Background

After more than two decades of the ICDP, 45 scientific drilling projects on five continents have been completed and several others are in operation or planning and preparation. ICDP-supported and co-funded projects range from drilling into volcanos, earthquake faults, and impact structures to characterize and understand the Earth’s interior and the processes therein and coring sediments in lakes and basins for paleoclimate research. Social media, blogs and not least of all the ICDP website have contributed to inform the scientific community as well as the general public and ICDP stakeholders during the operational phase about progress and achieved milestones of the projects. Outstanding findings from scientific drilling projects resulted in hundreds of peer-reviewed publications. However, a concise and easy-to-understand overview of the project goals, development, milestones and highlights, accessible to everyone, was often lacking.

The ICDP Fact Sheets are intended to provide such information in a comprehensive way and want to highlight facts and findings of 18 completed projects. The list is not yet complete, but will be completed and updated over time. For updates and any kind of comments or suggestions, please contact icdp-outreach@gfz-potsdam.de

Projects

- Barberton – Peering into the Cradle of Life (GC)
- Chesapeake Bay Impact Structure Deep Drilling Project (CE, GC)
- Chinese Continental Scientific Drilling Project (HM)
- Collisional Orogeny in the Scandinavian Caledonides (HM)
- Dead Sea Deep Drilling Project (GC)
- Fennoscandia Arctic Russia – Drilling Early Earth Project (HM)
- HOTSPOT Snake River Scientific Drilling Project (HM)
- Hominin Sites and Paleolakes Drilling Project (GC)
- Lake Bosumtwi Drilling Project (CE, GC)
- Lake El’gygytgyn Drilling Project (CE, GC)
- Lake Malawi Drilling Project (GC)
- Lake Petén Itzá Drilling Project (GC)
- Lake Qinghai Drilling Project (GC)
- Lake Titicaca Drilling Project (GC)
- Mallik 2002 Gas Hydrate Production Research Well (HM)
- PALEOVAN Program Lake Van Drilling Project (GC)
- San Andreas Fault Observatory at Depth (AE)
- Scientific Collaboration On Past Speciation Conditions in Ohrid (GC)
Goal & Scientific Objective

The aim of the project is to investigate conditions on the early Earth in which life emerged and evolved by (i) sedimentological and geochemical investigations of clastic sedimentary rocks to provide information on erosion, transport and deposition under Archean conditions, (ii) studies of tidal sequences to place constraints on the dynamics of the Earth-Moon system, (iii) petrological and chemical studies of komatiites to provide information about the temperature and geodynamic activity in the Archean mantle, (iv) geochemical and stable isotope studies of cherts and silicified volcanic and sedimentary rocks to determine the temperature and composition of Archean ocean waters, and (v) combined micropaleontology, biochemistry and biogeochemistry studies to search for and characterize traces of early life in the sedimentary and volcanic rocks.

Operational Achievements

More than 3000 m of core from 5 holes at 4 sites were recovered.

Volcanic core sites:
Tjakastad komatiite: BARB1: 420 m
Tjakastad komatiite: BARB2: 431 m

Sedimentary core sites:
Buck Reef hole: BARB3: 899 m
Mid Fig Tree hole BARB4: 538 m
Barite Valley hole BARB5: 763 m

Timeline

2008 ICDP proposal submission
2011 (July) – 2012 (May) drilling operations

Principal Investigators

Nicholas T. Arndt, Joseph Fourier University
Paul R.D. Mason, University of Utrecht
Michael Bau, Jacobs University Bremen
Allan Wilson, University of the Witwatersrand
Axel Hofmann, University of Johannesburg
Gary Byerly, Louisiana State University

Data & Sample Access

The core is stored and has been logged in facilities of the University of the Witwatersrand.

Web & Media Resources

http://barberton.icdp-online.org/
Scientific Findings

Petrographic analyses in combination with stable isotope and fluid inclusion analysis of quartz veins indicate that the veins and mineral assemblages formed during metamorphism at conditions of 230 to 400 MPa and 250 to 400°C.

The high salinity of fluid inclusions from the veins may be explained by fluid circulation through evaporites.

Komatiites and tholeiites do not show the expected unfractionated sulfur pool of juvenile magmatic sulfur, best be explained by alteration of oceanic crust through interaction with ambient seawater sulfate and incorporation of photolytic sulfate sulfur: Sedimentary pyrite in black shale samples exhibit a positive $\Delta^{33}S$ signature that clearly indicates photolytic elemental sulfur as the principal sulfur source.

The 760-m-long BARB5 core from the Barite Valley Syncline contains four Paleoarchean spherule layers. Chromium, Co, Ni, and highly siderophile element concentrations and respective interelement relations tend towards signatures comparable to compositional ranges for known chondrite groups, supporting the impact hypothesis for the formation of at least three of the four analyzed spherule layers.

Key Publications


The bright red bands are jasper (chert containing hematite or another form of oxidized iron), the dark maroon bands are hematite or mixtures of chert and hematite, and the white bands are pure chert.
Goal & Scientific Objective
The aim of this drilling project involves two main objectives: 1) to determine a one-million-year, continuous paleoclimatic record from detailed multidisciplinary investigations of the post-impact crater fill sediment for studying abrupt climate change, ecosystem dynamics and biogeochemistry, human-environment interactions and hydrocarbon system and source rock dynamics and 2) to obtain a complete section through the impact breccia deposits in the central parts of the crater, both on top of the central uplift and in the surrounding crater moat for shock metamorphism and crater morphology studies.

Operational Achievements
Sixteen holes were drilled at six locations within the lake, to a maximum depth of 540 m. A total of about 2.2 km of core material was obtained.
Phase I: Five drilling sites with 14 holes. Total sediment recovery was 1833 m.
Phase II: Two boreholes were drilled, to depth of 540 and 450 m, and recorded a total core length of 360 m.
Downhole geophysical measurements were conducted by OSG in the impact section of the two boreholes of Phase II including televiewer, gamma ray, full waveform sonic, resistivity, and magnetic susceptibility. Zero- and multi-offset vertical seismic profiling was performed by the University of Alberta.

Web & Media Resources
http://bosumtwi.icdp-online.org/
www.univie.ac.at/geochemistry/koeberl/bosumtwi

Timeline
2002 ICDP proposal submission
2004 (July – August) Phase I sediment coring
2004 (September – October) Phase II impact rock coring

Principal Investigators
Christian Koeberl, University of Vienna
Bernd Milkereit, University of Toronto
Jonathan T. Overpeck, University of Arizona
Christopher A. Scholz, Syracuse University

Data & Sample Access
Lake sediment cores are stored in the National Lacustrine Core Facility at the University of Minnesota.
Impact rocks are stored at Federal Institute for Geosciences and Natural Resources, Berlin.
All data are archived by the Operational Support Group of the ICDP and can be accessed via the ICDP website.

The GLAD-800 lake drilling system on Lake Bosumtwi
Scientific Findings

Major results include a complete petrographic and geochemical record of the impactite fill. The geophysical studies have allowed the development of significantly improved three-dimensional models of the crater’s volume.

The complete one million year lacustrine sediment fill was recovered from the crater, ending in impact-glass-bearing, accretionary lapilli fallout representing the initial days of sedimentation.

The measured porosities of impactites in both cores from impact rocks are extremely high (up to 38%) and bulk densities significantly lower than in metasediments, indicating a clear relation to the formation mechanism of the impactite units. Thus, the density and porosity data provide new constrains for seismic and gravity models.

The lowstands of Lake Bosumtwi evidenced from the seismic and sediment core data are interpreted as a response to increased aridity in this part of the equatorial tropics and may correlate to other observed continent-wide shifts in African climate over the past 100 ka, and possibly to rapid climatic shifts observed at high latitudes.

Key Publications


Goal & Scientific Objective
Drilling in the central Chesapeake Bay crater will provide important constraints on cratering processes in multi-layered marine targets in general and for comparison with results from the larger Chicxulub crater. Important features to be addressed are crater structure, crater materials and physical properties, salinity and other chemical attributes of ground water for water-resource management purposes, and the post-impact hydrogeologic history of the crater including any hydrothermal system.

Post-impact studies comprise the impact-produced local biotic crisis and recovery and the physical transition from high-energy impact environments to the normal shelf environment, the effects of impact cratering relative to other tectonic, sea-level, climate, and sediment-supply effects on the long-term evolution of the mid-Atlantic continental margin, and deep biosphere studies.

Operational Achievements
Three boreholes were drilled at the Eyreville site in several stages.
Eyreville A was drilled to a total depth of 940.9 m.
Eyreville B was derived from borehole A at 737.6 m depth and goes down to 1766.3 m total depth.
Eyreville C was drilled down to 140.2 m.

Web & Media Resources
http://chesapeake.icdp-online.org

Timeline
2004 ICDP proposal submission
2005 (September – December) and 2006 (April – May) drilling operations

Principal Investigators
Gregory S. Gohn, U.S. Geological Survey at Reston
Christian Koeberl, University of Vienna
Kenneth G. Miller, Rutgers University
Wolf Uwe Reimold, Humboldt University Berlin

Data & Sample Access
Sedimentary, Magmatic and Impact Rocks are stored at the U.S. Geological Survey at Reston.
**Scientific Findings**

1322 m of crater materials and 444 m of overlying postimpact Eocene to Pleistocene sediments have been recovered by scientific drilling.

The crater section consists (from bottom to top) of basement-derived blocks of crystalline rocks, a section of suevite, impact melt rock, lithic impact breccia, and cataclasites, a thin interval of quartz sand and lithic blocks, a granite megablock, sediment blocks and boulders, polymict, sediment-clast-dominated sedimentary breccias, and a thin upper section of stratified sediments.

The near-absence of shock metamorphism in the basal schist-pegmatite-granite unit suggests that the corehole did not reach the presumably shocked in situ crater floor, but instead sampled basement-rock blocks that slumped from higher on the transient-cavity wall toward the center of the cavity.

Chemical, isotopic and physical evidence have concluded that the saline water currently present in the Chesapeake Bay impact crater’s resurge breccia and crystalline blocks is a remnant of Early Cretaceous North Atlantic sea water with an average salinity twice that of modern sea water.

Given that several other locations along the North American Atlantic Coastal Plain have salinities greater than that of sea water at depth, we believe remnants of ECNA sea water probably persist at many other locations along the Atlantic margin as well.

**Key Publications**


Geological Society of America, Special Paper:


*Variably brecciated schist (top) and lithic breccia (bottom) from a depth of about 1,606 m.*
Goal & Scientific Objective

COSC is investigating mountain building processes in an old (Paleozoic), deeply eroded collisional mountain belt of Himalayan dimensions. Utilising this orogen, the Caledonides, as an analogue to comparable modern settings, such as the Himalayan mountain belt, will advance our understanding of such orogenic systems and how they affect the stability of the living environment. Key scientific targets are i) to research mountain building processes in the deep interior of an orogen and utilise this new knowledge to better understand how collisional mountain building operates, including the nature and occurrence of natural hazards in modern orogenic environments, ii) to investigate the environmental conditions before, during and after continent-continent collision (c. 440-390 Ma), iii) to study the recent (up to 100 ka) evolution of the surface temperature in northern Europe by borehole temperature inverse modelling, iv) to research the (deep) groundwater and thermal characteristics of old mountain belts and v) the composition of deep microbial communities and their energy sources.

After the drilling of COSC-2, two fully cored boreholes will provide a unique c. 5 km deep composite section through the foreland of a major orogen, in a key-locality for research on mountain building processes that has relevance for the study of past and present mountain belts around the globe.

Data & Sample Access

Technical and scientific data from the operational phase are available at https://doi.org/10.1594/GFZ.SDDB.ICDP.5054.2015. For site survey data and other surveys in the borehole, please contact the PIs.

The COSC-1 drill core is archived at the Core Repository for Scientific Drilling at the Federal Institute for Geosciences and Natural Resources (BGR), Berlin.

Operational Achievements

The borehole COSC-1 was drilled as the first of two c. 2.5 km deep drill holes, cored and open (no casing) from 102.7 m to total depth. Two additional boreholes of 50 and 100 m depth, respectively, were drilled before drilling of the main hole and equipped with seismometers for passive monitoring of the drilling operations.

April to August 2014: drilling operations at the main hole, final depth 2495.8 m.

Downhole logging and borehole vertical seismic profiling (VSP) conducted by OSG, GFZ and Lund University.

Core studies: MSCL (Multi Sensor Core Logging) including density and magnetic susceptibility; DMT core scanner, mud gas analyses (OLGA), geological logging.

Web & Media Resources

http://cosc.icdp-online.org/
www.facebook.com/collisionalorogeny/
Timeline
2009 COSC workshop proposal approved
2010 international COSC science workshop
2011 ICDP full proposal for COSC-1 approved
2014 COSC-1 borehole was drilled
2015 international COSC-2 science workshop
2017 ICDP full proposal for COSC-2 approved

Principal Investigators
Christopher Juhlin, Uppsala University, Sweden
David G. Gee, Uppsala University, Sweden
Randall Parrish, British Geological Survey
Christophe Pascal, Ruhr-University Bochum, Germany
Chin-Fu Tsang, Lawrence Berkeley National Laboratory, USA

Scientific Findings
During the COSC-1 drilling operations, a nearly complete 2.4 km long drill core was obtained. It sampled a section through the Lower Seve Nappe, which is a during orogeny highly affected and modified rock unit that was emplaced over hundreds of kilometres from the deep internal part to the foreland of the orogen (Lorenz et al. 2015). Since COSC is a two stage project and COSC-2 not yet drilled, the scientific findings are preliminary and restricted to COSC-1 only.

Detailed pressure-temperature studies on drill core samples unexpectedly proved that the Lower Seve Nappe was affected by very high pressure and temperature (up to the amphibolite/eclogite metamorphic facies boundary) in the interior of the mountain belt before it was emplaced onto less affected rocks of the continental margin (Jeanneret et al., in prep.). This on-going study is central for our understanding how mass and heat is transferred within a developing mountain belt.

The rock volume around the drill hole was extensively characterised by geophysical methods. Thus, it was possible to refine the interpretation of regional (>150 km) and COSC (c. 60 km site investigations) multi-disciplinary geophysical data sets and integrate them with the geological findings (Hedin et al. 2016, Wenning et al. 2016, Simon et al. 2017). This work is not finished yet, pending the drilling and investigations of the COSC-2 borehole.

The bedrock drilled in COSC-1 was surprisingly massive and does not provide good conductivity for groundwater. However, seven zones of limited groundwater inflow into the borehole could be detected and characterised (Doughty et al. 2016, Tsang et al. 2016). Such compact bedrock is not very favourable for deep microbial life. However, the limited results and COSC-specific methodological developments in both microbiology and hydrogeology did contribute significantly to applied studies about how to characterise relevant aspects of the subsurface for (mainly) engineering purposes (Eriksson et al. 2016, Dobson et al. 2016).

Key Publications
Goal & Scientific Objective
The main purpose of the project was to recover a long, continuous core to provide a high resolution record of the paleoclimate, paleoenvironment, paleoseismicity, and paleomagnetism of the Dead Sea Basin. In detail: (i) establish the behavior of abrupt hydrological-limnological events (e.g. catastrophic drying or rising of the lakes) by reconstructing the environmental, climatic and tectonic history of the region with high-resolution chronologies, complemented by varve counting, (ii) compare the limnological-hydrological history of the Dead Sea water-bodies with regional and global climatic records, and (iii) investigate the relation between human culture development and climatic changes in the region.

Operational Achievements
Drilling operations were performed by DOSECC using the Deep Lake Drilling System (DLDS). Three sites were multiple cored and ~720 m of sediment cores have been retrieved in total.

Site-1: Eight holes (two abandoned) were drilled at water depth of 300 m. The longest drill hole reached a depth of 459 m beneath lake floor (b.l.f.).

Site-2: one core was drilled at water depth of 11.5 m.

Site-3: three cores were drilled at water depth of 2.4 m. One hole reached a depth of 350 m (b.l.f.).

The ICDP Operational Support Group performed logging measurements on Site 1 in the boreholes 1A, 1B and on Site 3 in borehole 3C. Logging was done in temporarily cased and open borehole.

Web & Media Resources
http://deadsea.icdp-online.org/
www.youtube.com/watch?v=ZNeIVy-n26M

Timeline
2006 ICDP proposal submission
2010 (November) – 2011 (March) drilling operations

Principal Investigators
Mordechai Stein, Geological Survey of Israel
Zvi Ben-Avraham, Tel Aviv University
Steven L. Goldstein, Columbia University
Hans Joachim Brauer, GFZ Postdam
Amotz Agnon, Hebrew University of Jerusaleme
Gerald H. Haug, Max-Planck-Institute for Chemistry
Hiroyuki Kitagawa, Nagoya University
Daniel Raul Ariztegui, Université de Genève
Emi Ito, University of Minnesota at Minneapolis

Data & Sample Access
The cores are stored at the MARUM – IODP Bremen Core Repository.
Logging data are available on ICDP website on request.
Scientific Findings

The sedimentary record represents several glacial and interglacial cycles spanning an estimated interval of ~200,000 years. It can be divided into two dominant lithologies: salt layers interbedded with laminated mud, and massive and laminated marl interbedded with thin salt layers.

Two pronounced dry periods were detected at ~3500–3300 and ~3000–2400 cal. yr BP which are differently expressed in the sediment records. The results suggest that during the younger dry period period, the Dead Sea region experienced an overall dry climate, superimposed by an increased occurrence of flash floods caused by a change in synoptic weather patterns.

Key Publications


Stein, M.; Ben-Avraham, Z; Goldstein, S.L. (2011): Dead Sea Deep Cores: A Window Into Past Climate and Seismicity. Eos, Transactions, American Geophysical Union 92(49) 453


Thomas, C.; Ebert, Y.; Kiro, Y.; Stein, M.; Ariztegui, D.; the DSDDP Scientific Team (2016): Microbial sedimentary imprint on the deep Dead Sea sediment. The Depositional Record 2(1) 118-138. doi:10.1002/dep2.16
Goal & Scientific Objective

The objectives of the CCSD project were as follows:
(1) to obtain multi-parameter profiles of a 5158 m deep borehole in the Sulu Terrane, (2) to reconstruct the composition and structure of a deep continental orogenic root, (3) to reveal subduction and exhumation processes of UHP metamorphic terranes, (4) to search deep life in the borehole and constrain fluid–rock interaction, and (5) to establish a long-term, natural laboratory for the study of crustal dynamics and the evolution of deep continental crust using the CCSD-MH.

Operational Achievements

Three prepilot holes (CCSD-PP1, -PP2, -PP3) were drilled earlier in time. The main hole CCSD-MH was drilled in two phases and reached a depth of 5158 m. An intense downhole logging and testing program was carried out during and after the active drilling phase. Aside logging by service companies, OSG logging did also partake.

Web & Media Resources

http://www.ccsd.org.cn/English/index.htm
http://donghai.icdp-online.org/

Timeline

1998 ICDP proposal submission
2001 – 2005 drilling operations

Principal Investigators

Zhiqin Xu, Chinese Academy of Geosciences
Bolin Cong, Chinese Academy of Sciences
Borming Jahn, Academia Sinica
Hartmut Kern, University of Kiel
Juhn G. Liou, Stanford University
Roland Erich Oberhänsli, University of Potsdam
Paul T. Robinson, Dalhousie University
David B. Rowley, University of Chicago
Wencai Yang, Chinese Academy of Geosciences

Data & Sample Access

China Geological Survey, Cores and Samples Center of Land & Resources

CCSD Drilling in Donghai
Scientific Findings

Evidence of deep subduction of huge amount of supracrustal materials.

Apatite fission track analysis indicates an average uplift rate of ~ 35m/Ma during 89–30 Ma.

Crustal structure and pressure–temperature–time–deformation paths of the core samples and outcrop rocks indicate a dome-shaped nappe structure and syn-collisional exhumation of the HP and UHP slices in the Sulu Terrane.

About 20 species of bacteria and 4–5 species of archaea were identified of the CCSD-MH. Microbes show a great diversity, but the diversity decreases with depth. The deepest bacteria occur at 4406.49 m, which gives the bottom boundary for life under extreme conditions in a deep borehole.

Key Publications


**Goal & Scientific Objective**

The main goals of the Lake El’gygytgyn Drilling Project are to obtain, from analyses of the drill cores, new information on the formation of the impact crater, as well as to derive a climate history of the Arctic. That includes assessing the environmental dynamics recorded at El’gygytgyn against other arctic and lower latitude paleoenvironmental records and placing them in the context of exiting knowledge concerning the impacts and responses of different regions to past and future change. El’gygytgyn has the only currently known impact structure formed in siliceous volcanics, including tuffs. The impact melt rocks and target rocks provide a unique opportunity on Earth to study shock metamorphism of volcanic rocks.

**Operational Achievements**

On two sites were drilled four boreholes, one into permafrost deposits on lakeside (5011-3) and three into the lake sediments (5011-1 A – C). 5011-3 reached a depth of 141.5 m with 91% core recovery. 5011-1 completed three holes in the centre of the frozen lake:

- **Hole 1 A**: (146.58 m depth, 92% core recovery)
- **Hole 1 B**: (111.92 m depth, 98% core recovery)
- **Hole 1 C**: (517.3 m TD, 63% core recovery)

Downhole logging of hole 1 C was carried out by the ICDP Operational Support Group in the upper sedimentary section. On-site multi-sensor core logging was of the cores from 5011-1.

---

**Web & Media Resources**

- [www.geo.umass.edu/lake_e/index.html](http://www.geo.umass.edu/lake_e/index.html)
- [www.elgygytgyn.uni-koeln.de/](http://www.elgygytgyn.uni-koeln.de/)
- [http://lithosphere.univie.ac.at/impactresearch/elgygytgyn-crater/](http://lithosphere.univie.ac.at/impactresearch/elgygytgyn-crater/)
- [http://elgygytgyn.icdp-online.org/](http://elgygytgyn.icdp-online.org/)
- [www.youtube.com/playlist?list=PLA32489E0A3B358A](http://www.youtube.com/playlist?list=PLA32489E0A3B358A)

**Timeline**

- **2005**: ICDP proposal submission
- **2008 (October – December)**: permafrost drilling
- **2009 (January – May)**: lake and impact rock drilling

**Principal Investigators**

- Julie Brigham-Grette, University of Massachusetts Amherst
- Martin Melles, University of Cologne
- Pavel Sergeevich Minyuk, Far Eastern Branch of the Russian Academy of Sciences
- Christian Koeberl, University of Vienna

**Data & Sample Access**

Permafrost cores are stored at the Marum core repository at Bremerhaven, lake sediments in the National Lacustrine Core Facility at the University of Minnesota and impact rocks are stored at the Core Repository for Scientific Drilling at the Federal Institute for Geosciences and Natural Resources in Berlin.

Core, downhole and drill data available on the ICDP website (public).
Scientific Findings

The remarkable coherence of interglacial warmth across the western Arctic with repeated deglaciation events in West Antarctica supports the notion of strong long distance connections between the polar regions over the last 2.8 Ma.

Evidence from Lake El’gygytgyn shows that 3.6-3.4 Ma ago, summer temperatures were ~8°C warmer than today when atmospheric CO₂ concentration are comparable to those of today.

Multiproxy evidence suggests extreme warmth and polar amplification during the middle Pliocene, sudden stepped cooling events during the Pliocene-Pleistocene transition, and warmer than present Arctic summers until ~2.2 Ma, after the onset of Northern Hemispheric glaciation.

The drill core penetrated through postimpact sediments, impactites, and the fractured igneous basement. The impactite portion of the core was recovered from 316.08 to 517.30 m in depth below the lake bottom. A comparison between the similar sized Bosumtwi and El’gygytgyn impact craters shows that initial expectations of large amounts of impact melt within either of those craters were not confirmed.

Key Publications


Laminated section within the Pliocene
Goal & Scientific Objective
The main scientific goals of the FAR-DEEP project are: (i) to establish a well characterised, well dated, well archived section for the period 2500-2000 Ma; (ii) to document the changes in the biosphere and the geosphere associated with the rise in atmospheric oxygen; and (iii) to develop a self-consistent model to explain the genesis and timing of the establishment of the modern aerobic Earth System.

Applied objectives of the research having potential significant economic implications include (i) the search for natural fullerenes (otherwise a synthetically produced and expensive superconductor), and (ii) to obtain new data on the Shunga Event rocks, in essence a 2000 Ma old fossilised hydrocarbon reservoir, that can provide the petroleum industry with reliable information on the mechanisms and characteristics involved in the physical, chemical and isotopic transformation between in situ, migrated and seeped petroleum.

Operational Achievements
At three sites, fifteen holes were drilled and range in depth from 92 to 503 m. A total of 3650 meters of core were recovered.

Pechenga Greenstone belt: 6 holes
Imandra/Varzuga Greenstone Belt: 3 holes
Onega Basin: 6 holes

Web & Media Resources
http://far-deep.icdp-online.org/
http://www.geo.uni-potsdam.de/icdp_homepage/highlights/highlight02_FARDEEP.html

Timeline
2006 ICDP proposal submission
2007 (May – October) drilling operations

Principal Investigators
Victor A. Melezhik, Geological Survey of Norway
Anthony Edward Fallick, Scottish Universities Environmental Research Center
Christopher John Hawkesworth, University of Bristol
Lee Robert Kump, Pennsylvania State University
Harald Wolfgang Strauss, University of Münster

Data & Sample Access
Paleoproterozoic Rocks are stored at the Geological Survey of Norway.
Scientific Findings

The results of detrital zircon dating cover an age range from 3.5 to 1.9 Ga with a prominent age group between 2.9 and 2.6 Ga in all but two samples. The youngest zircons vary in age due to their stratigraphic position. Maximum depositional ages of 2.34 and 2.37 Ga for sediments from the Polisarka and Neverskrukk formations constrain the deposition of the Fennoscandian equivalent of the Huronian glaciation.

The range of carbon isotopic composition of bulk sedimentary organic matter includes signals of primary production via photosynthetic carbon fixation but also bacterial turnover of sedimentary organic carbon, e.g., via bacterial sulfate reduction as evidenced by abundant sedimentary pyrite.

Sedimentary rocks of the Seidorechka Formation (2.44 Ga) at the bottom of the FAR-DEEP succession captured Earth’s initial oxygenation and show small but decidedly mass-independently fractionated sulfur isotopes between 0.06 - 0.42‰.

Dolostones and siliciclastic rocks from the 2.0 Ga Tulomozero Formation recovered in the Onega Paleobasin contain plenty of evidence for the former presence of sulfate in the ocean.

Key Publications


Reuschel, M., Melezhik, V. H., Strauss H., Sulfur isotopic trends and iron speciation from the c. 2.0 Ga Pilgjärv Sedimentary Formation, NW Russia, Precambrian Research, Volume 196, 2012, Pages 193-203, ISSN 0301-9268

**Goal & Scientific Objective**
The primary goal of the HOTSPOT project is to document the volcanic and stratigraphic history of the Snake River Plain, which represents the surface expression of this hotspot, and to understand how it affected the evolution of the continental crust and lithospheric mantle. An additional goal is to evaluate the geothermal potential of southern Idaho.

**Operational Achievements**
Three drill holes at three sites were completed.
Kimama site was drilled Sep 2010 – Jan 2011 and reached a final depth of 1912 m. Cased and open hole logging was carried out in the deepest parts of the Kimama hole.
Kimberly site was drilled Jan 2011 – Jun 2011 and reached 1958 m depth.
Mountain Home site was drilled Jul 2011 – Jan 2012 to a final depth of 1821 m. Borehole logging was carried out to a depth of 1690 m.
Except for the uppermost 214 m of Kimberly, all holes were fully cored (total core recovery: 5.9 km).
Geophysical studies included high-resolution gravity and magnetic surveys, high-resolution seismic surveys (vertical seismic profile) and borehole geophysical logging. The latter include natural gamma, neutron hydrogen index, g-g density, resistivity, magnetic susceptibility and full vector magnetic field, 4-arm caliper, full waveform sonic and ultrasonic borehole televiwer imaging.

**Data & Sample Access**
Data is available on ICDP website. Volcanic Rocks are stored (Mtn. Home) at Utah State University and (Kimama and Kimberly) at U.S. Geological Survey, Core Research Center (CRC). Sedimentary Rocks are stored in the National Lacustrine Core Repository at the University of Minnesota.

**Web & Media Resources**
https://www.facebook.com/Project-Hotspot-Yellowstone-Snake-River-Plain-144194715624402/
www.usu.edu/geo/shervais/Shervais-USU-Geology/Project_Hotspot.html
http://snakeriver.icdp-online.org/

**Timeline**
2008 ICDP proposal submission
2010 (September) – 2012 (January) drilling operations

**Principal Investigators**
John W. Shervais, Utah State University
Barry B. Hanan, San Diego State University
Michael John Branney, University of Leicester
Dennis J. Geist, University of Idaho
Scott S. Hughes, Idaho State University
Alexander A. Prokopenko, University of Cologne
Francois Holtz, University of Hannover
Donald Bruce Dingwell, University of Munich
Jörg Erzinger, GFZ Potsdam
Cristina Maria Pinheiro De Campos, University of Munich
Douglas R. Schmitt, University of Alberta
Neil R. Banerjee, University of Western Ontario
Lisa A. Morgan, U.S. Geological Survey at Denver
Scientific Findings

Basalts near the bottom of the Kimama core hole are ~6 Ma in age, while rhyolite lava overlain by basalt in the uppermost Kimberly core hole has been dated at 6.25 Ma.

Basalts in the Kimama hole are at least 50% thicker than anticipated and preserve a remarkable record of essentially continuous mafic volcanism within the Axial Volcanic Zone. Clastic fluvial sediments have been found at ~1800 m depth.

Kimberly documents the intercalation of basalt and rhyolite immediately after the initial phase of rhyolite volcanism, and because it reveals the occurrence of massive rhyolite ignimbrites that may be up to 900 m thick. The Mountain Home penetrates an older basaltic basement, which underlies Pliocene-Pleistocene paleolake sediments that are over 600 m thick.

The Kimama well samples an aquifer three times thicker than normal (960 m), suppressing the thermal gradient A temperature gradient of 75-80°C/km underlies the aquifer. The Kimberly well taps a warm water aquifer at 55-60°C, while Mountain Home intersected a 135-140°C (or higher) geothermal resource with artesian flow to the surface.

Key Publications


Shervais, J.W.; Evans, J.P. (2014): Drilling Into the Track of the Yellowstone Hot Spot. Eos, Transactions, American Geophysical Union 95(10) 85-86


Drilling at Kimberley

Rhyolite with propylitic alteration
Goal & Scientific Objective
The goals of the HSPDP drilling project are to (i) collect continuous and long paleolake cores from basins, which are close to hominin fossil and archaeological sites of global significance, spanning critical intervals in human evolutionary history, (ii) assemble high-resolution and readily datable paleoclimate/paleoenvironmental records from these cores covering much of the past ~4 Ma of East African environmental history, (iii) evaluate models of climatic and tectonic forcing of environmental processes as they affect landscape resources, and (iv) test hypotheses linking climate change and variability to physical and cultural evolutionary adaptations.

Operational Achievements
About 2 km of sediment drill core from five basins were collected in Kenya and Ethiopia. Drilling sites (cored boreholes) includes
- NA: Northern Awash (3)
- CB: Chew Bahir (2)
- WT: West Turkana (1)
- BT: Baringo Tugen Hills (1)
- MA: Lake Magadi (4)

Geophysical downhole logging data were collected by ICDP’s Operational Support Group at BT, WT and MA. A multisensor core logger was deployed to the Tugen Hills/Baringo and West Turkana sites to collect mag. Susz. data on unsplit cores.

Timeline
2010 proposal submission
2013 (June) Tugen Hills/ Baringo Basin
2013 (June – July) West Turkana
2014 (February – March) Northern Awash
2014 (June – July) Lake Magadi
2014 (November) Chew Bahir

Web & Media Resources
http://hspdp.asu.edu/
http://homininsitedrilling.icdp-online.org/
www.facebook.com/HSPDP/
www.youtube.com/watch?v=B1iU0fBTfUw

Data & Sample Access
Cores are stored in the National Lacustrine Core Facility at the University of Minnesota. Data are available at ICDP website on request.

Principal Investigators
Andrew S. Cohen, University of Arizona
J. Ramón Arrowsmith, Arizona State University
Asfawossen Asrat, University of Addis Ababa
Anna Kay Behrensmeyer, Smithsonian Institution
Christopher J. Campisano, Arizona State Uni.
Craig Stratton Feibel, Rutgers University
Shimeles Fisseha, University of Addis Ababa
Roy A. Johnson, University of Arizona
John Kingston, University of Michigan
Henry F. Lamb, University of Wales
Emma Mbua , National Museums of Kenya
Daniel Ochieng OLAGO, University of Nairobi
Richard Bernhart Owen, Hong Kong Baptist Uni.
Richard Potts, Smithsonian Institution
Robin W. Renaut, University of Saskatchewan
Frank Schäbitz, University of Cologne
Jean Jacques Tiercelin, Université de Rennes Martin H. Trauth, University of Potsdam
Mohammed Umer (†), University of Addis Ababa
Giday Wolde Gabriel, Los Alamos Nat. Lab.
Scientific Findings

Collectively the cores cover in time many of the key transitions and critical intervals in human evolutionary history over the last 4 Ma.

A 20 ka long paleoclimate record from the Chew Bahir basin in southwest Ethiopia shows both orbitally-driven long-term transitions from favorable to unfavorable living conditions, including several and short abrupt excursions towards drier or wetter episodes.

Despite all data limitations, the results suggest that external environmental factors merely reduce the range of possible developments, while socio-cultural conditions favor particular concepts. Further incalculable factors play a role and human behavior has not been entirely climatically triggered.

Key Publications


Goal & Scientific Objective

The Lake Malawi Drilling Project want to gain (i) a continuous, high-resolution (annual-decadal) record of past climates in the continental tropics over the Brunhes epoch, and (ii) to determine if tropical African climate responded to changes in low-latitude precessional insolation (23-19 kyr) or to high-latitude ice volume (100 kyr and 41 kyr) forcing, in the last part of the Pleistocene. Furthermore (iii) assess the phasing of lake level changes in Lake Malawi in the last half of the Pleistocene, (iii) determine from the high-resolution Lake Malawi drill core records if high-frequency, climate variations are superimposed on glacial-interglacial timescale variations, (iv) establish how interannual African climate variability has changed in association with longer-term climate variations and (v) determine the long-term evolution of tropical East African climate.

Operational Achievements

Two sites were drilled and recovered more than 623 m of core.

At the Deep site, at 600 m water depth, were drilled four holes, one extended down to 380 m.

At the High-resolution site, three holes were drilled down to 40 m in 350 m water depth.

Downhole logging (spectrum and total gamma) inside drill pipe was performed by the ICDP Operational Support Group.

Data & Sample Access

Lake sediments are stored in the National Lacustrine Core Facility at the University of Minnesota (LacCore).

Web & Media Resources

http://malawidrilling.syr.edu/

http://malawi.icdp-online.org/

Timeline

2003 ICDP proposal submission

2005 (February – March) drilling operations

Principal Investigators

Thomas C. Johnson, University of Minnesota at Duluth

Christopher A. Scholz, Syracuse University

John William King, University of Rhode Island

Michael Richard Talbot (†), University of Bergen

Andrew S. Cohen, University of Arizona

Leonard S.N. Kalindekafe, Geological Survey Department of Malawi

Eric Onyango Odada, University of Nairobi

Michael B. Dolozi, University of Malawi
Scientific Findings

Geochronological analyses results suggest that the deep site in the central basin is about 1.5 Ma old at its base and that the holes in the north basin bottom out in shoreface sand deposits are about 80,000 years old.

The paleoclimate records indicate an interval of high-amplitude climate variability between 145,000 and ~60,000 years ago, when several severe arid intervals reduced Lake Malawi’s volume by more than 95%.

After 70,000 years ago climate shifted to more humid conditions and lake levels rose. During this latter interval however, wind patterns shifted rapidly and perhaps synchronously with high-latitude shifts and changes in thermohaline circulation. This transition to wetter, more stable conditions coincided with diminished orbital eccentricity, and a reduction in precession-dominated climatic extremes. The observed climate mode switch to decreased environmental variability is consistent with terrestrial and marine records from in and around tropical Africa.

Key Publications


Goal & Scientific Objective
The Mallik 2002 Gas Hydrate Production Research Well Program aimed to study and sample gas hydrate bearing sediments in a permafrost setting and to produce hydrocarbons by different stimulation tests. Three holes were drilled to penetrate a section with extensive gas hydrate accumulations in a depth interval from ~900 m - 1100 m below approx. 620 m of permafrost.

Operational Achievements
Three holes were drilled at 40 m distance, reaching a final depth of 1179 m (Mallik 3L-38), 1184 m (Mallik 4L-38) and 1165 m (Mallik 5L-38).

An extensive downhole measurement program including the full suit of open hole logs, porosity measurements, NMR and crosshole seismic experiments was executed by service companies.

Hydrate-bearing core has been retrieved from Mallik 5L-38 between 891 and 1150 m

In all wells, DTS (Distributed Temperature Sensor) cables were installed behind casing.

Several depressurization tests and a five-days thermal stimulation test were performed in the gas hydrate interval.

Data & Sample Access
Data holdings can be accessed on the ICDP website.

Web & Media Resources
http://mallik.icdp-online.org/
https://en.wikipedia.org/wiki/Mallik_gas_hydrate_site
www.youtube.com/watch?v=7OaQeeWxf0Y

Timeline
2001 ICDP proposal submission and approval
2001 - 2002 drilling/coring operations including production tests

Principal Investigators
Scott R. Dallimore, Geological Survey of Canada
Timothy S. Collett, U.S. Geological Survey
Takashi Uchida, Japan National Oil Corporation
Jörn Lauterjung, German Research Centre for Geosciences
Avinash Chandra, Indian Ministry of Petroleum and Natural Gas
Michael H. Weber, German Research Centre for Geosciences
Tetsuo Yonezawa, Japan National Oil Corporation
Scientific Findings

Investigations on drill core from Mallik 5L-38 have demonstrate that gas hydrate occurs within the pore space of medium grained sands with gas hydrate saturations between 50% and 90%

Isotope and chemical studies revealed that hydrocarbons trapped in gas hydrates at Mallik are not formed in-situ, but from thermal degradation of organic material at depths >4000 m. The precursor organic material of hydrocarbons is composed of a variety of higher land plants with a terrestrial origin

Gas hydrates probably formed from formerly free-gas reservoirs during the last ice age when ground temperatures dropped. Intrapermafrost hydrocarbons of microbial origin underline a complex thermal history of the area.

The cumulative production of gas from the gas hydrate interval during a five day thermal production test was 468 m³.

Key Publications


Goal & Scientific Objective
The Lake Ohrid is considered to be the oldest lake in continuous existence in Europe and a hotspot for endemism with more than 300 endemic species. The deep drilling of Lake Ohrid has four major aims: (i) to obtain more precise information about the age and the origin of the lake, (ii) to unravel the seismotectonic history of the lake area including effects of major EQs and associated mass wasting events, (iii) to obtain a continuous record containing information on volcanic activities and climate changes in the central northern Mediterranean region, and (iv) to better understand the impact of major geological/environmental events on general evolutionary patterns and shaping an extraordinary degree of endemic biodiversity as a matter of global significance.

Operational Achievements
Drilling was scheduled for spring 2012, but became postponed due to logistical issues. Drilling was finally executed 2013 with the Deep Lake Drilling System. On five sites, 13 drill holes were cored at water depths ranging from 125 to 260 m. The maximum drilling depth was 569 m below lake floor (b.l.f.) with a total core recovery of 2207.9 m:

- DEEP: 6 holes, max depth of 569 m b.l.f.
- Cerava: 2 holes, max depth of 90.5 m b.l.f
- Gradiste: 3 holes, max 123 m b.l.f.
- Pestani: 1 hole, max 194.5 m b.l.f.
- Lini: 1 hole, 10 m b.l.f.

All holes (except at Lini site) were logged by LIAG (Leibniz Institute for Applied Geophysics). MSCL (Multi Sensor Core Logger) was applied to cores from all sites. Additional zero-offset vertical seismic profiling was conducted at the DEEP site.

Data & Sample Access
Lake sediments are stored in University of Cologne, Institute of Geology and Mineralogy, and at the IODP core repository in Bremen. Data holdings can be accessed on the ICDP website.

Web & Media Resources
www.ohrid-drilling.org
http://ohrid.icdp-online.org

Timeline
2009 ICDP proposal submission
2011 pre-site studies including shallow hole
2013 (spring) drilling/coring operations

Principal Investigators
Bernd Wagner, University of Cologne
Thomas Wilke, University of Giessen
Andon Grazhdani, Universiteti Politeknik,
Goce Kostoski, Hydrobiological Institute Ohrid
Sebastian Krastel-Gudegast, University of Kiel
Klaus Reicherter, RWTH Aachen University
Giovanni Zanchetta, Università degli Studi di Pisa
Melanie J. Leng, British Geological Survey

Global Cycles and Environmental Change
SCOPSCO
Scientific Collaboration On Past Speciation Conditions in Ohrid
Macedonia
Scientific Findings

Data from borehole logging, core logging and geochemical measurements indicate that the sediment succession covers more than 1.2 million years.

Sedimentological, biological and geophysical studies reveal that the Ohrid basin formed during the Miocene and Pliocene and provides a continuous record of distal tephra deposition and climatic and environmental change in the central northern Mediterranean region.

The upper 247.8 m of the DEEP site represents the last 637 thousand years. Over this period, Lake Ohrid experienced significant environmental change, which is related to orbital-scale climate forcing and regional geological events but did not cause major extinction events. The potential high resilience of the ecosystem to past climatic and environmental changes together with relatively low extinction rates may explain the extraordinary degree of endemic biodiversity in the lake.

The SCOPSCO deep drilling campaign is the very first interdisciplinary study that was able to infer the relative contribution of biotic and abiotic characteristics in driving diversification rates in highly isolated ecosystems over an extended period of time.

Key Publications

doi:10.5194/sd-17-19-2014


Goal & Scientific Objective

The main objectives of the PALEOVAN project are the recovery and analysis of a long continental paleoclimate record in a sensitive, semiarid region. This includes exploration of the dynamics of lake-level fluctuations and hydrogeological development and analyzing organic matter content and composition (biomarkers). Further scientific goals are the temporal, spatial and compositional evolution of explosive volcanism as reflected in the succession of tephra deposits, as well as the reconstruction of earthquake activities. In addition the sediments may host key pathways for migration of continental and mantle-derived noble gases to be analyzed in pore waters.

Operational Achievements

Two sites were multiple-cored, Northern Basin (NB) with 4 and Ahlat Ridge (AR) with 7 holes.

The drilling took place in water depth of 245 m (NB) and 360 m (AR).

Cores were retrieved from sub-lake-floor depths of 140 m (NB) and 220 m (AR) depth.

The total length of recovered cores is over 800 m.

Downhole logging (by LIAG Leibniz Institute for Applied Geophysics), MSCL (Multi Sensor Core Logger), deep biosphere sampling and noble gas sampling was conducted at both sites. MSCL measured all recovered core sections and yielded wet bulk density, magnetic susceptibility, and p-wave velocity data.

Data & Sample Access

Downhole data and core description data are available on the ICDP website upon request.

Cores are stored at the MARUM – IODP Bremen Core Repository.

Web & Media Resources

http://van.icdp-online.org/
http://earth.esa.int/ers/ers_action/van.html
www.geo.uni-potsdam.de/ICDP_Homepage/highlights/
www.deuqua.org/2015/02/12/neuer-blog-artikel/ (in german)
www.youtube.com/watch?v=_Wpx93K7bGU (in german)

Timeline

2007 ICDP proposal submission
2010 (May-June) drilling operations

Principal Investigators

Thomas Litt, University of Bonn
Sebastian Krastel-Gudegast, University of Kiel
Michael Sturm, Eawag Switzerland
Rolf Kipfer, Eawag Switzerland
Sefer Örçen, University of Yüzüncü Yil
M. Namik Çagatay, Istanbul Technical University

Barge at drilling site
Scientific Findings

The Ahlat Ridge record encompasses more than 0.5 Ma of paleoclimate and volcanic/geodynamic history, providing the longest continental record in the entire Near East to date.

Lake Van evolved from a Ca-carbonate dominated freshwater body with a neutral pH to a high-pH Na-carbonate dominated saline water body.

The glacial/stadial vegetation in the Lake Van region during the last 0.6 Ma can be described as dwarf-shrub steppe and desert steppe with Ephedra, Artemisia, chenopods, grasses and forbs.

The Lake Van pollen record underlines the different environmental correspondence to global climate change in the continental interior of the Near East compared to the global ice volume and/or greenhouse gas.

Porewater salinity measurements enable reconstruction of past lake volumes. On long timescales, the salinity of Lake Van is likely to be directly linked to large-scale climate forcing.

Key Publications


Goal & Scientific Objective
The primary purpose of the Lake Petén Itzá Scientific Drilling Project (PISDP) was to recover complete lacustrine sediment sequences to study the following: (i) the paleoclimatic history of the northern lowland Neotropics on decadal to millennial timescales, emphasizing marine-terrestrial linkages (e.g., correlation to Cariaco Basin, Greenland ice cores), (ii) the paleoecology and biogeography of the tropical lowland forest, such as the response of vegetation to disturbance by fire, climate change, and humans and (iii) the subsurface biogeochemistry, including integrated studies of microbiology, porewater geochemistry, and mineral authigenesis and diagenesis.

Operational Achievements
Seven sites (mostly multiple cored) were drilled and a total of 1327 m of sediment was recovered. The deepest site reached 133 m below the lake floor.

Downhole logging was conducted by the ICDP Operational Support Group (OSG) at five sites using their slimhole logging tools.

Data & Sample Access
Cores are stored in the National Lacustrine Core Facility at the University of Minnesota. Data are available at ICDP website on request.

Web & Media Resources
http://peten-itzal.plo.org
www.youtube.com/watch?v=3HqOJrODP14

Timeline
2004 ICDP proposal submission
2006 (February – March) drilling operations

Principal Investigators
David A. Hodell, University of Cambridge
Flavio Anselmetti, University of Bern
Daniel Raul Ariztegui, Université de Genève
Mark Brenner, University of Florida
Jason H. Curtis, University of Florida
James M. Hall, Carnegie Institution for Science of Washington
Gerald H. Haug, Max-Planck-Institute Mainz
Judith Ann McKenzie, Swiss Federal Institute of Technology Zurich

Drill rig at Lake Petén Itzá
Scientific Findings

Sediment deposited between ca 200 and 85 ka reflect deposition during an initial transgression, followed by clay and carbonate-rich sediments without major gypsum units, reflecting rather sustained humid conditions resulting in high run-off and high detrital constituents.

Before 85 ka, the sediment record is characterized by a gravel-bearing and sand-bearing unit that forms an unconformity indicative of a major lake level lowstand (i.e. dry climate). Dry climate around this time was also inferred by study of sediments from low-latitude African lakes.

During the last ca 50 ka, lithological units are characterized by alternating clay and gypsum units. Gypsum units are associated with low lake levels (i.e. dry climate) and clay units with high lake levels (i.e. humid climate). Stacked palaeo-shorelines at 68 m, 64 m and 56 m coincide with gypsum units that indicate a stepwise increase in water levels from the lowstands during the arid last deglaciation 18 to 11 ka ago.

The Holocene lacks gypsum deposits, and was thus characterized by relatively high lake levels and humid climate. Human impact during the Maya epoch (ca 3.0 to 1.0 ka) is reflected by rapid clay deposition.

Analysis of ostracodes shows that the distribution of C. okeechobei and P. globula are not correlated with changes in physicochemical variables, indicating their broad hydrochemical tolerance.

Key Publications


Goal & Scientific Objective

The scientific objectives of the Lake Qinghai Drilling Project are (i) to obtain an improved understanding of the late Cenozoic environmental history of the Lake Qinghai region and the development of the East Asian monsoon climate, (ii) to understand the Late Cenozoic tectonic evolution of the Lake Qinghai basin and the growth of the northeastern margin of the Tibetan Plateau and its effects on regional climate, and (iii) to correlate Lake Qinghai environmental records with other regional and global paleoclimatic records to obtain a better understanding of the connection between regional climatic change, the development of the East Asian monsoon system, prevailing westerlies, and, ultimately, the evolution of global climate.

Operational Achievements

13 core holes were drilled offshore with a total length of 547.9 m

Two onshore holes were drilled down to a depth of 1108.9 m and 628.5 m, respectively. No downhole logging was performed.

Data & Sample Access

Core is stored at the University of Minnesota at Minneapolis, Department of Earth Sciences, National Lacustrine Core Repository (LacCore)

Web & Media Resources

http://qinghai.icdp-online.org/

Timeline

2002 ICDP proposal submission
2005 (July – September) drilling operations

Principal Investigators

Zhisheng An, Chinese Academy of Sciences

Steven M. Colman, University of Minnesota at Duluth

Gerald H. Haug, Max-Planck-Institute Mainz for Chemistry

Peter Molnar, University of Colorado at Boulder

Takayoshi Kawai, Association of International Research Initiatives for Environmental Studies
Scientific Findings

Radiocarbon dates indicate that these cores provide a record extending back to ca. 20 ka.

Results suggest that solar activity influences decadal regional temperatures, and that it is the East Asian summer monsoon as opposed to the Indian summer monsoon that acts as the dominate moisture source at the decadal scale within the local region.

Lake Qinghai millennial-centennial climate events in Holocene are linked with Westerlies changes, and with East Asian summer monsoon front shift as well as winter monsoon, on centennial-decadal scale Lake Qinghai climate changes are controlled more by solar activities.

Key Publications


Goal & Scientific Objective
SAFOD is driven by the need to answer fundamental questions about the physical and chemical processes controlling faulting and earthquake generation within a major plate-bounding fault zone. The principal goals of SAFOD are to (i) study the structure and composition of the San Andreas Fault at depth, (ii) determine its deformation mechanisms and constitutive properties, (iii) measure directly the state of stress and pore pressure in and near the fault zone, (iv) determine the origin of fault-zone pore fluids, and (v) examine the nature and significance of time-dependent chemical and physical fault zone processes (Zoback et al., 2007).

Operational Achievements
Pilot Hole (SAFOD-PH): vertical, 2168 m depth, complete downhole logs, no core
Main Hole (SAFOD-MH): deviated, 3993 m depth, intersects SAFZ between 3100-3400 m, drill core from 1462-1468 m, 3056-3067 m, 3990-3993 m plus 60 side wall cores, downhole logging by OSG, USGS and service companies
SAFOD-III: four side tracks penetrating the SAFZ at depth, side track E contained core from 3141 to 3154 m, side track G contained core from 3191 to 3200 m and from 3300 to 3313 m

Data & Sample Access
Data holdings from the SAFOD Project can be accessed on the ICDP and the Northern California Earthquake Data Center (NCEDC) website. SAFOD physical samples are curated at the Gulf Coast Repository at Texas A&M University, under the supervision of John Firth (firth@iodp.tamu.edu)

Web & Media Resources
www.earthscope.org/science/observatories/safod
http://safod.icdp-online.org
http://earthquake.usgs.gov/research/parkfield
www.youtube.com/watch?v=yJ3zql8SkfY
www.youtube.com/watch?v=pUgxXqwdOlO

Timeline
2002 Pilot Hole Drilling (SAFOD-PH)
2004 Phase I Main Hole Drilling (SAFOD-MH)
2005 Phase II Main Hole Drilling (SAFOD-MH)
2007 Side Tracking (SAFOD-III)

Principal Investigators
Mark D. Zoback, Stanford University
Stephen H. Hickman, USGS Menlo Park
William L. Ellsworth, USGS Menlo Park

Schematic cross section of the San Andreas Fault Zone showing the SAFOD wells (Source: USGS)
Scientific Findings

At SAFOD, the San Andreas Fault Zone is located between ~3150 to 3420 m depth, containing several discrete 2–3 m wide zones that exhibit very low P- and S-wave velocities and low resistivity.

Two of these zones are actively creeping and have progressively deformed the casing at measured depths of 3192 m and 3302 m.

The deformation zones are composed of highly foliated, incohesive fault gouge. Fault weakening is mainly driven by talc-bearing serpentine, saponite, and/or nano-coated clay minerals.

No evidence for high pore pressure was observed in the SAFZ which supports fault weakening models by low friction clay minerals. The SAF hydrologically separates Pacific Plate from North American Plate but serves partly as conduit for mantle-derived fluids.

Changes in seismic velocity caused by coseismic stress changes were monitored few hours before two earthquakes, suggesting that they may be related to pre-rupture stress-induced changes in crack properties.

Key Publications


Serpentine and foliated fault gouge in SAFOD-III drill core extracted at 3194 m depth. Source: Earthscope
Goal & Scientific Objective

The major focus of the Lake Titicaca Drilling Project is on tropical paleoclimatic (including glacial) reconstruction. Secondary goals include recovery of a record of regional Andean volcanic activity and elucidating the tectonic origin of the lake basin. Questions to be addressed include:

- What is the nature of climate change in tropical South America during the past 0.5 Ma?
- Are there Pleistocene millennial-scale changes in precipitation and temperature such as we have already observed in the Holocene and late glacial record of the lake?
- What are the linkages between tropical climate change and global change?
- To what extent was the climate of tropical South America affected by changing high-latitude boundary conditions (e.g. glaciation) and global surface temperature changes?
- What is the record of volcanic activity in the late Quaternary?
- What is the age and nature of seismically-identified basement underlying the late Quaternary sediments at our drill sites?
- What is the heat flow at these sites and is there any evidence for deep fluid flow?

Operational Achievements

Seven cores at three locations were drilled using the GLAD 800 drilling platform and coring system.

Over 625 m of mud was recovered from paired overlapping holes. The longest recovered sequence spans 136 m.

Drilling depths range from 53 to 139 m below lake floor at water depths between 40 and 232 m.

Data & Sample Access

Core is stored at the University of Minnesota at Minneapolis, Department of Earth Sciences, National Lacustrine Core Repository (LacCore)

Web & Media Resources

http://titicaca.icdp-online.org/
https://soundwaves.usgs.gov/1999/03/fieldwork.html
http://dosecc.com/lake-titicaca/

Timeline

2000 ICDP proposal submission
2001 (April – May) drilling operation

Principal Investigators

Paul A. Baker, Duke University
Sherilyn C. Fritz, University of Nebraska
Geoffrey O. Seltzer, Syracuse University

GLAD800 drilling platform on Lake Titicaca.
Scientific Findings

594 m of drill core have been recovered from seven boreholes at three sites. The longest recovered sequence consists of alternations between two primary lithologic units, indicative of four major glacial stages and the intervening interglacials.

A chronology based on radiocarbon, U-series ages on aragonite laminae, and tuning to the Vostok CO₂ record suggests that the drilled sequence extends over approximately the last 370,000 years.

Extrapolation of the radiocarbon chronology suggests that the most recent period of ice expansion in the cordillera surrounding the lake began approximately 60,000 ¹⁴C yr BP, following a major dry interval. A series of U-series dates on discrete aragonite layers suggests that the penultimate low stand of Lake Titicaca, rather than dating to the last summer solar minimum (~32,000 yr BP), is coincident with MIS5e, the penultimate interglacial stage (~125,000 yr BP).

In summary, the water balance of the lake is as strongly influenced by global-scale (an tropical) temperature changes and boundary conditions as by precession forcing of the South American summer monsoon.

Key Publications