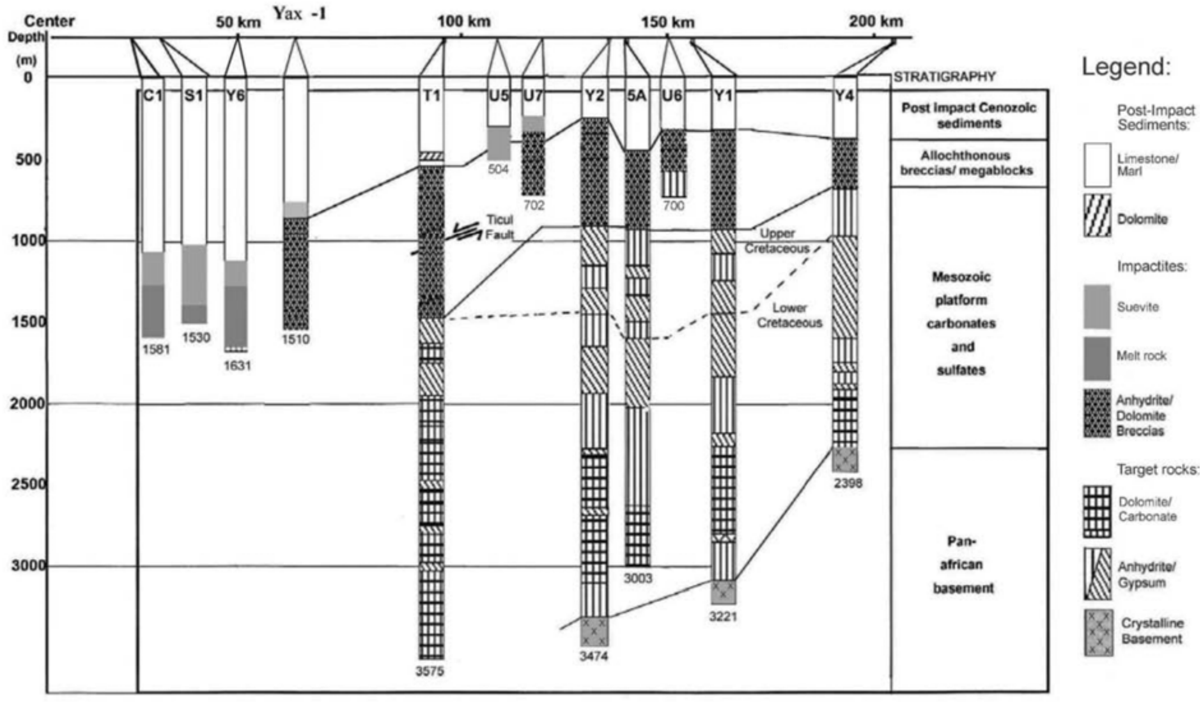

Fig. 7. Stratigraphy of various drill cores across the Chicxulub impact structure (Stöffler et al., 2004).

The onshore wells indicate that post-impact sediments deepen from a few hundred meters at radii > 90 km to ~1.1 km within the center of the post-impact basin, in agreement with the offshore seismic data. Within the post-impact basin, wells C1, S1, and Y6 penetrated a few hundred meters of suevitic breccia and only C1 reached the true impact melt rock near the central part of the peak ring; whereas, outside the basin, wells T1, Y2, Y5A, Y1, and Y4 penetrated a few hundred meters of melt-poor impact breccia. Several wells have penetrated thick sequences of Cretaceous rocks. Close to the structure, these sequences are ~2-km thick and comprise dolomites and carbonates, with some thick beds of Lower Cretaceous anhydrite. Wells Y1 and Y2 penetrated Paleozoic basement at ~3.3 km depth. UNAM well U5 shows Tertiary rocks above suevitic breccia. In U7, the suevitic breccia overlies "Bunte" breccia, composed mainly of sedimentary clasts rich in evaporitic material. In U6, the Tertiary rocks directly overlie this "Bunte" breccia, with an erosional contact between them. The "Bunte" breccia in the two UNAM wells could be the same impact breccia observed in Y4, Y1, Y5A, Y2 and T1. No onshore wells have penetrated peak ring material.

ICDP hole Yax-1 is located ~60 km radial distance from the crater center and is positioned interior of the crater rim (Fig. 7). Drilling recovered core from the Tertiary carbonate sequence, impact breccias, and underlying Cretaceous carbonates, down to the depth of 1511 m. The cores reveal many differences from pre-drilling predictions (Urrutia-Fucugauchi et al., 2004), including: 1) The proportion of basement material within the impact breccias is higher than observed at other craters; 2) The impact breccia layers are thinner than predicted; 3) There is a surprising lack of evidence for anhydrite in the impact breccias despite anhydrite layers in the target rocks. More detailed analysis of the Paleogene sedimentary succession in Yax-1 provides insight into crater excavation, evolution and infilling. Of five sedimentary sequences in Yax-1 the first three document abundant gravity flow and soft sediment deformed units that were likely deposited along the edge of one of the steeply dipping megablocks in the terrace zone (Whalen et al., 2007). The steep slope depositional environment may explain the dissolution of evaporates exposed during crater excavation and provides a reason for the preservation of only thin impact breccia layers at the position of Yax-1. These results have important implications for excavation models, crater structure, breccia emplacement, and crater formation. Improving our understanding of these processes is vital to test competing K/T extinction models, many of which call upon vaporization of the sulfur-rich anhydrite in the target lithology. We expect IODP drilling into the peak ring to provide additional surprises.

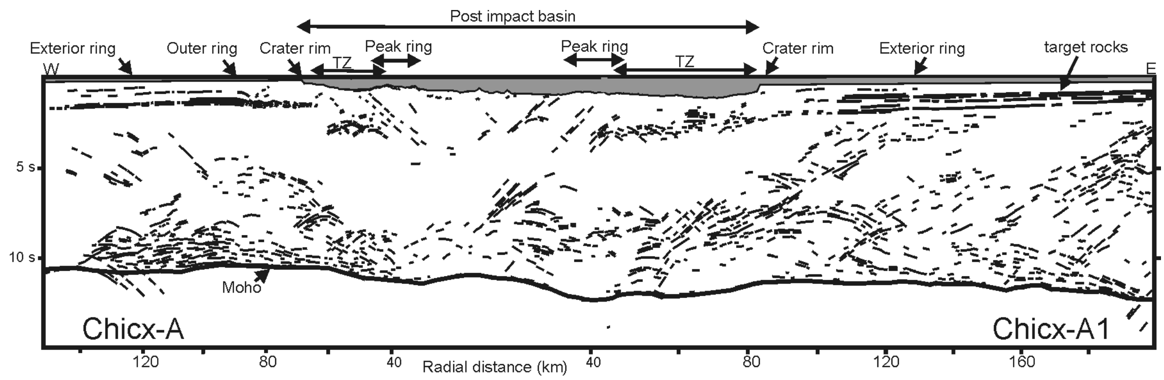

Fig. 8. Line drawing of Chicx-A/A1, from Morgan and Warner (1999)

3.3 Seismic reflection studies

Multi-channel seismic site survey data over the Chicxulub crater include regional profiles acquired in 1996 and 2005 and a more detailed grid acquired in 2005 (Fig. 6; Morgan et al., 1997; Morgan et al., 2005; Gulick et al., 2008). These data image the crater fill from the surface to the K-T boundary (Whalen et al., 2007), and image impact lithologies and structures to the base of the crust, at about 35 km depth (Figs. 8-9). The present-day K-T surface deepens to ~1 s two-way travel time (TWTT, ~1 km), revealing a ~145-km-diameter post-impact basin (colored gray in Fig. 8). Within this post-impact basin, there is an ~80-km-diameter topographic ring that appears analogous to peak rings observed on other planetary bodies (compare Figs. 1 and 9). Reflective pre-impact stratigraphy can be tracked around the crater. Large offsets in the stratigraphy define a 20-35 km-wide terrace (or megablock) zone (TZ in Fig. 8). The total vertical offset of the stratigraphy across this terrace zone is between 3 and 6 km; single offsets can be as large as 2.5 km. Melosh (1997) and Morgan and Warner (1999) have argued that the head scarp of this terrace zone is analogous to the crater rim in peak-ring craters. This crater rim marks the transition between faults separating slump blocks within the terrace zone and faults that are part of the ring structures that surround the central basin (Fig. 9; Gulick et al., 2008). The crater rim is absent to the northeast where a pre-existing Mesozoic basin existed (Gulick et al., 2008). In the east and west, the rim and transition in faulting offshore coincides with the ~82-km-radius gravity gradient and the onshore cenote ring (a chain-like series of sinkholes, Fig. 6; Morgan and Warner, 1999; Gulick et al., 2008).

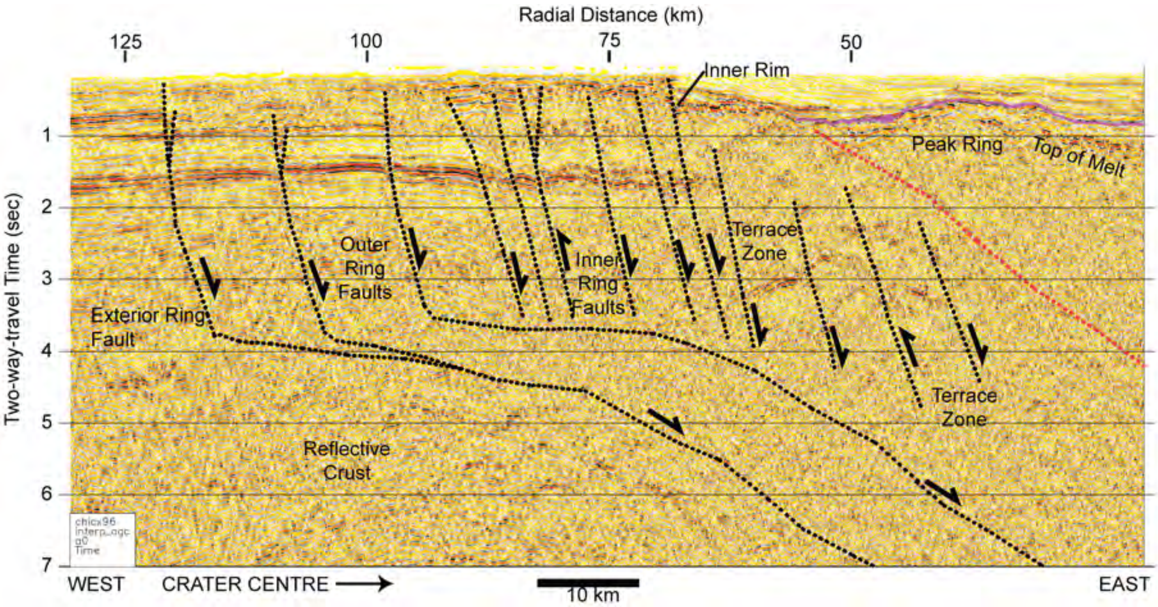

Fig. 9. Seismic reflection data along Chicx-A

At about 20–30 km outboard of the “crater rim” at Chicxulub, the relatively undisturbed, flat-lying, pre-impact stratigraphy is abruptly offset vertically by 400–500 m (outer ring; Figs. 8 and 9). The outer ring faults are observed out to radial distances of 90-120 km, giving a crater diameter of ~195-210 km (Morgan et al., 1997; Gulick et al., 2008). Exterior ring faulting occurs at some azimuths out to >125 km radius (Fig. 8). The surface topography on-shore shows subtle concentric highs at ~75, 95 and 120 km from the crater center (Pope et al., 1996) - at similar radial distances as the crater rim, outer ring, and exterior ring are observed in the seismic data, suggesting that these rings extend onshore.

Mapping of the K-T surface at Chicxulub and the pre-impact Mesozoic stratigraphy shows the crater to be asymmetric with greater relief on the peak ring in the west and north-west, greater depth of the terrace zone along the same azimuths, and absence of the crater rim to the northeast. These asymmetries correlate with what appears to have been a strongly dip-ping Cretaceous seafloor underlain by a pre-existing basin to the northeast suggesting the im-portant of target rock heterogeneity in final crater morphology (Gulick et al., 2008). These asymmetries also result in the peak ring being shallowly buried to the west and northwest (~750 m) and thus being accessible by drilling. Reconstruction of the Cretaceous seafloor pre-impact suggests that significant water cover (~650 m average in the transient crater) may have existed at the impact site and thus extinction mechanisms where sulfate-rich lithologies combine with water vapor to yield sulfate aerosols may be important (Gulick et al., 2008).

3.4. Chicxulub Peak Ring

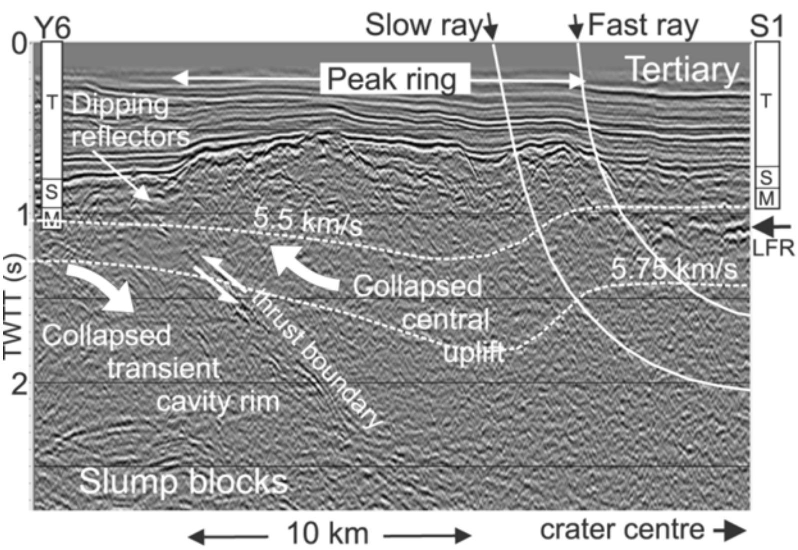

Fig. 10. Interpretation of seismic data across the peak ring, Morgan et al., 2000. Dashed lines indicate velocity contours. Rays traveling through the peak ring are slower than those traveling inside or outside the peak ring.

At an average radius of 40 km, an irregular, rugged peak ring that stands a few hundred meters above the basin floor is imaged at the Chicxulub impact crater (Fig. 10). The peak ring is roughly symmetric about the crater center; however, the depth to the top of the peak ring is asymmetric and varies from ~625 m in the west to ~1060 m in the east (Gulick et al., 2008). The peak ring lies above the slump blocks, and bright inward-dipping reflectors run from the outer edge of the peak ring to the inner edge of the slump blocks. Immediately beneath the peak ring seismic velocities are depressed, with this low-velocity region extending several kilometers beneath the peak ring and dipping towards the crater center (Fig. 10). A significant question answerable only by drilling is why the peak ring exhibits such low velocities (and densities).

On the basis of the seismic data, Brittan et al. (1999) proposed that the peak ring was formed by the interaction of the outwardly collapsing central uplift and the inwardly collapsing uplifted rim and that these dipping reflectors represented the boundary between the two collapse regimes (Fig. 10). Dynamic models (e.g. Collins et al., 2002) support Brittan et al.'s model (Fig. 11) and, if correct, predict that the peak ring is composed of deeply derived material, and that the stratigraphy within the peak ring is overturned. Vigorous post-impact hydrothermal circulation, expected in such crater environments (e.g., Newsom et al., 1986; Naumov, 2002; Abramov and Kring, 2003; Osinski, 2005; Osinski et al., 2005) could explain the enhanced dipping reflectivity beneath the peak ring (Gulick et al., 2008).

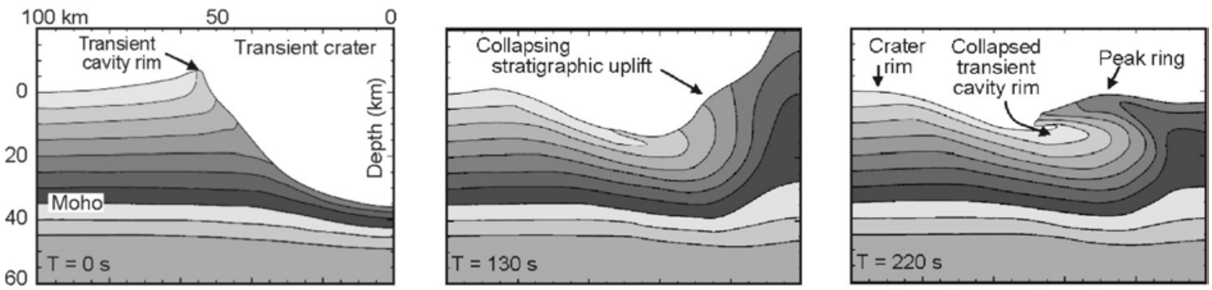

Fig. 11. Dynamic model for crater collapse (Collins et al., 2002).

4 SCIENTIFIC OBJECTIVES

4.1. Peak Ring Lithology, Structure, and Formational Mechanism

Currently, the peak ring at Chicxulub is the only accessible feature of its type on Earth or, indeed, in the solar system. The fundamental geological characteristics of peak rings at large impact structures cannot be ascertained through geophysical data alone, and it is essential that we obtain ground truth data through direct sampling. Such sampling represents a unique opportunity to validate existing models for peak ring formation, advance our understanding of large impact crater formation in the solar system, and calibrate models of environmental effects that ended the Mesozoic Era on Earth.

Drilling the peak ring at Chicxulub will determine the lithologic and structural character of a topographic peak ring, and test between competing models for its formation. Working hypotheses are based upon numerical models of transient cavity collapse and modification

(Figs. 3 and 11) and interpretations of geological observations at other large terrestrial craters (Fig. 4). For example, if the dynamic model in Fig. 3a is most appropriate, then the peak ring at Chicxulub would be formed from an overturned, but stratigraphically parautochthonous sequence, with uplifted basement rocks sitting directly above younger Mesozoic sediments (as at the Ries crater, Fig. 4a). The basement material that forms the peak ring may be broken into tens of meters to kilometer-sized blocks separated by discrete thrust faults, as interpreted from geophysical and geological data at the Vredefort structure (Fig. 16 in Grieve et al., 2008). In addition, we might expect thick zones of pseudotachylite within the peak ring, as observed several kilometers beneath the crater floor at Vredefort and Sudbury, and postulated to be a mechanism for weakening the rocks (Riller and Lieger, 2008). The faults, fractures and zones of pseudotachylite might explain the observed low velocity and density of the peak ring forming material.

An alternative to the above model is that the peak ring is formed by a more catastrophic downward and outward collapse of an over heightened structural uplift across and on top of the collapsed transient cavity rim (Fig. 3b). If deformation during collapse was this extreme, the peak ring would be geologically manifested as a megabreccia of basement overlying younger Mesozoic sediments, such as interpreted for Popigai (Fig. 4b) and in the cross-section of Chicxulub by Hildebrand et al. (1991). It is critical that we distinguish between these working hypotheses (and possibly others) for peak-ring formation. They provide fundamental constraints on the weakening of target materials during crater formation and the kinematics of transient cavity collapse at very large impact structures on the terrestrial planets. Moreover, once numerical models of peak ring formation are verified by ground truth data they can be more reliably used to quantify the energy of impact and the environmental consequences of large impacts on Earth. Constraining the environmental effects of the Chicxulub impact is a primary goal in the IODP Initial Science plan (page 44).

We propose to drill two holes: 1) Chicx03A will penetrate the material that forms the peak ring (Fig. 12a), and 2) Chicx-04A will drill through the outer edge of the peak ring, and the band of dipping reflectors potentially key to differentiating between formational mechanisms and to investigating any post-impact hydrothermal system and related biota (Fig. 12b).

Hole Chicx-03A (Fig. 12a) will sample the material that forms a topographic peak ring, and reveal the lithological and physical state of the peak-forming material, including porosity, fracturing and degree of shock. We will, thus, be able to 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, we will be able to distinguish whether the rocks have been uplifted from the upper crust or deeper and whether the rocks are highly fractured, porous, and/or contain thick zones of pseudotachylitic breccia, as seen in outcrops and drill core at Vredefort and Sudbury**.**

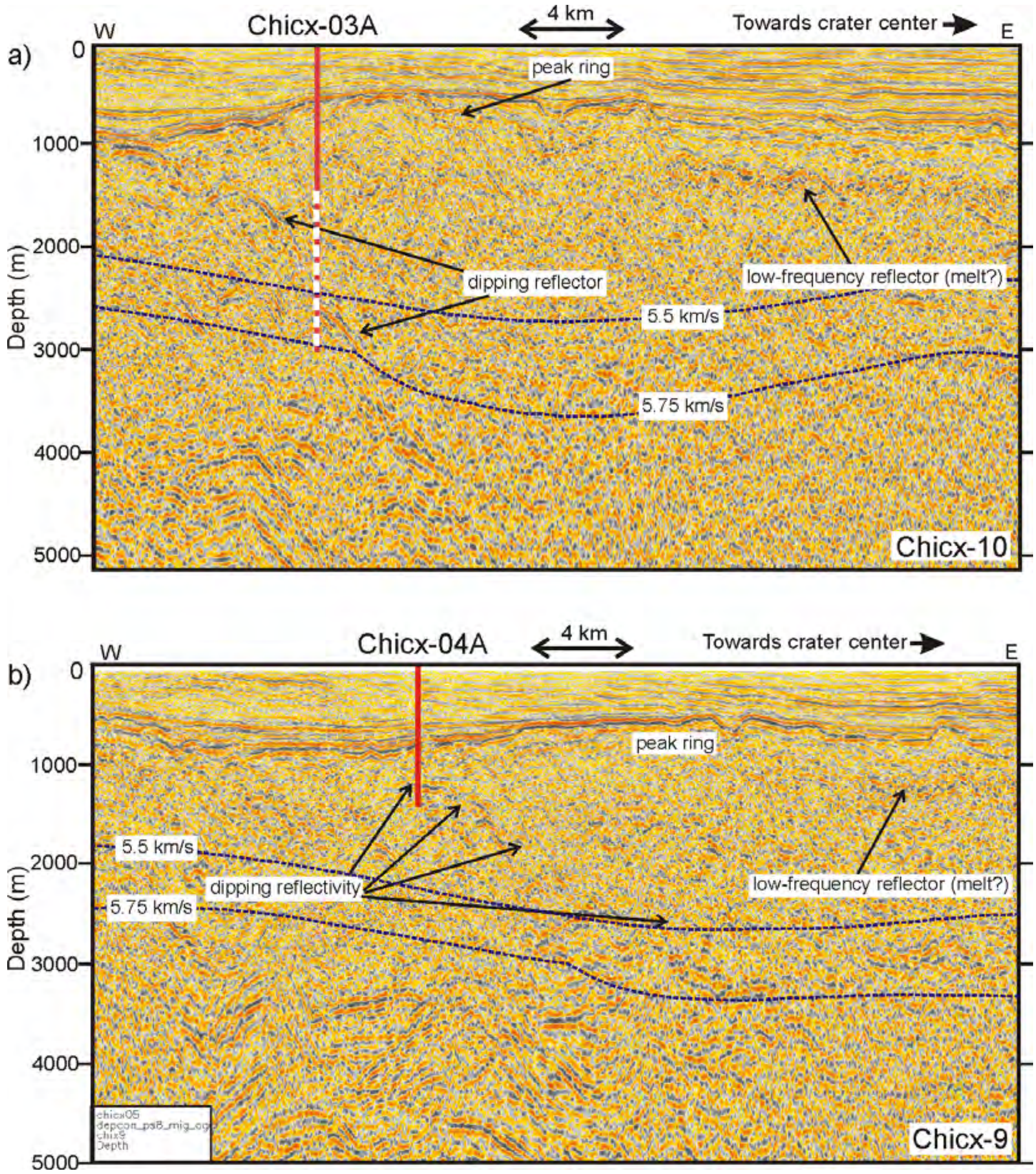

Fig. 12. Proposed IODP drill sites.

Hole Chicx-04A (Fig. 12b) will penetrate the enigmatic dipping reflectors that run from the outer edge of the peak ring and dip inwards. We suggest three working hypotheses for the cause of the dipping reflectivity: *1) The dipping reflectivity beneath the peak ring at Chicxulub is a lithologic boundary between uplifted basement lithologies and younger Mesozoic sediments (model 3a); 2) the dipping reflectivity is a thrust fault formed during peak ring emplacement (model 3b); 3) the dipping events are the result of vigorous hydrothermal circulation in the wake of peak ring emplacement that deposited hydrothermal minerals with this* *reflectivity marking a former hydrothermal conduit.* The origin of this reflectivity could well be some combination of these origins, such as a fault formed during peak ring emplacement that then served as a conduit for fluids post-impact.

One intrinsic and interesting feature of the peak ring at Chicxulub is that it is a seismic low-velocity zone (Figs. 10, 12), despite some model predictions that it consists of lithologies sourced from the formerly deeply buried basement of the Yucatán platform. In sampling these lithologies, we will test the hypothesis that *peak rings consist of lithologies that are deeply sourced but heavily brecciated and, hence, have higher porosities than surrounding impact and target rocks.* This hypothesis, if correct, has important consequences for questions of peak rings serving as habitat for exotic microbiology, due to the potential existence of macroporosity in the presence of significant hydrothermal circulation.

Peak rings are unique to large craters on silicate bodies, they are diagnostic of extremely high impact energies and their diameter is proportional to impact energy (Alexopoulus and McKinnon, 1994). The precise mechanism by which the transient cavity collapses to form a peak ring is dependent on the nature, spatial extent and duration of rock weakening, as well as the impact energy and near-surface rheology. Distinguishing between proposed models of peak-ring formation will therefore greatly enhance our ability to simulate large impacts, to estimate the environmental consequences of large impacts, and to investigate the effect of target properties on large crater formation. There are no peak rings on icy bodies, for example on the moons of Jupiter they are replaced by summit pit and central pit craters. Hence, understanding peak-ring formation is critical to understanding large cratering in general, and will help us determine whether the absence of peak rings on icy bodies is diagnostic of near-surface rheology, such as ice strength or the depth to a subsurface ocean.

4.2. Geomicrobiology of Chicxulub

Asteroid and comet impacts are known to cause severe disruption to surface biota, as is the case for the link between Chicxulub and the K/T extinctions, but what is their effect on the deep subsurface biosphere, where the majority of the Earth's biomass resides? This drilling project offers an opportunity to extend our understanding of the effects of the Chicxulub impactor from our current knowledge of its effects on the surface biosphere to the deep subsurface biosphere.

Impacts can fracture rocks, increasing their permeability. For example, it has been demonstrated that the shock processing of gneissic rocks at the 24-km-diameter Haughton crater in the Canadian Arctic have made them more porous and translucent and, therefore, more colonisable by cyanobacteria (Cockell, et al., 2002; Cockell et al., 2005). In addition, these rocks can harbour abundant culturable heterotrophic organisms (Fike, et al., 2003). In contrast, porous (sandstone) rocks may be impoverished as habitats due to impact-induced pore collapse (Cockell and Osinski, 2007). Only recently have these insights been applied to the deep subsurface biosphere. Drilling of the Chesapeake Bay impact crater has shown a deep region of impact-fractured rocks (Gohn et al., 2008), where microbial abundance dramatically increases in sections of core exhibiting evidence for high temperatures (impact glasses and melt). This observation suggests that impact allowed for improved deep subsurface recolonization after the hydrothermal system cooled. By contrast, other parts of the crater are impoverished, possibly caused by a combination of impact-induced hydrothermal sterilization and subsequent limitation of hydraulic conductivity, itself limiting the movement of microbes and nutrients back into the crater. Thus, patterns of microbial abundance can be linked to impact processes (Gohn et al., 2008). But how representative is this single data point? To further our understanding of the effects of impacts on the deep subsurface biosphere through time further data are required. The Chicxulub drilling project provides an exceptional opportunity to carry out a deep subsurface study using technical and contamination expertise developed with the ICDP at Chesapeake Bay and more generally developed by IODP in other (non-impact) sites.

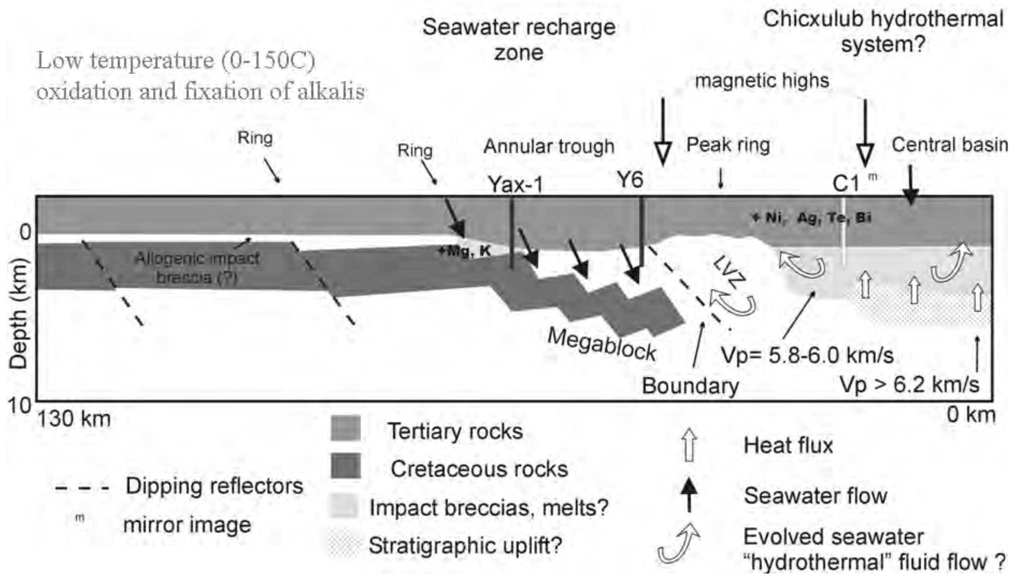

Figure 13. Possible hydrothermal system at the Chicxulub impact crater. The interaction of impact glass-rich suevite with downwelling seawater in the outer annular trough may possibly recharge higher temperature hydrothermal activity in the central impact basin. The high-porosity of the peak ring lithologies, and a paleo-topographic high within an active hydrothermal system, may prove to be an excellent environment for base metal deposition and exotic chemosynthetic species and mineralization. Figure courtesy of Doreen Ames.

The Chicxulub impact event created a large central uplift of relatively hot crust, generated a central melt sheet perhaps 3 km thick, and also deposited a layer of hot impact melt breccias within the basin interior. These hot materials drove a large subsurface hydrothermal system that chemically and mineralogically altered the Earth's crust, vented to the sea (Figure 13) and may have provided unique biological opportunities, just as hydrothermal vent systems do in the oceans. Chicxulub presents an opportunity to investigate the role of the hydrothermal system in influencing the post-impact conditions for subsurface life. Hydrothermal activity will affect the chemical composition and physical properties of the impact lithologies and may leach metals and sulfur from the rocks to produce extensive impact-related hydrothermal vent systems, such as that identified at the Sudbury crater (Ames et al., 1998). Detailed mineralogical and geochemical studies of the core will provide critical information on the temperatures and composition of hydrothermal fluids and the longevity of the system. This will provide a means of quantifying mass transfer.

Hydrothermal activity could both sterilize the deep subsurface, but also improve the habitat for prokaryotes. The high temperatures and pressures associated with impacts can have important effects on the suitability of rocks for microbial colonisation. Heavily fractured, brecciated rock will likely improve fluid flow in the hydrothermal system and the availability of nutrients and redox couples to a biota. The geochemical diversity of different rocks shattered and mixed within the breccia layer will also increase the potential for diverse geochemical gradients.

Geomicrobiology results at Chicxulub can be compared with those from the Chesapeake Bay impact crater (Gohn et al., 2008). These studies will have important implications for evolutionary strategies of early life on Earth, when the impact flux was much higher than today (Kring and Cohen, 2002; Zahnle and Sleep, 1997), and, possibly, Mars, where impacts may well have changed the conditions for habitability in the deep subsurface.

4.3. Hydrothermal Systems

Recent studies at large terrestrial impact craters indicate strong hydrothermal activity is likely related to and localized by the peak ring (Fig. 13). Alteration mineral assemblages produced by this type of activity have been described at other, albeit less-preserved, impact craters (e.g., Naumov, 2002) and detected at Chicxulub in the ICDP Yaxcopoil-1 core (e.g., Zurcher and Kring, 2004; Ames et al., 2004; Hecht et al., 2004; Kring et al., 2004; Lüders and Rickers, 2004). The alteration sequence in the Yaxcopoil-1 core is complex, but appears to have involved widespread metasomatic exchange of Na and K for Ca in plagioclase. Hydrothermal sphene, apatite, magnetite, bornite, and additional calcite were introduced with metasomatic feldspar. At lower-temperatures smectite replaced impact glasses, followed by or coincident with abundant calcite veins and open-space fillings.

Although the Yaxcopoil-1 core revealed hydrothermal alteration, it represents only a single point within a very large structure. Like hydrothermal systems at mid-ocean ridges, this impact-induced hydrothermal system may have altered a vast volume of the Earth's crust. The location of the Yaxopoil-1 core, ~60 km from the crater center, suggests an area of at least 11,300 km^2 may have been affected by hydrothermal activity and that a volume of crust exceeding 105 km^3 was likely chemically and mineralogically altered.

To verify the extent of the hydrothermal system and the magnitude of any chemical and mineralogical alteration of the crust, additional core is needed from other locations in the crater. Core from the peak ring is ideally located. A model of the thermal evolution of the Chicxulub system (Abramov and Kring, 2007) suggests the greatest hydrothermal alteration should occur in the peak ring, because it rises along the edge of the central melt sheet. The fracture density and degree of fracture filling by alteration assemblages will provide a measure of the permeability of the peak ring. The permeability of crater lithologies is the most important parameter affecting models of fluid flow and the thermal evolution of these types of systems. Because of these uncertainties, the calculated lifetime of the hydrothermal system is similarly uncertain, ranging from ~1 to ~3 million years (Abramov and Kring, 2007). Because the system was venting to the sea, seafloor precipitates may be captured in core that penetrates the peak ring. This will provide a direct measure of the chemical (and potentially biological) affect on seafloor conditions after the impact event.

4.4 Assessing the Environmental Effects of the Impact

Since Alvarez et al. (1980) proposed that a massive impact event caused the K-T mass extinction, many workers have debated the merits of the working hypothesis. One of the most fundamental questions that has arisen is "what damage did such an impact do to the Earth ecosystem?" The impact at Chicxulub was devastating. The energy released was equivalent to that of one Hiroshima explosion on every square kilometer of the entire Earth's surface (~100 million megatons of TNT), but how does one quantify the effect? The energy transfer from the impact itself to the environment remains poorly understood (in other words, how did the Chicxulub impact kill the dinosaurs?). The mechanism certainly propagated through the atmosphere as climate models show. However, to constrain such models and ultimately to understand the mass extinction process, it is of paramount importance to study the evolution and the response of the lithological components involved in the cratering event.

To model the environmental effects of the impact and assess potential killing mechanisms, it is necessary to constrain the deleterious pollutants released into the atmosphere by the Chicxulub impact. Apart from dust particles, volatile species of CO_2, SO_x and H_2O were released by shock devolatization of the target rocks. In the upper atmospheres, the intense frictional heating from the re-entering ejecta combined with the impact-released gases would destabilize the entire atmospheric circulation and cause, among other things, massive destruction of stratospheric ozone. At the surface, the IR radiation from the hot upper atmosphere may have caused heating strong enough to cause the development of major wildfires that filled the lower atmosphere with smoke, dust and pyrotoxins in a scenario reminiscent of a nuclear winter. After the initial heat pulse, dust and sulfates in the upper atmosphere caused an extensive period of cooling at the Earth's surface, accompanied by widespread acid rain resulting from a flushing of the sulfate aerosols from the lower atmosphere (Brett, 1992; Gulick et al., 2008). Finally, the CO_2 released in the impact and wildfires eventually accelerated the recovery of the biosphere, causing a long-term global warming effect (e.g., O'Keefe and Ahrens, 1999; Sigurdsson et al., 1992; Pope et al., 1994; Ivanov et al., 1996; Pierazzo et al., 1998; Lomax et al., 2000 and 2001; Pierazzo et al., 2003).

Quantifying the volume of pollutants (physical ejecta and chemical volatiles) released into the atmosphere is vital to modeling the ensuing catastrophic environmental perturbation resulting from the Chicxulub impact event (Pope et al., 1997). To quantify the pollutants, it is necessary to: 1) know the volume, composition and porosity of the rocks involved in the impact, 2) improve our understanding of how these target rocks responded during impact, particularly in relation to the release of volatiles (e.g., Martinez et al., 1995; Langenhorst et al., 2000; Ohno et al., 2004), or the relative proportion of material vaporized and/or melted (e.g., Jones et al., 2000; Claeys et al., 2003), 3) better constrain the size of the transient cavity, and, 4) better constrain the velocity and density of the impactor, and the direction of impact (e.g., Ivanov et al., 1996; Schultz, 1996; Pierazzo and Melosh, 1999). Drilling will provide better constraints on 1 and 3. To access the type and quantity of material injected into the atmosphere (proportion of dust versus volatiles, chemistry of the volatiles) the composition of the lithologies preserved today in the crater, in particular near the center, must be compared with the material expelled and deposited at close proximity to the crater, and the debris ejected and distributed worldwide. Only the Chicxulub impact is linked to a global mass extinction event, and only Chicxulub has an intact crater, proximal ejecta and a world-wide ejecta layer. Chicxulub thus offers a unique opportunity to investigate the cause of the breakdown in the global ecosystem at the end of the Cretaceous.

4.5. Post-impact Stratigraphy: Effects and Environment

Chicxulub provides an unprecedented opportunity to explore the pattern of biotic recovery and response of a carbonate platform system to a marine-target impact. Seismic data suggest an expanded post-impact record within the deeper-water impact basin compared to the more chemically and physically active shallow-water sediments outside the crater or from slope facies documented at Yax-1 (Whalen et al., 2007). Therefore, sediments overlying the peak ring in cores Chicx-03A and Chicx-04A are well suited for constraining short- and long-term post-impact effects. In fact, major drawbacks for documenting post-impact effects in Yax-1 were the depositional environment along the steep crater margin, leading to redeposition of material in gravity flows, and an unconformity between the latest Cretaceous and earliest Paleocene sediments (Arz et al., 2004; Keller et al., 2004; Whalen et al., 2007). Considering seismic expression (Fig. 12), similar problems may be encountered in Chicx-03A for the early Danian. However, Chicx-04A appears to record a more level-bottom environment that should provide an expanded post-impact record. Therefore, we aim at investigating the post-impact sequence of Chicx-03A and Chicx-04A by sedimentology including sequence stratigraphy, geochemistry (stable isotopes, elements), mineralogy, bio- and cyclostratigraphy, and backstripping analysis. In addition, a suite of geophysical logs will be acquired during drilling that are instrumental for correlating between the new holes, with previous drill holes, and with existing seismic data.

Specifically, these investigations are intended to achieve the following five major goals: (i) Ground truth the seismic reflection and geophysical logging data which are a key to post-impact effects and environment studies and provide the stratigraphic and lithologic control for the entire offshore basin (Pearson et al., 2007; Whalen et al., 2007; Gulick et al., 2008). (ii) Reveal the generation of impact-generated tsunamis. Since Chicxulub is a marine-target crater that formed on a northeastward deepening continental shelf (Gulick et al., 2008), huge tsunamis could have been generated and propagated to the surrounding regions (Matsui et al., 2002). Revealing the magnitude and duration of the tsunamis will contribute to understanding the sedimentology of the K-T boundary deposits around the Gulf of Mexico and the proto-Caribbean sea and provide baseline information about impact generated tsunamis (Goto et al., 2004). (iii) Detail the K-T boundary record. If an expanded K-T boundary interval is identified it will be investigated at sub-mm resolution for platinum group elements (PGEs) and biostratigraphy. The correlation of the impact breccia and the K-T boundary from within the Chicxulub impact basin to the distal ejecta and PGE anomalies found worldwide in the K-T boundary clay (Smit, 1999) would provide further clues to the currently debated K-T age of the Chicxulub impact (Keller et al., 2004, 2007; Schulte et al., 2008). (iv) Investigate the evolution of Paleogene climate, sea-level, and oceanography. Both Chicx-03A and 04A should provide us with an expanded section from the early Danian up to the late Eocene- Oligocene recording the most profound environmental changes in the Paleogene: the post-impact biotic recovery, a series of hyperthermal events of which the Paleocene-Eocene Thermal Maximum (PETM) was the most severe (Kennett and Stott, 1991; Zachos et al., 2003; Tripati and Elderfield, 2005), and the Eocene-Oligocene greenhouse-icehouse transition (e.g., Katz et al., 2008). Drilling will also not only allow testing of the established Yax-1 litho- and sequence stratigraphic models (Whalen et al., 2007), but also for extending the Paleogene sea-level record from the North-American shelf and Northern Gulf of Mexico into the tropical proto-Caribbean/Gulf of Mexico (e.g., Miller et al., 2005). (v) Document the long-term crater modification. The evolution of the sedimentary filling of the post-impact basin will be studied to constrain numerical models of the sedimentological evolution of this closed basin and its subsidence history.

4.6. Impact and melt breccias

Sites Chicx-03A and Chicx-04A will likely sample melt and other impact breccias within the central basin at Chicxulub. We intend detailed geochemical analyses of these rocks, to identify the major and trace elements, with emphasis on the siderophile elements (including the platinum-group elements – PGEs). In addition, a number of isotopic tracers will be quantified in order to develop mixing models for breccia formation and impactor contribution (e.g., Rb-Sr, Sm-Nd, Re-Os, Cr, O, C, S). The diverse range in Sr, Nd, and oxygen isotope compositions obtained so far, within the crater melts and the Haitian and Mexican melt glasses, suggests a complicated mixing and melting model (e.g., Koeberl, 1993; Kettrup et al., 2000), but these tracers are only sensitive to the terrestrial (i.e., target) lithologies. Building upon the work of Schuraytz et al. (1996), Kyte (1998) concluded that the Chicxulub impactor was a metal- and sulphide-rich carbonaceous chondrite based on the composition of a meteorite fragment from K-T boundary sediments drilled at DSDP Hole 576. If so then siderophile element and isotope tracers should be a better proxy for estimating the contribution from the impactor to the breccias as well as testing the hypothesis for impactor composition proposed by Kyte (1998). The use of siderophile element proxies (especially the PGEs) has been used to identify impactor compositions that generated lunar impact breccias (e.g., Norman et al., 2002; Puchtel et al., 2008). However, the situation on Earth is somewhat more complicated because of the roles of fluid transport and microbial activity. There is evidence of preferential mobility of the PGEs in hydrothermal systems (e.g., Wood, 1987; Gammons and Bloom, 1993; Gammons, 1995, 1996; Cave et al., 2003; Boily and Seward, 2005), as well as differential mobility due to microbial action (e.g., Lustig et al., 1998; Yong et al., 2002, 2003; Dahlheimer et al., 2007). The identification of Iridium-rich nuggets in K-T boundary deposits (Schuraytz et al., 1996) suggests the PGEs may also be fractionated because of different condensation temperatures. Thus, it is unlikely that the siderophile element contents of the impact and melt breccias from the Chicxulub proposed here will give a definitive answer for the nature of the impactor. Indeed, work from the Yaxcopoil-1 core (Tagle et al., 2004; Gelinas et al., 2004) suggest a negligible bolide contribution to the impact-induced lithologies. While it is possible that coupled PGE- isotopic analyses (i.e., Re-Os, Cr) could constrain the impactor signature (e.g., Shukolyukov and Lugmair, 1998; Tagle and Hecht, 2006), it is more likely that these analyses will show either a heterogeneous bolide contribution to the impact-induced lithologies (the signature of which has been modified by post impact processes thus masking the identity of the impactor), or show it to be uniformally absent. Either result will feed into our understanding of impact dynamics. Given the growing evidence for PGE mobility in hydrothermal and biological systems, perhaps the major contribution that siderophile element analyses, including the PGEs, could make to this project is to estimate contributions of post-impact hydrothermal and microbial activity (assuming a carbonaceous chondritic composition for the impactor).

4.6. Hydrogeology

The impact crater has had an important influence on the hydrology of the Yucatán peninsula, preferentially diverting groundwater around the “Ring of Cenotes” (Perry et al., 1995) which appears to be related to the crater rim (Morgan and Warner, 1999; Gulick et al., 2008). Recent increases in demand on fresh-water resources, and increasing concern about pollution of the ground-water, have emphasized the need to study the local hydrology and understand the influence the crater has on groundwater discharge. We therefore suggest making downhole permeability measurements and pore-water chemistry measurements in the proposed drill sites to further our knowledge about the hydrologic conditions of the crater region.

5. Relationship to IODP Initial Science Plan

The proposed drilling contributes to the IODP Initial Science Plan in the following areas: 1) *Environmental Change, Processes and Effects* as the investigation of Chicxulub will constrain its role in the single most catastrophic environmental and biological change in the last 100 Ma of Earth’s history, and investigate the resurgence of life in the wake of this environmental disaster. Additionally, we will penetrate the Paleocene-Eocene boundary across a high-resolution section and, thus, add to the record of that late Paleocene thermal maximum. 2) *The Deep Biosphere and Subseafloor Ocean* as we will investigate the role of large-scale impacts, in general, in creating or impoverishing habitats for life through changes in subsurface macro-porosity and the formation of chemically diverse hydrothermal systems, which may hold importance for the early evolution of life on Earth. We contend that drilling results from the K-T impact crater could well be transformative science, with a quantum leap in knowledge of large-scale cratering and both their deleterious and potentially positive effects, and represent a significant public and scientific success for IODP.

6 DRILLING STRATEGY

6.1. Site Location

We have mapped the peak ring offshore throughout the entire region of our seismic dataset. The peak ring is roughly symmetric about the crater center. Depth to the top of the peak ring, however, varies from ~625 m in the west to ~1060 m in the east. Drilling costs increase with target depth and, hence, drilling should occur where the depth to the peak ring is minimal. 3D mapping of the dipping reflection beneath the peak ring indicates that the western crater region is optimal for drilling a clearly-imaged example of this reflector.

Although one could potentially drill the peak ring onshore, there is no land seismic reflection data across the peak ring, and no way of accurately locating a hole at present. It is normally the case that marine seismic reflection data is of a higher quality than land data. This is particularly true in heavily populated and karsted areas. Air-filled karsts produce problems with statics and attenuation. Pemex acquired Vibroseis data onshore in the Yucatan: these data were poor, with little observable near-surface reflectivity (Antonio Camargo pers. comm.; we have requested access to these Pemex data). In addition, land seismic data acquisition is more expensive than marine acquisition by about a factor of 10, and the heavy population, nature reserves, and sub-tropical rain forest in the Chicxulub region would make it logistically nearly, impossible to acquire these data. We contend that our proposed offshore drilling will not necessarily cost more than the combination of land seismic acquisition (most likely of much poorer quality than our existing marine site survey) and onshore drilling.

6.2. Two-hole Drilling Strategy

In 548-Full2 we proposed to drill one 3000-m-deep hole through the peak ring material into the underlying dipping reflector (red-white dashed line in Fig. 12a) thereby accomplishing all of our primary objectives at a single site. However, in investigating platforms appropriate for the 15-25 m water depths it has become clear that to drill a 3000-m-deep hole would require a jack-up or semi-submersible rig which in today's (2008) market run an average of $500K per day. A significantly lower-cost alternative is drilling using a lift-boat with a cantilevered coring system. Coring systems of this type have a penetration capability of

~1500 m. However, this type of platform has the great advantage of being easy to move between multiple sites under its own power. Many lift-boats operate in both the Gulf of Campeche, Mexico and along the Gulf Coast in the US, they are less subscribed than jack-up rigs, and they run only $28-40K per day. The location of Chicxulub within the Gulf of Mexico provides for relative ease of scheduling and minimal mobilization/demobilization costs.

With these practical matters in mind we have developed a strategy of two holes that reach the drilling targets at shallower depths and greatly lower the overall cost. Chicx-03A (Figs. 6 and 12a) is located where the top of the peak ring can be reached at a shallow depth (700-750 m), and should sample ‘typical’ peak ring material. Chicx-04A (Figs. 6 and 12b) is located on the outside flank of the peak ring and will reach the dipping reflectors at a shallower depth (1300-1400 m) than imaged at Chicx-03A (2400-2600 m). Chicx-04A has the added benefit of sampling across an expanded sedimentary section including both the Paleocene-Eocene boundary and earliest Tertiary sediments - something our previous single hole drilling strategy lacked. Two shallower sites are cheaper than one deep site and enable a transect across the peak ring, which will significantly increase data on post-impact hydrothermal activity and lateral changes in lithology, deformation, and microbiology. We hope to add a third site to this transect under the auspices of ICDP to drill the melt sheet to the interior of the peak ring.

6.3. Time Estimates

The option of two 1500-m holes at Chicx-03A and Chicx-04A could be achieved in a total of about 56.4 drilling days (See tables provided in our Proponent Response Letter to the Science Planning Committee), including downhole logging, with one site move. The provided rates of penetration numbers were estimated based on ODP and IODP experience using a polycarbon diamond cutting bit, which may be ideal for penetrating both carbonate and brecciated lithologies. Rates of penetration assume the use of a powerful top-drive. Precise rates will depend on whether drilling is carried out using a lower weight-on-bit and higher rpm, or higher weight-on-bit and lower rpm. Our estimates are probably more appropriate for the latter style of drilling.

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Yong, P., J. P. G. Farr, I. R. Harris, and L. E. Macaskie (2002), Palladium recovery by immobilized cells of Desulfovibrio desulfuricans using hydrogen as the electron donor in a novel electrobioreactor, *Biotech. Lett.*, *24*, 205-212.

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Curriculum Vitae

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Higher Education:

University of Southampton, Department of Physics 1977-1980, BSc honours Geophysics
University of Cambridge, Department of Earth Sciences, 1984-1988, PhD in Geophysics.

Appointments:

Reader in Geophysics, Imperial College London, 2004 – date
Senior Lecturer in Geophysics, Imperial College, 2000 - 2004
Lecturer in Geophysics, Imperial College, 1995 - 2000
Senior Lecturer in Geophysics, Kingston University, 1991-1994
Senior Field Engineer, Schlumberger, based in Italy 1982-1984.
Field Geologist/Geophysicist, Kratos NL, Australia, 1980-1981

External positions:

External examiner, Geophysics BSc and MSci degrees, University College London
NERC college peer review panel
Integrated Ocean Drilling program (IODP) UK steering committee.

Recent Research Grants:

Source	**Title of Project**	**Start & Duration**
NERC	3D experiment across Chicxulub Supplement to 2 previous grants	2004 **Completed 2006**
Leverhulme	Angle of impact at Chicxulub	2003 **Completed 2006**
Consortium of 8 oil companies	ISSSA - interpolating sparsely sampled seismic acquisition	2003 **Completed 2006**
PPARC	Modelling high-velocity impacts	2006 36 months **Current**
TOTAL, Shell, Chevron, BG	3D Seismic Tomography	01/4/04 – 31/3/07 **Completed 2007**
PPARC	Wave equation helioseismology	10/07-09/10 **Current**
NERC	Waveform inversion across the oceanic crustal layer 2A/2B	03/08-02/10 **Current**
Leverhulme	Impact cratering	03/08-09-08 **Current**
TOTAL, Shell, Chevron, BG	Joint 3D inversion of full-wavefield p, s and CSEM data	06/08-05/11 **Current**

Recent Publications

1) Bell C., **Morgan** J. V., Hampson G. J. and Trudgill B. “Stratigraphic and sedimentological observations from seismic data across the Chicxulub impact basin”. Meteorit. Planet. Sci. 39, (2004), 1089-1098.

2) Rowe A. J., Wilkinson J. J., Coles B. J. and **Morgan** J. V., “Chicxulub: Testing for post-impact hydrothermal inputs into the Tertiary Ocean”, Meteorit. Planet. Sci. 39 (2004), 1223-1231.

3) Vermeesch P. M. and **Morgan** J.V., “Structure of Chicxulub: where do we stand?” Meteorit. Planet. Sci. 39, (2004), 1019-1034.

4) Urrutia-Fucugauchi J, **Morgan** J, Stoffler D, T et al., The Chicxulub Scientific Drilling Project (CSDP), Meteoritics & Planetary Science, 2004, Vol: 39, Pages: 787 - 790, ISSN: 1086-9379

5) Turtle E.P., Pierazzo E., Melosh H.J., Collins G.S., Reimold W.U., **Morgan** J.V. and Osinski G.R., “Impact structures: What does crater diameter mean?” in: Large Meteorite Impacts” Geological Society of America Special Paper 384 (2005) 1-24

6) Wünnemann K., **Morgan** J.V. and Jödicke H., “Is Ries a typical example of a middle-sized terrestrial crater?” in: Large Meteorite Impacts” Geological Society of America Special Paper 384 (2005) 67-84.

7) **Morgan** J, Warner M, Urrutia-Fucugauchi J, et al., Chicxulub crater seismic survey prepares way for future drilling, EOS, Transactions, American Geophysical Union, Vol: 86, (2005) 325 – 328.

8) Chironi, C., J. V. **Morgan**, and M. R. Warner, Imaging of intrabasalt and subbasalt structure with full wavefield seismic tomography, J. Geophys. Res., 111, (2006), B05313, doi:10.1029/2004JB003595.

9) Rao, Y., Wang, Y., **Morgan**, J., Crosshole seismic waveform tomography II: resolution analysis. Geophysical Journal International, Vol: 166, (2006) 1237 - 1248

10) **Morgan**, J., Lana, C., Kearsley, A., Coles, B., Belcher, C, Montanari, S., Diaz-Martinez, E., Barbosa, A., Neumann, V., Analyses of shocked quartz at the global K-P boundary indicate an origin from a single, high-angle, oblique impact at Chicxulub, EPSL 251, (2006) 264-279.

11) **Morgan**, J, Christeson, G, Gulick, S, Grieve, R, Urrutia, J, Barton, P, Rebolledo, M, Melosh, J, Joint IODP/ICDP scientific drilling of the Chicxulub impact crater, Scientific Drilling (2007) Vol: 4, Pages: 42 - 44, ISSN: 1816-8957.

12) Gulick, S., Barton, P., Christeson, G., **Morgan**., J., McDonald, M., Mendoza, K., Pearson, Z., Surendra, A., Urrutia, J., Vermeesch, P.M., Warner, M., 2008. Importance of pre-impact crustal structure for the asymmetry of the Chicxulub impact crater. Nature Geoscience 1, 131-135.

13) Grieve R., Reimold, U., **Morgan**, J.V., Riller, U., Vredefort, Sudbury and Chicxulub: Towards a composite model of a terrestrial impact basin. Meteoritics and Planetary Science. Accepted Oct 2007.

14) Vermeesch P.M., **Morgan** J.V., Structural uplift beneath the Chicxulub impact crater. JGR, accepted March 2008.

15) Collins, G.S., **Morgan**, J., Barton, P., Christeson, G.,L., Gulick, S., Urrutia-Fucugauchi, J., Warner, M., Wunnemann, K., 2008. Dynamic modeling suggests asymmetries in the Chicxulub crater are caused by target heterogeneity. Earth and Planetary Science Letters, accepted March 2008.

16) Christeson, G., Collins, G., **Morgan**, J.V., Gulick, S., P. S., Barton, P.J., Mantle topography beneath the Chicxulub impact crater, Geology, in review.

17) Bray, V.J., Collins, G.S., **Morgan**, J.V., Schenk, P.M., The effect of target properties on central peak crater morphology on the Moon and Ganymede, Meteoritics and Planetary Science, in review.

18) Artemieva, N., **Morgan**, J., Modeling the formation of the K-P boundary layer, Icarus, in review.

BIOGRAPHICAL SKETCH

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2007-present – Research Scientist, Institute for Geophysics, University of Texas at Austin
2001-2007 - Research Associate, Institute for Geophysics, University of Texas at Austin
2000 - Visiting Scientist, Ocean Research Institute, University of Tokyo, Japan (1 month)
1999-2001 - Palisades Geophysical Institute Postdoctoral Fellow, University of Texas at Austin

HONORS AND AWARDS:

2007 Consortium for Ocean Leadership Distinguish Lecturer
2007 Jackson School of Geosciences Research Achievement Award
2006 Jackson School of Geosciences Research Fellow
2005 Jackson School of Geosciences Young Scientist Fellow
2007 NSF-MGG Funded Project Structural controls Sumatra subduction zone
2005 NSF-ODP Funded Project Kumano Basin 3-D Imaging for NanTroSEIZE
2004 NSF-EAR Funded Project STEEP: ST. Elias Erosion and tectonics Project
2004 NSF-ODP Funded Project on Southeast Alaska High-Resolution Sediments
2003 NSF-ODP Funded Project on Chicxulub Impact Crater

SERVICE

IODP Site Survey Panel 2007-2010; Co-chair IODP Depth Scales Panel 2006-2007; IODP Scientific Measurements and Technology Panels 2001-2005, Univ. Delaware R/V Design Panel

RECENT FIELD PROJECTS:

June-July 2008	Co-chief scientist, Sumatra Seismic Experiment, R/V*Sonne*
Sept.-Nov. 2007	Shipboard scientist, NanTroSEIZE Expedition 314, D/V *Chikyu*
Jan.-Feb. 2005	Co-chief Scientist, Chicxulub Impact Crater Experiment, R/V *Maurice Ewing*
Aug.-Sept. 2004	Chief seismologist, Gulf of Alaska Glaciation Study, R/V *Maurice Ewing*
May-June 2003	Shipboard geologist, ROV observations in Nankai trough, M/V *Kairei*
Sept.-Oct. 2002	Shipboard scientist, AHC800 drilling on New Jersey Shelf, R/V *Knorr*
July-Aug. 2002	Shipboard geologist, ROV observations in Nankai trough, M/V *Kairei*
Aug.-Sept. 2001	Shipboard geophysicist, Geoclutter profiling on N. J. Shelf, R/V *Endeavor*
July-Aug. 2001	Shipboard scientist, Geoclutter sampling on N.J. Shelf, R/V *Cape Henlopen*
Jan.-Feb. 2001	Shipboard scientist, ODP Leg 196 to Nankai Trough, JOIDES *Resolution*
July 2000	Shipboard geophysicist, Shinkai 6500 cruise to Nankai Trough, M/V *Yokosuka*
June-Aug. 1999	Shipboard geophysicist, Nankai 3-D Seismic Experiment, R/V *Maurice Ewing*
Oct. 1996 & 1997	Shipboard scientist, Sea Cliff/ROV cruise to Cascadia, M/V *Laney Choest*
Aug. 1997	Shipboard geologist, ROV cruise to the Eel River Basin, R/V *Point Lobos*
June 1994	Shipboard geophysicist, Mendocino Seismic Experiment, R/V *Maurice Ewing*

FIVE MOST RELEVANT RECENT PAPERS (*Student first author):

Gulick, S., Barton, P., Christeson, G., McDonald, M., Mendoza, K., Morgan, J., Pearson, Z., Surrendra, A., Urrutia, J., Vermeesch, P., Warner, M., 2008, Importance of pre-impact crustal structure in the asymmetry of the Chicxulub impact crater: *Nature Geosciences*, v. 1, p. 131-135, DOI: 10.1038/ngeo103.

Berger, A.L.*, **Gulick, S.P.S.**, Spotila, J.A., Jaeger, J.M., Chapman, J.B., Lowe, L.A., Pavlis, T.L., Ridgeway, K.D., Willems, B., McAleer, R.J., 2008, Quaternary tectonic response to intensified glacial erosion in an orogenic wedge: *Nature Geosciences*, in review.

McDonald, M.*, **Gulick, S.**, Melosh, J., 2008, Oblique impacts and peak ring position: Comparing Venusian craters to Chiculub: *Geophysical Research Letters*, in press.

Lowe, L.*, **Gulick, S.,** Pavlis, T., Bruns, R., Mann, P., 2008, Localized deformation zones in the offshore leading edge of the Yakutat microplate, Gulf of Alaska: *AGU Monograph*, in press.

Gulick, S. P. S., Lowe, L., Pavlis, T., Mayer, L., 2007, Gardner, J., Geophysical insights into the Transition fault debate: Propagating strike-slip in response to stalling Yakutat block subduction in the Gulf of Alaska: *Geology*, v. 35, p. 763–766; doi: 10.1130/G23585A.

FIVE OTHER RECENT PAPERS

Chapman, J.B.*, Pavlis, T.L., **Gulick, S.**, Berger, A., Lowe, L., Spotila, J., Bruhn, R., Vorkink, M., Koons, P., Barker, A., Picornell, C., Ridgway, K., Hallet, B., Jaeger, J., McCalpin, J., 2008, Neotectonics of the Yakutat collision: Changes in deformation driven by mass redistribution: *AGU Monograph*, in press.

Collins, G.S., Morgan, J., Barton, P., Christeson, G., **Gulick, S.**, Urrutia, J., Warner, M., Wunnemann, K., 2008, Dynamic modeling suggests asymmetries in the Chicxulub crater are caused by target heterogeneity: Earth and Planetary Science Letters, in press.

Mosher, D.C., Austin, J.A., Jr., Fisher, D., **Gulick, S.P.S.**, 2008, Deformation of the northern Sumatra accretionary prism from high-resolution seismic reflection profiles and ROV observations: *Marine Geology*, in press, doi: 10.1016/jmergeo.2008.03.014.

Fisher, D., Mosher, D., Austin, J. A., Jr., **Gulick, S. P. S.**, Masterlark, T., and Moran, K., 2007, Active deformation across the Sumatran forearc over the December 2004 Mw9.2 rupture, *Geology*, v. 35, pp. 99-102.

Gulick, S.P.S., Goff, J.A., Austin, J.A., Jr., Alexander, C.R., Jr., Nordfjord, S., and Fulthorpe, C.S., 2005, Basal inflection-controlled shelf-edge wedges off New Jersey track sea-level fall: *Geology*, v. 33, no. 5, p. 429-432.

NON-UT SCIENTIFIC COLLABORATORS WITHIN THE LAST 48 MONTHS:

J. Jaeger: U. Florida, G. Moore: U. Hawaii, L. Mayer, J. Gardner: U. New Hampshire, J. Melosh: U. Arizona, J. Morgan, M. Warner: Imp. Coll. London, UK, P. Barton: Cambridge U., UK, J. Urrutia: UNAM, Mexico, P. Koons: U. Maine, T. Pavlis: U. New Orleans, R. Powell: N. Illinois U., J. Freymueller, M. Whalen: U. Alaska, A. Mix, N. Pisias, B. Finney, J. Stoner: Oregon State U., E. Cowan: Appalachian State U., D. Saffer: Pennsylvania State U., P. Zeitler, Lehigh Univ., R. Bruns, U. Utah, H. Tobin, U. Wisconsin, D. Mosher, Geol. Surv. Canada, D. Fisher, Penn. State. Univ., L. McNeill, T. Henstock, U. Southampton, J. Spotila, A. Berger, VA Tech.

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Relevant Publications

Vermeesch, P.M., J.V. Morgan, **G.L. Christeson**, P. Barton, and A. Surendra (2008), 3D joint inversion of travel-time and gravity data across the Chicxulub impact crater, *J. Geophys. Res.*, submitted.

Collins, G.S., J. Morgan, P. Barton, **G. Christeson**, S. Gulick, J. Urrutia, M. Warner, and K. Wünnemann (2008), Dynamic modeling suggests terrace zone asymmetry in the Chicxulub crater is caused by target heterogeneity, *Earth Planet. Sci. Lett.*, *270*, 221-230.

Gulick, S.P.S., P.J. Barton, **G.L. Christeson**, M. McDonald, K. Mendoza-Cervantes, J.V. Morgan, Z.F. Pearson, A. Surrendra, J. Urrutia-Fucugauchi, P.M. Vermeesch, and M.R. Warner (2008), Implications of structural asymmetries in the Chicxulub impact crater, *Nature Geosci.*, *1*, 131-135.

Morgan, J., M. Warner, J. Urrutia-Fucugauchi, S. Gulick, **G. Christeson**, P. Barton, M. Rebolledo-Vieyra, and J. Melosh (2005), Chicxulub Crater seismic survey prepares way for future drilling, *Eos Trans. AGU*, *86*, 325-328.

Morgan, J.V., **G.L. Christeson**, and C.A. Zelt (2002), 3D velocity tomogram across the Chicxulub crater: Testing the resolution, *Tectonophysics*, *355*, 215-226.

Christeson, G.L., Y. Nakamura, R.T. Buffler, J. Morgan, and M. Warner (2001), Deep Crustal Structure of the Chicxulub Impact Crater, *J. Geophys. Res.*, *106*, 21751-21769.

Morgan, J.V., M.R. Warner, G.S. Collins, H.J. Melosh, and **G.L. Christeson** (2000), Peak ring formation in large impact craters: Geophysical constraints from Chicxulub, *Earth Planet. Sci. Lett.*, *183*, 347-354.

Christeson, G.L., R.T. Buffler, and Y. Nakamura (1999), Upper crustal structure of the Chicxulub impact crater from wide-angle ocean bottom seismograph data, in Dressler, B.O., and V.L. Sharpton, eds., Large Meteorite Impacts and Planetary Evolution II: Boulder, Colorado, Geological Society of America Special Paper 339, 291-298.

Snyder, D.B., R.W. Hobbs, and the **Chicxulub Working Group** (1999), Ringed structural zones with deep roots formed by the Chicxulub impact, *J. Geophys. Res.*, *104*, 10743-10755.

Morgan, J., M. Warner, and the **Chicxulub Working Group** (1997), Size and morphology of the Chicxulub impact crater, *Nature, 390*, 472-476.

Synergistic Activities

Ocean Bottom Seismometer Instrument Pool (OBSIP) Management Committee, May 2006 - present

Science Steering and Evaluation Panel, IODP, May 2006 – August 2008
NSF proposal review panels, multiple times.
NSF/JOI panel: OOI (Ocean Observatories Initiative)/ORION Request for Assistance (RFA), September 2005
Site Survey Panel of Ocean Drilling Program, April 1997 - February 2000.

Collaborators & Other Affiliations

Collaborators (non-UTIG):

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- Steve (Stoney) Clark, University of Oslo
- Alejandro Escalona, University of Stavanger
- Jeff Karson, University of Syracuse
- Alan Levander, Rice University
- Beatrice Magnani, University of Memphis
- Joanna Morgan, Imperial College
- Gary Pavlis, Indiana University
- Terry Pavlis, University of Texas, El Paso
- Mike Warner, Imperial College
- Colin Zelt, Rice University

Graduate Advisor: G. Michael Purdy, Lamont-Doherty Earth Observatory
Postdoctoral Sponsor: Jan Garmany, independent consultant
Thesis Committees:

- Trevor Aitken, Masters Degree, UT, Spring 2005 (Committee Member).
- David Gorney, Masters Degree, UT, Spring 2005 (Committee Member).
- Matthew McDonald, Masters Degree, UT, Fall 2006 (Committee Member).
- Margaret Kroehler, Masters Degree, UT, Fall 2007 (co-supervisor).

Field Experience:

I have participated in more than 10 oceangoing field experiments since 1988 for the collection of seismic refraction, multi-channel seismic reflection, SeaMARC II, Sea Beam, AMS-120, Argo, and Alvin data. I was chief scientist on 3 recent cruises: a 2003 R/V *Maurice Ewing* cruise to acquire seismic data in the Hess Deep region, a 2004 R/V *Seward Johnson II* 2-ship cruise with the R/V *Maurice Ewing* to acquire seismic data in the SE Caribbean, and a 2004 R/V *Maurice Ewing* cruise to the Blanco Fracture Zone.

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DEPT. GEOLOGY
VRIJE UNIVERSITEIT BRUSSEL
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CURRENT POSITION

February 2001 – Present: Professor, Department of Geology, Vrije Universiteit Brussel, Brussels, Belgium

EDUCATION

Ph.D. in Geology, 1993. University of California at Davis, California, USA.

Master of Science (Geology), 1989. University of California at Davis, California, USA.

Licence en Sciences Géologique et Minéralogique, 1984. Université Libre de Bruxelles, Brussels, Belgium.

POSITIONS HELD

1996 – 2000, Senior Staff Scientist and Head of Analytical Laboratories, Institute für Mineralogie, Museum für Naturkunde von Humboldt Universitaet, Berlin, Germany.

October 1993 – 1995, Research Geologist, Department of Earth & Planetary Science, University of California at Berkeley, USA

Januari 1993 – September 1993, Postdoctoral Research Geochemist, Institute of Geophysics & Planetary Physics, University of California at Los Angeles, USA

1987 – 1992 Teaching and Research Assistant, Department of Geology, University of California at Davis, Courses Taught: Geochemistry, Planetary Geology, Sedimentology-Stratigraphy, Petrology, Oceanography and Introduction to Geology

1989 – 1991, Research Assistant (part time), Nuclear Chemistry Department, Lawrence Livermore National Laboratory, Livermore, California,

1984 – 1985, Research Assistant (Ph. D fellowship), Departement des Sciences de la Terre et de l'environnement, Université Libre de Bruxelles, Brussels, Belgium.

RESEARCH INTERESTS

Planetary Sciences, biogeoevolution of the Earth, impact event and mass extinction, global changes.

SELECTED PUBLICATIONS 2003 – 2008 (LIST AVAILABLE AS PDF FILES AT HTTP://WE.VUB.AC.BE/~DGLG)

Dypvik, H., P. Claeys, A. Deutsch, F. T. Kyte, T. Matsui, and M. Smelror, Drilling of the Mjølnir Structure, the Barents Sea, Eos Trans. AGU, 89(2), 15, 2008.

Schulte, P., Speijer, R.P., Brinkhuis H., Kontny, A., Claeys, Ph., Galeotti, S., and Smit, J., Comment on the paper: "Chicxulub impact predates K-T boundary: New evidence from Brazos, Texas" by Keller et al. (2007), Earth and Planetary Science Letters, In Press, Available online 11 January 2008 [IF 3.88]

Tagle, R., Ohman, T., Schmitt, R. T., Erzinger, J., and Claeys, Ph. Traces of an H-chondrite in the impact melt rocks from Lappajärvi impact structure, Finland, *Meteoritics and Planetary Science,42, 1841-1854, 2007* [IF 2.52]

Claeys, Ph. and Goderis S., Lethal billards, *Nature*, 449, 30-31, 2007 [IF 26.68]

Goderis, S., Tagle, R., Schmitt, R. T., Erzinger, J., and Claeys, Ph. Platinum group element in the impact melt from the Bosumtwi crater, Ghana, *Meteoritics and Planetary Science*, 42, 4/5, 731-741, 2007 [IF 2.52].

Kolo, K., Keppens, E., Préat, A., and Claeys, Ph., Experimental observations on fungal diagenesis of carbonate substrates: A study on sediment-microbes interaction, *Journal of Geophysical Research-Biogeosciences*, 112, G01007, doi: 10.1029/2006JG000203, 2007 [IF 2.80].

Tysmans, D., Claeys, Ph., Deriemaeker, L., Maes, D., Finsy, R., Van Molle, M., Size and shape analysis of sedimentary grains by Automated Dynamic Image Analysis, *Particle and Particle System Characterization,* 23, 381-387, doi: 10.1002/ppsc.200500965, 2006 [IF 0.64].

Martin, H., Albarède F., Claeys, Ph., Gargaud, M., Marty., B., Morbidelli, A., Pinti, D., Building of a habitable planet, Earth, Moon and Planets, 98, 97 – 151, DOI 10.007/s11038-006-9088-4, 2006 [IF 0.25].

Martin, H., Claeys, Ph., Gargaud, M., Pinti, D., Selsis, F., Environmental context, Earth, Moon and Planets, 98, 205 – 245, DOI 10.007/s11038-006-9090-x, 2006 [IF 0.25].

Lopez-Garcia, P., Moreira, D., Douzery, E., Forterre, P., Van Zuilen, M., Claeys, Ph., D. Prieur, Ancient fossil record and early evalution (ca. 3.8 to 0.5 Ga), Earth, Moon and Planets, 98, 247 – 290, DOI 10.007/s11038-006-9091-9, 2006 [IF 0.25].

Montmerle, T., Claeys, Ph., Gargaud, M., Lopez-Garcia, P., Martin, H., Pascal, R., Reisse, J., Selsis, F., Life on Earth … And elsewhere?, Earth, Moon and Planets, 98, 299 – 312, DOI 10.007/s11038-006-9093-7, 2006 [IF 0.25].

Kolo, K. and Claeys, Ph., In vitro formation of Ca-oxalates and the mineral glushinskite by fungal interaction with carbonate substrates and seawater, Biogeosciences 2, 277 – 293, 2005. [IF 2.13].

Tagle, R. and Claeys, Ph., An ordinary chondrite impactor for the Popigai crater, Siberia. Geochimica et Cosmochimica Acta, 69, 2877 – 2889, 2005. [SCI: Impact factor: 3.811]

Tagle, R., and Claeys, Ph., Comet or asteroid shower in the late Eocene, Science 305, 492 (+ online supplement), 2004. [IF 29.162]

Urrutia-Fugugauchi, J., Morgan, J., Stoeffler, D., and Claeys, Ph., The Chicxulub scientific drilling project (CSDP), Meteoritics and Planetary Science 39, 787 - 790, 2004. [IF 3.168].

Tagle, R., Erzinger, J., Hecht, L., Schmitt, R., T., Stoeffler, D., and Claeys, Ph., Platinum group elements in impactites of the ICDP Chicxulub drill core Yaxcopoil-1: Are there traces of the projectile, Meteoritics and Planetary Science 39, 1009-1016, 2004 [IF 3.168].

Claeys, Ph., Heuschkel, S., Lounejeva – Baturina, E., Sanchez – Rubio, E., Stöffler, D., The suevite of drill hole Yucatan 6 in the Chicxulub impact crater, Meteoritics and Planetary Science 38, 1299-1317, 2003. [IF 3.168]

Curriculum Vitae

NAME: Charles Seaton Cockell
AFFILIATION: Professor and Chair of Microbiology, Open University
ADDRESS Center for Earth, Space, Planetary and Astronomical Research (CEPSAR), Open University, Milton Keynes, MK7 6AA. Tel: 01908 652588. e-mail: c.s.cockell@open.ac.uk

EDUCATION / ACADEMIC POSITIONS

1986-1989 BSc, Bristol University, B.Sc. (2.1. Hons) in Biochemistry
1990-1994 D.Phil, Corpus Christi College, Oxford University
NASA Ames Research Center [1995-1997] NRC Associateship (National Research Council).
Visiting Scholarship, Dept. of Biology, Stanford University [1997-1998]
Visiting Scientist, Carnegie Institution, Stanford University [1998-1999]
Visiting Scientist, University of Arizona [1998-1999]
Research Scientist, British Antarctic Survey [2000-2005]

MEMBERSHIP OF PROFESSIONAL / SCIENTIFIC SOCIETIES

Member, American Society for Microbiology; Member, Society for General Microbiology; Fellow, Royal Geographical Society; Fellow, British Interplanetary Society; Fellow, Royal Astronomical Society; Fellow, Explorers Club of New York.

CURRENT PROFESSIONAL AFFILIATIONS

Vice-President, European Astrobiology Network Association
Member, Council, British Interplanetary Society
Senior Editor, Astrobiology
Editorial Board, Interdisciplinary Science Reviews
Editorial Board, International Journal of Astrobiology
Chair, Earth and Space Foundation

PAST PROFESSIONAL AFFILIATIONS

Founding President, Association of Mars Explorers (2002-2004)
Chair, UK Astrobiology Forum and Network (2001-2003)
Chair, Astrobiology Society of Britain (2003-2004)
Secretary, Federation of Astrobiology Organizations (2003-2004)

COMMITTEE AND EDITORIAL RESPONSIBILITIES

ESA Science, Exploration and Technology Advisory Group (2006-)
ESA Planetary Protection Working Group (2006-)
ESA ExoMars Rover Preliminary Science Team (2003)
ENMast (ESA-NASA Mars Science Planning Team) (2003-2004)
Series Editor, Astrobiology Series, Cambridge University Press (2004-)

SELECTED PUBLICATIONS :

Books

Cockell CS, Corfield R, Edwards E, Harris N. 2008. *An Introduction to the Earth-Life System*, Cambridge University Press. pp. 328

Cockell CS, Koeberl C, Gilmour I. 2006. *Biological Processes Associated with Impact Events*, Springer-Verlag, Heidelberg. pp 376. [Multi-author volume arising from the 10th ESF IMPACT Workshop in Cambridge in March 2003]

Cockell CS, Blaustein A. 2001. *Ecosystems, Evolution and UV Radiation*, Springer-Verlag, New York. pp221. [Multi-author volume bringing together a number of groups to look at UV effects on ecosystems and possible evolutionary consequences].

Popular Science Books

'Impossible Extinction – Natural Catastrophes and the Supremacy of the Microbial World', Cambridge University Press, March 2003 [translated into Greek and Japanese].

'Space on Earth – Saving our World by Seeking Others', MacMillan, November 2006.

Book Chapters

Cockell CS. 2007. Life under snow and ice. In M.J. Benton, ed. *The Seventy Great Mysteries of the Natural World*, London: Thames and Hudson (in press).

Cockell CS. Habitability. In G. Horneck, P. Rettberg, eds. Complete course in astrobiology, Wiley-VCH. p. 151-177.

Cockell CS. 2004. The geomicrobiology of impact-altered rocks. In Cockell CS, Koeberl C, Gilmour I, eds. *Biological Processes Associated with Impact Events*, Springer-Verlag, Heidelberg, p. 21-40.

Cockell CS, Lim DSS, 2004. Impact craters, water and microbial life. In Tokano T, ed. *Water on Mars*. Springer-Verlag, Germany, p. 261-275.

Cockell CS. 2001. The ultraviolet radiation environment of Earth and Mars, past and present. In Horneck G. Blaumstark-Khan C, eds. *Springer Lecture Notes in Astrobiology*. Springer-Verlag, New York, p. 219-230.

Selected recent scientific peer-reviewed publications

Herrera A, **Cockell CS**, Self S, Blaxter M, Reitner J, Arp G, Dröse W, Thorsteinsson T, and Tindle AG. 2008. Bacterial colonization and weathering of terrestrial obsidian in Iceland. *Geomicrobiology Journal* 25, 25-47

Cockell, C.S., Herrera, A. 2008. Why are some microorganisms boring? *Trends in Microbiology* 16, 101-106.

Gohn G, Koeberl C, Miller KG, Reimold U, Browning JC, **Cockell CS,** Horton JW, Kenkman T, Kulpecz AA, Powars DS, Sanford WE, Voytek MA. 2008. Deep drilling of the Chesapeake Bay impact crater reveals new insights into impact processes. *Science* (in press)

Cockell, C.S. 2008. The interplanetary exchange of photosynthesis. *Origins Life Evol. Biosphere* 38, 87-104.

Talbot HM, Summons RE, Jahnke LL, **Cockell CS**, Rohmer M, Farrimond P. 2008. Cyanobacterial bacteriohopanepolyol signatures from cultures and natural environmental settings. *Organic Geochemistry* 39(2), 232-263.

Raven, JA, **Cockell CS**. 2006. Influence on Photosynthesis of starlight, moonlight, planetlight and light pollution (Reflections on photosynthetically active radiation in the universe). *Astrobiology*, 6, 668-675.

Osinski GR, Lee P, Spray JG, Parnell J, Lim DSS, Bunch TE, **Cockell CS**, Glass B. 2005. Geological overview and cratering model for the Haughton impact structure, Devon Island, Canadian High Arctic. *Meteoritics and Planetary Science*, 40, 1759-1776.

Parnell J, Lee P, Osinski GR, **Cockell CS**. 2005. Application of organic geochemistry to detect signatures of organic matter in the Haughton impact structure. *Meteoritics and Planetary Science*, 40, 1879-1885.

Cockell CS, Lee P, Broady P, Lim DSS, Osinski GR, Parnell J, Koeberl C, Pesonen L, Salminen J. 2005. Effects of asteroid and comet impacts on habitats for lithophytic organisms - A synthesis. *Meteoritics and Planetary Science*, 40, 1901-1914.

Cockell CS, Bland PA. 2005. The evolutionary and ecological benefits of asteroid and comet impacts. *Trends in Ecology and Evolution*, 20, 175-179.

Peck LS, Clark MS, Clarke A, **Cockell CS**, Convey P, Detrich HW, Fraser KPP, Johnston IA, Methe BA, Murray AE, Romisch K, Rogers AD. 2005. Genomics: applications to Antarctic ecosystems. *Polar Biology*, 28, 351-365.

Cockell CS, Schuerger AC, Billi D, Friedmann EI, Panitz C. 2005. Effects of a simulated martian UV flux on the cyanobacterium, Chroococcidiopsis sp 029. *Astrobiology*, 5, 127-140.

Rettberg P, **Cockell CS** 2004. Biological UV dosimetry using the DLR-biofilm. *Photochemical and Photobiological Sciences*, 3, 781-787.

Cockell CS, Raven JA. 2004. Zones of photosynthetic potential on Mars and the early Earth. *Icarus*, 169, 300-310.

Cockell CS. Stokes MD. 2004. Widespread colonization by polar hypoliths. *Nature*, 431, 414.

Cockell CS. 2004. Impact-shocked rocks – insights into Archean and extraterrestrial microbial habitats (and sites for prebiotic chemistry?). *Adv. Space Res*., 33, 1231-1235.

Cockell CS, Cordoba-Jabonero C. 2004. Coupling of climate change and biotic UV exposure through changing snow-ice covers in terrestrial habitats. *Photochemistry and Photobiology*, 79, 26-31.

Clark MS, Clarke A, **Cockell CS**, Convey P, Detrich HW, Fraser KPP, Johnston IA, Methe BA, Murray AE, Peck LS, Romisch K, Rogers AD. 2004. Antarctic Genomics. *Comparative and Functional Antarctic Genomics*, 5, 230-238.

Cockell CS, Rettberg P, Horneck G, Scherer K, Stokes DM. 2003. Measurements of microbial protection from ultraviolet radiation in polar terrestrial microhabitats. *Polar Biology*, 26, 62-69.

Cockell CS, Osinski GR, Lee P. 2003. The impact crater as a habitat : effects of impact-processing of target materials. *Astrobiology*, 3, 181-191.

Cockell CS., Lee P, Osinski G, Horneck G, Broady P. 2002. Impact-induced microbial endolithic habitats. *Meteoritics and Planetary Science*, 37, 1287-1298.

Cockell CS, Lee P. 2002. The biology of impact craters - a review. *Biological Reviews*, 77, 279-310.

Gareth S. Collins

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Nationality: British   Date of Birth: 4th March 1977   Marital Status: single

Education:

Doctor of Philosophy, 2002
Imperial College, London, U.K.
Dissertation Title: Numerical Modeling of Large Impact Crater Collapse
Awarded T.H. Huxley Prize, 2002, for Best Ph. D. Thesis.

Bachelor of Science in Geophysics with Mathematics, 1998
University of Liverpool, U.K.
First class with honours
Awarded John Patterson Prize for highest grade in Earth Science, 1996, 1997 & 1998.

Professional and Research Experience:

NERC Advanced Research Fellow: Oct 2007 – present
3D Numerical Modelling of Large, Rapid, Violent Geologic Processes
Dept. Earth Science and Eng., Imperial College London

- 3D numerical simulations of terrestrial impact events; comparison with observations.
- Extending modelling to large landslides and water waves generated by impacts and landslides

NERC Research Fellow: Oct 2004 – Oct 2007
Impact cratering on Earth: Bridging the gap between modelling and observation
Dept. Earth Science and Eng., Imperial College London

- Numerical simulations of terrestrial impact events; comparison with observations.
- Developing a world-class computer program for simulating impact phenomena.
- Development of porosity and dilatancy models for use in simulations of impact events

Research Associate: May 2002 – September 2004.
Lunar and Planetary Laboratory, University of Arizona

- Numerical simulations of impact cratering on Earth and the Moon
- Numerical simulations of acoustic fluidization and long run-out avalanches
- Development of constitutive models for use in numerical simulations of impact events

Advisor: Prof. H. Jay Melosh

My research involves the development and application of sophisticated numerical models specifically designed for the simulation of impact cratering events. I am currently funded to better constrain the formation and environmental consequences of impact craters on Earth. I have already contributed substantially to this field with my pioneering work on the formation of the Chicxulub impact crater, Gulf of Mexico, and the Chesapeake Bay impact crater, USA.

My other research interests include the effect of target properties on the impact process; the environmental effects of impacts, their hazard to the Earth and mitigation/deflection methods; constitutive relations for geologic materials under impact conditions; other violent geologic processes, for example long-runout avalanches. This work involves collaboration with a multi-national groups of scientists and the development and application of complex computer algorithms.

Highlights:

- In the last 5 years I have published 13 papers in international peer-reviewed journals or books on a range of impact-related topics, including a brief communication in *Nature*
- I have published over 30 extended abstracts, presented at international meetings such as AGU, EGU, LPSC, and GSA.
- I have given two invited presentations at international meetings on impact cratering (2003, 2006) and a solicited presentation at EGU (2006).
- I was on the scientific committee for an international workshop on impact cratering (09/2008)

Gareth S. Collins

International and UK Collaboration

- Impact model development, modeling impacts into porous targets and modeling terrestrial impact events (Kai Wünnemann, Thomas Kenkmann, Natural History Museum, Berlin, Germany)
- Interaction of impactors and ejecta with the atmosphere (Dr. N. Artemieva, Institute for the Dynamics of Geospheres, Moscow, Russia)
- Validation of hydrocodes used for impact simulations (Dr. E. Pierazzo et al., PSI, Tucson, USA)
- Modeling small and large-scale impacts into water-covered targets (Dr. M. Burchell, Kent, UK)
- Modeling impacts into porous targets: Validation (Dr. E. Taylor, OU, UK)
- Can impacts generate chondrules? (Dr. F. Ciesla, Carnegie Institution of Washington, USA)
- I have participated in two international crater drilling workshops: Deep Drilling in the Central Crater of the Chesapeake Bay impact structure (ICDP/USGS, 2004) and Scientific Drilling of the Chicxulub Impact Crater (IODP/ICDP, 2006).

Public Outreach

- I am co-developer of an interactive web program [www.lpl.arizona.edu/ImpactEffects] for estimating the environmental consequences of impact events. The site received half a million visits on the day of release and continues to be a popular site with both the general public and scientific community.
- I have been interviewed by several journalists and TV production companies regarding my work. This has lead to several popular news articles (BBC News, Sky and Telescope, Geology Today, THES) and a live radio interview on the Today program (BBC Radio 4; April, 2004).
- In 2001, I helped present the “Deep Impact: the true story” exhibit at the Royal Society Summer Science Exhibition. I have also given several general-audience lectures on impacts and their effects.

PhD Supervision

- Veronica Bray: Cratering on the icy satellites. Using crater observation and modeling to probe the subsurface of the icy satellites (with Dr. Jo Morgan, IC)
- Cian Wilson: Towards a physically realistic model of impact cratering (with Prof. Chris Pain, IC; CASE sponsorship from AWE)
- Thomas Davison: Consequences of planetesimal collisions in the early solar system

Software Development

- I have 8 years experience developing a 2D hydrocode (iSALE) for simulating impact events of all scales in layered, complex-rheology and porous targets.
- I maintain an early version of the code (SALES-2) distributed free of charge from a web page at the University of Arizona, and online documentation for iSALE at Imperial College.
- I am currently involved in developing a 3D version of iSALE, and a 3D finite element impact cratering model in collaboration with AMCG at Imperial College.

Teaching

- Taught well-received undergraduate class on fundamental mathematical methods for Earth scientists (awarded departmental bonus for course success, 2005-present)
- Guest lecturer for Ph. D.-level Surface Processes class (LPL 2004)
- Undergraduate tutorials on porous flow and avalanche mechanics (2004-2006)

Curriculum vitae

Kazuhisa GOTO

Born: Kyoto Prefecture, Japan; 1977

Education:
B. S., 1999, Geology, Tohoku University
M. S., 2001, Geology, University of Tokyo
Ph. D., 2004, Geology, University of Tokyo

Employment:
2004-2005 21 COE researcher, University of Tokyo,
2005-present Assistant Professor, Graduate School of Engineering, Tohoku University

Research subject:
Geology, Tsunami engineering

Social activity:

Publication list (recent 5 years):

Nakano, Y., **Goto, K**., Matsui, T., Tada, R., Tajika, E., 2008, PDF orientations in shocked quartz grains around the Chicxulub crater. Meteoritics & Planetary Science. (accepted)

Shiki, T., Tachibana, T., Fujiwara, O., **Goto, K**., Nanayama, F., and Yamazaki, T., 2008g, Characteristic features of tsunamites. in Tsunamiites - Features and Implication, Elsevior, Belrin, 319-340.

Goto, K., 2008, The genesis of oceanic impact craters and the impact-generated tsunami deposits. in Tsunamiites - Features and Implication, Elsevior, Belrin, 277-298.

Goto, K., Tada, R., Tajika, E., Matsui, T., 2008, Deep-sea tsunami deposits in the proto-Caribbean sea at the Cretaceous-Tertiary boundary. in Tsunamiites - Features and Implication, Elsevior, Belrin, 251-276.

Goto, K., Imamura, F., Keerthi, N., Kunthasap, P., Matsui, T., Minoura, K., Ruangrassamee, A., Sugawara, D., Supharatid, S., 2008. Distributions and Significances of the 2004 Indian Ocean tsunami deposits -Initial results from Thailand and Sri Lanka-. in Tsunamiites - Features and Implication, Elsevior, Belrin, 105-122.

Goto, K., Tada, R., Tajika, E., Iturralde-Vinent, M. A., Matsui, T., Yamamoto, S., Nakano, Y., Oji, T., Kiyokawa, S., Garcia, D., Otero, C., Rojas, R., 2008, Lateral lithological and compositional variations of the Cretaceous/Tertiary deep-sea tsunami deposit in northwestern Cuba. Cretaceous Research. Vol. 29, No.2, 217-236.

Abe, I., **Goto, K**., Imamura, F., Shimizu, K., 2008, Numerical simulation of the tsunami generated by the 2007 Noto Hanto earthquake and implications for unusual tidal surges observed in Toyama Bay. Earth, Planets and Space. Vol. 60, 133-138.

Imamura, F., **Goto, K**., Ohkubo, S., 2008, A numerical model for the transport of a boulder by tsunami. Journal of Geophysical Research -Ocean. 113, C01008, doi:10.1029/2007JC004170.

Goto, K., Imamura, F., 2007, Numerical models for sediment transport by tsunamis. The Quarternary Research, Vol. 46, No. 6, 463-475.

Goto, K., Chavanich, S. A., Imamura, F., Kunthasap, P., Matsui, T., Minoura, K., Sugawara, D., Yanagisawa, H., 2007, Distribution, origin and transport process of boulders transport by the 2004 Indian Ocean tsunami at Pakarang Cape, Thailand. Sedimentary Geology, Vol. 202, 821-837.

Hatsukawa, Y., Miyamoto, Y., Toh, Y., Oshima, M., Gharaie, M. H. M., **Goto, K**., Toyoda, K., 2007, High-sensitive elemental analysis Using Multi-parameter Coincidence Spectrometer, GEMINI-II, Journal of Radioanalytical and Nuclear Chemistry, Vol. 272, No.2, 273-276, DOI: 10.1007/s10967-007-0514-5.

Imamura, F., Koshimura, S., **Goto, K**., Yanagisawa, H., Iwabuchi, Y., 2006, Global disaster: The 2004

Indian Ocean tsunami. Journal of Disaster Research. Vol. 1, 131-135.

Goto, K., Tada, R., Tajika, E., Bralower, T. J., Hasegawa, T., and Matsui, T., 2004, Evidence for ocean water invasion into the Chicxulub crater at the Cretaceous/Tertiary boundary. Meteoritics & Planetary Science, v. 39, n.6-7, 1233-1247.

Goto, K., and Otsuki, K., 2004, Size and spatial distributions of fault populations: Empirically synthesized evolution laws for the fractal geometries. Geophysical Research Letters. Vol. 31, L05601, doi:10.1029/2003GL018868.

Tada, R., Iturralde-Vinent, M. A., Matsui, T., Tajika, E., Oji, T., **Goto, K**., Nakano, Y., Takayama, H., Yamamoto, S., Kiyokawa, S., Toyoda, K., Garcia-Delgado, D., Diaz-Otero, C., Rojas-Consuegra, S., 2003, K/T boundary deposit in the proto-Caribbean basin. American association of petroleum Geologists Memoir, Vol. 79, 582-604.

Richard A.F. Grieve
Chief Scientist, Earth Sciences Sector, Natural Resources Canada
580 Booth Street, Ottawa, Ontario, K1A 0E4, Canada
(613) 995-5372; rgrieve@nrcan-rncan.gc.ca

Education:

B.Sc. (Hons.), Aberdeen, 1965
M.Sc., Toronto, 1967
Ph.D., Toronto, 1970
M.A., Brown, 1983
D. Sc., Aberdeen, 1985

Employment:

1974-1982: Research Scientist, Earth Physics Branch, Energy, Mines and Resources, Canada.
1980-1981: Visiting Professor, Dept. Geological Sciences, Brown University, Providence, RI, U.S.A
1982-1984: Associate Professor, Dept. Geological Sciences, Brown University, Providence, RI, U.S.A.
1984-1986: Research Scientist, Earth Physics Branch, Energy, Mines and Resources, Canada.
1986-1997: Research Scientist, Geological Survey of Canada, Energy, Mines and Resources, Canada.
1997-2001: Chief Geoscientist, Earth Sciences Sector, Natural Resources Canada.
2001-2008: Chief Scientist, Earth Sciences Sector, Natural Resources Canada.

Experience:

Publication of 240 scientific papers and book “Impact Structures in Canada”.

Management and organisational experience as:
1987-1995: Section Head, Geophysics Division,
2000: A/Director General Marine and Sedimentary Branch,
1997-2001: Chief Geoscientist, Earth Sciences Sector,
2001-2008: Chief Scientist, Earth Sciences Sector.

Numerous assignments in planetary geoscience, e.g., (in the past 16 years):
1991-1992: Space Exploration Preparatory Committee, Long Term Space Plan Working Group, Canadian Space Agency,
1991-1993: Barringer Award Committee, Meteoritical Society,
1991-1995: Meteorites and Impact Advisory Committee, Canadian Space Agency,
1992-1995: Lunar and Planetary Geology Review Panel, NASA,
1992-1996: Vice Chairman, Commission on Comparative Planetology, International Union of Geologic Sciences,
1992-1996: International Observer: European Science Foundation Network, Impact and

Evolution of the Earth,
1995-1997: Organizing Committee, 2nd International Conference on Large Scale Impacts and Planetary Evolution, Sudbury, Canada,
1996-2000: Barringer Award Committee, Meteoritical Society,
1999-2000: Chairman, Barringer Award Committee, Meteoritical Society,
2000-2002: National Remote Sensing Advisory Committee (Geoscience), CCRS,
2000 - :Shoemaker Impact Award Committee, Geological Society of America,
2001 - : Barringer Family Fund Committee.

Editorship:
1980: Guest editor, Comparative Planetology: Implications for the Proto-Archean, PreCambrian Research.
1981: Assoc. editor, Proceedings of the Conference on Multi-Ring Basins.
1981: Assoc. editor, 12th Lunar and Planetary Science Conference.
1982-1984: Assoc. editor, Journal of Geophysical Research.
1987-1990: Editor, Canadian Geophysical Atlas.
1988-2004: Assoc. editor, Meteoritics and Planetary Science.
1992-1994: Co-editor, Large Scale Meteorite Impact and Planetary Evolution, Geological Society America, Special Paper 293.
1997-1999: Editorial board, Geology.
1997 - : Assoc. Editor, Episodes.

Relevant Awards and Honors:
- Fellow Meteoritical Society
- Certificate of Achievement, American Men and Women of Science
- Harold C. Urey Fellow, Lunar and Planetary Institute
- Biographical citation, Canadian Who's Who
- Barringer Medal, Meteoritical Society
- Mars-crossing asteroid named "Grieve"
- Fellow Royal Society of Canada
- Biographical citation Who's Who in Science and Engineering
- Biographical citation, Marquis Who's Who in the World
- Von Humboldt Forschungpreistrager, Institut für Planetologie, Munster, Germany
- German Science Foundation, Mercator Professor, Humboldt University Berlin, Germany
- Leverhulme Lecturer, Imperial College, London, UK

CURRICULUM VITAE Prof. Dr. Christian KOEBERL

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Education and Scientific History

- Born in Vienna, Austria, 18.Feb.1959; from 1978 studies in "technical chemistry" at the Technical University of Vienna, - from 1980 also astronomy and chemistry at the Univ.of Vienna; from 1981/82 also at the University of Graz.
- Graduation, Ph.D. (in astronomy and chemistry), May 1983, University of Graz, Austria
- 1983 - 1985: Research Assistant, Geo- and Cosmochemistry, Institute of Analytical Chemistry, University of Vienna.
- 1985 - 1990: Assistant Professor, Institute of Geochemistry at the University of Vienna.
- 1986 - 1996: Lecturer for Chemistry in Art at the University of Applied Arts in Vienna;
- 1989/90 "Habilitation" in "Geo- and Cosmochemistry", named "Universitätsdozent".
- 1990 - present: tenured as Associate Professor for Earth Sciences (Geo- and Cosmochemistry); Institute of Geochemistry, University of Vienna (from 2003, at the Department of Geological Sciences, University of Vienna).
- 1994 - 2000: Adjunct Professor, Department of Earth Sciences, Dartmouth College, NH, USA.
- 2007-2010: Visiting Research Professor, Open University, Milton Keynes, United Kingdom
- From 2008: Head of Department (Department of Lithospheric Research, University of Vienna)
- From 2008: Deputy Head of Geosciences Center of the Austrian Academy of Sciences

Personal Details

Austrian citizen; married, no children; languages: German and English (fluent in speaking, reading, and writing), French and Italian (basic knowledge, reading)

Research Activities and Interests

Research interests: impact cratering; archean geology; general planetary sciences; meteorites; general and isotope geochemistry, cosmochemistry. Multidisciplinary and integrated studies of all aspects of impact crater studies and impact process (including petrology, geology, and geophysics (integrated/interdisciplinary studies)); analytical geo- and cosmochemistry; antarctic meteorites, lunar meteorites, cosmic dust; upper mantle; diamonds; most research in collaboration with international institutions, including chemical, mineralogical, petrological, and isotopic studies to arrive at integrated studies.

Teaching

Since 1987 teaching of classes and lab courses from different areas within geo- and cosmochemistry and planetary sciences; e.g., classes on planetary sciences, geochemistry; classes and lab courses on topics in analytical geochemistry, rock and mineral analysis, and general chemistry for earth scientists; at the University of Vienna, University of Salzburg, and University of Applied Arts, Vienna; teaching also during visiting professor appointments at the Dept. of Geology, University of the Witwatersrand (Johannesburg) and at the Dept. of Earth Sciences, Dartmouth College (USA).

Supervision of M.Sc. (diploma) and Ph.D. theses: completed MSc theses – 6, completed PhD theses: 13. Currently (2008) 1st advisor for 2 M.Sc. and 5 Ph.D. students (at the Univ. of Vienna); 3 postdocs.

Visiting Appointments (long duration)

- July - December 1988, Visiting Scientist at the Lunar and Planetary Institute and NASA Johnson Space Center in Houston, Texas, USA. Additional appointments over several months in 1989, 1990, and 1991.
- 11/1992 – 01/1993, 5-6/1993, 11/1994, and 9-10/1995: Visiting Investigator at the Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC, USA.
- 8-10/1993: Visiting Professor, Dept. Geology, Univ. Witwatersrand, Johannesburg, South Africa.
- January-March 1994: Visiting Professor, Dept. Earth Sciences, Dartmouth College, New Hampshire, USA.
- 2007-2010: Visiting Research Professor, Dept. Earth Sciences + Planetary and Space Science Research Institute, Open University, Milton Keynes, United Kingdom

Honors and Awards

- 1987 – Antarctica Service Medal of the United States of America
- 1988 – Fulbright Senior Visiting Scholar, USA.
- 1994 – Fellow of the Meteoritical Society
- 1995 – Meritorious Service Award, Geochimica et Cosmochimica Acta
- 1996 – START-Award of the Federal Ministry of Science, Austria
- 1997 – Novartis Award for Chemistry
- 2000 – Fellow of the Geological Society of South Africa
- 2004 – elected corresponding member of the Austrian Academy of Sciences
- 2006 – elected Full Member of the Austrian Academy of Sciences
- 2006 – Asteroid (15963) named "Koeberl"
- 2007 – Barringer Medal and Award of the Meteoritical Society

Scientific Service, Administrative and Editorial Activities

- 1985-1988 Member, Scientific Advisory Committee, Austrian Space Agency (ASSA)
- Chairman of the Organizing Committee and the Program Committee of the "52nd Annual Meeting of the Meteoritical Society" (450 participants, held in Vienna, Austria, July-August 1989).
- Scientific Organizer (with W.A. Cassidy, Univ. Pittsburgh) and local organizer of the "Workshop on Differences between Antarctic and Non-Antarctic Meteorites", sponsored by NASA and University of Vienna, held in Vienna, July 1989.
- Local Organizer, "Workshop on Cosmogenic Nuclide Production Rates", NASA and University of Vienna,Vienna, July 1989.
- Member, Organizing Committee, 8th Intern. Conf. "Modern Trends in Activation Analysis", Vienna, Austria, Sept. 1991.
- Member, Organizing Committee, 3rd Intern. Conference on "Nuclear and Radiochemistry", Vienna, Austria, Sept. 1992.
- Member, Scientific Organizing Committee, Intern. Symposium "Meteoroids and their parent bodies", Smolenice, Czech Republic, July 1992.
- Member of the "Conference Committee", 3rd International Conference of Natural Glasses, Jena, Germany, 21.-23.3.1996.
- Member, Organizing Committee, 62nd Annual Meeting, Meteoritical Society, Johannesburg, South Africa, July 1999.
- Chairman, Organizing Committee and Program Committee, International Meeting on "Catastrophic Events and Mass Extinctions: Impacts and Beyond", Vienna, Austria, July 9-12, 2000.
- Co-Convener, Field Forum "Bolide Impacts on Wet Targets", Geolog. Society of America, April 22–28, 2001, NV+UT, USA
- Co-organizer, Field Forum "Processes on the Early Earth", Geological Society of America and Geological Society of South Africa, July 4-9, 2004, South Africa.
- Co-convener Penrose Conference "The Late Eocene Earth", Monte Conero, Italy, October 2007.
- Member, Organizing Committee, "Large Meteorite Impacts and Planetary Evolution IV", 18-22.8. 2008, Vredefort, South Africa.
- Associate Editor, *Geochimica et Cosmochimica Acta* (since 1990)
- Associate Editor, *Proceedings of Lunar and Planetary Science* (1990-1992)
- Associate Editor, *Geochemical Journal* (from 1998)
- Editorial Board, *Geology* (1999-2001, and 2005-2007)
- Series Editor, *Impact Studies*, Springer (from 2001)
- Associate Editor, *Geological Society of America Bulletin* (from 2006)
- Editor, *Geological Society of America Bulletin* (from 2009)
- Member, EUROMET Working Group
- Scientific Secretary, European Science Foundation Network on "Impact Cratering" (1993-1995)
- Member, Nominating Committee, Meteoritical Society (1997/8)
- Councillor, Meteoritical Society (2001-2004)
- Member, Publications Committee, Meteoritical Society, and Joint Publications Committee, Meteoritical and Geochemical Societies (2002-2004) (Chairman of Committee 2006-2007)
- Member, Leonard Medal Committee of the Meteoritical Society (2005-2009)
- Chairman, European Science Foundation (ESF) Scientific Program "Response of the Earth System to Impact Processes" (IMPACT), 1998-2003.
- Member, European Space Agency (ESA) review panel (Stone-Biopan) (2001)
- Team Leader (Geochemistry/Petrology), Chicxulub deep drilling project (ICDP)
- Member, Science Advisory Group, International Continental Scientific Drilling Program (ICDP) (from 2002)
- Co-ordinator + principal investigator, ICDP deep drilling project, Bosumtwi structure (Ghana) (2002-2005)
- Member, Science Board of the International Geological Program (IGCP) of the UNESCO (from 2004)
- Chairman, Working Group 3, IGCP/UNESCO Science Board (2005- 2008)
- Member, NASA Review Panel Planetary Geology & Geophysics (2005)
- Member, Science Advisory Committee, DOSECC (from 2004); from 2006 Chairman of Committee
- Member, Board of Directors, DOSECC (Drilling, Observation and Sampling of the Earths Continental Crust) (from 2006)
- Member, Clarke Award Committee, Geochemical Society (from 2007)
- Member of various committees and working groups of the Austrian Academy of Sciences (from 2006)
- Member, Barringer Award and Medal Committee of the Meteoritical Society (2008-2011)

Publications: Total: 12 books (4 authored or co-authored, 8 edited or co-edited) published, as of 2008 3 more in planning; over 310 peer-reviewed research publications; over 380 abstracts and other non-reviewed publications.

<u>5 relevant publications:</u>

Poag, C.W., **Koeberl**, C., and Reimold, W.U. (2004) Chesapeake Bay Crater: Geology and Geophysics of a Late Eocene Submarine Impact Structure. Impact Studies, vol. 4, Springer Verlag, Heidelberg, 522 pp

Tuchscherer, M.G., Reimold, W.U., **Koeberl**, C., and Gibson, R.L. (2005) Geochemical and petrographic characteristics of impactites and Cretaceous target rocks from the Yaxcopoil-1 borehole, Chicxulub impact structure, Mexico: Implications for target composition. Meteoritics and Planetary Science 40, 1513-1536.

Harms, U., **Koeberl**, C., and Zoback, M.D. (eds.) (2007) Continental Scientific Drilling. Springer, Heidelberg, 366 + X pp.

Koeberl C., Milkereit B., Overpeck J.T., Scholz C.A., Amoako P.Y.O., Boamah D., Danuor S.K., Karp T., Kueck J., Hecky R.E., King J., and Peck J.A. (2007) An international and multidisciplinary drilling project into a young complex impact structure: The 2004 ICDP Bosumtwi impact crater, Ghana, drilling project – An overview. Meteoritics and Planetary Science 42, 483-511.

Gohn G.S., **Koeberl** C., Miller K.G., Reimold W.U., Browning J.V., Cockell C.S., Horton J.W., Kenkmann T., Kulpecz A.A., Powars D.S., Sanford W.E., and Voytek M.A. (2008) Deep drilling yields new insights into the Chesapeake Bay impact event. Science, in press.

DAVID A. KRING

ABBREVIATED BIOGRAPHICAL INFORMATION AND BIBLIOGRAPHY AUGUST 2008

EDUCATION

1984 B.S. with Honors, Geology and Astrophysics,
Indiana University

1989 Ph.D., Geology,
Harvard University

ABBREVIATED LIST OF PREVIOUS AND CURRENT POSITIONS

1984-88 Research Assistant, Department of Geological Sciences, Harvard University, and Division of Planetary Sciences, Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts

1988-93 Research Associate (Faculty of Science), Lunar and Planetary Laboratory, Department of Planetary Sciences, University of Arizona, Tucson, Arizona

1993-99 Senior Research Associate (Faculty of Science), Lunar and Planetary Laboratory, Department of Planetary Sciences, University of Arizona, Tucson, Arizona

1999-2006 Associate Professor (Faculty of Science), Department of Planetary Sciences, Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona

2000-2006 Director, NASA Space Imagery Center, Department of Planetary Sciences, Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona

2001-2006 Associate Professor (Faculty of Science), Department of Geosciences, University of Arizona, Tucson, Arizona

2006-present Visiting Scientist for the Lunar Exploration Initiative, Lunar and Planetary Institute, Universities Space Research Association, Houston, Texas

ABBREVIATED LIST OF PROFESSIONAL COMMITTEES

1999-present Chair, Eugene M. Shoemaker Impact Cratering Award Committee, Geological Society of America

1999-2000 Member, Geological Society of America Joint Technical Program Committee

1999-2002 Member, Barringer Award Committee, The Meteoritical Society

1999-2001 Co-Investigator, Chicxulub Scientific Drilling Project

2000-present Scientific Advisor, The Barringer Crater Company

2001 Chair, G.K. Gilbert Award Committee, Planetary Geology Division, Geological Society of America

2002-present Chair, Barringer Family Fund for Meteorite Impact Research Award Committee, The Barringer Crater Company

2002-2003 Chair, Barringer Award Committee, The Meteoritical Society

ABBREVIATED LIST OF AWARDS AND HONORARIES

2000 Honored with asteroid 8391 being named Kring

2004 Named a Fellow of the Meteoritical Society

ABBREVIATED LIST OF PROFESSIONAL SOCIETIES

American Geophysical Union

Geological Society of America (Chair, Planetary Geology Division, 1999-2000)

Meteoritical Society (Deputy Treasurer, 2001)

ABBREVIATED LIST OF PUBLICATIONS

D. A. Kring and W. V. Boynton, "Altered spherules of impact melt and associated relic glass from K/T boundary sediments in Haiti," *Geochim. Cosmochim. Acta 55*, pp. 1737—1742, 1991.

A. R. Hildebrand, G. T. Penfield, **D. A. Kring**, M. Pilkington, A. Camargo Z., S. Jacobsen, and W. V. Boynton, "The Chicxulub Crater: A possible Cretaceous-Tertiary boundary impact crater on the Yucatán Peninsula, Mexico," *Geology 19*, pp. 867–871, 1991.

D. A. Kring and W. V. Boynton, "The petrogenesis of an augite-bearing melt rock in the Chicxulub structure and its relationship to K/T impact spherules in Haiti," *Nature 358*, pp. 141–144, 1992.

D. A. Kring, A. R. Hildebrand, and W. V. Boynton, "Provenance of mineral phases in the Cretaceous-Tertiary boundary sediments exposed on the southern peninsula of Haiti," *Earth Planet. Sci. Letters 128*, pp. 629–641, 1994.

D. A. Kring, "The dimensions of the Chicxulub impact crater and impact melt sheet," *J. Geophys. Res. 100*, pp. 16,979-16,986, 1995.

D. A. Kring, H. J. Melosh, and D. M. Hunten, "Impact-induced perturbations of atmospheric sulfur," *Earth Planet. Sci. Letters 140*, pp. 201–212, 1996.

D. A. Kring, “Air blast produced by the Meteor Crater impact event and a reconstruction of the affected environment,” *Meteoritics and Planetary Science 32*, pp. 517–530, 1997.

E. Pierazzo, **D. A. Kring**, and H. J. Melosh, “Hydrocode simulation of the Chicxulub impact event and the production of climatically active gases,” *J. Geophys. Res. 103*, pp. 28607–28626, 1998.

D.A. Kring, “Impact events & their effect on the origin, evolution, and distribution of life,” *GSA Today 10(*8), pp. 1-7, 2000. Invited paper.

B.A. Cohen, T.D. Swindle, and **D.A. Kring**, “Lunar meteorites support the lunar cataclysm hypothesis,” *Science 290*, 1754-1756, 2000.

D.A. Kring and B.A. Cohen, “Cataclysmic bombardment throughout the inner solar system 3.9-4.0 Ga,” *Journal of Geophysical Research 107(E2)*, pp. 4-1 through 4-6, doi: 10.1029/2001JE001529, 2002.

D.A. Kring and D.D. Durda, “Trajectories and distribution of material ejected from the Chicxulub impact crater: Implications for post-impact wildfires,” *Journal of Geophysical Research 107(E8)*, pp. 6-1 through 6-22, doi: 10.1029/2001JE001532, 2002.

D.A. Kring, “Environmental consequences of impact cratering events as a function of ambient conditions on Earth,” *Astrobiology 3(1)*, pp. 133-152, 2003. Invited paper.

D.A. Kring, L. Zurcher, F. Hörz, and J. Urrutia Fucugauchi, “Impact Lithologies and Their Emplacement in the Chicxulub Impact Crater: Initial Results from the Chicxulub Scientific Drilling Project, Yaxcopoil, Mexico,” *Meteoritics and Planetary Science 39*, 879-897, 2004.

L. Zurcher and **D.A. Kring**, “Post-impact hydrothermal alteration in the Yaxcopoil-1 hole, Chicxulub impact structure, Mexico,” *Meteoritics and Planetary Science 39*, 1199-1221, 2004.

A. Gelinas, **D.A. Kring**, L. Zurcher, and J. Urrutia Fucugauchi, O. Morton, and R.J. Walker “Osmium isotope constraints on the proportion of bolide component in Chicxulub impact melts,” *Meteoritics and Planetary Science 39*, 1003-1008, 2004.

D.D. Durda and **D.A. Kring**, “Ignition threshold for impact-generated fires,” *J. Geophysical Research 109*, E08004, doi: 10.1029/2004JE002279, 2004.

L. Zurcher, **D.A. Kring**, D. Dettman, and M. Rollog, “Stable isotope record of post-impact fluid activity in the Yaxcopoil-1 borehole, Chicxulub impact structure, Mexico,” In *Large Meteorite Impacts and Planetary Evolution III*, (T. Kenkmann et al., eds.), *Geological Society of America Special Paper 384*, 223-238, 2005.

D.A. Kring, “Hypervelocity collisions into continental crust composed of sediments and an underlying crystalline basement: Comparing the Ries (~24 km) and Chicxulub (~180 km) impact craters,” *Chemie der Erde 65*, 1-46, 2005. Invited paper.

R.G. Strom, R. Malhotra, T. Ito, F. Yoshida, and **D.A. Kring**, “The origin of planetary impactors in the inner solar system,” *Science 309*, 1847-1850, 2005.

O. Abramov and **D. A. Kring**, “Numerical modeling of impact-induced hydrothermal activity at the Chicxulub crater,” Meteoritics and Planetary Science 42, pp. 93-112, 2007.

D. A. Kring, “The Chicxulub impact event and its environmental consequences at the Cretaceous-Tertiary boundary,” Palaeogeography, Palaeoclimatology, Palaeoecology 255, pp. 4-21, 2007. Invited paper.

I.S. Puchtel, R.J. Walker, O.B. James, and **D.A. Kring**, “Osmium isotope and highly siderophile element systematics of lunar impact melt rocks: Implications for the late accretion history of the Moon and Earth,” Geochimica et Cosmochimica Acta 72, pp. 3022–3042, 2008.

Brief curriculum vitae

Takafumi MATSUI

Born: Shizuoka Prefecture, Japan; 1946

Education:
B. S., 1970, Geophysics, University of Tokyo
M. S., 1973, Geophysics, University of Tokyo
Ph. D., 1976, Geophysics, University of Tokyo

Employment:
Assistant Professor, Geophysical Institute, University of Tokyo, 1978
Associate Professor, Geophysical Institute, University of Tokyo, 1992
Associate Professor, Department of Earth and Planetary physics, University of Tokyo, 1994
Professor, Department of Complexity physics and Engineering, Graduate school of Frontier Sciences, University of Tokyo, 1999-present

Research subject:
Geophysics, Planetary Sciences, Comparative planetology, Astrobiology

Social activity:

Publication list (recent 5 years):

Nakano, Y., Goto, K., Matsui, T., Tada, R., Tajika, E., 2008, PDF orientations in shocked quartz grains around the Chicxulub crater. Meteoritics & Planetary Science. (accepted)

Goto, K., Tada, R., Tajika, E., Iturralde-Vinent, M. A., Matsui, T., Yamamoto, S., Nakano, Y., Oji, T., Kiyokawa, S., Garcia, D., Otero, C., Rojas, R, Lateral lithological and compositional variations of the Cretaceous/Tertiary deep-sea tsunami deposit in northwestern Cuba. Cretaceous Research, Vol. 29, No.2, 217-236., 2008

Y. Sekine, H. Imanaka, T. Matsui, B.N. Khare, E.L.O. Bakes, C.P. McKay, S. Sugita, The role of organic haze in Titan's atmospheric chemistry I: Laboratory investigation on heterogeneous reaction of atomic hydrogen with Titan tholin, Icarus, 194, p.186-200, 2008

Y. Sekine, S. Lebonnois, H. Imanaka, T. Matsui, E.L.O. Bakes, C.P. McKay, B.N. Khare, S. Sugita, The role of organic haze in Titan's atmospheric chemistry II: Effect of heterogeneous reaction to the hydrogen budget and chemical composition of the atmosphere , Icarus, 194, p.201-211, 2008

Barnouin-Jha O.S., S. Yamamoto, T. Toriumi, S. Sugita, and T. Matsui, Non-intrusive measurements of crater growth, Icarus, 188, 506-521,2007

Fuyuki, M., S. Sugita, S. Hasegawa, T. Kadono, and T. Matsui, Spectroscopic observation of thermal dissociation of SiO2 in impact-induced vapor, Earth Planet. Space, 59, 437-451,2007

K. Goto, S. A. Chavanich, F. Imamura, P. Kunthasap, T. Matsui, K.Minoura, D. Sugawara, H. Yanagisawa, Distribution, origin and transportprocess of boulders transport by the 2004 Indian Ocean tsunami atPakarang Cape, Thailand. Sedimentary Geology, 202, 821-837.

K. Goto, F. Imamura, N. Keerthi, P. Kunthasap, T. Matsui, K, Minoura,A. Ruangrassamee, D. Sugawara, S. Supharatid, Distributions andSignificances of the 2004 Indian Ocean tsunami deposits -Initial resultsfrom Thailand and Sri Lanka-. in Tsunamiites - Features and Implication, Elsevier, Belrin 105-122.

K. Goto., R. Tada., E. Tajika., T. Matsui., Deep-sea tsunamideposits in the proto-Caribbean sea at the Cretaceous-Tertiary boundary.in Tsunamiites - Features and Implication, Elsevier, Belrin, 251-276.

Mousis O., Y. Alibert, Y. Sekine, S. Sugita, and T. Matsui, The role of Fischer-Tropsch catalysis in jovian subnebula chemistry, *Astron. Astrophys.*, 459, p. 965-968, 2006.

Sekine, Y., S. Sugita, T. Shido, T. Yamamoto, Y. Iwasawa, T. Kadono, and T. Matsui, An experimental study on Fischer-Tropsch catalysis: Implications for impact phenomena and nebular, *Meteorit. Planet. Sci*., 41,715-729, 2006. Yamamoto, S., K. Wada, N. Okabe, and T. Matsui, Transient crater growth in graluar targets: An experimental study of low velocity impacts into glass sphere targets, Icarus 183, 215-224, 2006,

Wada, K., H. Senshu, and T. Matsui, Numerical simulation of impact into granular material, Icarus 180, 528-545,2006,

S. Yamamoto, K. Wada, N. Okabe, T. Matsui,Transient crater growth in granular targets: An experimental study of low velocity impacts into glass sphere targets,Icarus, 183, 215-224, 2006

Sekine, Y., S. Sugita, T. Shido, T. Yamamoto, Y. Iwasawa, T. Kadono, and T. Matsui, An experimental study on Fischer-Tropsch catalysis: Implications for impact phenomena and nebular, Meteoritics and Planetary Science, 41, 5, p.715-729, 2006

Yamamoto, S., T. Kadono, S. Sugita, and T. Matsui, Velocity distributions of high–velocity ejecta from regolith targets, Icarus, 178, 264-273, 2005

Sekine, Y., S. Sugita, T. Shido, T. Yamamoto, Y. Iwasawa, T. Kadono, and T. Matsui, The role of Fischer-Tropsch catalysis in the origin of methane-rich Titan, Icarus, 178, 154-164,2005

Wada, K., H. Senshu, and T. Matsui, Numerical simulation of impact cratering on granular material, Icarus, 180, 528-545,2005

J. O. Campos-Enriquez, F. J. Chavez-Garcia, H. Cruz, J. G. Acosta-Chang, T. Matsui, J. A. Arzate, M. J. Unsworth and J. Ramos-Lopez, Shallow crustal structure of Chicxulub impact crater imaged with seismic, gravity and magnetotelluric data: inferences about the central uplift, *J. Geophys Int.*157, 515-525,2004

Imanaka, H., B.N. Khare, E.L.O. Bakes, C.P. McKay, D.P. Cruikshank, S. Sugita, T. Matsui, and R.N. Zare, Laboratory experiments of Titan tholin formed in cold plasma at various pressures: Implications for nitrogen-containing polycyclic aromatic compounds in Titan Haze, Icarus, 168 , 344 - 366, 2004.

K. Goto., R. Tada., E. Tajika., T. J. Bralower., T. Hasegawa, and T. Matsui., Evidence for ocean water invasion into the Chicxulub crater at the Cretaceous/Tertiary boundary. *Meteorit. Planet. Sci*., 39, 1233-1247, 2004.

R. Tada., M. A. Iturralde-Vinent., T. Matsui., E. Tajika., T. Oji., K. Goto., Y. Nakano., H. Takayama., S. Yamamoto., S. Kiyokawa., K. Toyoda, etal. ,K/T boundary deposit in the proto-Caribbean basin. *AAPG Memoir*, 79, 582-604, 2004.

Y. Sekine., S. Suigta, T. Kadono, and T. Matsui, Methane production by large iron meteoritic impacts, *J. Geophys. Res., 108(E7)*, 5070, 10.1029/2002JE002034, 2003.

H.J. MELOSH

BORN: June 23, 1947, Paterson, New Jersey
ATTENDED: Princeton University, 1965-1969, A.B. (physics) magna cum laude
Caltech 1969-1972, Ph.D. (physics and geology)

Academic Experience

Graduate Teaching Assistant, Caltech, 1969-1971
Visiting Scientist, CERN (Geneva, Switzerland), 1971-1972
Research Associate, University of Chicago, Enrico Fermi Institute, 1972-1973
Instructor in Geophysics and Planetary Science, Caltech, 1973-1975
Assistant Professor of Planetary Science, Caltech, 1976-1978
Associate Professor of Planetary Science, Caltech, 1978-1979
Associate Professor of Geophysics, SUNY, Stony Brook, 1979-1982
Associate Professor of Planetary Science, Univ. of Arizona, 1982-1985
Professor of Planetary Science, Univ. of Arizona, 1985-present
Halbouty Distinguished Visiting Chair, Texas A&M University, October 2000
Regents Professor of Planetary Science, Univ. of Arizona, January 2004

Fellowships and Honors:

Phi Beta Kappa
Sigma Xi
NSF Fellowship, 1969-1972
Best Scientific Secretary Prize, Int'l Summer School of Theoretical Physics, Erice, Sicily, 1972
Fellow of the Meteoritical Society (July, 1988)
Fellow of the Geological Society of America (November, 1988)
AGU Editor's Citation for Excellence in Refereeing, Tectonics (July, 1989)
Fellow of the American Geophysical Union (January 1993)
Paul Simon Guggenheim Fellow, 1996-1997.
Barringer Medal of the Meteoritical Society, 1999
Asteroid 8216 name “Melosh” Approved by the IAU, 2000
Gilbert Medal of the Geological Society of America, 2001
Fellow of the American Association for the Advancement of Science, October 2001
Member, National Academy of Sciences, Elected 29 April 2003
Humboldt Prize Fellowship, August 2005-2006
Member: American Geophysical Union, Geological Society of America, Meteoritical Society, American Astronomical Society, Division of Planetary Sci., AAAS

Five Recent Publications

RICHARDSON, J. E., MELOSH, H. J., GREENBERG, R. J. and O'BRIEN, D. (2005) The global effects of impact-induced seismic activity on fractured asteroid surface morphology, *Icarus* **129**, 325-349.

WÜNNEMANN, K., COLLINS, G. S., and MELOSH, H. J. (2006) A strain-based porosity model for use in hydrocode simulations of impacts and implications for transient-crater growth in porous targets, *Icarus* **180**, 514-527.

BART, G. D., and H. J. MELOSH (2007), Using lunar boulders to distinguish primary from distant secondary impact craters, *Geophys. Res. Lett.*, 34, L07203, doi:10.1029/2007GL029306.

RICHARDSON, J. E., MELOSH, H. J., LISSE, C. M., CARCICH, B. (2007) A ballistics analysis of the Deep Impact ejecta plume: Determining comet Tempel 1's gravity, mass and density. . *Icarus* **190**, 357-390..

McDONALD, M., MELOSH, H. J., GULICK, S. (2008) Oblique impacts and peak ring position: Comparing Venusian craters to Chicxulub, *Geophys. Res. Lett.*, 35, L07203, doi:10.1029/2008GL033346.

Five Relevant Publications

MELOSH, H.J. (1989) *Impact Cratering: A Geologic Process*. Oxford University Press, 245 pp.

MELOSH, H. J. (2007) A Hydrocode Equation of State for SiO_2, Meteoritics and Planetary Science 42, 2079-2098.

COLLINS, G. S., MELOSH, H. J. and IVANOV, B. A. (2004) Damage and deformation in numerical impact simulations, Meteoritics and Planetary Science, **39**, 217-231.

GOLDIN, T. J., WÜNNEMANN, K., MELOSH, H. J., COLLINS, G. S. (2006) Hydrocode modeling of the Sierra Madera impact structure, *Meteoritics and Planetary Science* **41**, 1947-1958.

MORGAN, J., CHRISTESON, G, GULICK, S., GRIEVE, R. URRUTIA, J., BARTON, P., ROBOLLEDO, M., MELOSH, J. (2007) Joint IODP/ICDP Scientific Drilling of the Chicxulub Impact Crater, *Scientific Drilling*, **4**, 42-44.

BIOGRAPHICAL SKETCH OF ELISABETTA PIERAZZO

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Education:

- Laurea in Physics at the University of Padua, Padova, Italy, Spring 1988.
- **Ph.D.** in Planetary Sciences at the University of Arizona, Tucson, AZ, Fall 1997.

Professional Experience:

1/2008-Present. *Senior Scientist*, Planetary Science Institute, Tucson, AZ.

9/2004-Present. *Adjunct Assistant Research Scientist*, Lunar & Planetary Laboratory, Univ. of Arizona, Tucson, AZ.

2/2002-12/2007. *Research Scientist*, Planetary Science Institute, Tucson, AZ.

Fall 2005-2006-2008. *Instructor* for NATS 102 "*The Universe and Humanity: Origin and Destiny*," Tier 1 Natural Science Course in the general education curriculum at the Univ. of Arizona, Tucson, AZ.

1/98-2/2002. *Research Associate*, Lunar & Planet. Laboratory, Univ. of Arizona, Tucson, AZ.

Research Interests:

- Study of how lithologies affect impact cratering through modeling of known and well-studied terrestrial impact structures.
- Investigating impact cratering on Mars: material ejection and post-impact conditions.
- Validation of numerical codes used for impact cratering modeling.
- Investigating the effects of the Chicxulub impact event on the global climate of the end-Cretaceous, and study of impact expansion plumes and their relation with stratigraphic impact layers.

Professional Activities:

- Associate Editor, *Meteoritics and Planetary Sciences*; since 2003
- Member of the scientific organizing committee for the 2008 *Large Meteorite Impacts meeting*, 18-22 Aug. 2008, Vredefort Dome, South Africa.
- Member of the Program Committee of the *Lunar & Planetary Science Conference*; 2006-2007-2008.
- Member of the *Hazards and Resources subcommittee* of the NASA Space Science Enterprise Strategic Plan 2006.
- Co-convener Workshop: *Bridging the Gap 2: Effect of target properties on the impact cratering process*, Sep 22-26 2007 Canadian Space Agency Headquarters, Canada.
- Co-convener LPI *Workshop: Impact Cratering: Bridging the Gap Between Modeling and Observations*, Feb. 7-9 2003, Houston, (TX).
- NASA Education & Public Outreach ROSS Review Panel 3; 2004.
- NASA Planetary Geology and Geophysics Review Panel; 2000-2001-2004-2008.
- NASA Astrobiology Institute CAN Cycle-3 Review Panel; 2003.
- **Principal Investigator:** NASA Planetary Geology & Geophysics, Mars Fundamental Research, Education/Public Outreach Programs.

Relevant Publications

I. Pierazzo E., N. Artemieva, E. Asphaug, E. Baldwin, J. Cazamias, R. Coker, G.S. Collins, D.A. Crawford, T. Davison, D. Elbeshausen, K.A. Holsapple, K.R. Housen, D.G. Korycansky, K. Wünnemann: *Validation of numerical codes for impact and explosion cratering*. Meteoritics Planet. Sci. 2008. Submitted.

II. Artemieva, N.A., E Pierazzo: *The Canyon Diablo impact event: 1. Projectile motion through the atmosphere*. Meteoritics Planet. Sci. 2007. In revision.

III. Turtle E.P., E. Pierazzo, R.U. Reimold, J.G. Spray, H.J. Melosh, G. Collins, J. Morgan, G. Osinski:

Impact structures: What does crater diameter mean? Large Meteorite Impacts (T. Kenkmann, F. Hörz, A. Deutsch Eds.), Geol. Soc. Am. Special Paper 384, 1-24, 2005.

IV. Pierazzo E., G.S. Collins: *A brief introduction to hydrocode modeling of impact cratering*, Henning D., Burchell M., and Claeys P. (eds.), Impact Studies: Cratering in Marine Environments and on Ice (Springer, New York), 323-340, 2003.

V. Turtle E.P., E. Pierazzo, D.P O'Brien: *Numerical Modeling of Impact Heating and Cooling of the Vredefort Impact Structure,* Meteoritics Planet. Sci. 38, 293-303, 2003.

VI. Stöffler D., N.A. Artemieva, E. Pierazzo: *Modeling the Ries-Steinheim impact event and the formation of the moldavite strewn field*. Meteoritics Planet. Sci., 37, 1893-1908, 2002.

VII. Turtle E.P., E. Pierazzo, O'Brien: *Numerical modeling of impact heating and cooling of the Vredefort impact structure*, Meteoritics & Planet. Sci. Submitted (4/02).

VIII. Turtle E.P., E. Pierazzo: *Constraints on the Thickness of an Europan Ice Shell from Impact Crater Simulations,* Science 234, 1326-1328, 2001.

IX. Pierazzo E., H.J. Melosh: *Understanding oblique impacts from experiments, observations, and modeling,* Ann. Rev. Earth Planet. Sci. 28, 141-167, 2000.

X. Pierazzo E., H. J. Melosh: *Melt production in oblique impacts,* Icarus 145, 252-261, 2000.

XI. Pierazzo E., H. J. Melosh: *Hydrocode modeling of oblique impacts: The fate of the projectile,* Meteoritics and Planet. Sci. 35(1), 117-130, 2000.

XII. Pierazzo E., H. J. Melosh: *Hydrocode modeling of Chicxulub as an oblique impact event*, EPSL 165, 163-176, 1999.

XIII. E. P. Turtle and E. Pierazzo: *Constraints on the size of the Vredefort impact crater from numerical modeling,* Meteoritics and Planetary Sci. 33, 483-490, 1998.

XIV. Pierazzo E., D. A. Kring, H. J. Melosh: *Hydrocode simulation of the Chicxulub impact event and the production of climatically active gases*, JGR 103, 28607-28626, 1998.

Relevant Invited Conferences/Symposia presentations

- **12/2007:** AGU Fall Meeting 2007, San Francisco, CA: *The effect of material properties on the impact cratering process*.
- **9/2007:** Workshop entitled Bridging the Gap 2: Effects of Target Properties on the Impact Cratering Process, Montreal, Canada: *Environmental effects associated with impact events*
- **9/2006:** IODP/ICDP Scientific Drilling of the Chicxulub Impact Crater, Potsdam, Germany: *Potential environmental effects of a large-scale impact*
- **5/2006:** Keynote speaker at the 40th ESLAB Symposium on Impact Cratering in the Solar System, Noordwijk, NL: *Numerical modeling of impact cratering*
- **7/2005:** Workshop on The Role of Volatiles and Atmospheres on Martian Impact Craters, Laurel, MD: *Impact cratering and material models: Subsurface volatiles on Mars.*
- **11/2004:** Guest lecturer at the Short Course on "Role of Water: The Geophysical and Geochemical Constraints on the Distribution, the State and Reaction of Water in the Earth", Sendai, Japan: *Environmental catastrophes associated with large impact events: The Cretaceous/Tertiary boundary impact event.*
- **11/2004:** 24th Meeting of the Geologic Society of America, Denver, CO: *Hydrocode modeling of impact events.*
- **6/2004:** Guest lecturer at the 2004 Adler Planetarium Astro-Science Workshop on "Impacts in the Solar System".
- **1/17/2003:** Major Terrestrial Impacts: Modelling and Visualization. Open Colloquium of the American Museum of Natural History, NY: *Modeling the KT Cratering Event.*

Curriculum Vitae

NAME: Mario Rebolledo Vieyra

PLACE AND DATE OF BIRTH: Mexico City, December 30, 1966

MARITAL STATUS: single

CURRENT EMPLOYMENT: Senior Research Scientist , Centro de Investigación Científica de Yucatán, A.C., Unidad Quintana Roo.

ADMINISTRATIVE POSITIONS: Director of the Center for Studies on Water.

EDUCATION

Undergraduate:

Bachelor of Science: Oceanology, Facultad de Ciencias Marinas, Universidad Autónoma de Baja California, Mexico. March, 1991.

Graduate

MSc, Seismology, División de Ciencias de la Tierra, Centro de Investigación Científica y Educación Superior de Ensenada. December 1994.

PhD. Geophysics, Instituto de Geofísica, UNAM, March 2002. With honors. Alfonso Caso Medal, to the best 2002 Promotion PhD Thesis.

EXPERIENCE

- Director, Centro para el Estudio del Agua, CICY, A.C, since January 2005.
- Senior Research Scientist, Centro para el Estudio del Agua, CICY, A.C., since May 2007.
- Research Associate, Centro para el Estudio del Agua, CICY, A.C., May 2004 to May 2007.
- Post-doctoral fellow at Laboratoire des Sciences du Climat et de l'Environnement, Unité Mixte de Recherche CNRS-CEA, Gif-sur-Yvette, Francia. October 2002 to April 2004.
- Post-doctoral fellow, Instituto de Geofísica, UNAM, March 2002 to September 2002.
- Chief of the Digital Documentation laboratory of the Core Respository fo the Chicxulub Scientific Drilling Project. December 2001 to March 2002.
- Chief of the Digital Documentation laboratory of the Core Respository fo the UNAM Scientific Drilling Project. 2001.
- Responsible of the Chicxulub Shallow Drilling Project Core Repository, UNAM, 2000 to 2002.

Oceanographic campaigns

- Picasso, Leg 2, R/V Marion Dufresne, IFEP, June, 2003.
- FAMEX, Leg 1, R/V l'Atalante, IFREMER-UNAM, March, 2002.
- Seeps, R/V Atlantis, Univ. Of Oregon, April, 2001.
- Sedimentos III, R/V El Puma, UNAM, April, 2000.
- Plume, Leg 3, R/V Thomas Washington, SCRIPPS-CICESE, July, 1991.

TEACHING EXPERIENCE

- Teacher assitante to Dr. Avto Gogichaisvili, course: Paleomagnetisme and environmental magnetism, Posgrado en Ciencias de la Tierra, UNAM, 2000 to 2001.
- Teacher, Physics, "Curso de Introducción a las Ciencias de la Salud", Medicine School, Universidad Anáhuac, 1999.
- Instructor, Topography, Facultad de Ciencias Marinas, U.A.B.C., 1997
- Teacher, Non-renewable marine resources, Facultad de Ciencias Marinas, U.A.B.C., 1994

- Teacher, Structural Geology, Facultad de Ciencias Marinas, U.A.B.C., 1993

Scientific Publications (in peer-review)

Rebolledo-Vieyra, M. and J. Urrutia-Fucugauchi, 2006, Magnetostratigraphy of the Cretaceous/Tertiary boundary and early Paleocene sedimentary sequence from the Chicxulub Impact Crater, Earth Planets Space, Vol. 58 (No. 10), pp. 1309-1314

Michaud, F., J.Y. Roger, J. Bourgois, J. Dyment, T. Calmus, W. Bandy, M. Sosson, C. Mortera-Gutiérrez, B. Schiler, **M. Rebolledo-Vieyra**, B. Pontoise, 2006, Oceanic-ridge subduction vs. slab break off: Plate tectonic evolution along the Baja California Sur continental margin since 15 Ma, Geology, v. 34, no. 1, pp. 13-16.

Morgan, J., M. Warner, J. Urrutia-Fucugauchi, S. Gulick, G. Christeson, P. Barton, **M. Rebolledo-Vieyra** and J. Melosh, 2005, Chicxulub Crater Seismic Survey Prepares Way for Future Drilling, Eos, Transactions, American Geophysical Union, Vol. 86, No. 36, 6 September, pp. 325-328.

Bandy, W., Michaud, F., Bourgois, J., Calmus, T., Dyment, J., Mortera, C., Ortega-Ramirez, J., Sichler, B., Sosson, **M., Rebolledo-Vieyra**, M., Bigot-Cormier, F., Diaz, O., Hurtado, A. D., Pardo, G., and Trouillard-Perrot, C., 2005, Subsidence and Strike-slip Tectonism of the Upper Continental Slope off, Manzanillo, Mexico: Tectonophysics, v. Aceptado.

Hueda-Tanabe, Y., Soler-Arechalde, A.M., Urrutia-Fucugauchi, J., Barba, L., Manzanilla, L., **Rebolledo-Vieyra, M**., and Goguitchaichvili, A., Archaeomagnetic Studies in Central Mexico - Dating of Mesoamerican Lime-Plasters: Physics of the Earth and Planetary Interiors. Vol. 147, No. (2-3): 269-283.

Rebolledo-Vieyra, M. and J. Urrutia-Fucugauchi, 2004, Magnetostratigraphy of the impact breccias and post-impact carbonates from borehole Yaxcopoil-1, Chicxulub impact crater, Yucatan, Mexico: Meteoritics and Planetary Sciences, v. 39, p. 821-830.

Urrutia-Fucugauchi, J., Soler-Arechalde, A.M., **Rebolledo-Vieyra, M.,** and Vera-Sánchez, P., 2004, Paleomagnetic and rock-magnetic study of the Yaxcopoil-1 impact breccia sequence, Chicxulub impact crater (Mexico): Meteoritics and Planetary Sciences, v. 39, p. 843-856.

Keller, G., Stinnesbeck, W., Adatte, T., **Rebolledo-Vieyra, M**., Urrutia-Fucugauchi, J., Kramar, U., and Stüben, D., 2004, Chicxulub impact predates K-T boundary mass extinction: Proceedings of the National Academy of Sciences, v. 101, no. 11, p. 3753-3758.

Marin, L. E., Virgil L. Sharpton, Jaime Urrutia Fucugauchi, Jan Smit, Paul Sikora, Chip Carney, **Mario Rebolledo-Vieyra**, 2001, Stratigraphy at Ground Zero: A Contemporary Evaluation of Well Data Within the Chicxulub Impact Basin: International Geology Review. , Vol. 43, No. 12 pp. 1145-1149.

Rebolledo-Vieyra, Mario, J. Urrutia-Fucugauchi, L. E. Marín, A. Trejo-García, V.L. Sharpton and A.M. Soler-Arechalde, 2000, UNAM Scientific Shallow Drilling Program into the Chicxulub Impact. International Geology Review, Vol. 42, No. 10 pp. 928-940.

Dr. Mario Rebolledo Vieyra
July 26, 2007
Cancún, Quintana Roo, Mexico

Dr. rer. nat. Dipl.-Min. Wolf Uwe Reimold
Museum für Naturkunde (Mineralogy), Humboldt-University Berlin

Research Interests

Impact cratering studies (Impactite Mineralogy, Geochemistry, Geochronology; Crater geology and geophysics), Ore genesis

Academic Training

1977	Diploma, Mineralogy, Westf. Wilhelms-Universität Münster (Germany)
1980	Dr. rer. nat., Mineralogy, WWU Münster (magna cum laude)
1980-82	Post-Doc, NASA Johnson Space Center/Lunar and Planetary Institute, Houston

Professional Experience

1982-83	Scientific Co-worker at WWU Münster
1984-86	CSIR-FRD Research Fellow/Senior Research Fellow at Bernard Price Inst. of Geophysical Res., Univ. of the Witwatersrand (Wits Univ.), Johannesburg
1986-97	Senior Research Associate, then Senior Research Officer, Senior Lecturer, Wits Univ., Johannesburg
1998-2005	Associate Professor, from 5/2003 Full Professor of Mineralogy, School of Geosciences, Wits Univ., Johannesburg
1999-2005	Head, Impact Cratering Research Group, School of Geosciences, Wits Univ.
Since 1/2006	Chair for Mineralogy+Petrography, Humboldt-University Berlin
Since 6/2006	Deputy Head, Research - Museum for Natural History, Berlin

Funded Projects (last 5 years)

2001-2002	National Geographic Society grant for structural and environmental geological analysis of the collar of the Vredefort Dome, South Africa (1 PhD)
2002-2005	American Chemical Society (ACS), Petroleum Research Fund grant for study of the Yaxcopoil-1 ICDP drillcore, Chicxulub impact structure, Mexico (1 PhD)
2000-2005	Annual support from National Research Foundation (South Africa) (for research, conference travel, postgraduate student grants) for impact-related projects (incl. ICDP drilling of the Bosumtwi and Chesapeake Bay impact structures; continental sections across the P-Tr boundary in the Karoo basin)
2000-2005	Regular supplementation of funds from industrial and private foundations (incl. PAST Foundation, Johannesburg and Barringer Family Trust, USA)
since 2006	DFG grants for Ries Crater Ejecta Plume and Vredefort Central Uplift research

Cooperation or Consultancy in National and International Committees (last 5 years)

- Scientific Advisory Board, iThemba Labs Accelerator Group - 2004
- South African Heritage Resource Authority APM Permit Committee – 2004-2005
- Member, Board of Directors, Council for Geoscience (Geological Survey) of RSA – 2004-2005
- Member, Technical Committee of Board of Council for Geoscience
- Member of Council, Geological Society of South Africa – 1995-2005
- President, Geological Society of South Africa – 2002/3 term
- Member, Task Team for Development of the Tswaing Crater Museum – 2004-2005
- Member, Expert Team for Development of Ries Geopark

Editorial Activities

- AE, Geochimica et Cosmochimica Acta – since 2001

- Member Editorial Board, Impact Studies Series (Sprinter-Verlag) – since 2000
- AE, Meteoritics and Planetary Science (MAPS) – since 2003
- Member Editorial Board, South African Journal of Geology – since 2006
- Guest Editor, several special issues in CMRE (Ethiopian Ore Deposits) and MAPS
- Guest Editor, Geol. Soc. Amer. Spec. Pap. 405 (Processes on the Early Earth)
- AE, GSA Bulletin – since 1/2008

Other Professional Service Activities (national and international – selected)

- Chair, Org. Comm. for 62nd Ann. Meet. Meteoritical Society, Johannesburg 1999
- Science Team Leader, ICDP Chicxulub Project, 2001-2002
- Science Team Leader, ICDP Bosumtwi Project, 2004-2005
- Principal Investigator, ICDP Chesapeake Bay Project, since 2004
- Co-Chair, GSA-GSSA Field Forum (Processes on the Early Earth), 2004
- Co-Chair, Org. Comm. for GeoscienceAfrica 2004, Johannesburg 2004
- Co-Organizer of SAHRA-GSSA Workshop on Geoconservation in Africa 2005
- Co-Chair, Large Meteorite Impacts IV Conference, August 2008
- Member, Board of Trustees, Ernst-Mach-Institute (Freiburg)

Awards and Nominations (last 5 years)

- President, Geological Society of South Africa – 2002/3
- Fellow of the Meteoritical Society – 2004
- Chairman Fellows Committee, Geological Society of South Africa – 2004/5
- Honorary Research Professor, University of the Witwatersrand – since 1/2006
- "De Beers Alex L. Du Toit Memorial Lecturer" of the Geol. Soc. S. Africa, 2006
- Nominated for Draper Memorial Medal Award, Geol. Soc. South Africa, 2006
- Corresponding Member, Austrian Academy of Sciences, 2007

Selected Publications (last 5 years)

Riller, U. and **Reimold, W.U.** (2005). Guest Editors, Meteoritics and Planetary Science, Special Issue in Honor of D. Stoeffler, vol. 40, Nos. 9/10.

Reimold, W.U. and Gibson, R.L. (2006). Guest Editors, Geological Society of America Special Paper "Processes on the Early Earth", GSA SP 405, 407pp.

Koeberl, C., Milkereit, B. and **Reimold, W.U.** (2006). Guest Editors, The ICDP Drilling Project in Bosumtwi, Ghana. Meteoritics and Planetary Science, special issues, vol. 42, Nos. 4 and 5, 477-896.

Poag, W., Koeberl, C., and **Reimold, W.U.** (2004). The Chesapeake Bay crater: Geology and geophysics of a Late Eocene submarine impact structure. Monograph, Impact Studies Series, Springer Verlag, Heidelberg-Berlin, 522pp.

Reimold, W.U. and Gibson, R.L. (2005). Meteorite Impact! The Danger from Space and South Africa's Mega-Impact, the Vredefort Structure. Chris v. Rensburg Publ., Johannesburg, 319pp. (ICRG No. 80).

- 2nd Edition, Chris van Rensburg Publ., Johannesburg/Council for Geoscience, Pretoria, issued January 2006.

W.U. Reimold – Contributing Author: T.S. McCarthy and B. Rubidge (2005). The Story of Earth & Life. Struik Publ., Cape Town, 333pp.

MICHAEL T. WHALEN

Professional Preparation

Post Doctoral Associate	University of Miami (RSMAS)	1993-1995
Ph.D. Geology	Syracuse University	1993
M.S. Geology	University of Montana	1985
B.A. Geology/Anthropology	Rutgers University	1982

Appointments

2001-present	Associate Professor, Dept. of Geology and Geophysics, and Geophysical Institute, University of Alaska Fairbanks
1999-2001	Assistant Professor, same as above
1993-1995	Post-Doctoral Research Associate, Division of Marine Geology and Geophysics, RSMAS, University of Miami
1991-1992	Adjunct Instructor, State University of New York College at Oswego
1986-1991	Instructor, Syracuse University College, Syracuse, New York

Recent Publications

*Whalen, M.T., Eberli, G.P., van Buchem, F.S.P., Mountjoy, E.W., and Homewood, P.W., 2000, Bypass Margins, Basin-Restricted Wedges And Platform-to-Basin Correlation, Upper Devonian, Canadian Rocky Mountains: Implications For Sequence Stratigraphy Of Carbonate Platform Systems: Journal of Sedimentary Research, v. 70, p. 913-936.

Whalen, M.T., Pearson, Z.F., and Gulick, S.P., 2007, Toward a Sequence Stratigraphy of the Chicxulub Impact Basin Infill: Integration of Lithostratigraphy, Biostratigraphy, and Seismic Stratigraphy, Final Report of JOI Pre-drilling Activity Proposal, 26 p.

Kelly, L.N., Whalen, M.T., McRoberts, C.A., Hopkin, E., and Tomsich, C.S., 2007, Sequence Stratigraphy and Geochemistry of the Upper Lower to Upper Triassic of Northern Alaska: Implications for Paleo-redox History, Source Rock Accumulation, and Paleoceanography, Alaska Division of Geological & Geophysical Surveys Report of Investigation 2007-1, 50 p.

Whalen, M.T., and Day, J.E., 2008, Magnetic Susceptibility, Biostratigraphy, and Sequence Stratigraphy: Insights into Devonian Carbonate Platform Development and Basin Infilling, Western Alberta. Papers on Phanerozoic Reef Carbonates in Honor of Wolfgang Schlager. SEPM (Society for Sedimentary Geology) Special Publication 89, p. 291-314.

Dumoulin, J.A., Whalen, M.T., and Harris, A.G., 2008, Lithofacies, Age, and Sequence Stratigraphy of the Carboniferous Lisburne Group in the Skimo Creek area, Central Brooks Range, Alaska, in Haeussler, P. J., and Galloway, J. P., Studies by the U.S. Geological Survey in Alaska, 2006, USGS Professional Paper 1739-B, 64 p.

*** 2001 Canadian Society of Petroleum Geologists Best Paper Award for a paper dealing with the petroleum geology of Canada**

Selected Recent Abstracts and Other Publications

Pearson, Z.F., Whalen, M.T., Gulick, S.P., and Norris, R., 2006, Annealing The Chicxulub Impact: Tertiary Yucatan Carbonate Platform Development and Basin Infilling, Geological Society of America Abstracts with Programs, Vol. 38, No. 7, p. 297.

Whalen, M.T., Day, J.E., Missler, R.J., Over, D.J., 2006, Magnetic Susceptibility, Biostratigraphy, and Sequence Stratigraphy: Insights Into Late Devonian Sea Level and Climate Change, Western Canada, Geological Society of America Abstracts with Programs, Vol. 38, No. 7, p. 266

Day, J.E., and Whalen, M.T., 2006, Extinction Patterns Of Western Laurussian Tropical Benthic Faunas Suggest Intensification of Latiduinal Temperature Gradient and Rapid Climate Change as Major Cause of Late Frasnian Kellwasser Extinctions, Geological Society of America Abstracts with Programs, Vol. 38, No. 7, p. 267.

Whalen, M.T., Pearson, Z.F., Perez-Cruz, L., Urrutia Fucugauchi, J., Norris, R., Bralower, T.J., and Gulick, S.P., 2007, Sedimentologic and Stable Isotope Response to the PETM at Chicxulub, American Geophysical Union Joint Assembly Abstract U34A-06.

Whalen, M.T., Pearson, Z.F., Gulick, S.P., and Norris, R., 2007, Chicxulub Crater Infilling and Yucatan Carbonate Platform Development: Implications for the Evolution of Large Terrestrial Impact Craters, American Geophysical Union Fall Meeting Abstract U22A-05.

Day, J.E., Whalen, M.T., and Over, D.J., 2007, Middle-Early Upper Devonian Brachiopod Sequence In The Kakwa Provincial Park Area Of Eastern British Columbia, Western Canada, Geological Society of America Abstracts with Programs, Vol. 39, No. 6, p. 73.

Da Silva, A.C., Mabille, C., Potma, K., Weissenberger, J., Whalen, M.T., & Bouvlain, F., 2008-in press, Magnetic susceptibility evolution and sedimentary environments on carbonate platform sediments and atolls, comparison of the Frasnian from Belgium and from Alberta, Canada, Palaeogeography, Palaeoclimatology, Palaeoecology.

Synergistic Activities

1) Member of the College of Science Engineering and Mathematics Dean's Committee on Instructional Technology that designed and implemented smart classroom construction across UAF campus.
2) Professional Reviews
   Reviewer for 8 proposals submitted to NSF, 7 submitted to Petroleum Research Fund-American Chemical Society. Peer-reviewer for 37 scientific manuscripts.
3) Community Outreach: Annual participant in University of Alaska Fairbanks Science Open House and local science fair judge. Geologic fieldtrip leader for local high school groups.
4) Volunteer or remunerated geologic consultant for 8 field stratigraphic and mapping projects conducted by the Alaska Division of Geologic and Geophysical Surveys

Collaborators And Other Affiliations

Collaborators:
J.E. Day, Illinois State Univ.; G.P. Eberli, RSMAS, Univ. of Miami; B.B. Ellwood, Louisiana State Univ.; S.P. Gulick, UT Austin Institute for Geophysics; C.L. Hanks and W.K. Wallace, Univ. of Alaska Fairbanks; P.W. Homewood, Sultan Qaboos Univ., Al Khod, Oman; J. Jensen, Texas A&M Univ.; M.M. Joachimski, Erlangen, Germany; D.J. Over, SUNY, Geneseo; C. McRoberts, SUNY, Cortland

Graduate and Postdoctoral Advisors:
G.P. Eberli (Postdoctoral advisor), RSMAS, Univ. of Miami, Miami, Florida: C.R. Newton (Ph.D. advisor), Syracuse Univ., Syracuse, New York; G.D. Stanley (M.S. advisor), Univ. of Montana, Missoula, Montana

Graduate Students:
Erik Hulm, M.S. 1999; Michelle McGee, Ph.D. 2004; Landon Kelly, M.S. 2004; Jesse White, M.S. 2007, Diana Jozwik, M.S. student (current), Zulmacristina Pearson, M.S. student (current), Rebecca Missler, M.S. student (current), Dolores van der Kolk, M.S. student (current), Joshua Payne, M.S. student (current).

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Current Post: Professor, Institute of Geophysics

(Investigador Titular C) Director Institute 1997-2005, Chairman, Department Geomagnetism and Geophysical Exploration, Institute of Geophysics, UNAM (1984-1997)

Education:

Ph D	School of Physics, University of Newcastle upon Tyne, England (1977-1980).
M Sc	Faculty of Sciences, Department of Physics, National University of Mexico.
B.Sc	Faculty of Engineering, National University of Mexico (Honours).

Research Interests: Paleomagnetism, rock magnetism, exploration geophysics (gravity, magnetics, electromagnetics), Quaternary paleoenvironments and paleoclimates, impact craters and tectonics

Thesis Advisor: PhD students: 21
Other activities:

Associate Editor Bulletin of the Geological Society of America (1999-2001). Associate Editor Journal of Geophysical Research (1993-1995, American Geophysical Union). Associate Editor Quaternary Research (2004-), Associate Editor Geofisica Internacional (1994-2008, Union Geofisica Mexicana). Associate Editor Geologica Acta (2002- Spain), Associate Editor Revista Mexicana de Ciencias Geologicas (2003-), Associate Editor Boletin Sociedad Geologica Mexicana (2003-2006), Associate Editor Revista de Ingenieria (1997-1999). Associate Editor Revista Geofisica (2000- OEA-IPGH). Editor in special volumes for Geofisica Internacional (1981, 1983, 1986, 1986, 1988, 1989, 1992, 1993, 1995), Physics of the Earth and Planetary Interiors (1990), Quaternary International (1997), Tectonophysics (2000), Meteoritics and planetary Science (2004). Editor of 3 volumes of Proceedings for the Mexican Geophysical Union (1984, 1985, 1986) and the Mexican Quaternary Union (1990). Editor of GEOS Bulletin (1985-1987).

International Secretary of the American Geophysical Union 2006-2008 and 2008-2010
Member Board Directors International Year of Planet Earth 2007-2009
Member Board Directors, American Institute of Physics 2008-2009
Member of Executive Committee ICDP 2002-2005 and Science Advisory Group International Continental Scientific Drilling Program (ICDP) 1997-1999 and 2000-2002.
Secretary-Treasurer of the Mexican Academy of Sciences 2004-2006.
President of the Mexican Union for Quaternary Studies 2003-2007.
President of the College of Geophysical Engineers 2002-2006
President of Mexican Geophysical Union 1985-1987

Chairman National Committee for International Lithosphere Program 1984-1990, 2000-present.
Chairman Latin America Regional Committee of American Geophysical Union 1991-1992 and re-elected 1993-1995
President of Latin-American Group of Paleomagnetism 1985-1987 Member Executive Committee of Tephrachronology INQUA 1989-1991 and 1992-1993
Member of the Earth and Marine Sciences Committee of National Council of Science and Technology, Mexico (CONACYT) 1991-1992 and 1992-1993

Recent Publications:

1. Rebolledo Vieyra, M., Urrutia Fucugauchi, J., 2004. Magnetostratigraphy of the impact breccias and post-impact carbonates from borehole Yaxcopoil-1, Chicxulub impact crater, Yucatan, Mexico. *Meteoritics and Planetary Sciences*, v. 39, p. 821-830.
2. Urrutia-Fucugauchi, J., Alva-Valdivia, L.M., Goguitchaichvili, A., Rivas, M.L., Morales, J. 2004. Paleomagnetic, rock magnetic and microscopy studies of historic lava flows from the Paricutin volcano, Mexico: implications for the deflection of paleomagnetic directions. *Geophysical Journal International*. v. 156, p. 431-442.
3. Ruiz-Fernandez A.C., Paez-Osuna, F., Urrutia-Fucugauchi, J., Preda, M. R. 2004. Historical trace metal fluxes in the Mexico City Metropolitan Zone as evidenced by a sedimentary record from the Espejo de los Lirios lake. *Journal of Environmental Monitoring,* 6 (5) p. 473-480.
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CURRICULUM VITAE Ulrich Peter Riller

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Date of birth	February 11, 1965
Place of birth	Biberach/Riss, Germany
Marital Status	married
Academic degrees	Diploma in Geology · Doctor of Philosophy · Habilitation · Professor of Earth Sciences

Scientific Interests Structural geology, neo-tectonics, volcano-tectonics, impact tectonics

Academic Career

Since 2008	Full Professor of Earth Sciences at McMaster University, Hamilton, Canada
2006 / 2007	Visiting Professor at the University of Toronto, Canada
2005	Interims Director of the Institute for Mineralogy of the Museum of Natural History, Humboldt-University Berlin, Germany
2002 - 2007	Professor of Impact Geology, Humboldt-University Berlin, Germany
2002	Habilitation at the Free University Berlin, Germany
1999 - 2002	Assistant Professor at the GeoForschungsZentrum Potsdam, Germany
1997 – 1998	Assistant Professor at the University of Giessen, Germany
1997	Post doctoral fellow at the University of Würzburg, Germany
1992 - 1996	Dissertation at the University of Toronto, Canada
1986 - 1992	Study of Geology at the University of Tübingen, Germany

Services for the international scientific community

- Co-Organizer: Large Meteorite Impact Conference IV, South Africa (2008)
- Organizer of the European Science Foundation workshop in Berlin on the Drilling Project of the Barberton Greenstone Belt, South Africa (2007)
- Referee of the European Science Foundation (since 2006)
- Convener at the Ann. Meeting of the German Mineral. Society “Early Earth Processes and Astrobiology”
- Member of the scientific committee of the 19th Latin-American Colloquium at Potsdam/Berlin (2005)
- Guest Editor of *Meteoritics and Planetary Science*
- Member of the steering committee *Archean Environmental Studies: The Habitat of Early Life* of the European Science Foundation
- Organisation of the Special Session “Comparing modelled and observed quantities in convergent orogenic belts” at the AGU-EGU Joint Assembly in Nice, France (2003)
- Convener at the 17th Latin-American Colloquium in Stuttgart (2001)
- Referee of the EU-Project: *Synthesis of systematic resources* (SYNTHESIS)
- Referee of the German Science Foundation
- Reviewer of the Collaborative Research Program (SPP 1135) of the German Science Foundation “Dynamics of Sedimentary Basins“
- Reviewer for international journals: *NATURE, GEOLOGY, GSA Bulletin, GSA Special Paper, TECTONICS, Can. J. of Earth Sciences, Meteoritics and Planetary Science , J. of Geophys. Research, J. of the Geol. Soc. of London, J. of Struct. Geology, J. of African Earth Sci., Bull. of Volcanology, Prec. Res.*

Peer-reviewed publications since 2006

Adriasola, A. and **Riller, U.** 2008. Emplacement of sulphide-rich quartz-diorite melts in the Whistle-Parkin offset dike of the Sudbury Igneous Complex, Canada. *Zeitschrift für Angewandte Geologie*. (in press).

Riller, U. 2008. The Creighton and Murray plutons, Eastern Penokean Orogen, Canada. In: Rousell, D. H. & Lesher, M., Field guide to the Geology of the Sudbury Area. *Ontario Geological Survey*. (in press).

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Hongn, F. and **Riller, U.** 2007. Tectono-magmatic evolution of the western margin of Gondwana inferred from syntectonic emplacement of Paleozoic granitoid plutons in NW-Argentina. *Journal of Geology*. Vol. 115, 163-180.

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Petrinovic, I.A., **Riller, U.**, Brod, J.A., Alvarado, G. and Arnosio, M. 2006. Bimodal volcanism in a tectonic transfer zone: Evidence for tectonically controlled magmatism in the southern Central Andes, NW Argentina. *Journal of Volcanology and Geothermal Research,* Vol. 152, 240-252. doi:10.1016/j.jvolgeores.2005.10.008.

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IODP Site Summary Forms:

548-Full3

Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New [ ] **Revised** [X]

Section A: Proposal Information

Title of Proposal:	Chicxulub: Drilling the K-T Impact Crater
Date Form Submitted:	9/29/06
Site Specific Objectives with Priority (Must include general objectives in proposal)	1: Constrain formational processes and lithology of peak ring 2: Determine origin of dipping reflections 3: Core and log the Cenozoic basin
List Previous Drilling in Area:	ICDP drill site Yaxcopoil-1 located at edge of inner basin onland. No drilling of a peak ring has occurred anywhere.

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	Chicx-02A	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Peak Ring, Chicxulub Impact Crater
Latitude:	Deg: 21	Min: 27.33 N	Jurisdiction:	Mexico
Longitude:	Deg: 89	Min: 57.09 W	Distance to Land:	25 km
Coordinates System:	WGS 84, X	Other ( )		
Priority of Site:	Primary:	Alt: X (Complete)	Water Depth:	17 m

Section C: Operational Information

	Sediments	Basement
Proposed Penetration: (m)	1500	
	What is the total sed. thickness? 7500 m	
		Total Penetration: 1500 m
General Lithologies:	Carbonates, impact breccia, hydrothermal minerals or melt, lithic breccia	
Coring Plan: *(Specify or check)*	APC, XCB, RCB, etc	
	1-2-3-APC ☐ VPC* ☐ XCB ☐ MDCB* ☐ PCS ☐ RCB ☐ Re-entry ☐ HRGB ☐	** Systems Currently Under Development*

Wireline Logging Plan:

Standard Tools		Special Tools				LWD	
Neutron-Porosity	☒	Borehole Televiewer	☐	Formation Fluid Sampling	☐	Density-Neutron	☐
Litho-Density	☒	Nuclear Magnetic Resonance	☐	Borehole Temperature & Pressure	☐	Resistivity-Gamma Ray	☐
Gamma Ray	☒	Geochemical	☐	Borehole Seismic	☒	Acoustic	☐
Resistivity	☒	Side-Wall Core Sampling	☐				
Acoustic	☒						
Formation Image	☒			Others ( )		Others ( )	

Max.Borehole Temp. :	*Expected value (For Riser Drilling)* ______________°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:90	Logging:10	Total On-Site:100
Future Plan:	*Longterm Borehole Observation Plan/Re-entry Plan*		

Hazards/ Weather:

Please check following List of Potential Hazards

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐
Shallow Water Flow	☐	Currents	☐	Methane Hydrate	☐
Abnormal Pressure	☒	Fractured Zone	☒	Diapir and Mud Volcano	☐
Man-made Objects	☐	Fault	☐	High Temperature	☐
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐
CO_2	☐				

What is your Weather window? (Preferable period with the reasons)

Not in the hurricane season or in August (vacation month for Mexicans). Note abnormal pressure listed to the left is an underpressue due to breccias.

Form 2 - Site Survey Detail

IODP Site Summary Forms:

Please fill out information in all gray boxes

New [ ] *Revised* [X]

Proposal #: 548-Add3	Site #: Chicx-02A	Date Form Submitted: 9/29/06

	Data Type	SSP Requir-ements	Exists In DB	Details of available data and data that are still to be collected
1	High resolution seismic reflection			Primary Line(s): Location of Site on line (SP or Time only) Crossing Lines(s):
2	Deep Penetration seismic reflection		X	Primary Line(s): Line A of 1996 BIRPS survey- CDP 18183 (Location of Site on line (SP or Time only) Crossing Lines(s): Line 17b of 2005 UTIG/Cambridge Survey- CDP 3049
3	Seismic Velocity†		X	Determined through 2-D and 3-D refraction studies
4	Seismic Grid		X	1996 and 2005 grids available
5a	Refraction (surface)		X	Available
5b	Refraction (near bottom)		X	Available
6	3.5 kHz			TBD Location of Site on line (Time)
7	Swath bathymetry			Not applicable due to shallow water depth, can build map from 3.5 and/or seismic
8a	Side-looking sonar (surface)			Not applicable.
8b	Side-looking sonar (bottom)			Not applicable
9	Photography or Video			Available nearby
10	Heat Flow			Not available.
11a	Magnetics		X	Aeromag available
11b	Gravity		X	Aerogravity and ships gravity available
12	Sediment cores			Onshore data available.
13	Rock sampling			
14a	Water current data			
14b	Ice Conditions			None.
15	OBS microseismicity			None.
16	Navigation			Flat seafloor within 10s of km radius
17	Other			

SSP Classification of Site:	SSP Watchdog:	Date of Last Review:
SSP Comments:		

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.

IODP Site Summary Forms:

Form 3 - Detailed Logging Plan

New [ ] *Revised* [X]

Proposal #: 548-Add3	Site #: Chicx-02A	Date Form Submitted: 9/29/06
Water Depth (m): 17	Sed. Penetration (m): 3000	Basement Penetration (m): 0

Do you need to use the conical side-entry sub (CSES) at this site? Yes ☐ No ☒

Are high temperatures expected at this site? Yes ☐ No ☒

Are there any other special requirements for logging at this site? Yes ☐ No ☒

If "Yes" Please describe requirements:______________________________

What do you estimate the total logging time for this site to be: 7-10 days

Measurement Type	Scientific Objective	Relevance (1=high, 3=Low)
Neutron-Porosity	Suggest the standard suite of logs plus a VSP be run to determine the petrophysics, properly tie with cores and seismic, and calibrate models of impact cratering and peak ring formation.	1
Litho-Density	See above.	1
Natural Gamma Ray	See above.	2
Resistivity-Induction	See above.	1
Acoustic	See above.	1
FMS	See above.	1
BHTV	See above.	3
Resistivity-Laterolog	See above.	2
Magnetic/Susceptibility	See above.	2
Density-Neutron (LWD)		
Resitivity-Gamma Ray (LWD)		
Other: Special tools (CORK, PACKER, VSP, PCS, FWS, WSP		

Form 4 – Pollution & Safety Hazard Summary

IODP Site Summary Forms:

Please fill out information in all gray boxes

New [ ] *Revised* [X]

Proposal #: 548-Add3	Site #: Chicx-02A	Date Form Submitted: 9/29/06

1	Summary of Operations at site: (Example: Triple-APC to refusal, XCB 10 m into basement, log as shown on page 3.)	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 lithic breccia. Exact logging and drilling plan will be in part dependent on the MSP chosen.
2	Based on Previous DSDP/ODP drilling, list all hydrocarbon occurrences of greater than background levels. Give nature of show, age and depth of rock:	None.
3	From Available information, list all commercial drilling in this area that produced or yielded significant hydrocarbon shows. Give depths and ages of hydrocarbon-bearing deposits.	Hydrocarbon show observed in drilling of slump block at edge of the inner crater during ICDP Yaxcopoil-1. Expected to be because of cretaceous downthrown blocks originating from outside the transient cavity. These slump blocks will not be drilled in our proposed IODP-ICDP drilling.
4	Are there any indications of gas hydrates at this location?	None.
5	Are there reasons to expect hydrocarbon accumulations at this site? Please give details.	None.
6	What “special” precautions will be taken during drilling?	Need to handle problem of underpressures in breccia drilling.
7	What abandonment procedures do you plan to follow:	
8	Please list other natural or manmade hazards which may effect ship’s operations: (e.g. ice, currents, cables)	Shallow water and thus must be an MSP.
9	Summary: What do you consider the major risks in drilling at this site?	Shallow water requires a MSP, possibly simply sinking a Lousiana barge is easiest or some kind of a lift-barge/mini-jack-up. Need capability to seal hole at depth in the breccias. Suggest gain information from ICDP Chesapeake drilling team.

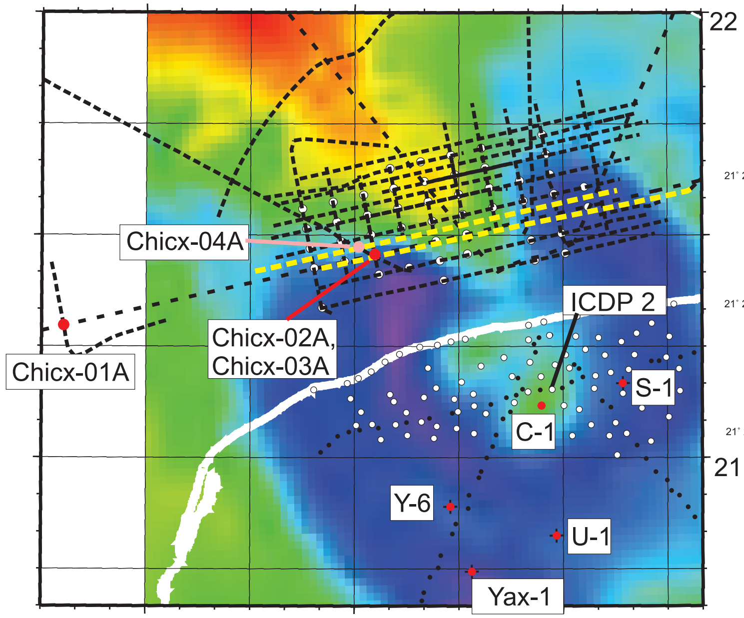
IODP Site Summary Forms:

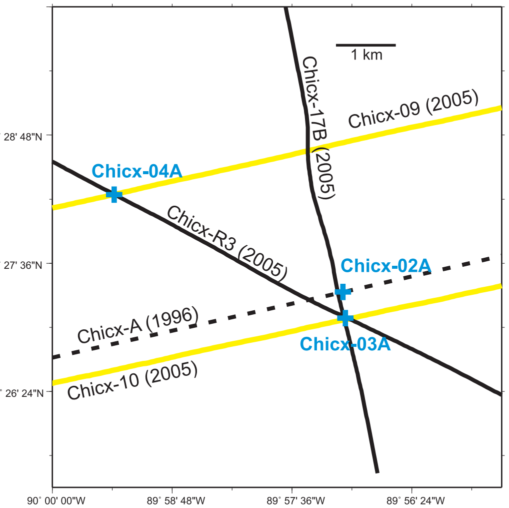
Form 5 – Lithologic Summary

New [ ] *Revised* [X]

Proposal #: 548-Add3	Site #: Chicx-02A	Date Form Submitted: 9/29/06

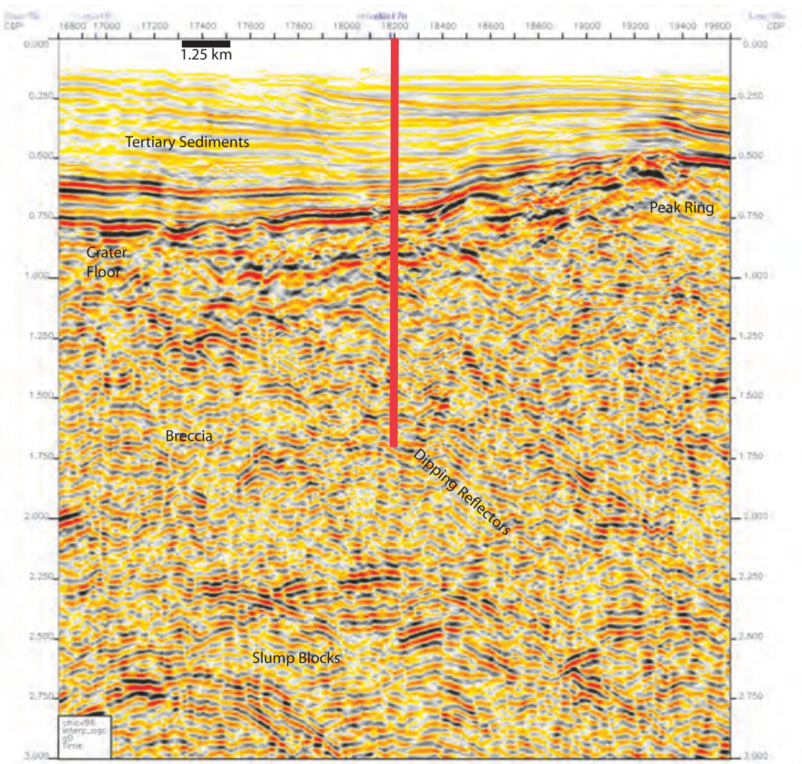
Sub-bottom depth (m)	*Key reflectors, Unconformities, faults, etc*	*Age*	*Assumed velocity (km/sec)*	*Lithology*	*Paleo-environment*	*Avg. rate of sed. accum. (m/My)*	*Comments*
300	Lower-upper crater fill boundary	23 Ma	2250	Carbonate	Carbonate platform		
625	K-P boundary	65 Ma	3250	Carbonate	Slope deposits over impact crater		
2550	Dipping reflector	65 Ma	4375	Impact Breccia & Hydrothermal minerals or melt	Peak Ring		
2850	Breccias below Dipping reflector	65 Ma	5500	Hydrothermal minerals or melt & Lithic Breccia	Hydrothermal vent in wake peak ring emplacement? Underlain by ground surge or airfall deposits		



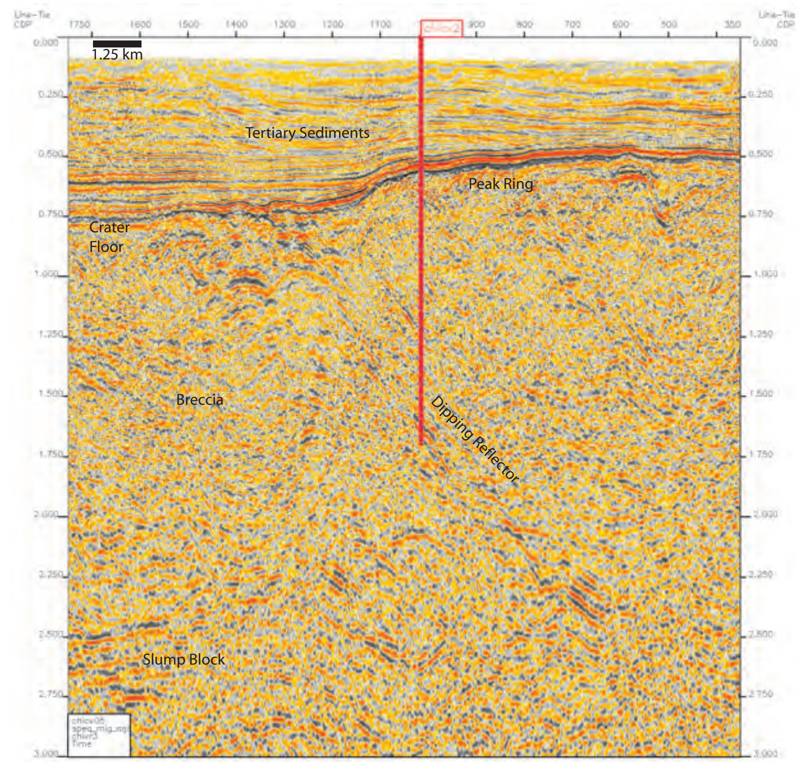


Contingency site 02A: Located at line crossing of Chicx-A (CDP 18183) (bottom left) from the 1996 survey and Chicx-17b (CDP 3049) (bottom right) from 2005 survey. Seismic data below are in two-way-travel time.

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 &
chix17Bmigspqdpthagc.segy & CHI_A_KMIG.segy
MCS images=chicx17b_site2and3.tif &
chicxa_site2_revised.tif & chicx17b_site2and3_depth.tif



Line A from the 1996 BIRPS cruise that crosses our Line 17b from the 2005 survey at the position of the proposed borehole, Chicx-02A. Borehole is shown to a depth of 1700 ms (~2.5 km). Proposed to be drilled with Jackup rig given the 17 m water depth. Imaged geology includes Tertiary basin above crater floor above impact breccia in the west (left) that transitions to peak ring floored by a dipping contact with breccia to the east (towards the crater center). This borehole is designed to acquire the Tertiary section including the immediately post-impact sediments, to sample the peak ring, and potentially to examine the breccia and dipping reflector at the base of the peak ring.



Line 17b from our 2005 R/V Maurice Ewing cruise that crosses our Line A from the 1996 survey at the position of the proposed borehole, Chicx-02A. Borehole is shown to a depth of 1700 ms (~2.5 km). Proposed to be drilled with Jackup rig given the 17 m water depth. Imaged geology includes Tertiary basin above crater floor above impact breccia in the north (left) that transitions to peak ring floored by a dipping contact with breccia to the south (towards the crater center). This borehole is designed to acquire the Tertiary section including the immediately post-impact sediments, to sample the peak ring, and potentially to examine the breccia and dipping reflector at the base of the peak ring.

548-Full3

IODP Site Summary Forms:

Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New X **Revised**

Section A: Proposal Information

Title of Proposal:	Chicxulub: Drilling the K-T Impact Crater
Date Form Submitted:	9/29/06
Site Specific Objectives with Priority (Must include general objectives in proposal)	1: Constrain formational processes and lithology of peak ring 2: Determine origin of dipping reflections 3: Core and log the Cenozoic basin
List Previous Drilling in Area:	ICDP drill site Yaxcopoil-1 located at edge of inner basin onland. No drilling of a peak ring has occurred anywhere.

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	Chicx-03A	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Peak Ring, Chicxulub Impact Crater
Latitude:	Deg: 21	Min: 27.0846 N	Jurisdiction:	Mexico
Longitude:	Deg: 89	Min: 57.0648 W	Distance to Land:	25 km
Coordinates System:	WGS 84, X	Other ( )		
Priority of Site:	Primary: X	Alt:	Water Depth:	17 m

Section C: Operational Information

	Sediments	Basement
Proposed Penetration: (m)	1500 What is the total sed. thickness? 7500 m	
		Total Penetration: 1500 m
General Lithologies:	Carbonates, impact breccia, hydrothermal minerals or melt, lithic breccia	
Coring Plan: *(Specify or check)*	APC, XCB, RCB, etc 1-2-3-APC ☐ VPC* ☐ XCB ☐ MDCB* ☐ PCS ☐ RCB ☐ Re-entry ☐ HRGB ☐ ** Systems Currently Under Development*	

Wireline Logging Plan:

Standard Tools		Special Tools				LWD	
Neutron-Porosity	☒	Borehole Televiewer	☐	Formation Fluid Sampling	☐	Density-Neutron	☐
Litho-Density	☒	Nuclear Magnetic Resonance	☐	Borehole Temperature & Pressure	☐	Resistivity-Gamma Ray	☐
Gamma Ray	☒	Geochemical	☐	Borehole Seismic	☒	Acoustic	☐
Resistivity	☒	Side-Wall Core Sampling	☐				
Acoustic	☒						
Formation Image	☒			Others ( )		Others ( )	

Max.Borehole Temp. : *Expected value (For Riser Drilling)* ____________°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:90	Logging:10	Total On-Site:100

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

Hazards/ Weather:

Please check following List of Potential Hazards

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐
Shallow Water Flow	☐	Currents	☐	Methane Hydrate	☐
Abnormal Pressure	☒	Fractured Zone	☒	Diapir and Mud Volcano	☐
Man-made Objects	☐	Fault	☐	High Temperature	☐
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐
CO_2	☐				

What is your Weather window? (Preferable period with the reasons)

Not in the hurricane season or in August (vacation month for Mexicans). Note abnormal pressure listed to the left is an underpressue due to breccias.

Form 2 - Site Survey Detail

IODP Site Summary Forms:

Please fill out information in all gray boxes

New [X] *Revised* [ ]

Proposal #: 548-Add3	Site #: Chicx-03A	Date Form Submitted: 9/29/06

	Data Type	SSP Requir-ements	Exists In DB	Details of available data and data that are still to be collected
1	High resolution seismic reflection			Primary Line(s): Location of Site on line (SP or Time only) Crossing Lines(s):
2	Deep Penetration seismic reflection		X	Primary Line(s): Line 10 of 2005 UTIG/Cambridge Survey- CDP 1721 Crossing Lines(s): Line 17b of 2005 UTIG/Cambridge Survey- CDP 3085 Line R3 of 2005 UTIG/Cambridge Survey- CDP 1017
3	Seismic Velocity†		X	Determined through 2-D and 3-D refraction studies
4	Seismic Grid		X	1996 and 2005 grids available
5a	Refraction (surface)		X	Available
5b	Refraction (near bottom)		X	Available
6	3.5 kHz			TBD Location of Site on line (Time)
7	Swath bathymetry			Not applicable due to shallow water depth, can build map from 3.5 and/or seismic
8a	Side-looking sonar (surface)			Not applicable.
8b	Side-looking sonar (bottom)			Not applicable
9	Photography or Video			Available nearby
10	Heat Flow			Not available.
11a	Magnetics		X	Aeromag available
11b	Gravity		X	Aerogravity and ships gravity available
12	Sediment cores			Onshore data available.
13	Rock sampling			
14a	Water current data			
14b	Ice Conditions			None.
15	OBS microseismicity			None.
16	Navigation			Flat seafloor within 10s of km radius
17	Other			

SSP Classification of Site:	SSP Watchdog:	Date of Last Review:
SSP Comments:		

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.

Form 3 - Detailed Logging Plan

IODP Site Summary Forms:

New [X] *Revised* [ ]

Proposal #: 548-Add3	Site #: Chicx-3A	Date Form Submitted: 9/29/06
Water Depth (m): 17	Sed. Penetration (m): 3000	Basement Penetration (m): 0

Do you need to use the conical side-entry sub (CSES) at this site? Yes ☐ No ☒

Are high temperatures expected at this site? Yes ☐ No ☒

Are there any other special requirements for logging at this site? Yes ☐ No ☒

If "Yes" Please describe requirements:____

____

What do you estimate the total logging time for this site to be: 7-10 days

Measurement Type	Scientific Objective	Relevance (1=high, 3=Low)
Neutron-Porosity	Suggest the standard suite of logs plus a VSP be run to determine the petrophysics, properly tie with cores and seismic, and calibrate models of impact cratering and peak ring formation.	1
Litho-Density	See above.	1
Natural Gamma Ray	See above.	2
Resistivity-Induction	See above.	1
Acoustic	See above.	1
FMS	See above.	1
BHTV	See above.	3
Resistivity-Laterolog	See above.	2
Magnetic/Susceptibility	See above.	2
Density-Neutron (LWD)		
Resitivity-Gamma Ray (LWD)		
Other: Special tools (CORK, PACKER, VSP, PCS, FWS, WSP		

Form 4 – Pollution & Safety Hazard Summary

IODP Site Summary Forms:

Please fill out information in all gray boxes

New [X] *Revised* [ ]

Proposal #: 548-Add3	Site #: Chicx-03A	Date Form Submitted: 9/29/06

1	Summary of Operations at site: (Example: Triple-APC to refusal, XCB 10 m into basement, log as shown on page 3.)	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 lithic breccia. Exact logging and drilling plan will be in part dependent on the MSP chosen.
2	Based on Previous DSDP/ODP drilling, list all hydrocarbon occurrences of greater than background levels. Give nature of show, age and depth of rock:	None.
3	From Available information, list all commercial drilling in this area that produced or yielded significant hydrocarbon shows. Give depths and ages of hydrocarbon-bearing deposits.	Hydrocarbon show observed in drilling of slump block at edge of the inner crater during ICDP Yaxcopoil-1. Expected to be because of cretaceous downthrown blocks originating from outside the transient cavity. These slump blocks will not be drilled in our proposed IODP-ICDP drilling.
4	Are there any indications of gas hydrates at this location?	None.
5	Are there reasons to expect hydrocarbon accumulations at this site? Please give details.	None.
6	What “special” precautions will be taken during drilling?	Need to handle problem of underpressures in breccia drilling.
7	What abandonment procedures do you plan to follow:	
8	Please list other natural or manmade hazards which may effect ship’s operations: (e.g. ice, currents, cables)	Shallow water and thus must be an MSP.
9	Summary: What do you consider the major risks in drilling at this site?	Shallow water requires a MSP, possibly simply sinking a Lousiana barge is easiest or some kind of a lift-barge/mini-jack-up. Need capability to seal hole at depth in the breccias. Suggest gain information from ICDP Chesapeake drilling team.

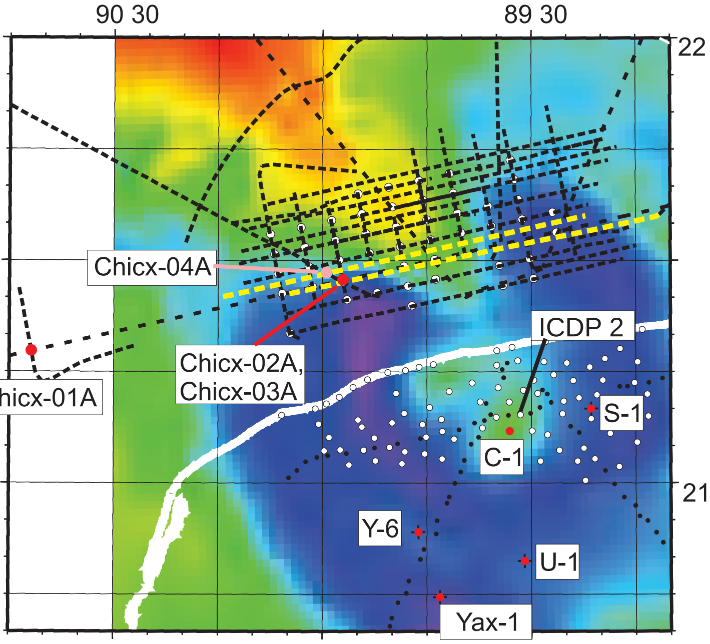
IODP Site Summary Forms:

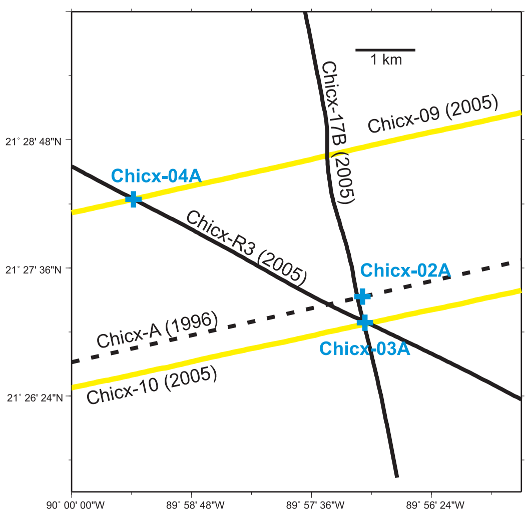
Form 5 – Lithologic Summary

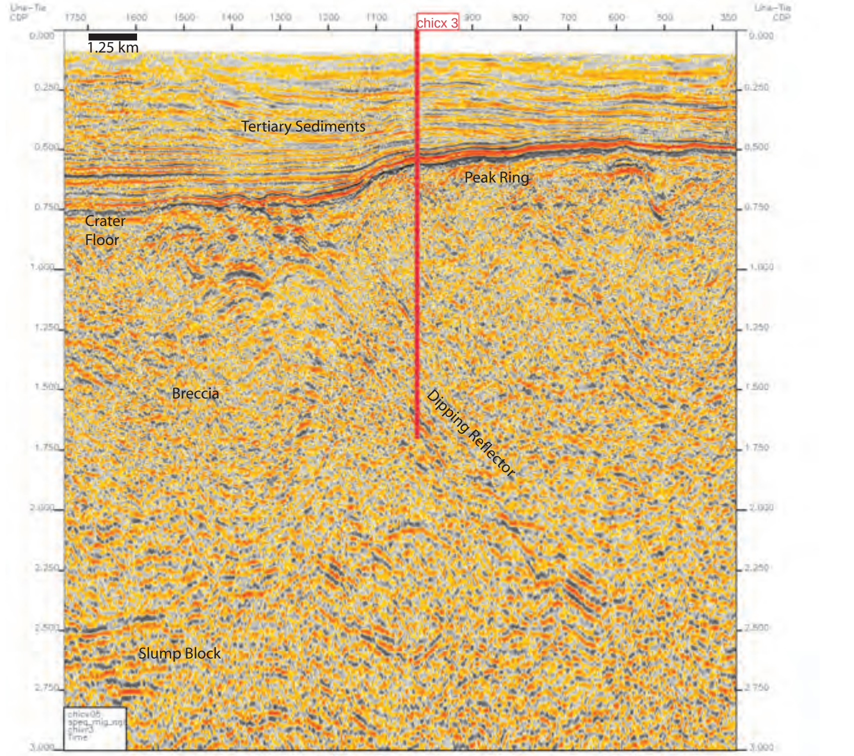
New [X] *Revised* [ ]

Proposal #: 548-Add3	Site #: Chicx-03A	Date Form Submitted: 9/29/06

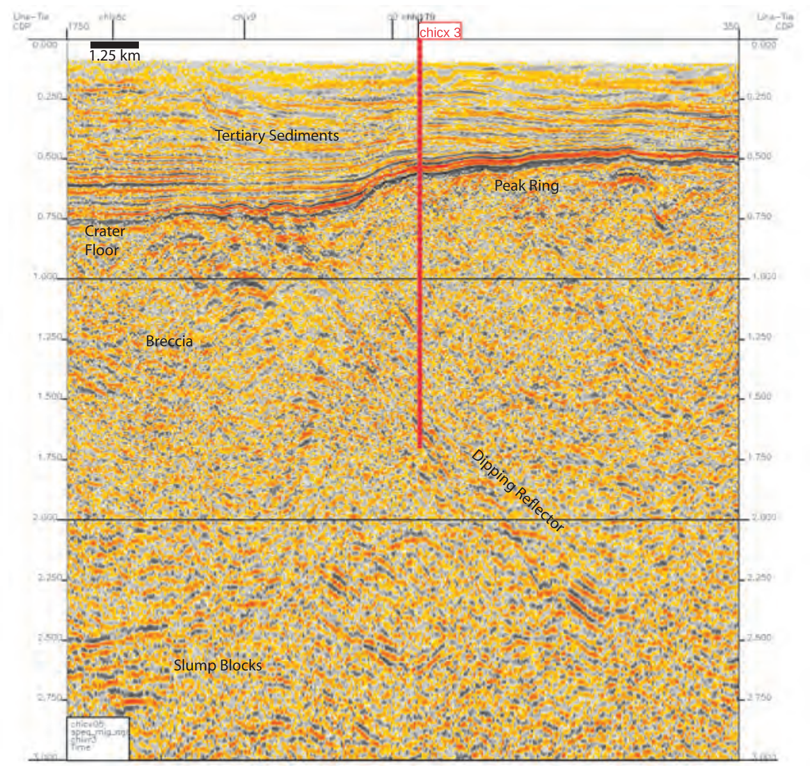
Sub-bottom depth (m)	*Key reflectors, Unconformities, faults, etc*	*Age*	*Assumed velocity (km/sec)*	*Lithology*	*Paleo-environment*	*Avg. rate of sed. accum. (m/My)*	*Comments*
300	Lower-upper crater fill boundary	23 Ma	2250	Carbonate	Carbonate platform		
625	K-P boundary	65 Ma	3250	Carbonate	Slope deposits over impact crater		
2550	Dipping reflector	65 Ma	4375	Impact Breccia & Hydrothermal minerals or melt	Peak Ring		
2850	Breccias below Dipping reflector	65 Ma	5500	Hydrothermal minerals or melt & Lithic Breccia	Hydrothermal vent in wake peak ring emplacement? Underlain by ground surge or airfall deposits		



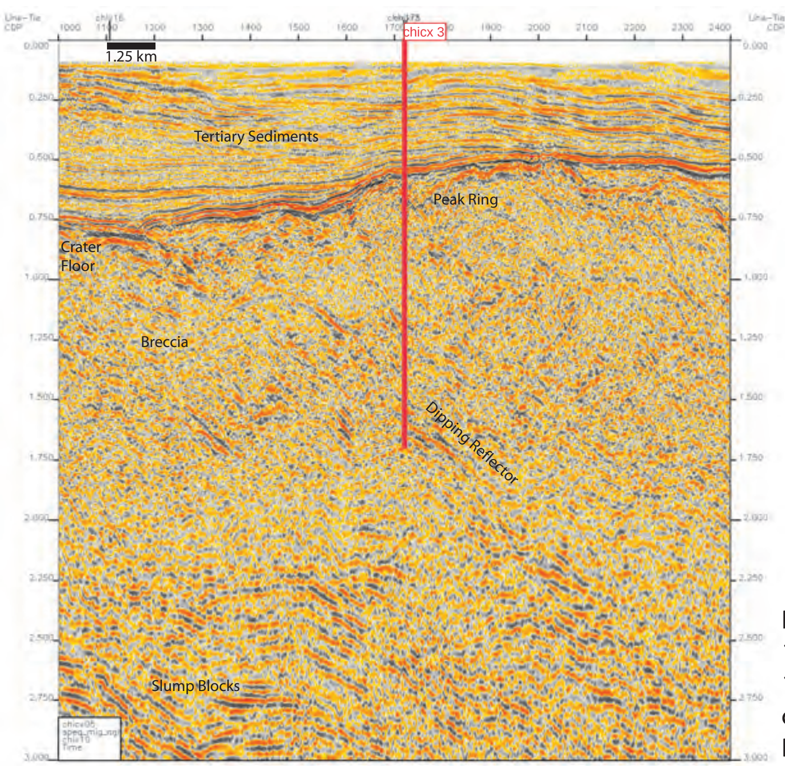




Line 17b from our 2005 R/V Maurice Ewing cruise that crosses our Lines 10 and R3 at the position of the proposed borehole, Chicx-03A. Borehole is shown to a depth of 1700 ms (~2.5 km). Proposed to be drilled with Jackup rig given the 17 m water depth. Imaged geology includes Tertiary basin above crater floor above impact breccia in the north (left) that transitions to peak ring floored by a dipping contact with breccia to the south (towards the crater center). This borehole is designed to acquire the Tertiary section including the immediately post-impact sediments, to sample the peak ring, and potentially to examine the breccia and dipping reflector at the base of the peak ring.



Line R3 from our 2005 R/V Maurice Ewing cruise that crosses our Lines 17b and 10 at the position of the proposed borehole, Chicx-02A. Borehole is shown to depth of 1700 ms (~2.5 km). Proposed to be drilled with Jackup rig given the 17 m water depth. Imaged geology includes Tertiary basin above crater floor above impact breccia in the northwest (left) that transitions to peak ring floored by a dipping contact with breccia to the southeast (towards the crater center). This borehole is designed to acquire the Tertiary section including the immediately post-impact sediments, to sample the peak ring, and potentially to examine the breccia and dipping reflector at the base of the peak ring.



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 depth of 1700 ms (~2.5 km). Proposed to be drilled with Jackup rig given the 17 m water depth. Imaged geology includes Tertiary basin above crater floor above impact breccia in the west (left) that transitions to peak ring (to the right) floored by a dipping contact with breccia to the east (towards the crater center). This borehole is designed to acquire the Tertiary section including the immediately post-impact sediments, to sample the peak ring, and potentially to examine the breccia and dipping reflector at the base of the peak ring.

Primary site 02A: 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

IODP Site Summary Forms:

548-Full3

Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New [X] **Revised** [ ]

Section A: Proposal Information

Title of Proposal:	Chicxulub: Drilling the K-T Impact Crater
Date Form Submitted:	9/29/06
Site Specific Objectives with Priority (Must include general objectives in proposal)	1: Determine origin of dipping reflections 2: Core and log the Cenozoic basin
List Previous Drilling in Area:	ICDP drill site Yaxcopoil-1 located at edge of inner basin onland. No drilling of a peak ring has occurred anywhere.

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	Chicx-04A	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Peak Ring, Chicxulub Impact Crater
Latitude:	Deg: 21	Min: 28.6578 N	Jurisdiction:	Mexico
Longitude:	Deg: 89	Min: 57.4404 W	Distance to Land:	29 km
Coordinates System:	WGS 84, X	Other ( )		
Priority of Site:	Primary:	Alt: X (if peak ring defeats us)	Water Depth:	17 m

Section C: Operational Information

	Sediments	Basement
Proposed Penetration: (m)	1500 What is the total sed. thickness? 7500 m	
		Total Penetration: 1500 m
General Lithologies:	Carbonates, impact breccia, hydrothermal minerals or melt, lithic breccia	
Coring Plan: *(Specify or check)*	APC, XCB, RCB, etc 1-2-3-APC ☐ VPC* ☐ XCB ☐ MDCB* ☐ PCS ☐ RCB ☐ Re-entry ☐ HRGB ☐ ** Systems Currently Under Development*	

Wireline Logging Plan:

Standard Tools		Special Tools				LWD	
Neutron-Porosity	☒	Borehole Televiewer	☐	Formation Fluid Sampling	☐	Density-Neutron	☐
Litho-Density	☒	Nuclear Magnetic Resonance	☐	Borehole Temperature & Pressure	☐	Resistivity-Gamma Ray	☐
Gamma Ray	☒	Geochemical	☐	Borehole Seismic	☒	Acoustic	☐
Resistivity	☒	Side-Wall Core Sampling	☐				
Acoustic	☒						
Formation Image	☒			Others ( )		Others ( )	

Max.Borehole Temp. : *Expected value (For Riser Drilling)*

____________°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:90	Logging:10	Total On-Site:100

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

Hazards/ Weather:

Please check following List of Potential Hazards

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐
Shallow Water Flow	☐	Currents	☐	Methane Hydrate	☐
Abnormal Pressure	☒	Fractured Zone	☒	Diapir and Mud Volcano	☐
Man-made Objects	☐	Fault	☐	High Temperature	☐
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐
CO_2	☐				

What is your Weather window? (Preferable period with the reasons)

Not in the hurricane season or in August (vacation month for Mexicans). Note abnormal pressure listed to the left is an underpressue due to breccias.

Form 2 - Site Survey Detail

IODP Site Summary Forms:

Please fill out information in all gray boxes

New [X] *Revised* [ ]

Proposal #: 548-Add3	Site #: Chicx-04A	Date Form Submitted: 9/29/06

	Data Type	SSP Requir-ements	Exists In DB	Details of available data and data that are still to be collected
1	High resolution seismic reflection			Primary Line(s): Location of Site on line (SP or Time only) Crossing Lines(s):
2	Deep Penetration seismic reflection		X	Primary Line(s): Line 9 of 2005 UTIG/Cambridge Survey- CDP 6897 Crossing Lines(s): Line R3 of 2005 UTIG/Cambridge Survey- CDP 1381
3	Seismic Velocity†		X	Determined through 2-D and 3-D refraction studies
4	Seismic Grid		X	1996 and 2005 grids available
5a	Refraction (surface)		X	Available
5b	Refraction (near bottom)		X	Available
6	3.5 kHz			TBD Location of Site on line (Time)
7	Swath bathymetry			Not applicable due to shallow water depth, can build map from 3.5 and/or seismic
8a	Side-looking sonar (surface)			Not applicable.
8b	Side-looking sonar (bottom)			Not applicable
9	Photography or Video			Available nearby
10	Heat Flow			Not available.
11a	Magnetics		X	Aeromag available
11b	Gravity		X	Aerogravity and ships gravity available
12	Sediment cores			Onshore data available.
13	Rock sampling			
14a	Water current data			
14b	Ice Conditions			None.
15	OBS microseismicity			None.
16	Navigation			Flat seafloor within 10s of km radius
17	Other			

SSP Classification of Site:	SSP Watchdog:	Date of Last Review:
SSP Comments:		

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.

IODP Site Summary Forms:

Form 3 - Detailed Logging Plan

New [X] *Revised* [ ]

Proposal #: 548-Add3	Site #: Chicx-04A	Date Form Submitted: 9/29/06
Water Depth (m): 17	Sed. Penetration (m): 1750	Basement Penetration (m): 0

Do you need to use the conical side-entry sub (CSES) at this site? Yes ☐ No ☒

Are high temperatures expected at this site? Yes ☐ No ☒

Are there any other special requirements for logging at this site? Yes ☐ No ☒

If "Yes" Please describe requirements:____________________

What do you estimate the total logging time for this site to be: 3-5 days

Measurement Type	Scientific Objective	Relevance (1=high, 3=Low)
Neutron-Porosity	Suggest the standard suite of logs plus a VSP be run to determine the petrophysics, properly tie with cores and seismic, and calibrate models of impact cratering and peak ring formation.	1
Litho-Density	See above.	1
Natural Gamma Ray	See above.	2
Resistivity-Induction	See above.	1
Acoustic	See above.	1
FMS	See above.	1
BHTV	See above.	3
Resistivity-Laterolog	See above.	2
Magnetic/Susceptibility	See above.	2
Density-Neutron (LWD)		
Resitivity-Gamma Ray (LWD)		
Other: Special tools (CORK, PACKER, VSP, PCS, FWS, WSP		

Form 4 – Pollution & Safety Hazard Summary

IODP Site Summary Forms:

Please fill out information in all gray boxes

New [X] *Revised* [ ]

Proposal #: 548-Add3	Site #: Chicx-04A	Date Form Submitted: 9/29/06

1	Summary of Operations at site: (Example: Triple-APC to refusal, XCB 10 m into basement, log as shown on page 3.)	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 lithic breccia. Exact logging and drilling plan will be in part dependent on the MSP chosen. This site is design as a contingency for the event that we penetrate the peak ring but get stuck before reaching the dipping reflector. In which case we would propose drilling Site Chicx-02C where the dipping reflector can be reached at a shallower depth.
2	Based on Previous DSDP/ODP drilling, list all hydrocarbon occurrences of greater than background levels. Give nature of show, age and depth of rock:	None.
3	From Available information, list all commercial drilling in this area that produced or yielded significant hydrocarbon shows. Give depths and ages of hydrocarbon-bearing deposits.	Hydrocarbon show observed in drilling of slump block at edge of the inner crater during ICDP Yaxcopoil-1. Expected to be because of cretaceous downthrown blocks originating from outside the transient cavity. These slump blocks will not be drilled in our proposed IODP-ICDP drilling.
4	Are there any indications of gas hydrates at this location?	None.
5	Are there reasons to expect hydrocarbon accumulations at this site? Please give details.	None.
6	What "special" precautions will be taken during drilling?	Need to handle problem of underpressures in breccia drilling.
7	What abandonment procedures do you plan to follow:	
8	Please list other natural or manmade hazards which may effect ship's operations: (e.g. ice, currents, cables)	Shallow water and thus must be an MSP.
9	Summary: What do you consider the major risks in drilling at this site?	Shallow water requires a MSP, possibly simply sinking a Lousiana barge is easiest or some kind of a lift-barge/mini-jack-up. Need capability to seal hole at depth in the breccias. Suggest gain information from ICDP Chesapeake drilling team.

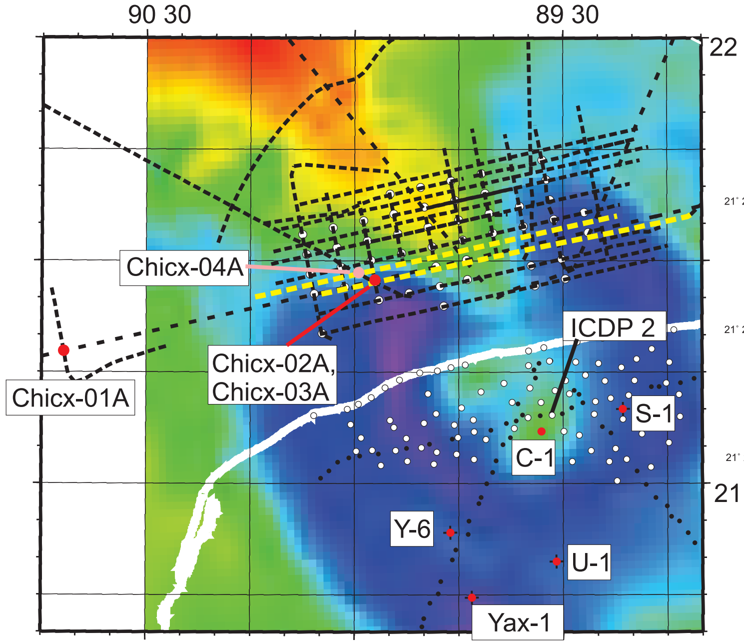
Form 5 – Lithologic Summary

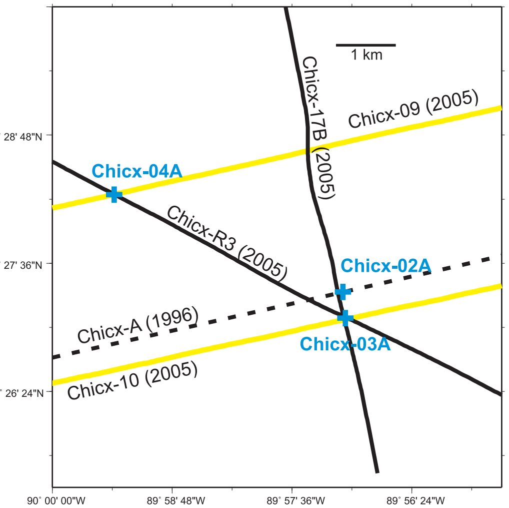
IODP Site Summary Forms:

New [X] *Revised* [ ]

Proposal #: 548-Add3	Site #: Chicx-04A	Date Form Submitted: 9/29/06

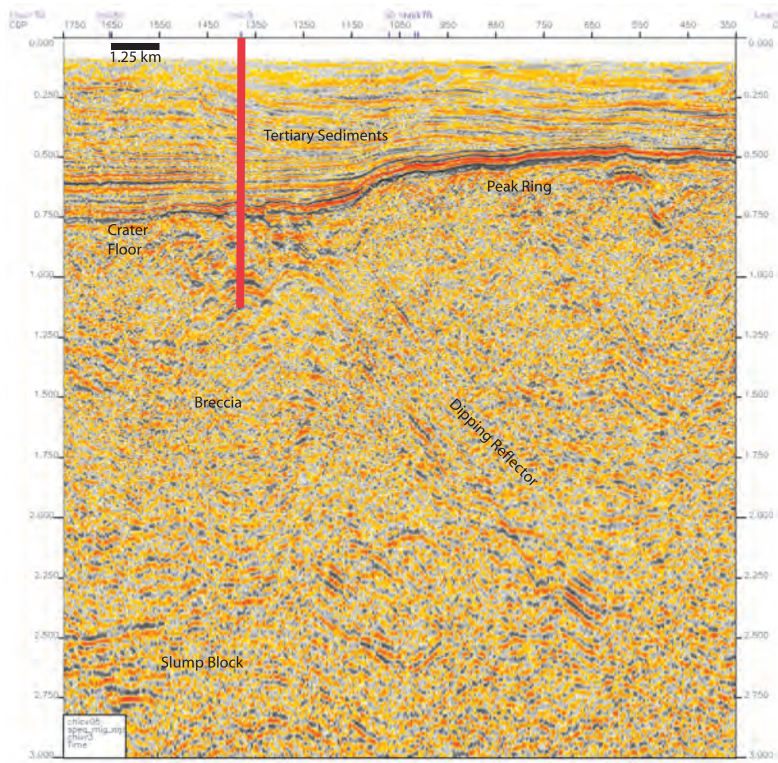
Sub-bottom depth (m)	*Key reflectors, Unconformities, faults, etc*	*Age*	*Assumed velocity (km/sec)*	*Lithology*	*Paleo-environment*	*Avg. rate of sed. accum. (m/My)*	*Comments*
300	Lower-upper crater fill boundary	23 Ma	2250	Carbonate	Carbonate platform		
900	K-P boundary	65 Ma	3250	Carbonate	Slope deposits over impact crater		
1450	Dipping reflector	65 Ma	4375	Impact Breccia & Hydrothermal minerals or melt	Edge of Peak Ring		
1750	Breccias below Dipping reflector	65 Ma	5500	Hydrothermal minerals or melt & Lithic Breccia	Hydrothermal vent in wake peak ring emplacement? Underlain by ground surge or airfall deposits		



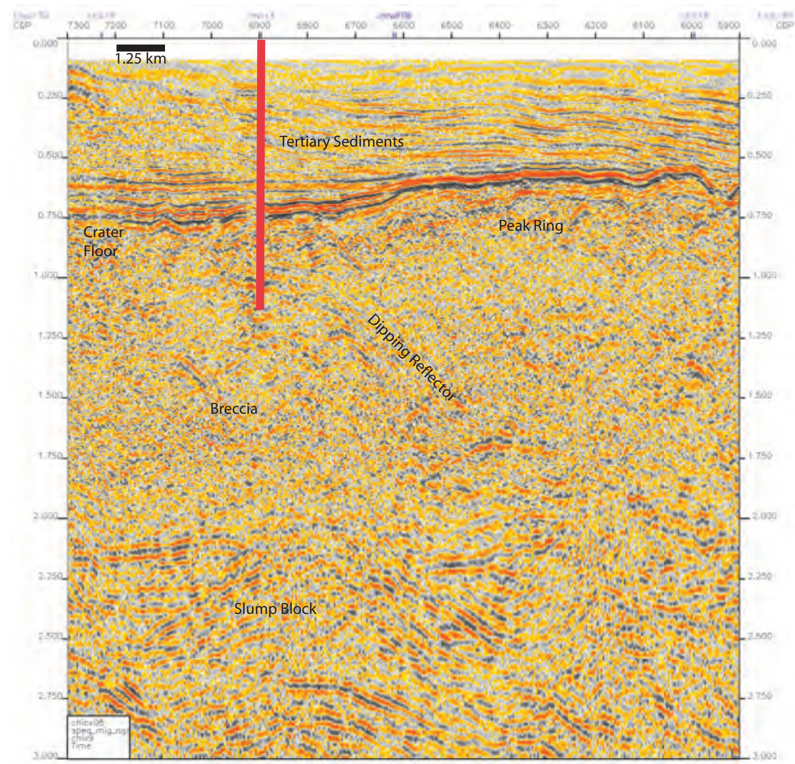


Contingency site 04A: Located at line crossing of Chicx-R3 (CDP 1381) (bottom left) and Chicx-9 (CDP 6897) (bottom right) both from 2005 survey. Seismic data below are in two-way-travel time.

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= chix9speq75_mig_agc.segy & chix9migspeqdpthagc.segy & chixR3migspeq_agc.segy & chixR3migspeqdpthagc.segy
MCS images=chicxr3_site4_revised.tif & chicxr3_site4_depth.tif & chicx9_site4_revised.tif & chicx9_site4_depth_rev.tif



Line R3 from our 2005 R/V Maurice Ewing cruise that crosses our Line 9 from our survey at the position of the proposed borehole, Chicx-04A. Borehole is shown to a depth of 1100 ms (~1.5 km). Proposed to be drilled with Jackup rig given the 17 m water depth. Imaged geology includes Tertiary basin above crater floor above impact breccia in the northwest (left) that transitions to peak ring floored by a dipping contact with breccia to the southeast (towards the crater center). This borehole is designed to serve as a contingency well if TD if the dipping reflectors are not reached at Chicx-03A. Chicx-04A would acquire the Tertiary section including the immediately post-impact sediments, and then reach the dipping reflector at the base of the outer limit of the peak ring (where its shallowest).



Line 9 from our 2005 R/V Maurice Ewing cruise that crosses our Line R3 from our survey at the position of the proposed borehole, Chicx-04A. Borehole is shown to a depth of 1100 ms (~1.5 km). Proposed to be drilled with Jackup rig given the 17 m water depth. Imaged geology includes Tertiary basin above crater floor above impact breccia in the northwest (left) that transitions to peak ring floored by a dipping contact with breccia to the southeast (towards the crater center). This borehole is designed to serve as a contingency well if TD if the dipping reflectors are not reached at Chicx-03A. Chicx-04A would acquire the Tertiary section including the immediately post-impact sediments, and then reach the dipping reflector at the base of the outer limit of the peak ring (where its shallowest).

Suggested reviewers:

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