Joint ICDP/IODP workshop Potsdam 11-12th September 2006

Future drilling of the Chicxulub impact crater

Workshop organisers

Jo Morgan, Earth Science and Engineering, Imperial College London, UK
Gail Christeson, UTIG, University of Texas at Austin, Texas, USA
Sean Gulick, UTIG, University of Texas at Austin, Texas, USA
Richard Grieve, NRCan, Ottawa, Canada
Jaime Urrutia-Fucugauchi, Instituto de Geofisica, UNAM, Mexico
Mario Rebolledo-Vieyra, CICY, Cancun, Mexico
Penny Barton, Earth Sciences, University of Cambridge, UK
Mike Warner, Earth Science and Engineering, Imperial College London, UK
Jay Melosh, Lunar Planetary Laboratory, Tucson, Arizona, USA

Executive Summary

A workshop on joint ICDP/IODP drilling of the Chicxulub impact crater was held at GFZ, Potsdam, Germany, from 11-12th September 2006 to discuss proposals for future drilling at Chicxulub. On the first day twelve speakers gave presentations on our current understanding of large impact craters and of Chicxulub in particular. Each speaker was asked to identify important scientific questions that remained unanswered. On the second day workshop participants split into groups to discuss their scientific interests, and to consider which drill holes would best address the key scientific questions. Each group then presented a summary of their discussions. Two holes were identified as critical to improving our understanding of large craters and Chicxulub in particular: 1) an offshore hole through the crater's topographic peak ring and 2) an onshore hole near the crater center through the melt sheet and into the structural uplift. Based upon the workshop consensus, we submitted an IODP addendum for the deadline of 1st October 2006, and propose to submit an ICDP proposal for a Jan 15th 2007 deadline. Provisional science teams for proposals to IODP and ICDP were identified.

Outline

(1) Introduction
(2) Workshop schedule
(3) Proposed holes
(4) Discussion groups
(5) Summary of presentations by group leaders
(6) Conclusion from discussions
(7) Updated list of PIs
(8) List of workshop attendees and interested parties

(1) Introduction

Proposal IODP 548 to drill Chicxulub offshore was reviewed by the Science Planning Committee (SPC) in 2003 . At that time site survey data across the proposed holes were about to be acquired, and investigations related to ICDP drilling onshore at Yaxcopoil-1 were ongoing. The SPC recommended that, after we acquire the new seismic data, we should hold a workshop to review the results from Yaxcopoil-1 drilling and the new seismic survey. Recently IODP and ICDP have both indicated an interest a joint venture and recommended that we pursue such a collaboration for Chicxulub which lies partly onshore and partly offshore. In June/July 2004 results from Yaxcopoil-1 drilling were published in two consecutive volumes of Meteoritics and Planetary Science, and in February 2005 we acquired a new suite of seismic data across the crater. In response to these developments a joint ICDP/IODP workshop was held from 11-12th September 2006 at GFZ, Potsdam. An open invitation to the workshop was advertised in EOS and elsewhere, and ~50 replies were received from the scientific community.

The aim of the workshop was to review our understanding of Chicxulub, obtain a consensus on the major scientific questions that remain unanswered, and use our discussions to identify drilling targets and drill sites.

(2) Workshop Schedule

Day 1 Monday 11th September

Session Chair: Jaime Urrutia

9:00 Introduction to purpose of workshop (Jaime Urrutia)
9.10 Large impacts: structure and cratering mechanics (Richard Grieve)
9.40 Large craters: Dynamic modelling (Gareth Collins)
10:10 Potential environmental effects of a large-scale impact (Betty Pierazzo)

Coffee

11:10 Post-impact biota evolution (Charles Cockell)
11:40 Post-impact hydrothermal systems (Doreen Ames)
12:10 Crater structure from geophysical models (Gail Christeson)
12:40 Allochthonous impactites at Chicxulub as revealed from drill cores (Dieter Stoeffler)

Lunch

Session Chair: Penny Barton

14:15 Chicxulub ejecta and potential environmental effects (Jay Melosh)
14:45 UNAM & Yax-1 drilling, post-impact transition (Jaime Urrutia)
15:15 Chicxulub tsunami deposits (Takafumi Matsui)
15:45 Tertiary basin infilling (Michael Whalen)
16:30 Poster session
18:30 Conference dinner

Day 2 Tuesday 12th September

Session Chair: Gail Christeson

9.00 Introduction to previously proposed holes (Jo Morgan)
9.30 Joint ICDP/IODP Drilling: IODP Perspective (Ken Miller)
10:00 Joint ICDP/IODP Drilling: ICDP Perspective (Ulrich Harms)
10:15 Logistics (Sean Gulick)

Coffee

11:00 Split into groups for discussion

13:15 Lunch

Session Chairs: Richard Grieve and Sean Gulick

14:00 5-10 minute presentations by group leaders
15:00 General discussion of potential drilling sites and themes for proposals
16:30 Selection of PIs and group leaders
17:00 Closing remarks (Sean Gulick)

(3) Proposed holes

Participants were asked to consider two offshore holes, Chicx-01A and Chicx-02A, that are already part of IODP proposal 548, and one onshore hole to be located somewhere in the central basin inside the peak ring (Figures 1 and 2).

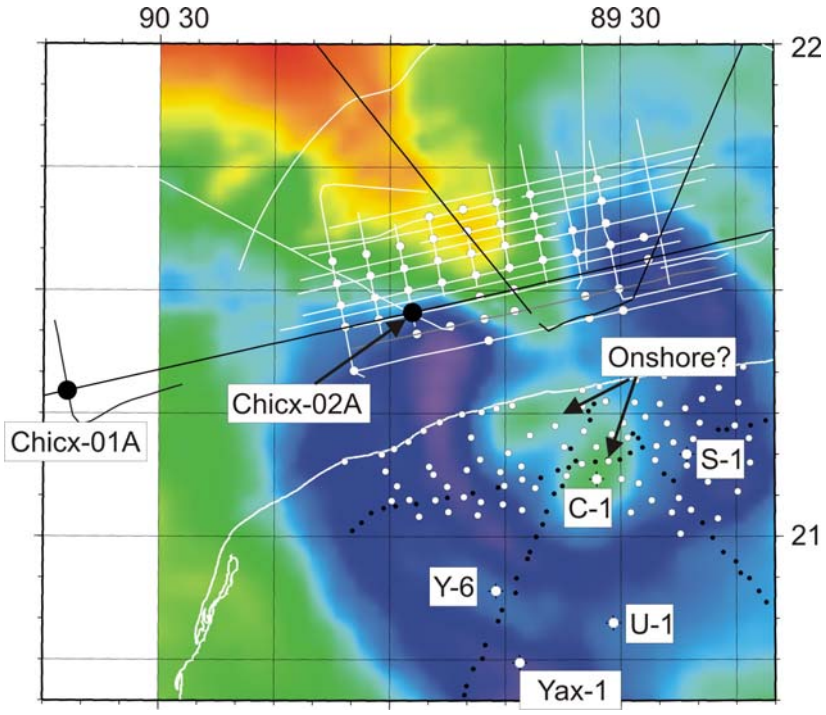


Figure 1

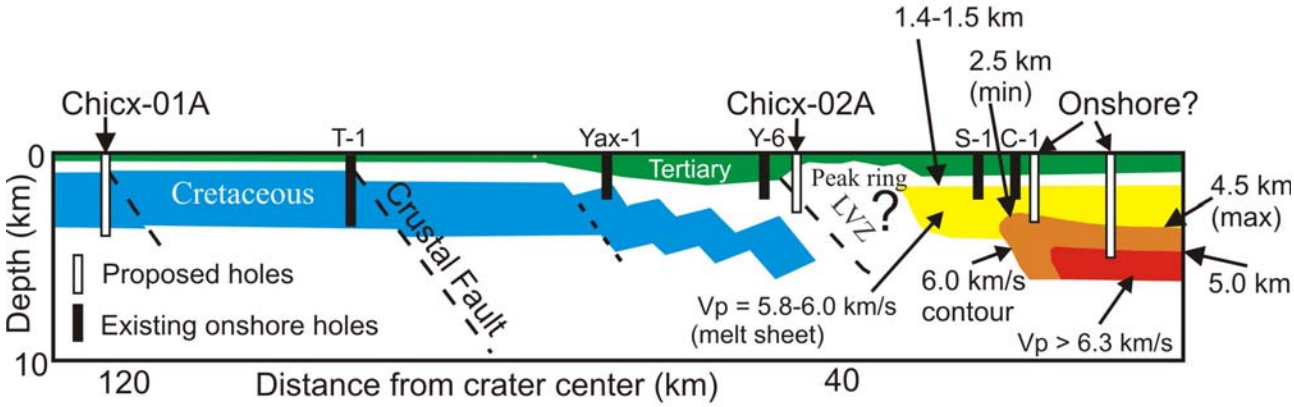


Figure 2

Expected lithological profiles:

Chicx-01A: ~200-300m Tertiary, 300-400m ejecta, 3500-4000m Mesozoic, ~200 m Paleozoic.

Chicx-02A: ~700m Tertiary, 1.4 km impact breccia above fractured basement with dipping reflectors from ~2.4 km on.

Onshore hole: ~1.2 km Tertiary, 200 m suevitic impact breccia, 1-3 km melt (~1 km if close to hole C-1, ~3 km if located nearer the crater center), 200 m fractured basement (structural uplift).

Participants were asked to choose 1 offshore hole and one onshore hole. Discussion groups were identified according to participant's declared interests, and participants were asked to choose which discussion group(s) they would like to contribute to. Group leaders were chosen on the basis of their previous experience and to reflect international representation, and several participants (underlined) were asked to lead discussions and report back to group leaders.

(4) Discussion groups

1) Crater materials (Group leader Koeberl & Wittmann)
Plume formation and ejecta emplacement
Wittmann, Schonian, Salge, Artemieva, Melosh, Stoeffler, Kring

Genesis impactites
Horton, Koeberl, Claeys, Hecht, Tagle, Lutke, Kreher-Hartmann, Stoeffler, Kiyokawa, Wittmann, Schonian, Neal, Peucker-Ehrenbrink

2) Crater mechanics and modeling, environmental effects (Group leader Wunnemann)
Crater formation
Wunnemann, Collins, Pierazzo, Melosh

Global effects (ejecta, tsunamis, release gases)
Melosh, Pierazzo, Artemieva, Matsui, Dypvik

3) Post impact (Group leader Rebolledo)
Post impact bio-, magneto- stratigraphic record
Keller, Rebolledo, Vajda, Wigforss-Lange, Cockell, Dypvik, Urrutia, Schulte, Perez Cruz

Post impact geochemistry/isotopic record
Peucker-Ehrenbrink, Neal, Kiyokawa

Post-impact infill
Whalen, Tsikalas, Dypvik, Goto, Pearson, Miller, Ferrow

Cenozoic climate, sea level change
Dypvik, Miller, Schulte

4) Hydrothermal (Group leader Kring)
Hydrothermal circulation in impactites and post-impact sediments
Kring, Ames, Ferrow, Peucker-Ehrenbrink, Neal,

5) Crater structure/geophysics (Group leader Herrick)
Tsikalas, Urrutia, Rebolledo, Herrick, Mayr, McDonald, Christeson

6) Drilling logistics/costs (Group leader Sean Gulick)
Gulick, Morgan, Miller, Urrutia, Harms

(5) Summary of presentations by discussion group leaders

Group 1 Crater materials. Report by Christian Koeberl & Axel Wittmann
Priority 1: Onshore hole near (but not exactly at) crater center. Location to be chosen to obtain thickest melt sheet sequence possible. Scientific targets: to characterise melt sheet, investigate whether melt sequence is layered, document secondary mineralization, determine whether sequence is clast rich, determine total volume of melt, and search for a projectile component.

Priority 2: Chicx-02. Scientific target: to validate dynamic models of crater and peak ring formation (is flap overturned, how are breccias formed and distributed?).

Additional remarks. Both holes will need to be at least 3 km deep to penetrate into the structural uplift (onshore) and through the dipping reflectors offshore (Chicx-02A). Additional seismic profile(s) would be required to locate onshore hole. The core should be archived at an international facility.

Group 2 Crater mechanics and modeling, environmental effects. Report by Kai Wunnemann

Four key questions were identified:

1) What was the pre-impact target? Chicx-01A will be used to constrain geophysical/numerical models and for assessing environmental consequences
2) How do peak rings form? Peak rings are diagnostic of impact energy, are gravity (not target) dependent, and unique to large craters. Chicx-02A will be used to determine material above and below dipping reflectors, physical state of material, and cause of reflectivity.
3) Did impact-generated tsunamis occur? Drill holes can be used to investigate resurge and immediate post-impact erosion, and post-impact water depths inside and outside the crater.
4) How much impact melt was produced? Important because melt volume is connected to impact energy.

Conclusions: Peak-ring hole (Chicx-02A) is highest science priority. Chicx-01A requires 3-4 km depth to be useful. Onshore hole requires 3-4 km depth to be useful. Optimum depth of Chicx-02A is 5-km; it can be useful at 3-km; dipping reflector can be reached at ~2 km. Possible compromise: two shallow (< 2.5 km holes) through peak ring?

Group 3 Post impact Report by Mario Rebolledo

Key scientific interests:

- Recovery of biota
- Recovery and characterization of sedimentation regime
- Paleo-climate and sea level changes
- Crater modification

Priority offshore: Chicx-02A. Hole has potential for recovery of more complete Tertiary section with possible preservation earliest Paleocene. Good hole for hydrothermal and deep biosphere investigations, and integration with seismic data.

Onshore hole: Deeper water and expanded Tertiary section.

Both holes will be used to investigate biotic recovery, post-impact modification, paleo-climate and oceanography, tracking biologic and hydrothermal activity, bio- sequence- and magneto-stratigraphy, isotopic record, and depositional environment.

Group 4 Hydrothermal Report by David Kring

Hydrothermal activity would be best documented with holes through the peak ring (Chicx-02A) and within the central basin. The latter could be close to either S-1 or C-1.

Additional remarks. Chicx-02A and onshore hole would ideally be deep, but a shallow hole that penetrates the top part of impactites (in both cases) would provide useful data. An onshore hole close to C-1 would provide a better measure of how hydrothermal activity varies radially, and would provide data with the longest spatial range. The peak ring is considered to be a zone of high hydrothermal activity, and an onshore hole close to S-1 (just inside the peak ring) will provide data across the peak ring (Y-6 is just outside the peak ring and Chicx-02A will be through the peak ring).

Group 5 Crater structure/geophysics Report by Robbie Herrick

Priority offshore – hole to investigate peak ring formation, amount and nature of uplift. Hole will determine the composition of the peak ring, nature of the dipping reflectors, and material below the dipping reflectors.

Priority onshore – a hole though the melt sheet. Hole will be used to determine input energy, interaction w/ fallback material and ocean, and melt sheet dynamics.

Additional remarks. Peak ring hole should be far enough into center of peak ring to be sure that it samples “typical” peak ring material, but as far radially outwards as possible to sample dipping

reflectors at a shallow depth. Onshore hole must sample melt sheet material, but ideally would penetrate through melt sheet. Recommendation that hole be drilled at point where basement is close to surface.

Group 6 Logistics Presented by Sean Gulick

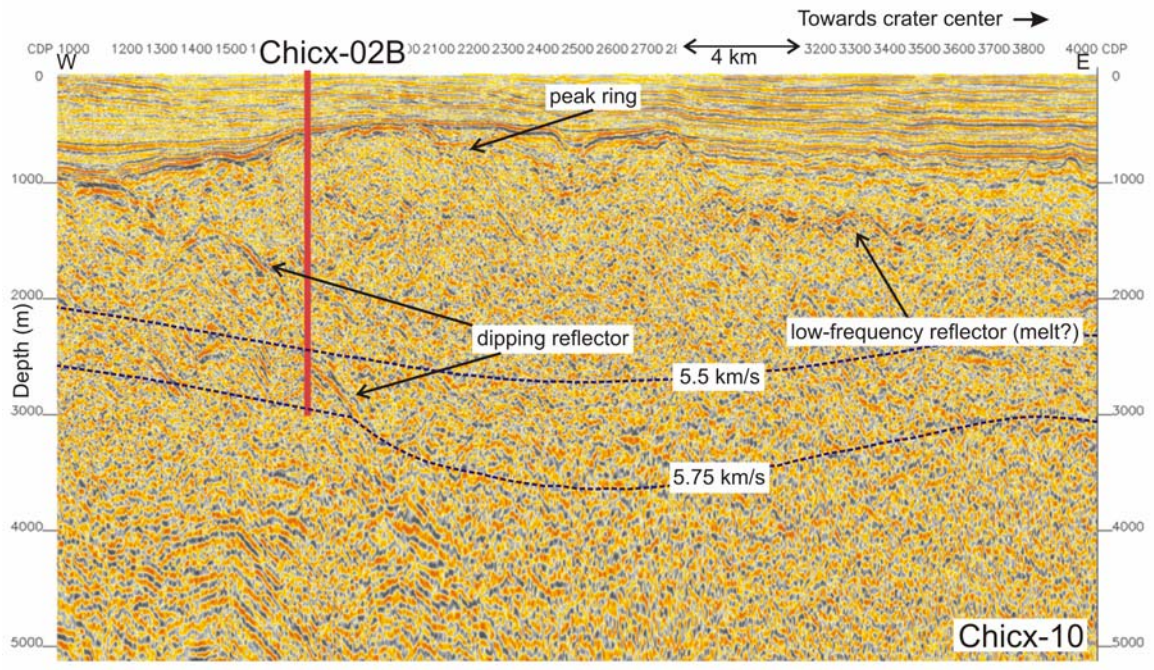
An offshore jack-up rig would be prohibitively expensive at this time, with a 3 km hole costing upwards of 40 million dollars. If jack-ups return to day rate costs of a few years ago the cost of a 3 km hole could reduce to upwards of 11 million dollars. An offshore barge could cost a lot less with a preliminary estimate of around 10 million dollars. The cost of a 3-km onshore hole would be between 4 and 8 million dollars.

(6) Conclusion from discussions

Two holes were identified by workshop participants as critical to improving our understanding of large craters and Chicxulub in particular: 1) an offshore hole through the crater's topographic peak ring (the already proposed IODP drill site Chicx-02A) and 2) an onshore hole near the crater center through the melt sheet and possibly into the structural uplift. Site Chicx-01A, proposed as a 4.5 km deep reference site in IODP 548-Full2, was considered to be a lower priority by the majority of workshop attendees. Workshop participants would like this to be a joint program between IODP and ICDP, with IODP taking the lead on the offshore peak ring site and ICDP taking the lead on the onshore melt sheet site. Both cores should be co-located, ideally at the IODP core repository in Bremen or College Station. This joint endeavor would also benefit if Preliminary Results and Scientific Proceedings volumes for both holes were published through the IODP scientific report and publication series. We are encouraged by the precedent set by the onshore New Jersey sites of Legs 150X and 174AX that IODP can continue to preserve the scientific integrity of onshore-offset transect through joint archiving.

Offshore hole location Workshop participants agreed that Chicx-02B (where 3 lines cross) was the best location for a peak ring drill site (Figure 3). The key scientific targets of this hole are to determine the composition of the peak ring, the nature of the dipping reflectors, and the composition of the material below the dipping reflectors. A site on the inside flank of the peak ring has the potential to provide information about impactites, but would not reach the dipping reflectors. A site further to the outside flank of the peak ring would reach the dipping reflectors at a shallower depth, but would not necessarily sample 'typical' peak ring material.

Figure 3



Onshore hole location The companion site identified as critical to our understanding of the Chicxulub impact crater is a hole through the melt sheet near the crater center. The best location for this hole is likely to be onshore near industry well C-1 (which was not cored), where the top of the melt sheet was found at a depth of ~1300 m below the surface based on well cuttings. Gravity data and preliminary velocity models suggest that the structural uplift is close to surface (at 2.5-3 km depth) at C-1. A well-constrained geophysical model across the central crater is under development and will be used to site this hole.

(7) Updated List of PIs

The day after the workshop, we compiled a list PIs for the IODP proposal to include appropriate international representation, to highlight the members of the community who are putting the effort into the proposal, to add expertise in scientific disciplines, and to ensure cross-collaboration between the ICDP and IODP proponent-groups.

IODP PIs: Morgan, Grieve, Gulick, Urrutia, Koeberl, , Melosh, Cockell, Matsui, Christeson Rebolledo, Barton
Morgan, Gulick, Christeson, and Barton have acquired and are analyzing the seismic dataset integral for properly positioning and interpreting the IODP and ICDP drill sites. After drilling they will integrate results the geophysical data to calibrate the three-dimensional model of the crater. Grieve is an expert on terrestrial impact structures. Urrutia and Rebolledo are experts in magneto-stratigraphy of the Chicxulub impact crater and have offered to serve as IODP's liaisons with the Mexican officials and public for any permitting and PR needs. Koeberl is an expert in crater materials. Melosh is an expert on crater mechanics. Cockell is an expert on geomicrobiology. Matsui is an expert on impact tsunamis.

ICDP
Uwe Reimold was nominated as lead-PI but has declined the role.

Others who volunteered to help with the IODP and/or ICDP proposals were: Doreen Ames (Canada, hydrothermal issues and modification stage), Natalia Artemieva (Russia, numerical modeling), Philip Claeys (Belgium, geochemistry/petrology) Gareth Collins (UK, numerical modeling), Robert Herrick (USA, geophysics), Gerta Keller (USA, Cretaceous-Paleogene deposits), Thomas Kenkmann (Germany, structural geology, kinematics, and dynamics of impact cratering), Shoichi Kiyokawa (Japan, geochemistry impactities), David Kring (USA, crater materials and hydrothermal issues), Ken Miller (USA, Stratigraphy), Clive Neal (USA, platinum group elements), Gordon Osinski (Canada, terrestrial craters) Uwe Reimold (Germany, impact cratering and associated rock and mineral deformation), Peter Schulte (Germany, Paleocene, climate), Jan Smit (Netherlands, sedimentology/biostratigraphy), Michael Whalen (USA, stratigraphy of post-impact basin).

(8) Workshop Attendees

Doreen Ames	Canada	Geological Survey of Canada	dames@nrcan.gc.ca
Natalia Artemieva	Russia	Institute for Dynamics Geospheres	artemeva@psi.edu
Penny Barton	UK	Cambridge University	pb29@cam.ac.uk
Gail Christeson	US	University of Texas	gail@ig.utexas.edu
Philippe Claeys	Belgium	Vrije Universiteit Brussel	phclaeys@vub.ac.be
Charles Cockell	UK	Open University, UK	C.S.Cockell@open.ac.uk
Gareth Collins	UK	Imperial College	g.collins@imperial.ac.uk
Henning Dypvik	Norway	University of Oslo	henning.dypvik@geo.uio.no
Embaio Ferrow	Sweden	Lund University	Embaie.Ferrow@geol.lu.se
Kazuhisa Goto	Japan	University of Tokyo	kgoto@tsunami2.civil.tohoku.ac.jp
Sean Gulick	US	University of Texas	sean@ig.utexas.edu

Richard Grieve	Canada	NRCan	RGrieve@NRCan.gc.ca
Robbie Herrick	US	University Alaska Fairbanks	rherrick@gi.alaska.edu
J. Wright Horton	US	USGS, Reston	whorton@usgs.gov
Gerta Keller	US	Princeton	gkeller@princeton.edu
Shoichi Kiyokawa	Japan	Kyushu University	kiyokawa@geo.kyushu-u.ac.jp
Christian Koeberl	Austria	University of Vienna	christian.koeberl@univie.ac.at
Birgit Kreher-Hartmann	Germany	Friedrich-Schiller-Universität Jena	Birgit.Kreher@uni-jena.de
David Kring	US	LPI	kring@lpi.usra.edu
Sabine Lütke	Germany	Institut für Planetologie, Münster	bardagi@nwz.uni-muenster.de
Matt McDonald	US	UTIG	mcdonald@utig.ig.utexas.edu
Takafumi Matsui	Japan	University of Tokyo	matsui@k.u-tokyo.ac.jp
Sibylle Mayr	Germany	Technical University Berlin	s.mayr@tu-berlin.de
Jay Melosh	US	University of Arizona	jmelosh@lpl.arizona.edu
Ken Miller	US	Rutgers	kgm@rci.rutgers.edu
Jo Morgan	UK	Imperial College	j.v.morgan@imperial.ac.uk
Clive Neal	US	Notre Dame	neal.1@nd.edu
Zulmacristina Pearson	US	Univ. Alaska, Fairbanks / UTIG	ftzfr@uaf.edu
Ligia Perez Cruz	Mexico	UNAM	perezcruz@geofisica.unam.mx
Bernard P-Ehrenbrink	US	Woods Hole	behrenbrink@whoi.edu
Elisabetta Pierazzo	US	University of Arizona	betty@psi.edu
Mario Rebolledo	Mexico	CICY	marior@cicy.mx
Tobias Salge	Germany	Natural History Museum	tobias.salge@rz.hu-berlin.de
Frank Schonian	Germany	Natural History Museum	frank.schoenian@museum.hu-berlin.de
Peter Schulte	Germany	Universität Erlangen	schulte@geol.uni-erlangen.de
Dieter Stoeffler	Germany	Natural History Museum	dstoeffler@web.de
Roald Tagle	Belgium	Vrije Universiteit Brussel	roald1@web.de
Filippos Tsikalas	Norway	Univ. of Oslo	filippos.tsikalas@geo.uio.no
Jaime Urrutia	Mexico	UNAM	juf@geofisica.unam.mx
Vivi Vajda	Sweden	Lund University	Vivi.Vajda@geol.lu.se
Michael Whalen	US	University of Alaska, Fairbanks	mtwhalen@gi.alaska.edu
Jane Wigforss-Lange	Sweden	Lund University	jane.wigforss-lange@geol.lu.se
Axel Wittman	Germany	Natural History Museum	Axel.Wittmann@MUSEUM.HU-Berlin.de
Kai Wunnemann	Germany	Natural History Museum	kai.wuennemann@MUSEUM.HU-Berlin.de

LOCAL Attendees

Uli Harms	Germany	GFZ Potsdam	ulrich@gfz-potsdam.de
Bonnie Wolf-Boehnisch	Germany	Potsdam University	bwb@geo.uni-potsdam.de
Conze Ronald	Germany	GFZ Potsdam	conze@gfz-potsdam.de
Knut Behrends	Germany	GFZ Potsdam	knb@gfz-potsdam.de
Bernhard Prevedel	Germany	GFZ Potsdam	prevedel@gfz-potsdam.de

Interested parties who were unable to attend the workshop

Heinrich Bahlburg	Germany	Westfälische Wilhelms-Universität	bahlbur@uni-muenster.de
Thomas Kenkman	Germany	Natural History Museum	Thomas.Kenkmann@MUSEUM.HU-Berlin.de
Jose Manuel Grajales	Mexico	IMP	mgranishi@yahoo.com
Lutz Hecht	Germany	Natural History Museum	Lutz.Hecht@museum.hu-berlin.de
Markus Harting	Netherlands	Utrecht University	m.harting @geo.uu.nl
Ulrich Riller	Germany	Natural History Museum	ulrich.riller@museum.hu-berlin.de
Gordon Osinski	Canada	CSA	Gordon.Osinski@space.gc.ca
Uwe Reimold	Germany	Natural History Museum	Uwe.Reimold@MUSEUM.HU-Berlin.de
Jan Smit	Netherlands	Vrije Universiteit	smit@geo.vu.nl