Volume 5, March 2003

NEWSLETTER

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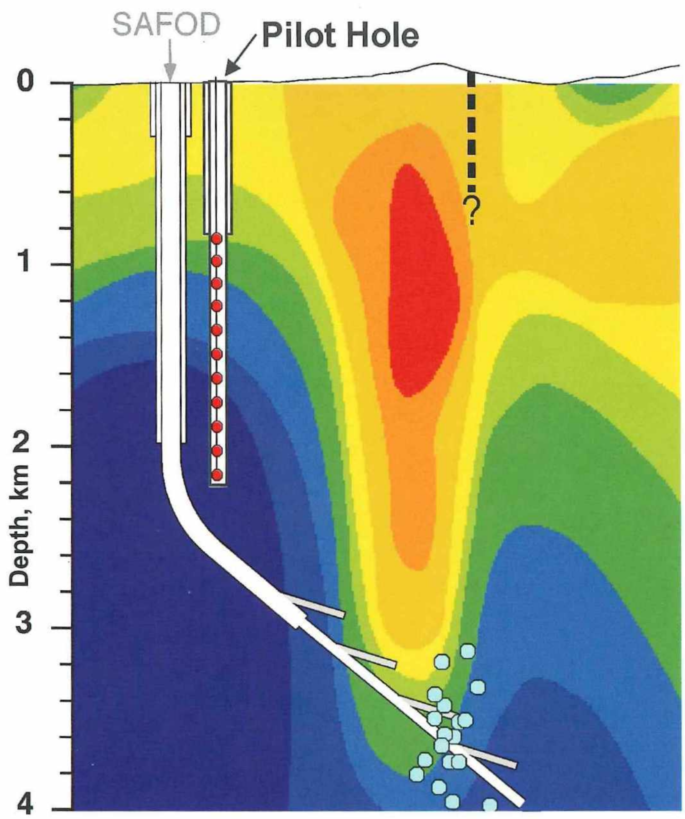
International Continental Scientific Drilling Program



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IDDP - Iceland
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International Continental Scientific Drilling Program

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Volume 5, March 2003

International Continental Scientific Drilling Program

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Coverpage Figure: Sketch of San Andreas Fault Zone Observatory at Depth. A 2 km deep pilot well funded by ICDP was drilled in 2002 and now serves to monitor seismicity at depth.

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United Nations Educational, Scientific and Cultural Organization.

Unzen Scientific Drilling Project (USDP): Hot Conduit Ahead

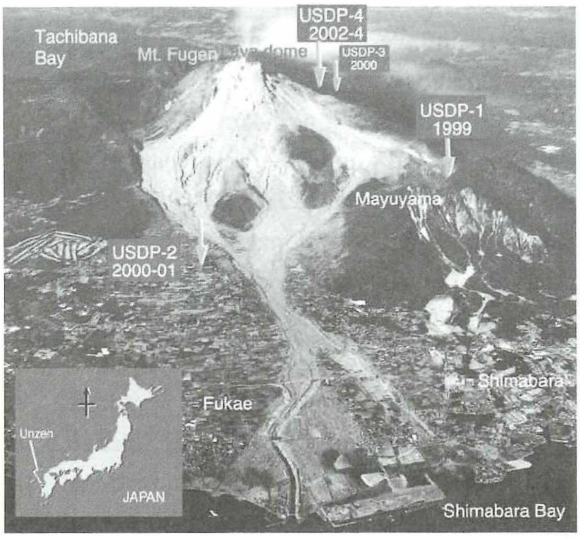

Fig. 1: Aerial view on Mt. Unzen during the last eruption. Arrows show location of drillholes. USDP-4 is the planned new deep borehole through the conduit

Japanese and foreign researchers held an opening ceremony on February 13, 2003 to begin the world's first volcano-drilling experiment of penetrating into the still-hot feeder dyke of the volcano Mount Unzen in Nagasaki Prefecture, Southwest Japan. The joint project by researchers from Japan and foreign research institutes is funded by ICDP and science and technology promotion funds of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in Japan.

Five principal investigators have the responsibility of science handling of the conduit drilling, including samples description-partition and logging experiments. Over 60 scientists comprise an international team of the conduit drilling project at Unzen.

Why drilling into the conduit of Unzen?

Volcanic eruptions of felsic magma cause large disasters. More than 50% of the recent volcanic disasters are due to mass flows, such as pyroclastic/debris flows, debris avalanches and tsunamis. In more explosive events, volcanic ash and gas cause other serious problems. Thus it is vitally important to understand not just when a volcano will erupt, but how it will erupt.

Felsic volcanoes are abundant in island arcs and continental margins, where cities with large populations are concentrated. Unzen Volcano is such a volcano, where the latest eruption occurred in 1990-95. About ten thousand pyroclastic flows were produced due to partial collapses of a growing lava dome, threatening the lives of people around the volcano.

Eruptions of felsic magmas are either explosive, like Pinatubo's eruption in 1991 (lava fragmentation within the conduit) or effusive, like the latest eruption at Mount Unzen, with almost no ash eruptions (collapse of extruded lava), despite a very similar magma composition and fluid content. Evidently, a degassing process where the volatile component escapes effectively from magma during its ascent is the major factor controlling whether volcanism is explosive or non-explosive.

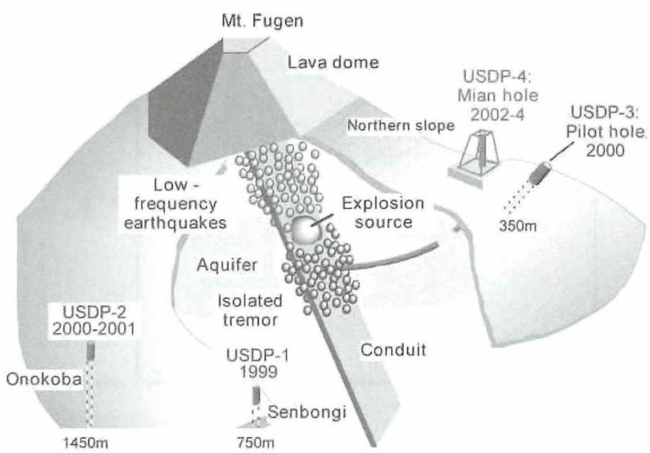

Fig. 2: Image of conduit drilling at Mount Unzen. The Conduit is a plate-shaped dike shown in red.

The upper part of the magmatic conduit is believed to be the place where most degassing occurs, based upon what is known about the pressure-dependent solubility of volatiles in magma and on the source location of geophysical signals during eruption. In-situ inspection of the conduit and its wall rock is the most effective approach to understand the mechanism. Drilling into the conduit of the latest lava dome at Unzen is a most desirable goal, because the lava that solidified in the conduit is still hot. With this challenging scientific project, the combination of direct information on degassing obtained by drilling with geophysical signals obtained during the eruption can solve the problem of eruption mechanisms of felsic magma. In addition, the meanings of geophysical signals can be more correctly interpreted for predicting eruptions and the development of hydrothermal systems after eruption can be elucidated.

The size and position of the magma conduit beneath Mount Unzen has been determined by the seismic signals monitored during the eruption (small circles in Fig. 2) and by seismological experiments (colored waves in Fig. 3). The points of the magmatic pressure sources and the basement structure of the volcano could be determined as well. The size of the feeder dyke is estimated to be at least 100 m wide by 20 m thick.

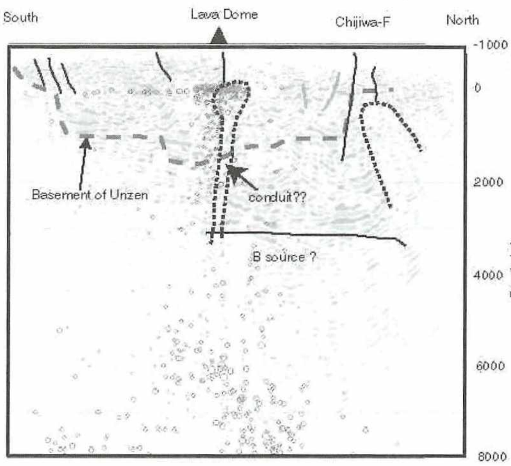

Fig. 3: South-north cross section of Mount Unzen, showing subsurface structure of a volcanic graben and the location of the conduit, which are illustrated with seismological reflection

International Cooperative Research to clarify eruption mechanisms and magmatic activity by conduit drilling near the summit of Mt. Fugen, Unzen Volcano, in Nagasaki Prefecture southwest of Japan, which caused serious damage with its volcanic activities including pyroclastic flow during 1990-1995, has been started under a six-year plan consisting of two phases in FY1999. The research named "Unzen Volcano: International Cooperative Research with Scientific Drilling for Understanding Eruption Mechanisms and Magmatic Activity" is funded by the Special Coordination Funds for Promoting Science and Technology. Research organizations participating during the 1st phase (FY1999 to FY2001) included Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology; National Research Institute for Earth Science and Disaster Prevention, and institutes of Japanese, American and German universities; e.g., Earthquake Research Institute, University of Tokyo, Geophysical Institute, University of Alaska, Fairbanks, etc.

During the 1st phase, in FY1999, a 750 m-depth drilling into the volcano's flank was carried out at Minami Senbongi (3 km away from the summit), Shimabara City, and from FY2000 to FY2001, a 1460 m deep drilling at Shin-Ohnokoba (3.5 km from the summit), to clarify the volcanic history and structure of Unzen Volcano. In the 2nd phase (from FY2002), a 1750 m-length drilling near the summit was started to understand the eruption mechanism and evaluate the eruption models built after the eruption. Research participants during the 2nd phase include also American and European researchers.

Setsuya Nakada, University of Tokyo, Japan

Status of the Hawaii Scientific Drilling Project

The HSDP completed its first phase of drilling in September 1999 with a total depth cored of nearly 3,100 m. Core recovery was very successful, with more than 95% of the total depth producing useable cores. At the conclusion of the drilling activities for Phase I, our intent was to allow between 18 months and 2 years for the science team to conduct analyses of the cores and conduct downhole geophysical logging in the borehole. Publication of the results of the core analyses are revealing important, and fundamental, insights into mantle plume processes, the interaction of the plume with the overlying crust, and the structure and evolution of ocean island volcanoes. Twenty or more publications are expected from the Phase I cores and downhole geophysical measurements.

Our planned hiatus between drilling phases has stretched considerably longer than initially planned due to difficulties in securing a rotary drilling rig capable of completing our Phase II objectives. Only one drilling rig was available in Hawaii that could support the required drilling string and our efforts to lease that rig ultimately proved unsuccessful. When this result became apparent, our drilling engineer undertook a process of screening and acquisition of the required components for an appropriately-sized rotary drilling system that would enable us to cost-effectively complete our Phase II drilling. We are happy to report that this effort is now complete and we expect to have the drilling and coring systems on-site and ready to drill by mid-April (of 2003).

In brief, our drilling plan is to complete rig-up and shake-down of the rig by the end of April. Our first drilling task will be to repair a casing leak in the $9^{5/8}$ inch casing; this may take up to one week to accomplish. When that work is complete, we will then open the uncased section of the borehole between 1830 m and 3100 m to a diameter of 6.5" (166 mm). This process will also require that we straighten the bottom section of the borehole – which may require a downhole motor – and will also require that we rotary drill somewhat beyond the depth drilled in Phase I. The latter will allow us to reach a depth where the rock is stable enough to securely cement the bottom string of casing. We expect that the final depth of the cased hole will be between 3200 m and 3400 m. The hole-opening effort will take between 30 and 60 days.

At the completion of the hole opening process, there will be a brief halt in drilling activities (~7 to 10 days) to allow borehole geophysical measurements to be made. After that work is complete, casing will be cemented in place and the coring program will begin. We have obtained some new coring tools that may allow us to recover 20 or more meters of core per day. This rate will, however, be dependent on the stability of the hole as well as the degree of fracturing in the core. As we learned from our Phase I coring, penetration rates can be very slow in unstable, fractured formations. If conditions are adverse, our plan is to suspend continuous core recovery and alternately core and then rotary drill in an effort to balance core recovery against penetration rate. However, if conditions are favorable, we should be able to reach our target depth in about 70 days of coring. We do, however, have equipment that will allow us to core to much greater depths (~6,000 m) if our budget and downhole conditions allow.

Donald M. Thomas, University of Hawaii, USA

Scientific Drilling in Lake Malawi, East African Rift

Plan for Drilling in December 2003 to February 2004

Introduction

This project will conduct drilling operations in Lake Malawi, in the southern end of the East African Rift Valley. Lake Malawi is one of the world's largest, deepest (maximum water depth of 700 m), and oldest lakes (2-7+ ma). It is the largest lake in the southern hemisphere after Lake Tanganyika, and is situated between 9? and 14? S. It is one of the most exciting sites on the continents for paleoclimate studies at that latitude and occupies part of Africa's Great Rift Valley, the archetypical continental rift system

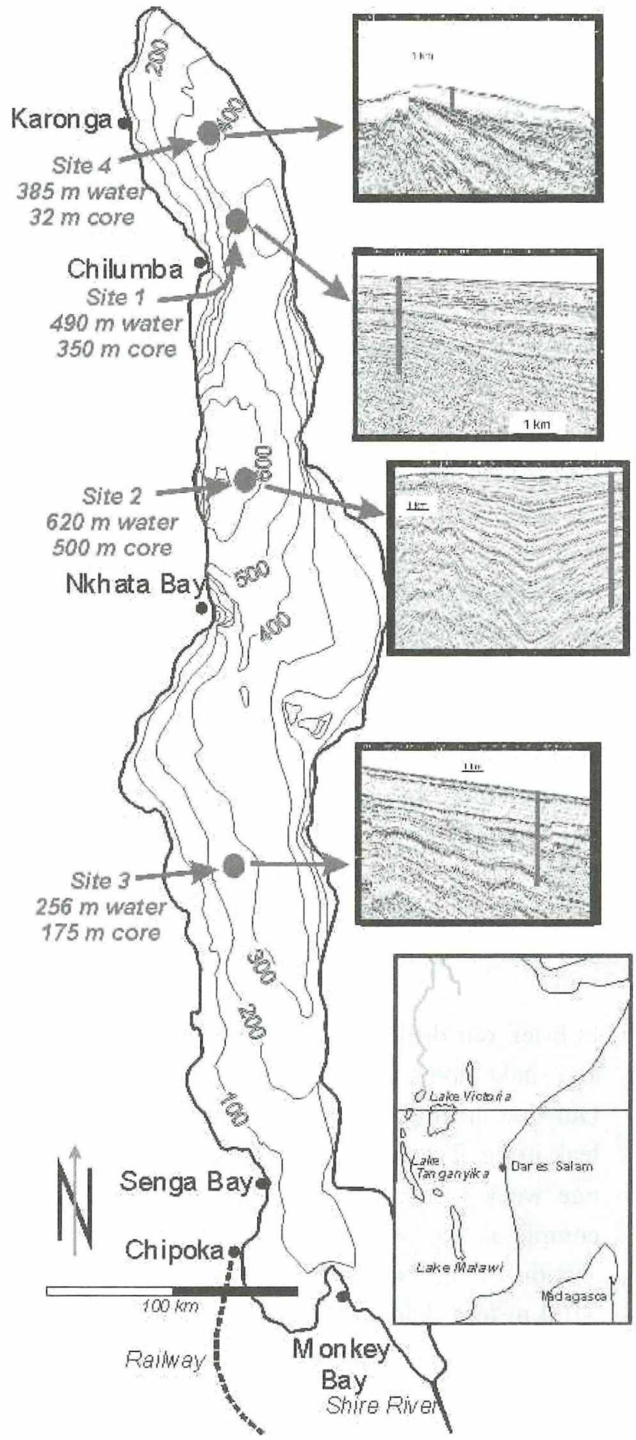

Fig.1: Sketch map of Lake Malawi with proposed drill sites and the results of seismic surveys that determine drilling depth as indicated in the map.

Key Scientific Questions and Objectives

The top scientific objective of the project is to obtain a continuous, high-resolution (annual-decadal) record of past climates in the continental tropics over the past ~800 kyr. Other scientific objectives of the drilling program intersect several fields, including extensional basin evolution and neotectonics, evolutionary biology, and the environmental background to human origins.

Site Selection and Drilling Strategy

Seismic site survey data is in hand for all the proposed drill sites:

1) The top priority site (SITE 2) is situated in the central basin, southeast of the deepest part of the lake. It is here that seismic reflection site survey data indicate the best prospects for continuous cores of hemipelagic sediment. Such a depositional setting, in an area with no major stratigraphic hiatuses, offers the best chance to recover a continuous section of high-quality paleoclimate proxy records back through the Bruhnes-Matayama boundary. Thus a core through this site will allow us to

construct a detailed chronostratigraphy, and be a basis for correlations between other sites that may contain punctuated paleoclimate records.

2) A site in the southern part of the lake (13? S) will allow us to record a southern hemisphere tropical signal, as well as nearshore facies that developed during lake lowstands (SITE 3).

3) We intend to recover from the north basin a core that should contain a rich record of volcanic ashes from the last part of the Pleistocene. (SITE 1). SITE 4 in the north basin is most likely to recover a section of finely laminated, varved sediments, and is a site where ~10 m piston cores have recovered a high-resolution record of climate change over the past 25,000 years that can be linked to the GRIP ice core record on a millennial scale and the Cariaco basin on a decadal to centennial scale.

Logistical and Engineering Considerations

We will use the C-100 rig, operated by Seacore Ltd., in conjunction with the GLAD800 sampling tool system, operated by DOSECC. The rig will be mounted on the barge *Viphya*, a 52 m vessel operated by Malawi Lake Services. Our project will require the installation of a moonpool and dynamic positioning system on the barge, for station keeping during drilling. Barge modifications will be completed at the port in Monkey Bay (in south), and drilling equipment mobilization will be completed at the container facility in Chilumba, at the north end of the lake.

Project Management

Syracuse University will provide oversight of field operations, in conjunction with the investigators from other institutions. The Malawi Department of Mines, and the Tanzania Petroleum Development Corporation are providing local infrastructure, permitting and liaison support. An on-site project manager will to report to the PI's, and will be in charge of local logistics and day-to-day operations. Personnel from the University of Rhode Island will oversee the operations of the whole-core logging facility, to be set up at the Senga Bay laboratory.

Seismic Site Survey Data

Several vintages of seismic reflection data are available from Lake Malawi. These include basin-scale multichannel seismic data acquired in the mid-1980's (~3500 line-km), and intermediate-resolution (small airgun) single- and multi-channel seismic reflection data acquired in 1992, 1995, and 2001 (~6000 line-km). Additionally over 200 sediment cores and several hundred surface sediment samples have been acquired from the lake during various research cruises, as have ~10,000 km of analog echosounder and high-resolution seismic reflection data.

Schedule

Barge modifications and mobilization will occur in November and December 2003. Drilling operations will commence from the northern port of Chilumba in late December 2003 and will continue until February 2004. A total of about 43 days of drilling and barge transit time is scheduled. We plan to double core at each of the four sites to depths of 32 – 200 m using the Hydraulic Piston Corer, and then continue to greater depths using other sampling tools. We intend to drill to 500 m subbottom at Site 2, in Lake Malawi's Central Basin. During the course of the entire campaign we plan to recover a total of 1350 m of core.

Christopher A. Scholz, Syracuse University, Syracuse, NY, USA

Progress of the Iceland Deep Drilling Project: March 2003

Overview

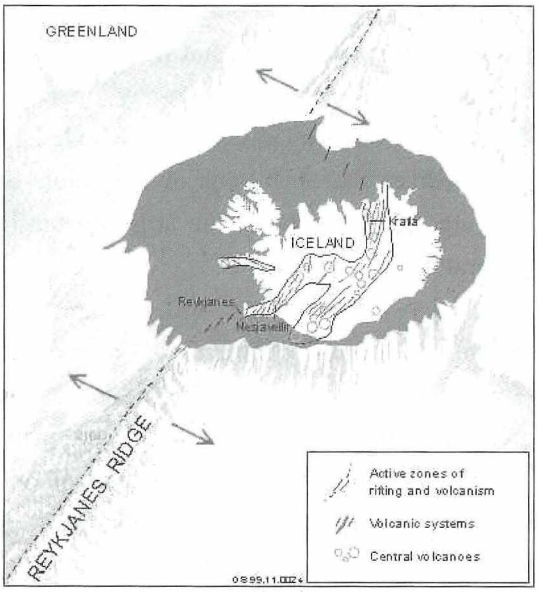

Fig. 1: Iceland and its zones of active rifting and volcanism. The locations of three drill fields, Reykjanes, Nesjavellir and Krafla, being considered for the IDDP are shown.

The Iceland Deep Drilling Project (IDDP) is a long-term program to improve the economics of geothermal energy by producing supercritical hydrous fluids from drillable depths. Supercritical fluids have higher enthalpy than steam produced from two-phase systems. Large changes in physical properties near the critical point can lead to extremely high flow rates. If the IDDP is an economic success the same approach could be applied in high-temperature volcanic geothermal systems elsewhere, an important step in enhancing the geothermal industry worldwide. Given Iceland's unique position as the largest landmass astride the Mid-Atlantic Ridge, the wide-ranging scientific and engineering program that is an integral part of the IDDP will be of global significance. As well investigating supercritical phenomena, drilling in this environment can address a wide range of world-class scientific questions, such as the formation of ophiolites, hydrothermal ores, and black smokers on mid-ocean ridges.

Introduction

Over the next several years the Iceland Deep Drilling Project, IDDP, expects to drill and test a series of boreholes that will penetrate supercritical zones believed to be present beneath three currently exploited geothermal systems in Iceland, Krafla, Nesjavellir and Reykjanes. This requires drilling to depths greater than 4 to 5 km, in order to produce hydrothermal fluids at temperatures of 400 to 600°C. Iceland is a particularly favorable location for research on supercritical fluids as repeated seismicity and volcanic activity in the rift environments create high permeability and high temperatures at drillable depths. These circumstances are the product of the special geological environment of Iceland, a coincidence of a mantle plume with the divergent plate boundary of the Mid-Atlantic Ridge (Figure 1).

The IDDP was founded in 2000, by an Icelandic energy consortium, composed of three leading energy companies in Iceland: Hitaveita Sudurnesja Ltd., Landsvirkjun, and Orkuveita Reykjavikur; and Orkustofnun, a government institute. The steering committee of IDDP, **DeepVision**, is composed of representatives of these companies. The principal aim of DeepVision is to enhance the economics of high temperature geothermal resources. A two year feasibility study was launched in 2001, addressing basic questions such as: Can 4-5 km deep and 400-600 °C hot wells be drilled safely? Can they produce fluids? What will be the advantages and disadvantages, and the overall economics? Where should the first IDDP well be drilled? The feasibility study concluded with a report earlier this year. The report is divided into **Part 1** on geosciences and site selection (Fridleifsson et al., 2003), **Part 2** on drilling technique (Thorhallsson et al. 2003), and **Part 3** on fluid handling and evaluation (Albertsson et al., 2003). The feasibility study was financed by the energy companies and is now being evaluated by them.

A Science Applications Group of Advisors (**SAGA**) has advised DeepVision and the three Principal Investigators (the authors of this report) about the science program and engineering planning of IDDP. Deep Vision is interested in integrating scientific investigations into the engineering aims of the IDDP to the mutual advantage of both. SAGA was established in 2001 with both Icelandic and international membership, with financial support from the International Continental Scientific Drilling Program (**ICDP**). The financial support has allowed discussions in detail of how drilling and scientific issues can be best interlinked. An IDDP/ICDP start-up meeting was held in Reykjavík in June 2001, followed by a workshop on drilling techniques optimized for science goals in March 2002, and a science workshop in October 2002. The essence of these workshops and recommendations to IDDP are described in SAGA reports 1, 2 and 3, respectively, all available IDDP website (http://www.os.is/ iddp/) and linked to the ICDP website (http://www.icdp-online.org/). Input from the IDDP/ICDP workshops and SAGA reports was used in the feasibility report, focused on the many scientific aspects. Approximately 40 separate proposals submitted by the international scientific community were reviewed at the October workshop to provide a framework for a comprehensive science program for the IDDP.

The Feasibility Report will be reviewed by the energy companies and the SAGA group by March 31[st] 2003. At that point, potential partners and collaborators will have open access to the report. Assuming a favorable response by Deep Vision, detailed planning and funding for drilling and science could commence later this year. Deep Vision has already had discussions with some potential international industrial partners. If suitable partnerships and funding are arranged in timely fashion, we anticipate that drilling could begin in 2004 or 2005.

Siting of the IDDP drillholes

In order to meet the principal goals of IDDP, advanced and costly drilling techniques are necessary, and a special fluid handling system designed to study and evaluate the quality of the supercritical fluid with respect to production of energy and/or chemicals (Thorhallsson et al., 2003; Albertsson et al., 2003). The first prerequisite, however, for a successful operation of the IDDP is to optimize selection of the IDDP drillsites. Each of the three sites selected for consideration by the IDDP displays a different stage in the tectonic development of the mid-ocean ridge. In siting the first IDDP drillhole, the safest ground for attempting a successful drillhole, is to plan on intersecting supercritical conditions within a hydrothermal upflow zone deeper than 3.5 km.

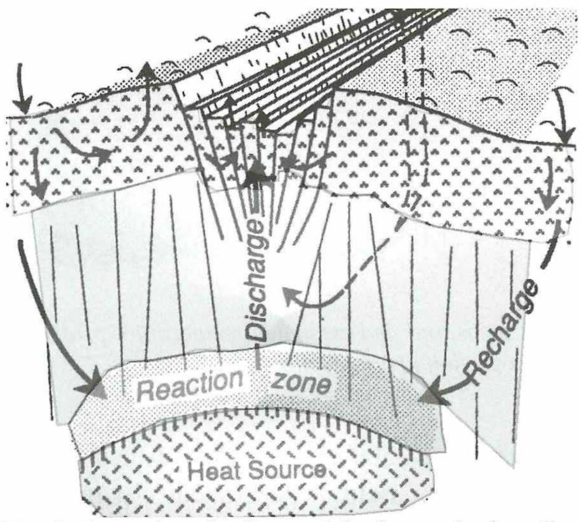

Fig. 2: A simple ophiolite model adequately describes the Reykjanes system

The **Reykjanes** site represents an immature stage of rifting, a subaerial rift zone astride the Reykjanes Mid-ocean Ridge, with a heat source that probably is an active sheeted dike swarm. The Reykjanes system may be adequately described by the simple ophiolite model shown in Figure 2. It contains evolved saline fluid of oceanic origin. The heat source may be rather deep-seated, while uncertainty still exists on the temperature distribution below 1300 m depth within the center of the drillfield. However, evaluation of seismic data at Reykjanes suggests the depth to the semi-brittle boundary, at about 600°C, may be as shallow as at 4-5 km depth, and the depth to the brittle/plastic boundary at 750-800°C may be about 6 km deep.

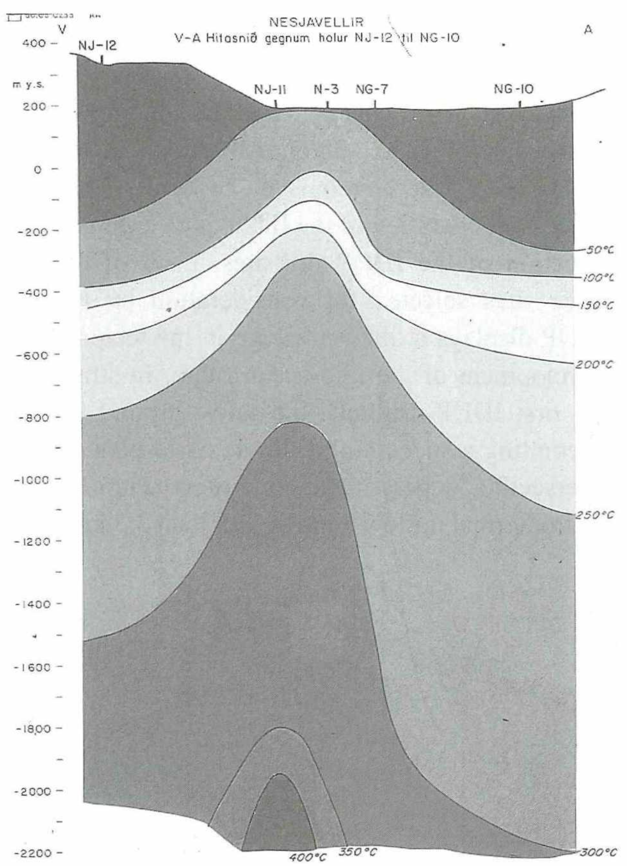

Fig. 3: A measured and estimated temperature profile in a W-E cross section at Nesjavellir.

Last year a 2500 m deep well drilled in the Reykjanes field penetrated permeable formations. The well, RN-12, is barefoot, 12 ¼" wide production well, and at the moment one of the most feasible IDDP drilling target at Reykjanes. If a 10 ¾" cemented casing was installed, the well could be deepened to some 4 km depth by a drilling system like the DOSECC hybrid coring system. Downhole temperature data from well RN-12 will appear later this year. However, this deep well was drilled as a standard production well and will probably not be available for deepening for scientific purposes within the next few years? Another drilling target for an IDDP well at Reykjanes has also been suggested (Fridleifsson and Albertsson, 2000) at a 2000 year old eruptive fissure zone outside the production field at Reykjanes. That drilling option is still valid, while ideally a 2.5 km deep well should be drilled there and compared to temperature data from RN-12 before a final decision on the IDDP drillsite at Reykjanes is made. The situation at Reykjanes with respect to near future drilling plans by Hitaveita Sudurnesja Ltd. is likely to be clarified this year.

The fluids encountered in the Reykjanes system are of seawater salininty and origin, and there is no reason to expect the salinity to decrease with increased depth. For that reason the Reykjanes system resembles the ocean floor hydrothermal systems (black smokers), as well as saline fluids in most high-temperature systems world wide. Thus the Reykjanes system may have greater scientific international interest, as compared to the Krafla and Nesjavellir systems which both involve dilute fluids of meteoric origin. The fluid chemistry in the latter two systems, however, is probably simpler to deal with. Accordingly, during the experimental phase of IDDP, the IDDP/ICDP workshops recommended the first IDDP drillhole should penetrate into a dilute fluid system.

At the **Nesjavellir** drill field, within the Hengill central volcano in SW-Iceland, the maximum measured downhole temperature surpassed 380°C at 2.2 km (Steingrímsson et al. 1990). The main hydrothermal upflow zone there, shown in a W-E cross section in Figure 3, is one of the most feasible drilling target considered for the IDDP drillhole. A deep drillhole can be drilled from either side of the upflow zone, and it is quite likely that supercritical conditions can be reached at a relatively shallow depth. In the feasibility report, several drillsites were recommended for an IDDP well, while a new inclined well from the left side in Figure 3, received the highest priority, aiming to meet a supercritical zone at 3-4 km depth. At present there is some uncertainty that an IDDP well will be permitted at Nesjavellir within the next few years, as the drillfield is both within a sensitive area, and due to a very recent plan by the Orkuveita Reykjavikur company to increase the power production at Nesjavellir from 90 to 120 MWe within the next 2-3 years. The situation at Nesjavellir with respect to IDDP should clarify this year.

The heat source in **the Krafla** volcano is a shallow cooling magma chamber that appears to underlie the drill field. Accordingly, high temperatures are expected at shallow depths. The closeness to a magma chamber, and its recent activity, may possibly bring problems such as experience during the 1975-1984 volcanic episode. Then the hydrothermal fluids were seriously affected by volcanic gases, manifested in extensive deposits and acid fluids in some wells in a part of the drill fields, even though the effect of the volcanic episode has diminished substantially in recent years. The reservoir fluid is apparently dilute and easy to handle but there are signs from one well which temporarily discharged superheated fluid, that at a greater depth there may exist a more saline brine from which HCl-rich steam can boil. Magmatic gases only affected the westernmost drill field in Krafla, the Leirbotnar field, but left the Suðurhlíðar and Hvíthólar fields intact. The temperature distribution in the Leirbotnar and Suðurhlíðar fields is shown in Figure 4 in a W-E cross section (from Gudmundsson, 2001). The main upflow zone at Hveragil, separating the two drill fields, Leirbotnar and Suðurhlíðar, is the most attractive drilling target for IDDP.

The temperature distribution within the Krafla drill field, shown in Figure 4, indicate that only about 35°C greater temperature is needed to reach the critical point below most of the drill field on the west side. This suggests that supercritical conditions exist at a depth of 3.5 km or less. Most importantly, in a situation like this, the IDDP well should be targeted to intersect with the main upflow zone at 450-550°C between the heat source and the overlying hydrothermal system.

In the feasibility report, several drilling targets were considered at Krafla, and a priority order made. In this case, as within the other drillfields, Landsvirkjun, the energy company holding the field, would need to make one or more drillsites available before we can proceed any further. We anticipate that a decision regarding available drillsites for the IDDP will be reached later this year.

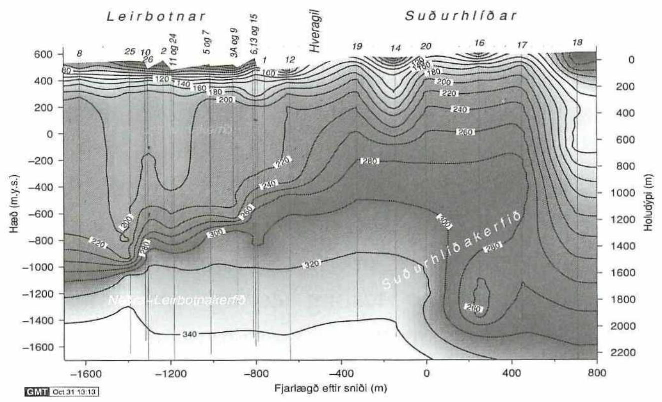

Fig. 4. Temperature distribution across the Krafla drill fields in a W-E cross section.

The cost of the IDDP drillholes

The feasibility study makes clear that an IDDP drillhole to 5 km can be safely drilled to meet 400-600°C hot supercritical fluid. If the fluid temperature is above 450°C, electricity production from the superheated steam discharging from deeper supercritical fluid reservoir, should be more economic than conventional two phase flow. Uncertainty exists on the effect of salinity and the overall chemical composition of the fluid on the production characteristics at such high temperatures and pressures. In order to secure the well during flow testing, a replaceable "pipe" has been designed. After testing, this "pipe" will be removed and the IDDP hole can then be reamed before production, if needed.

Provisional cost estimates assume an IDDP drillhole to reach supercritical conditions is likely to cost in the range between US $ 14-15 million, including continuous core from 2.4 km to 5 km depth. SAGA strongly recommends obtaining as much core as possible for scientific studies. For comparison, an estimate for a conventional production well to 5 km depth without any coring ranges between US $ 8-9 million. This is about 3 times more expensive than a conventional geothermal production well of 2 km depth. However, a 5-10 fold increase in power output per well is predicted for supercritical conditions. While these figures are provisional and may change, they serve as a guide in decision making. The high cost of coring mostly hinges on the relatively slow penetration rate.

The incremental cost of scientific coring is of obvious concern. For this reason, an alternative approach to core down from an existing geothermal well in Iceland was also considered at the 2nd IDDP/ICDP workshop in October 2002. This option should be considered as a "pilot hole" or "well of opportunity" since it would be testing coring and sampling technology in the pressure-temperature zones defined as being of highest scientific interest. The option has a cost advantage since much of the large diameter drilling and casing would already have been installed. One such coring option exists in the Krafla drill field (KJ-18) and another at Nesjavellir (NJ-12). However such coring options at Reykjanes (such as the well RN-12) are not much different from the first coring phase of a dedicated IDDP well. The relative merits of these options involve the present condition of the wells, their scientific advantages, and the need for permission by the owners for IDDP to gain access to the wells. The feasibility report has already addressed the first of these two issues, while the willingness of the energy companies to make such a well available to the IDDP should be clear within the next few months. A cost estimate for well KJ-18 pilot coring in Krafla to 4 km depth, for example, approached US $ 6 million.

The discussion on various IDDP drilling options, from pilot coring to full-scale wells, should conclude within the next few months. Depending on the decisions made by the Icelandic energy companies later this year, an application for an ICDP drilling proposal may be realized in January 2004.

Conclusion

In conclusion, some 14 different drilling targets have been evaluated, 4-5 in each of the three geothermal drillfields of Nesjavellir, Krafla and Reykjanes. Feasible targets for supercritical conditions exist within each of these geothermal systems. The supercritical targets are believed to exist at relatively shallow depth within the Nesjavellir and the Krafla systems, but maybe somewhat deeper in the Reykjanes system. The Icelandic energy companies are now reviewing the comprehensive feasibility report and if that review and their economic analysis is favorable, will need to give permission for IDDP drilling within their drillfields before further actions towards funding and science planning can be made.

Acknowledgements

We are most grateful for financial support from the International Scientific Drilling Program to organize the scientific program of the IDDP. Access to all the data presented in the IDDP feasibility report, currently being reviewed by the owners, the Icelandic energy companies, is gratefully acknowledged.

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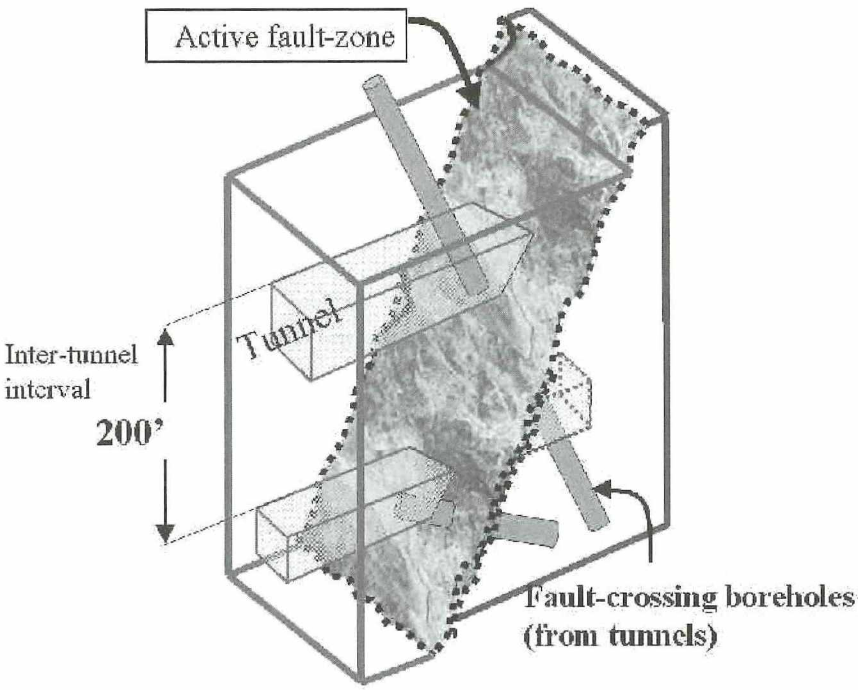
DAFSAM: DRILLING ACTIVE FAULTS IN SOUTH AFRICA MINES

Research plans of DAFSAM project as defined during the 1st workshop, September 23-26, 2002, Parys, Witwatersrand basin, South Africa

OVERVIEW

More than 70 scientists, engineers and managers met for a four days workshop in Khaya Ibhusei, Parys, South Africa. The participants, 26 of them coming from Japan, US, Germany, Canada and Israel, have one central objective: to develop a comprehensive research plan on active faults in the gold mines of South Africa. The results of the presentations and discussions are outlined here.



The physics of earthquake processes has remained enigmatic due partly to a lack of direct and near-field observations that are essential for the validation of models and concepts. We propose to remove this limitation by conducting research in deep mines that are unique laboratories for full-scale analysis of seismogenic processes. The access to active faults at focal depths allows direct observations of ruptured fault-zones and measurements of near-field parameters before, during and after earthquakes. The mines provide a 'missing link' that bridges between the failure of simple and small samples in laboratory experiments, and earthquakes along complex and large faults in the crust. There is no practical way to conduct such analyses in any other environment.

The DAFSAM project is centered on drilling supported by the ICDP. As the mines allow access to fault-zones down to 4 km depth, the drilling from the tunnels is relatively inexpensive. Moreover, it will be possible to carry out a suite of geological and seismological studies, as well as to directly measure both stress and strain in the vicinity of active faults at significant depth. The research operations will be funded by additional resources. First, the project utilizes the billions of dollars of infra-structure in the deep South African mines. Second, as the project will contribute to mine safety and hazard control, the it is anti-cipated that the mines and South African agencies (e.g., SIM-RAC - Safety in Mines Research Advisory Committee) will support part of the studies. Finally, the majority of research funding will be provided by national agencies of the international participants.

The scientific objectives are the characterization of near-field behavior of active faults before, during and after earthquakes. We intend to measure the stress field (orientation, magnitude, heterogeneity, time variations) at the fault proximity, to characterize the fault zone structure (fault rocks and geometric complexity) and the fault zone seismic signature (guided waves and shear-wave splitting). We will determine the rupture energy balance (temperature and microstructure measurements), assess the nonlinear rheology (damage and healing) and determine rupture parameters. The DAFSAM project includes several complementary studies of the analyses of time-dependent geochemical composition of the fault-rocks as well as the possible interaction between fault slip and microbiological activity.

The practical benefits of the DAFSAM project will be evident in several fields. *1.* Contributions to mining production and safety, particularly in areas where significant ore reserves are situated adjacent to large structures. *2.* Students of disadvantaged groups of South Africa will be involved in various parts of this international project, contributing to the diversity of the professional work force in South Africa. *3.* The anticipated improvements in understanding of earthquake processes by the DAFSAM research will contribute to the reduction of seismic hazards on a global scale.

SCIENTIFIC OBJECTIVES

NEAR-FIELD SEISMIC STUDIES

Despite many years of intense theoretical and observational research, there is no theoretical foundation that relates particle acceleration (or velocity) in the earthquake zone to the stresses (or energy) and material properties. Faults in deep mines provide opportunities for conducting fundamental observations on the evolution of stress, energy, and material properties associated with fault motion. Seismometers located in boreholes normal to an active fault, with dense instrument spacing in the immediate vicinity of the fault, will provide unprecedented in-situ information on fault dynamics. The following studies have been identified as key opportunities for seismological investigations : (1) Monitoring the nucleation phases of fault instabilities. (2) Determination of "opening mode" and motion asymmetry across the fault. (3) Dynamic and static stress drops and rupture velocity. (4) Fault zone guided waves and anisotropy. (5) Energy radiation normal to fault. (6) Interaction among sub parallel faults. The simultaneous studies with 3D networks around the fault will also allow us to place the high resolution borehole information at specific points on the fault in the context of the entire rupture history.

BOREHOLE MEASUREMENTS

In active tectonic environments the monitoring of fault behavior and its changes with time are conducted by instrumentation in low-noise, deep boreholes. The measurements usually include high precision strain, tilt, stress, pore pressure, displacement, temperature, velocity and acceleration. The borehole data define the background state of stress, strain, material properties, and, most importantly, time changes of these parameters as failure occurs. By drilling into active faults in deep mines we will expand the above concepts into an environment where we can monitor fault failure within the near-field and thus resolve long-standing questions of the physics of failure and earthquakes. The mine tunnels can be used as starting points in the use of borehole drilling to prospect faults and regions surrounding them. For example, it will be possible to directly measure the stress state acting on the faults at depth that have had recent earthquakes, or might potentially have earthquakes in the future. These measurements will permit testing a variety of theories based on laboratory studies of the faulting process and dynamic models of earthquake rupture. The opportunity to make such measurements in the context of the other studies discussed here is truly unprecedented. In the initial phase of this project we will: [1] Define displacement and strain time histories on and near active faults during slip initiation and earthquake nucleation; [2] Detect the nucleation process near faults, and [3] Determine physical model(s) of fault failure using the available geophysical, geologic and laboratory data. It is anticipated that we will derive the physics of the approach and nucleation of the fault failure as well as the post-failure behavior. These obvious benefits in understanding the earthquake process can be achieved only by precise monitoring and analysis of the behavior of active faults in deep mines.

STRUCTURAL ANALYSIS

The central objective of the structural analysis is to characterize the evolution of fault-zones during the seismic cycle by multi-scale mapping and testing of fault-zones before and after earthquakes at their focal depth. Several outstanding open problems will be examined. First, the in-situ evolution of fault-rocks from fragmentation during an earthquake to the establishment of mature gouge-zones. Second, the characterization of the 3D geometry, and mechanical and physical properties of active fault-zones. Third, the processes of brittle, dynamic failure of intact rocks under natural loading of continuous rock body. The planned integration of disciplines (from geochemistry, through structural geology to seismology) will allow critical evaluation of fundamental concepts in fault-zone and earthquake mechanics. In particular, the understanding of in-situ slip instability, mechanics of dynamic earthquakes, the energy balance of faulting and earthquakes and the links between fault-zone properties and seismic behavior.

INJECTION EXPERIMENTS

The injection of fluids into stressed fault zones stimulated seismicity in a wide range of cases observed around the world. SIMRAC recognized and supported a project for injecting fluids into faults at several sites in the deep mines in 1988-94 to trigger potentially damaging seismic events. The experiment succeeded to trigger small events, but they were too small to relieve significant load.

We anticipate that Phase 1 of DAFSAM will provide a detailed data set of seismic behavior, structure, mechanical and hydrological properties at two active faults zones. These observations and their analyses will indicate if fluid injection into a fault-zone in the deep mines could trigger a significant earthquake ($M > 3$). If the scientific insights as well as the engineering and legal assessments will indicate that seismic event stimulation is possible, we will propose to conduct a controlled earthquake experiment in Phase 2.

GEOCHEMISTRY, MICROBIOLOGY, AND HYDROLOGY

Active fault zones may provide a unique habitat for microbial life due to enhanced surface area, saturated pore space, permeability and access to nutrient supplies. Drilling into active fault zones will expand the knowledge base of subsurface biological diversity and will permit the determination of the biogeochemical and hydrological factors limiting the occurrence of life underground. Initial site characterization prior to a seismic event, coupled to examination subsequent to an event, could answer central questions: Do seismic events trigger biological and chemical activity? Do microbial communities populating the pores of the rock matrix differ from those in fissure water? Are unstable minerals (and/or glass) created during fault slip? Do new high free energy surfaces created during faulting facilitate intense secondary mineralization and population by microbes?

The access to continuous drilling cores and the on site, immediate analysis of the solid, fluid, and microbial content will minimize contamination and pore water degassing and ensures anaerobic conditions necessary to sustain certain life forms.

PRACTICAL BENEFITS

HAZARD AND SAFETY

Seismic events and rock bursts are a significant cause of fatal accident and injuries in the South African Mining industry. Research on fault behavior has been undertaken by SIMRAC in South Africa, but additional understanding is particularly important today as the industry tries to access pillars adjacent to faults. It is vital to determine the stability state of the fault, the stress state in the surrounding rock mass, the directions of energy release and possible damage patterns to design appropriate support. The outcome of the proposed research will allow the development of procedures for Identifying seismic potential of hazardous structures (unlocking ore bodies that otherwise would not be produced).

Monitoring hazardous structures to detect changes in quantities related to seismic hazard. Installation and continuous monitoring of seismic and other instrumentation to detect medium and short term changes.

EDUCATION AND OUTREACH

DAFSAM can make an important contribution to the education of young black South African students in the field of mine seismology. Specifically goals include: Projects for South African students at the Honors, MSc and PhD levels. Projects on problems related to the DAFSAM project could be conducted at the universities of Witwatersrand or Pretoria with input from local researcher. Funding for South African student projects will be sought within the funding structures in South Africa. It is important that short courses or field workshops will be offered by the international participants of DAFSAM to facilitate interaction between the SA students and international participants. One or more international postdoctoral fellows are to spend a significant period of time at one of the South African universities during the course of the project. The overriding three to five year goal of the DAFSAM project would be to produce between one and three MSc level graduates who are black South Africans in the field of mine seismology.

PROJECT PLAN

We propose a two-phase approach for the DAFSAM project. Phase 1 (2003-04) includes the deployment of drilling to characterize stress field, structure, and rheology in two-three selected sites in the deep gold mines. The drilling will be accompanied by detailed site characterization and continuous monitoring of time variations of stress, strain, seismic behavior and creep for 2-3 years. Phase 2 (2005-07) includes full deployment of up to 5 sites with the facilities needed to characterize complete seismic cycle of stress accumulation and release. Based on the results of Phase 1, we will consider the possibility of controlled earthquake experiment by fluid injection into a carefully selected fault zone. For Phase 1, we will attempt to answer these major questions:

- How do we identify potentially active faults in a reliable manner?
- What is the stress field (orientations, magnitudes and heterogeneity) in the vicinity of an active fault?
- What is the geological structure (geometry, composition, rheology, fluids, damage, anisotropy) of the studied faults?
- What are the inter-relations between stress, strain, structure, and seismic-activity?
- What are the scales and processes of seismic event nucleation?
- What are the dynamics of the rupture process (scaling heterogeneity, energetics)?

SITE SELCTION

We plan two different types of drilling sites:

Site I. Drilling, instrumentation and monitoring at a fault for long-term monitoring (up to seven local boreholes).

Site II. Drilling into faults that generated recently large earthquakes ($M > 4.0$) for frictional-heat analysis (up to two boreholes with no instrumentation or monitoring).

Hundreds of active faults intersect the many tunnels of the gold mines in the Witwatersrand basin. To select the most suitable drilling sites for DAFSAM Phase 1, we defined 18 criteria that cover the main aspects of the seismology, geology, rock mechanics, mining and safety interests and logistics. We examined 12 sites and ranked each of them according the defined criteria and a short list of 4-5 sites was recognized. Selecting the finalist two will be based on further discussion; at least one selected site will overlap one of the three existing sites of the Japanese experiment as the DAFSAM work will be complementary to the Japanese experiments.

Tom Dewers and **Ze'ev Reches**, University of Oklahoma, Norman, USA and the **DAFSAM working group**

ICDP international workshop "Lake Biwa and Lake Suigetsu: Recorders of Global Paleoenvironments and Island Arc Tectonics"

The ICDP international workshop "Lake Biwa and Lake Suigetsu: Recorders of Global Paleoenvironments and Island Arc Tectonics" was held at the Faculty of Science, Kyoto University, Kyoto, Japan from 21st to 25th of November, 2002 (Photo1). The workshop was financially supported by the ICDP, the Japan Association of Quaternary Research, and the Asian Lake Drilling Program (ALDP).

Photo 1: Kyoto University, Faculty of Science

The aim of the workshop was to discuss the scientific value and strategy of the proposed coring program in Lake Biwa and Lake Suigetsu, and to set up a steering committee for the project.

The participants comprised an international group of 57 specialists from Japan, USA, Germany, France, China and South Korea. The workshop program consisted of a symposium, a field excursion, and a business meeting. The symposium (22 and 23 November) hosted 21 oral presentations and 12 posters. The presentations were classified into 6 sessions, which were (i) the project's outline, (ii) the tectonics around Lake Biwa and Lake Suigetsu, (iii) chrono-stratigraphy of the target lakes, (iv) palaeoenvironment and palaeoclimate, (v) Commitment of ICDP and ALDP, as well as a (vi) general discussion. The summary of each session is briefly presented below:

Project's outline

Dr. S. Saito from the Japanese national committee of ICDP gave an overview of the structure and strategy of the committee and the current state of ICDP projects in Japan. Following this, the organizing committee of the workshop reviewed the history of research on Lake Biwa and Lake Suigetsu especially underlining the tectonic setting of the lakes, studies on the previously recovered cores, and future perspectives. Finally, Dr. A. Brauer from GFZ, Germany summarized the outline of the ICDP organization and also reported the latest achievement of the high-resolution analytical work on the terrestrial sediment cores.

Tectonics of Lake Biwa and Lake Suigetsu

Prof. K. Takemura of the Kyoto University first summarized the tectonic settings of the regions around the lakes. Dr. M. Hashimoto reported the recent data of the seismic activity around the Lake Biwa basin. Prof. F. Kumon presented a trial reconstructing of climate changes and tectonic history from the grain size data and turbidite sequence in the core samples. Dr. N. Kitada presented the newly established database of intensive coring around the region of the Great Hansin Earthquake, and showed how the tectonic history can be reconstructed by integrating multiple core data.

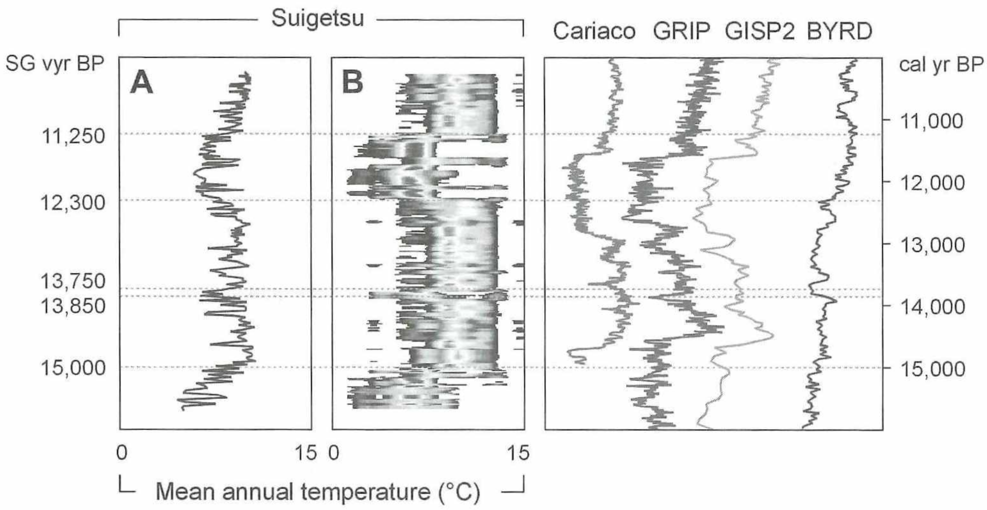


Fig.1: Comparison between the Last Termination climate record from Lake Suigetsu (A, B) and other climate records (right) using a common time scale. A: raw mean annual temperatures (Tann) for Lake Suigetsu, reconstructed from pollen data. B: smoothed and calibrated versions of A [red (high) to blue (low) probability gradient]. Cariaco: grey scale variations in the laminated marine record from Cariaco basin. GRIP, GISP2, BYRD: variations in stable oxygen isotope ratios of the ice cores (by Nakagawa, T.).

Chrono-stratigraphy of the Lakes

Establishing the chrono- stratigraphy of sediment cores is crucial to quantify the time resolution of the proxies, and to detect synchrony/asynchrony of events between the regions. Dr. H. Kitagawa proposed intensive analyses of the cosmogenic isotopes such as ^{10}Be for the sediment core from lake Biwa. Dr. K. Yamada reviewed the existing dates of Lake Biwa stratigraphy and proposed to improve the age control by U-Th/He dating and ^{40}Ar/^{39}Ar dating on single tephra grains. Dr. Y. Nagahashi underlined the importance of tephra-based correlation of Japanese lakes and proposed the project of micro tephra analyses of the Lake Biwa and Lake Suigetsu cores. Prof. A. Hayashida summarized the existing palaeomagnetic studies of Lake Biwa cores and drew out the future perspectives. Then Prof. Kenneth Velosub introduced the latest development of palaeomagnetic measurement methods and proposed to apply the new methods to the project of Lake Biwa and Lake Suigetsu. Accordingly, Prof. M. Torii demonstrated how the new methods contributed to improve the quality of work in the palaeomagnetic study in the Okhotsk Sea.

Palaeoenvironment and palaeoclimate

Studies of environmental reconstruction using different disciplines were proposed in this session. Dr. M. Okuda compiled long pollen profiles from different sites worldwide and proposed high-resolution pollen analyses on the Lake Biwa core sample. Dr. T. Nakagawa presented the latest palynological study on Lake Suigetsu core and underlined the importance of precise age control and quantitative climate reconstruction (Fig. 1). Prof. de Beaulieu compared climate proxy curves from the crater lakes, France and Vostok ice core, and explained the interest of including Japanese sites into the intercontinental correlation of proxies. Dr. M. Kuwae reported the results of diatom analyses on the previous Lake Biwa core and explained the future research proposal. Prof. P. A. Meyers reviewed the recent studies of the organic geochemistry and expressed its relevance to the future research project of Lake Biwa and Lake Suigetsu. Prof. K. Toyoda presented the latest works of the inorganic geochemical analyses in Lake Biwa and Lake Suigetsu and proposed to extend it in the future IDCP project in the lakes.

Commitment of ICDP and ALDP

Possible support from two international organizations was discussed in this session.

Dr. D. Schnurrenberger (University of Minnesota) introduced the system and performance of the transportable coring system GLAD800, which is the property of ICDP and which is operated by DOSECC, and may be possibly employed as coring equipment for the Lake Biwa and Lake Suigetsu coring project. Prof. Y. Yasuda, the chairperson of the ALDP, also spoke on the possible link between the high-resolution analyses on the cores from the target lakes and environmental archaeology in the Eurasian continent.

General discussion

In the last session, an open discussion on the practical aspects of the project such as coring sites, coring method, budget size and source, people to involve, research networking, international conferences, etc. was held. The group photo (Photo 2) was taken at the end of this session (23 November).

Photo 2 Group photo at Seminar room of Kyoto University

Posters were presented in the foyer of the symposium hall during the two days of oral presentations. The authors from Japan, Korea and China presented their latest studies of terrestrial cores, palaeomagnetism, lacustrine sedimentology, volcanology and coring database, and proposed to extend their works to the cores from Lake Biwa and Lake Suigetsu.

Most of the participants of the workshop joined the field excursion on the 24 November. The party first arrived at Mt. Hiei to look over the Lake Biwa basin, then descended toward the water body stopping at several outcrops to understand the tectonic history of the basin. After reaching the lakeshore, the party visited the 1976-coring site at the mouth of Yasu River and the Lake Biwa Museum. In the afternoon the party stopped at few more lacustrine outcrops to understand the terrace system of the lake and to see some tephra layers. Then the group went to Lake Suigetsu to see the setting of the lake basin, stopping at the Torihama shell mound to understand the relevance of the project to the environmental archaeology, and another outcrop which shows Eemian marine sediment (the evidence of tectonic movement of the Lake basin).

A business meeting was organized on the last day of the workshop (25 November). The attendance was limited to the invited speakers (including ICDP and ALDP representatives) and members of the organizing committee. The purpose was to discuss the future plans for the project. The steering committee members were chosen. Coring site and target depth, short-term (one year) and long-term (few years) working schedules, core handling strategy, some practical deadlines, place and required implementation to store the samples, ways to generate publicity for the project and guidelines for open participation were also discussed and fixed.

An abstract volume and the workshop program are available at the website (http://www.vgs.kyoto-u.ac.jp/icdpbiwa/).

Keiji Takemura, Kyoto University, Japan, takemura@bep.vgs.kyoto-u.ac.jp and

The Organizing Committee of the ICDP workshop in Kyoto, 2002

Drilling, coring, testing and instrumentation of the AIG-10 Borehole, Aigion, Gulf of Corinth, Greece

The drilling project in Aigion was carried out within the framework of the DGLab Corinth program. Its objective is to investigate the mechanical behavior of faults through the instrumentation of deep boreholes intersecting active faults. Particular emphasis is placed on documenting the role of fluids on fault behavior and the role of earthquake faulting on regional hydrogeology. DGLab itself is part of an European Union funded program called "The Corinth Rift Laboratory". It is centered on the south shore of the Corinth rift near the city of Aigion. This rift is the most seismically active zone in Europe and the fastest opening rift in the world. European academic and private laboratories as well as oil companies are joining efforts to investigate fault mechanics and their relationship with fluid flow and earthquakes. Further details about this program are available at: http://www.corinth-rift-lab.org.

ICDP co-funded the drilling and experiments in the first borehole of the program, the AIG-10 well drilled between July 7, 2002 and September 23, 2002.

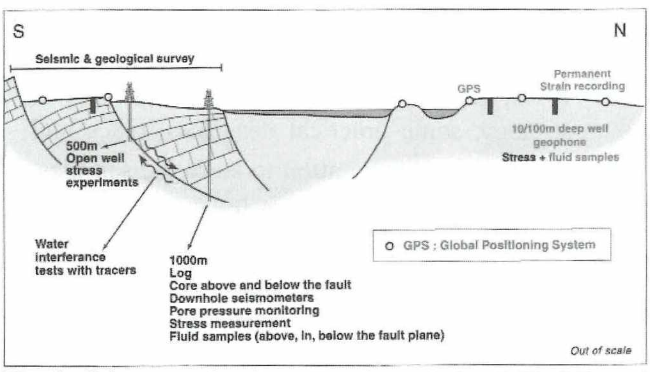


Fig. 1: Schematic sketch section through the Gulf of Corinth showing principal instrumentation and location of the AIG-10 and other planned wells.

Drilling and coring program

The borehole was drilled by a German contractor with a B5R drilling rig in combination of Rotary Drilling and Wireline Diamond Coring technique in order to allow for both, a 12 ¼" and 9 5/8" drilling diameter (0 – 708.8 m) and high-quality coring in the fault section of the borehole (708.8 – 787.4 m, 101 mm core diameter). The relatively large diameter was chosen to enable later full instrumentation.

Thirty core runs yielded 71% core recovery; losses in the upper coring section were due to highly sheared strata. Nevertheless, the main fault zone was fully cored without any loss of material. Coring operations were performed with a Bentonite-Polymer-Freshwater mud at pump rates of 140 to 300 l/min, with 20 to 30 kN weight on bit and topdriven 130 to 150 rot/min. The lowermost part of the well between 787.4 m and the final depth of 1001 m was rotary drilled (6 ¾"). The well was cased and cemented to 708,4 m (7 5/8"). The inclination was less than 3° at 330° azimuth, and the bottom hole temperature did not exceed 31°C. All of which paved the road for testing and experimenting in the cased and open borehole sections.

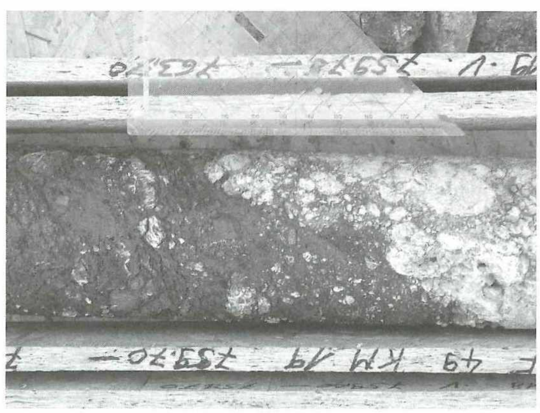


Fig. 2: Core sample with the Aigion fault proper

Geology of the intersected strata

The northern Peloponnesus is geologically and tectonically characterized by thrust sheets separating several tectonic units. The AIG10 borehole and the surrounding area is located in the Olonos-Pindos Unit comprising normal bedding with from bottom to top the Jurassic-lower Cretaceous Radiolarite Series, followed by the Cretaceous-Tertiary Platy Limestone Series and Tertiary Flysch Sandstone. The structural bedding of this unit is governed by thrust faults as well as synthetic and antithetic normal faults. The mainly SE dipping thrust faults and the related NW-verging folds are part of a Miocene thrust tectonism. The major north or south dipping normal faults, however, are belonging to the actual rifting of the Gulf of Corinth since Pliocene times. The Olonos-Pindos Unit is deformed into a series of multiple imbricates and is itself overthrusted on the allochtone Tripolitza unit. The multiple imbricates and duplex structures are leading to changing stratigraphic sequences and a heterogeneous lithology. This complex tectonic structure is a key for explaining the succession in the AIG10 borehole log.

The Corinth graben fillings in the AIG10 log (Fig. 3) comprise at the top argillaceous sand ground (soil), Holocene and Pleistocene clays, marls and Meganitas river deposits. This 154 m thick sequence up is characterized by sandy middle and fine gravels, intercalated with silty and clayey layers, which can react as aquicludes. From 154 m to 358 m the expected Eocene-Pleistocene "Gilbert-Type" Delta conglomerates were encountered. They consist of well rounded limestone, marl, and sandstone detritus as well as subangular rounded radiolarites and cherts of the Olonos-Pindos Unit.

A 20 m thick transition zone to marine sediments and a thick dark gray marine clay follows down to 496 m depth. This (Pleistocene?) calcareous, plastic fat clay is less silty and comprises fossils and nannoplancton. After a reddish clay sequence the top of the Mesozoic Olonos-Pindos Unit is reached at 496 m depth in the Radiolarite Series. At approximately 696 m to 698 m depth a thrust fault was observed, characterized by calcite cuttings, along which the Jurassic radiolarites were overthrusted on Cretaceous limestone. The heterogeneous sequence between 506 m and 696 m depth points to related penetrative faulting and thrusting.

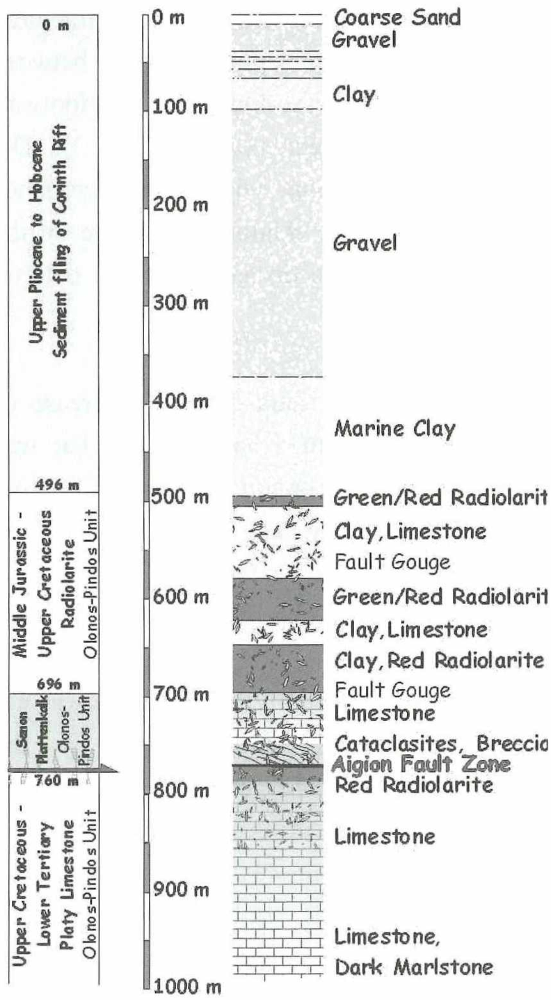


Fig. 3: Stratigraphic and lithological column of the Aigion borehole.

The Cretaceous Limestone Series below the thrust fault zone consists mainly of light-brown or greenish-gray limestone and marlstone cuttings as well as red marl and silicious marl. Coring started at 708.8 m depth and retrieved cores show the well fractured and platy character of the Olonos Pindos Limestones. At a depth of approximately 745 m a lithologic sequence with very clear cataclastic characteristics was found. Below 745 m depth, the Olonos-Pindos Platy Limestones are intensively brecciated and several cataclastic bands have be recognized. These shear bands and cataclastic zones indicate a major normal fault, regarded as the Aigion fault proper. The core of the breccia is apparently reached at 756 m depth and is at least 4 m thick. This fault zone separates well fractured and karstified platy, micritic limestone from highly fractured radiolarite. At 760 m depth the contact between the hangingwall (limestone) and the footwall (radiolarite) has been reached (Fig. 2). The fault plane is dipping ~60° N in accordance with the dip of the Aigion fault plane on the surface; the surface distance between outcrop and well is 470 m.

After crossing the fault zone an increase of water pressure from 5 bar up to 10 bar was recognized. These conditions suggest sealing characteristics of the fault causing artesian well flow. The highly fractured and brecciated radiolarites as well as high influx of water caused core loss so that the transition from radiolarite to the underlying limestone was not recovered in core but located by the geophysical logs in 772 m depth. Due to high fluid pressures the coring was stopped at 787,4 m depth and drilling was continued by rotary technique up to the total depth of 1001 m. Cutting analysis confirmed mainly well fractured light gray limestone with abundant young calcite such as in the lowermost cores from 774 m to 787,4 m depth.

Geophysical logging and testing

A series of geophysical well logs were obtained and hydraulic tests performed in the AIG 10 borehole. The ICDP Operational Support Group obtained logs in two campaigns for a project funded by the German Science Foundation, focusing on the generation of a regional thermo-hydraulic model of the larger Aigion area. First logs were taken when drilling reached 708 m (casing); the second series was obtained when the borehole reached the final depth. Standard GFZ logging tools (Mud Parameter, Spectral Gamma, GR-BCS-DIL and MSFL) were employed to collect data on borehole conditions and on wall-rock petrophysics. In addition, as part of this project, two pump tests were performed to investigate the hydraulic properties of the formations and their hydraulic conditions. The first test was carried out between a depth of 211 m and 256 m in conglomerates; the second test between 708 m and 744 m in the Olonos-Pindos Limestone, respectively.

The combined indications, mainly from resistivity, sonic and caliper logs, supported also by the GR and Potassium logs reveal the main fault zone between 755 m and 770 m. The indications strongly point to at least three separate fault planes within the 15 m wide fault complex. The apparent thickness of this steeply dipping fault system appears wider than in the core analysis as these logging sondes read deeper into the rock.

Further on, three additional logs were obtained by Schlumberger Company (FMI, UBI, and DSI under 3 different borehole pressures). DSI (Dipole Shear Sonic Imager) shows some seismic anisotropy consistent with a maximum horizontal stress oriented in the direction N 110 ° E. It also outlines zones of strong Stoneley wave attenuation be possibly linked with water production zones and correlated with karstic zones as identified through UBI (Ultrasonic Borehole Imager). The water production zone extends from the fault (760 m) down to the bottom of the well at 1000 m.

A three day production tests demonstrated the production of 48 m^3/h, increasing slightly with time (clean up of borehole connection to the water reservoir), and a surface pressure build up of 8 bars when flow was stopped. The drilling-induced bottom hole temperature of 32° C indicates a thermal gradient smaller than 15°/km due to a fast regional downgoing flow.

A vertical seismic profile experiment showed that the fault offset is about 180 m, with a

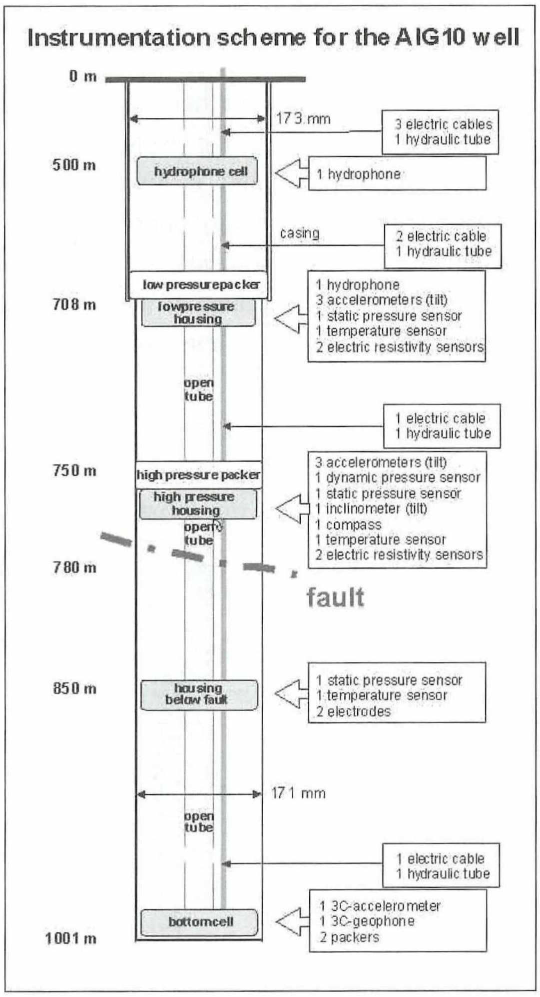


Fig.5:Planned instrumentation of the Aigion 10 well

beginning of faulting activity at around 50 000 years ago. One of the horizons in the Quarternary conglomerates seen on both sides of the fault is well dated at 35 000 years.

One of the most important outcome of the borehole is the demonstration that the normal faults can act as hydraulic barriers with a significant consequence on the regional flow pattern, and therefore on the regional heat flow.

The well was left with dense mud after the hydraulic tests had been run in order to equilibrate the hydraulic overpressure. The direct stress measurements have been postponed till a workover rig is brought back on site for an exchange of heavy mud with water prior to the stress measurements and the installation of the permanent monitoring equipment (to be conducted in early May 2003). The permanent monitoring includes a 3-component accelerometer (sampled up to 150 Hz), a 3-components geophone system (sampled up to 25 000 Hz) at 1000 m; two packers (one just above the fault, another one 40 m above it, within the casing); distributed temperature and pressure transducers along the well, along with electrodes for electrical resistivity measurements. Hydrophones (sampled at 25 kHz) are located at 700 and 500 m. Crude tiltmeters and compass are also set at 760 m.

A workshop will be held in Aegion, June 3 to 8, 2003 to presenting and discuss new data and results.

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The Dead Sea as a Global Paleo-Environmental Archive: The Prospects of Scientific Deep Drill

Overview

The Dead Sea depression, the lowest on Earth (currently at 416 m below mean sea level - m bmsl) has been intermittently filled by water bodies during the Neogene-Quaternary. Tectonic activity along the Dead Sea - Transform (DST) fault perpetuates the steep morphology despite the intensive sedimentation, totaling over 10 km in thickness (Fig. 1). The size and composition of the water bodies have evolved in time, reflecting the changing tectonic and climatic conditions in the region. The Dead Sea basin is located in the desert fringe between the sub-tropic and Mediterranean climatic zones hence the limnological history of the water bodies provides a sensitive recorder of latitudinal climate changes across these climatic zones. In addition, the DST was the locus of mankind migration out of Africa and historical development, what illuminates the limnological and climatic evolution of the region in a unique perspective.

Lakes Amora, Lisan and the Dead Sea occupied the Dead Sea basin during the Pleistocene-Holocene (the past several hundred of years). Lake Amora emerged in the early or mid –Pleistocene and declined towards 80 kyr BP (Kaufman et al. 1992; Waldamnn, 2003). Lake Lisan filled the depression between 70 to 14 kyr BP (Kaufman 1971, Kaufman et al. 1992, Schramm et al. 2000, 2003, coinciding with the last-Glacial period in the northern latitudes and corresponding to the marine isotope Stages (MIS) 2, 3, and 4. Around 17 kyr BP, Lake Lisan commenced declining, approaching its minimum stand (< 500 m mbsl) at ~ 13-12 kyr BP (Stein, 2002). During most of the Holocene the Dead Sea stabilized around 400 m mbsl

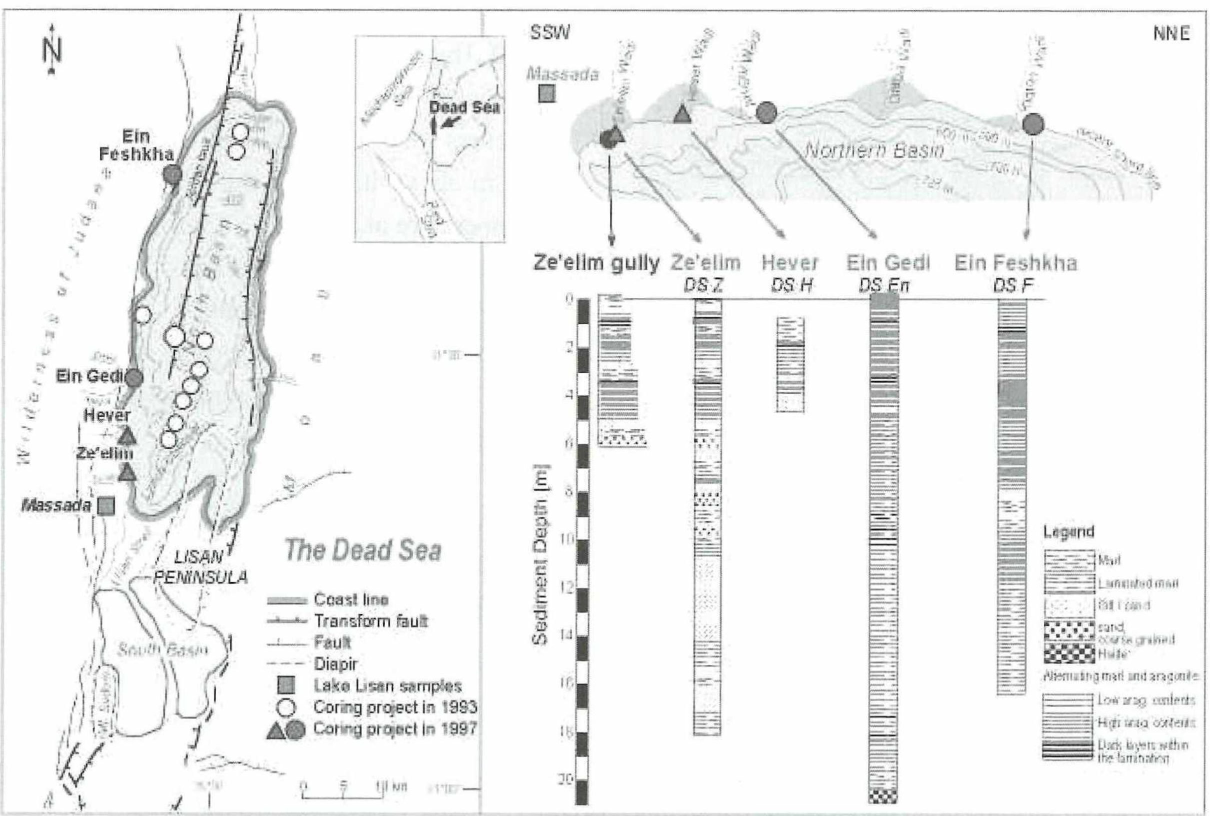

Fig. 1: Location map; coring sites Zeélim and Hever (red triangles) lie directly in the active fan whereas the sites Ein Gedi and Ein Feschka (red circles) are situated beside small fans within a coastal sedimentation environment

(Ken-Tor et al., 2003; Migowski et al., 2003). As of 1930, following slight climatic changes, which were later amplified by artificial diversion of freshwater from the Jordan valley, a continuous decline in the water level of the Dead Sea has been recorded (Klein, 1985) which has culminated to a rate of some 80cm/y in recent years. The steep slopes of the valley, and the preservation in desert environment allow recognition of paleo-shorelines, and their systematic dating shows similar rates of level decline of Lake Lisan flowing the last Glacial maximum (Bartov et al., 2002).

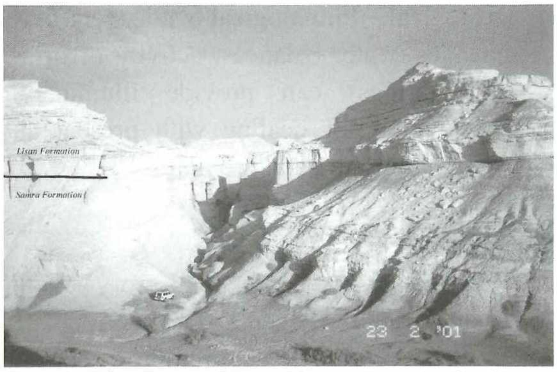

Fig. 2: The Samra-Lisan Formations in the Perazim Valley. The transition between the formations lies between 80-70 kyr BP

The sediments deposited in the water bodies are mainly authigenic aragonite, gypsum and salt, and clastic material transported by floods and winds. The aragonite appears in thin (~0.5-1 mm thick) laminae alternating with detrital laminae of similar thickness (mainly dolomite, calcite, quartz, clay minerals, halite and gypsum). Figure 2 shows the Lisan Fm. overlies Samra Fm. section at the Perazim Valley. The unconformity that marks the transition from the Samra to Lisan section occurs between 80-70 kyr BP (Waldmann et al., 2003). The production of aragonite and gypsum requires supply of bi-carbonate and sulfate to the lake. The aragonite precipitates during episodes of enhanced freshwater supply establishing a density-layered structure (bottom layer = the hypersaline brine). Gypsum forms thick layers (hard benches in Figure 2) that were formed during dry conditions, enhanced evaporation and overturn events in the lakes (Stein et al., 1997).

The aragonite is preserved in its primary state due to the dry climate in the Dead Sea basin and the high Mg/Ca ratio of interstitial soluble salts (precipitated from the former pore water) (Katz and Kolodny, 1989; Stein et al., 1997). Thus, the sediments are suitable for geochemical studies and for absolute dating because they inherit and preserve the chemical information of the lake water. The excellent preservation and high U concentrations (~3ppm) of Lisan aragonites make them useful for ^{234}U-^{230}Th dating (Kaufman, 1971; Kaufman et al., 1992; Schramm et al., 2000, 2003). In addition, the sediments can be dated by radiocarbon, allowing a comparison between U-series and radiocarbon ages down to ~ 40 kyr BP (Schramm et al, 2000).

The high-resolution U-series calendar chronology of the Lisan Fm. allows the comparison with global climatic archives. The episodes of high-stand conditions in Lake Lisan (aragonite facies) are correlated with the glacial (cold) episodes in the north Atlantic, while low stands are correlated with warmer intervals (Stein, 2001). However, extreme arid events in Lake Lisan were found to coincide with abrupt cooling (H-events) in the North Atlantic (Bartov et al., 2003, Fig 3). The sequences of the Dead Sea lacustrine sections contains long intervals of annually precipitated laminae (= varves) that together with the U-Th ages open the way to study climatic and hydrological events on time-scales ranging from millennial to sub-decadal and annual (e.g. Prasad et al., 2003). Moreover, the Lisan Dead Sea sediments are recorders of the paleomagnetic properties (Marco et al, 1998, 1999), as well as faithful monitors of paleo-earthquakes (Marco et al, 1996; Ken-Tor et al, 2001; Migowski et al., 2003, Fig. 4).

The sections that are exposed on the margins of the Dead Sea basin are sensitive to lake level changes that induce depositional discontinuities. The importance of recovering a core from the deep basin of the Dead Sea lies in the potential to achieve a continuous sedimentary record of the past ~ 300-400 kyr.

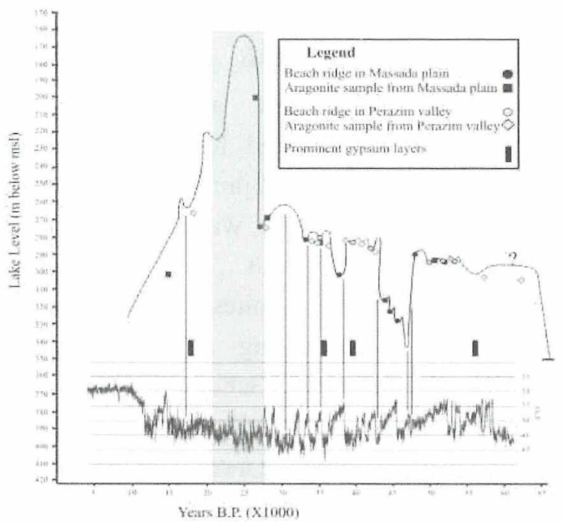

Fig. 3: Reconstruction of level curve of Lake Lisan (Bartov et al., 2002).

Preparatory Workshop

To define the goals of a deep drilling project in the Dead Sea, a workshop, which was financially supported by ICDP was convened at the Luckenwalde, Germany in January 2002. The participants included researchers that were involved in various aspects of Dead Sea studies (from Israel, Jordan, Germany, USA and Switzerland), researchers involved in drilling projects of other lakes (e.g. Lake Malawi), who brought both their scientific and operational experience and representatives of ICDP and GLAD 800, who reviewed the technology and the operational system.

The major points that were raised in the workshop concerning the Dead Sea drilling project are outlined below:

I. THE UNIQUENESS/OPPORTUNITIES OF THE DEAD SEA BASIN AS A GLOBAL ENVIRONMETAL SITE

- Location at the Desert fringe between the Mediterranean and sub-tropical climatic zones - a record sensitive to N-S migration of the climatic zones.
- Locus of pre-historical and historical human development, starting as the major route of mankind migration out of Africa – provides an opportunity to investigate the links between human development and environmental changes.
- The seismic cycle is longer than the typical dating uncertainty, where the latter is reduced for the historical period – an opportunity to investigate the spatial and temporal paleoseismic behavior.
- The Dead Sea is a major natural resource for the neighboring countries. Its rapid decline in recent years may cause an environmental catastrophe (e.g. collapse of the shorelines). Hence, exploring the geological – limnological history (e.g. level changes, water balances, activity of brines and springs) can provide illuminating information for dealing with present and future environmental problems.

II. DRILLING PROGRAM GOALS

- Recover the sedimentary history of the basin during the past 300-400 kyr.
- Establish a high-resolution calendar chronology by U-series dating of authigenic aragonite.
- Establish annual chronology by laminae counting.
- Establish the geochemical and limnological evolution of the water bodies.
- Establish the paleohydrology of the drainage area.
- Compare the sedimentary record of the core with that of the shallow-margins and establish a high–resolution level curve.
- Establish the behavior of abrupt hydrological-limnological events (e.g. catastrophic drying or rising of the lakes).
- Compare the limnological-hydrological history of the lake with regional and global climatic records (e.g. Red Sea and Mediterranean –deep sea cores, speleothems and ice cores). This comparison will be done in several timescales: from millennial to decadal.
- Understand the impact of catastrophic global events such as the Heinrich cold spells on the East Mediterranean climate.

- ➢ Establish the paleomagnetic history of the Dead Sea basin; determine secular variation curves and geomagnetic excursions
- ➢ Determine the abundance of cosmogenic isotope (^{14}C and ^{10}Be) and link them to the geomagnetic record of the sediments.
- ➢ Establish an high-resolution paleoseismic record (by identification and dating of seismites)
- ➢ Study the history of wind-blown desert-dust to the lakes and monitor paleo-storm tracks.
- ➢ Integrate all geochemical-hydrological-limnological information within comprehensive paleoclimatic models and link it with global climatic models for studied period.
- ➢ Investigate the tectonic history of the Dead Sea basin during the past 300-400 kyr
- ➢ Investigate the relation between human culture development and climatic changes in the region.

Geophysical, gravity, magnetic and bathymetric surveys

The selection of the drilling site requires high-resolution information on the bathymetry and seismic structure of the Dead Sea. Preliminary geophysical studies undertaken over the past three decades in the Dead Sea area (summarized by Ben Avraham, 1997), and will be complemented within the framework of the present project.

A deep seismic refraction experiment was carried out in 1977 along 600 km of the DST (Ginzburg et al., 1979, 1981). This was followed by a seismic refraction experiment in the eastern side of the Dead Sea (El Isa et al., 1987; 1990). A deep refraction profile using ocean bottom seismometers has inferred a >10km thick sediment fill (Ginzburg and Ben-Avraham, 1992). Geophysical data for the southern basin were obtained by oil drilling. The northern basin was studied by marine geophysical techniques. Neev and Hall (1979) shot continuous seismic reflection profiles for the northern basin of the Dead Sea. They identified four prominent reflectors, which could mark the transitions between the different formations of the Dead Sea group. Marine gravity data were collected in 1988 in the northern basin using a Bell Aerospace BGM-3 marine gravity system (ten Brink et al., 1993). Neev and Hall, (1979) conducted a magnetic survey in 1974 over the northern basin. Frieslander and Ben-Avraham (1989) report a detailed magnetic survey (along 900 km of track lines) from 1983 using a G-866 EG&G Geomatrix magnetometer (An aeromagnetic survey with a dense grid (total length of lines ~ 1000 km) was conducted in 1987 west of the Lisan Peninsula (Ram, 1989).

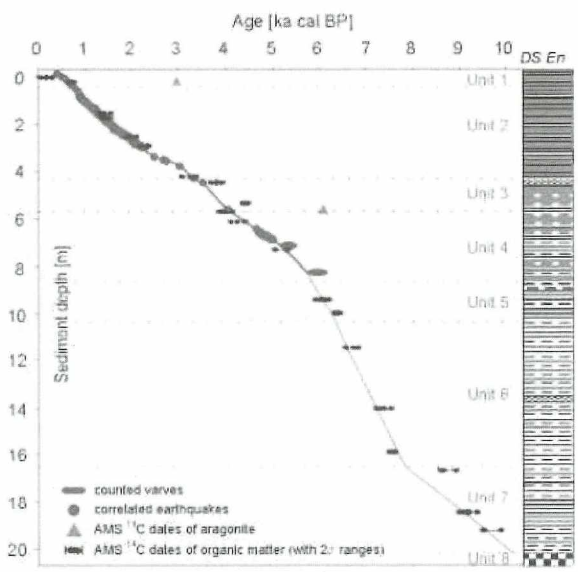

Fig.: 4: The chronology of seismic events in the Ein Gedi core (see Fig. 1 for location)

John Hall and his team in the Geological Survey of Israel and the Survey of Israel, converted the 1:50,000 topographical maps of Israel and its surrounding into a digital terrain model (DTM) with elevations to decimeter resolution every 25 m on the local Israel geographic grid (Hall et al., 1990; Hall, 1993). The Dead Sea bathymetry was compiled from previous surveys of Lynch (1849), Neev and Emery (1967) and Neev and Hall (1978). The DTM allows preparation of three-dimensional maps comparable to actual satellite images. The DTM allows performing a number of mathematic al operations on the data (e.g. hypsometric maps).

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Taiwan Chelungpu-fault Drilling Project (TCDP):
Investigating Physics of Faulting for a Recent Large Earthquake

The significance of the Taiwan Chelungpu-fault Drilling Project (TCDP) is to obtain a physical sample of the fault where large displacements occurred during the 1999 Chi-Chi, Taiwan, earthquake, to measure the physical properties and mechanical behavior of the rocks above and below the fault zone and to thoroughly document the state of stress that exists in these rocks following such a large slip event. Physical examination of the fault surface and laboratory analyses of fault rocks and fluids in the laboratory should make it possible to infer important features, such as its dynamic frictional characteristics. The large amount of fault slip at or near the surface of the ruptured Chelungpu fault provides a unique opportunity to study first-hand the physical mechanisms involved in faulting during large earthquakes. In-situ studies of the behavior of thrust faults, that ruptured during the 1999 Chi-Chi, Taiwan, earthquake presents clear advantages in the analysis of seismogenesis because they are shallowly dipping, making them amenable to imaging and drilling. To keep the budget for this project modest, we proposed drilling a 2-km-deep hole with continuous coring over the bottom 1.5 km.

The Chelungpu-fault Drilling Project will help answer the following hypotheses related to earthquake physics and will contribute in important ways to fault zone studies :

- ***Hypothesis #1:*** *Fault zone was lubricated while generating large slip and slip velocity.*
- ***Hypothesis #2****: weak faults; i.e. slip under conditions of low resolved shear stress*
- ***Hypothesis #3:*** *Physical properties mechanical state of the fault zone change with time throughout the earthquake cycle (interseismic and coseismic).*

Scientific Teams

The following teams have been assembled to assure that the key aspects of the science program are met:

a) Geophysical and Geological Site Characterization

High resolution reflection profiling, geologic mapping, geophyical mapping (MT, gravity..) has been made at the proposed drilling site. See next section for a detail decription of these site characterization studies.

b)Downhole Measurements

Estimates of the current stress field will be done using a number of techniques developed over the past 10-15 years. For example, modifications of the traditional hydraulic fracturing technique will be used in conjuction with BHTV (ultrasonic bolehole televiewer) and FMI (Formation MiscroImager) logs to identify the nature of stress-induced breakouts and tensile. Together, these methodologies can be used to determine stress magnitudes and orientation made over the entire depth range. Continuous temperature measurements will be performed at various depths using high precision thermistors. We willl then monitor temperature profiles for an extended period of time to: 1) determine the terrestial heat flow precisely; and 2) to detect thermal anomalies due to heat generation from the earthquake and transient fluid flow in the fault zone. We also plan to measure physical properties, mechanical state, in-situ measurements of pore pressure and permeability measurements, and fluid sampling.

c) Core and Laboratory Analyses

Estimates of shear localization, heat generation, and slip velocity will be done using microstructures, major/trace chemical compositions, mineral assemblage and crystal structure, and C/O isotopes. Laboratory measurements of permeability and other physical rock properties and rock friction/strength experiments will also be made on the core samples. In addition, we will use a variety of thermogeochronologic laboratory techniques to place constraints on burial depth (temperature), shear heating along the fault surface, and temporal variations in pore fluid temperature and pressure. Analyses for vitrinite, fluid inclusion P/T conditions, and electron spin resonance (ESR) in precipitates, physical properties (porosity, grain density, permeability, magnetic fabric) will be conducted. Tomographic x-ray scanning imaging of whole core will be done to image internal core structure. Core and logging handling will be done according to ICDP protocols.

d) Mechanical testing of core samples

Strength, permeability, and frictional behavior will be determined on samples of fault gauge and surrounding country rock for e.g input into numerical simulations of dynamic rupture propagation and weakening during the Chi-Chi earthquake. These mechanical tests will also provide quantitative constraints on deformation mechanisms and constitutive behavior inferred from microstructural and geochemical observations on core samples. The tests will be conducted under realistic in-situ conditions of temperature, effective stress and pore fluid chemistry using facilities at the U.S. Geological Survey in Menlo Park, California.

e) Borehole Measurements and Monitoring

A deep borehole into an active fault provides the opportunity to make ongoing geophysical observations. When drilling of the 2-km-deep Chelungpu fault hole ends, several types of measurements and borehole monitoring efforts will be made.

1) Temperature measurements at a variety of elapsed times to correct for drilling-induced thermal disturbances.

2) Monitoring with a strainer in the casing across the fault zone for fluid flow and long-term variations in water level. Borehole seismometers to monitor deeper seismic activity. Observations of seismic waves traveling up the fault zone. These observations will be compared with those from other faults.

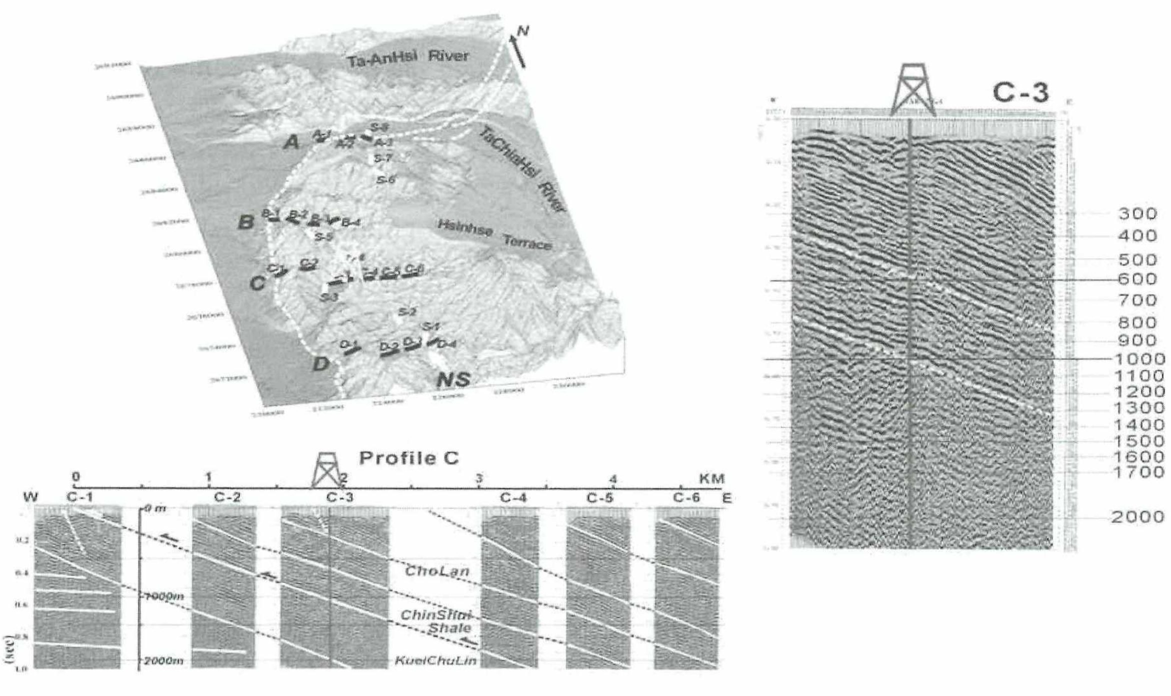


Fig. 1: Location of the proposed drilling site and the reflection images

f) Stratigraphy

The continuous cores of latest Miocene to Pliocene age recovered by drilling will provide a continuous stratigraphic record (in contrast to the intermittent record that outcrops may provide) that documents the sedimentation over this time interval. By examining the stratigraphy and sedimentary facies on continuous cores and other regional geologic data, the timing for development of the Taiwan foreland basin will be addressed.

Proposed Site Characterization

Right after the occurrence of the Chi-Chi earthquake several seismic reflection profiles along and across the Chelungpu fault have been carried out. In view of the site conditions and geology a drilling site along profile C has been proposed.

The seismic images of profile C show several geological formations such as the ChoLan formation, ChinShui Shale formation and KueiChuLin formation. The Chi-Chi earthquake is believed to have ruptured from south to north along the ChinShui Shale, based upon geological and geophysical investigations. It is proposed to conduct a 2-km-deep drilling program with continuous coring near the fault plane at TaKung in Profile C-3. According to the seismic image, the fault plane will be reached at the depth of about 1.0 km; the well will penetrate the Cholan and the Chinshui formation and hit at the bottom the Keichulin formation.

International Scientific Collaboration in the TCDP

The project to drill the Chelungpu fault was discussed at recent workshops sponsored by the International Continental Scientific Drilling Program (ICDP) and at the 2001 International Symposium of East Asian Tectonics (iSEAT). Scientists from Taiwan, Japan, US and France gathered in Taiwan to present results from geological and geophysical investigations related to the Chi-Chi earthquake and Chelungpu fault. A follow-up meeting was also held in Menlo Park, California in December 2001 to include US participants that were unable to attend the Taiwan workshop (see Mori et al., 2002). Prior to the ICDP and iSEAT workshops, two shallow holes (~300 m), sponsored by the Japan Science and Technology Agency, were drilled at the northern and southern ends of the Chi-Chi earthquake rupture zone. Both boreholes penetrated the fault at shallow depths (200 to 350 meters) and fault surfaces were identified by thin (1-3 cm) highly deformed layers within broader (several tens of meters) damaged zones. Samples from the southern part of the Chelungpu fault (the Nantou hole) contained signs of extremely fine-grained, and possibly melted, rocks presumably resulting from the earthquake. This rupture zone at the northern site (Fengyaung hole) was also identified on the basis of its high water content.

Relation to Other Fault-Zone Drilling Projects

This is a project to drill into a fault that has had a large amount of slip in a recent earthquake. This large slip documented during the recent Chi-Chi earthquake enables measurements of coseismic heat production, thereby providing a unique direct measurement of dynamic frictional resistance to slip during an earthquake for which the subsurface distribution of slip is well known.

The drilling of the Nojima fault following the M7.2 Kobe earthquake in 1995 was primarily to study fault physical properties and the fault healing process following the earthquake. This project involved drilling several holes to penetrate the fault at several depths down to 2 km, where the fault was 2 m thick. It will be interesting to compare estimates of fault width and fault zone properties from the proposed 2-km-deep Chelungpu fault hole with results from the Nojima fault.

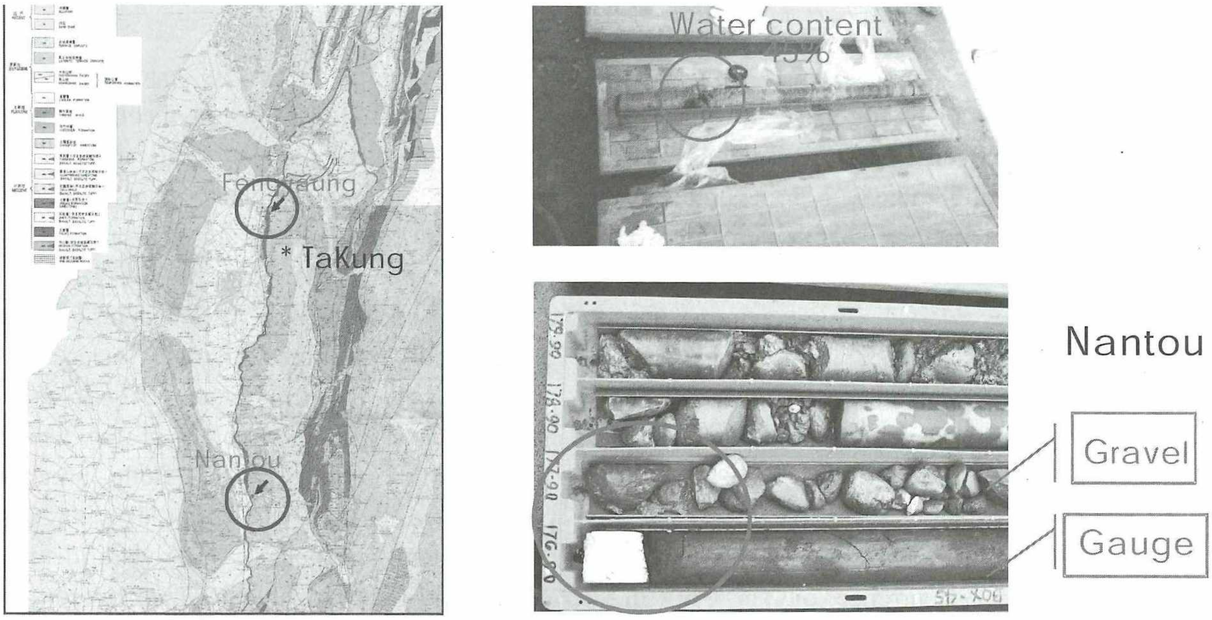


Fig. 2: Locations of the proposed 2-km hole and two shallow holes, Fengyaung and Nantou, and photographs of the core near the possible ruptured zone.

The San Andreas Fault Observatory at Depth (SAFOD) project plans to drill into a section of the San Andreas fault at Parkfield, California, where repeating earthquakes are occurring. SAFOD is designed to directly sample fault zone materials, measure a wide variety of fault zone properties, and continuously monitor a creeping and seismically active fault zone at depth. Results from SAFOD will provide an interesting comparison to the Chelungpu fault drilling project, where large slip has recently occurred beneath the proposed drill site. For this reason, all three Principal Investigators from the SAFOD project have been closely involved in development of the TCDP.

Currently active fault-zone drilling projects have focused on strike-slip faults (Nojima and Mozumi faults in Japan, San Andreas fault in the United States) and normal faults (the Corinth Rift). The TCDP presents an opportunity to expand the knowledge of fault properties and mechanical behavior to reverse-faulting regimes, and will compliment seismogenic-zone drilling currently being planned e.g. in the Nankai subduction zone. Drilling of the Chelungpu fault addresses the question of what physical properties and dynamic processes control the distribution of large slip during an earthquake and will help set the scientific stage for seismogenic-zone drilling.

Kuo-Fong Ma, Institute of Geophysics, National Central University, Taiwan

Proposals to ICDP

The ICDP is driven by unsolicited proposals prepared and submitted by science teams from ICDP member countries. A successful proposal must

- address a geoscientific problem of global interest
- focus on world geological sites
- demonstrate an essential need for drilling
- be of societal relevance and
- avail of an international team of experts.

It is interesting to note that, to date, most of the submitted project proposals, usually ranging between 10 to 20 per year, have generally fulfilled these tough criteria. Therefore, the review panel of ICDP, the Science Advisory Group (SAG), has recommended the majority of the submitted proposals for consideration in the Executive Committee (EC) of ICDP. Although additional site surveys or detailed technical plans are often requested prior to the preparation of a full proposal or prior to final funding, the EC has approved new proposals every year.

Most Principal Investigators (PI´s) have taken advantage of the ICDP opportunity to fund international workshops, which not only serve to define science and drilling goals but help to form an international team of experts and initiate the writing of a full proposal. A full drilling proposal is then usually submitted to the ICDP in the following one or two years. The full proposal should include a detailed budget plan which combines funds from ICDP and other agencies. The necessity for combined funding is due to ICDP's restriction to the allocation of funds for drilling and drilling-related operations only. Hence, a conscientious balancing and tapping of different money sources is necessary.

The Ocean Drilling Program, ODP is an important partner of ICDP due to future joint projects e.g. in coastal areas or in land–sea transect proposal. Representatives of both programs are present at different meetings, respectively, e.g. the German annual ICDP and ODP meetings are a joint convention. In addition, ODP and ICDP have now almost identical proposal regulations and forms to allow for an easy exchange of proposals between both programs and to provide proponents the possibility to apply to both programs with the same proposal. Like in ODP, abstracts of project proposals to ICDP are now being posted on the ICDP website, upon the consent of the proponents.

To learn more:
www.icdp-online.org

How many science teams have requested ICDP funding from 1996 to 2003?

- **106** proposals have been submitted (workshop, letter, and full proposals)
- **20 Workshops** have been conducted and
- **13 Drilling operations** were funded.

Project categories for deep drilling proposals:

1. 40 proposals: Paleoclimate, lacustrine basins (up to 1000 m continuous coring)
2. 16 proposals: Volcanism and heat transport (2 to 5 km, continuous coring)
3. 15 proposals: Stress, earthquakes and faults (1 to 4 km, options for 10 km, spot coring)
4. 10 proposals: Plate dynamics and orogenesis (5 km + more, continuous cores)
5. 7 proposals: Impacts and extinctions (1 to up to 6 km, continuous cores)
6. 1 proposal: Gas hydrates in permafrost (1 km, spot cores)

Other proposals not listed above requested e.g. technical equipment or tool development.

Uli Harms, ICDP, GFZ Potsdam, ulrich@gfz-potsdam.de

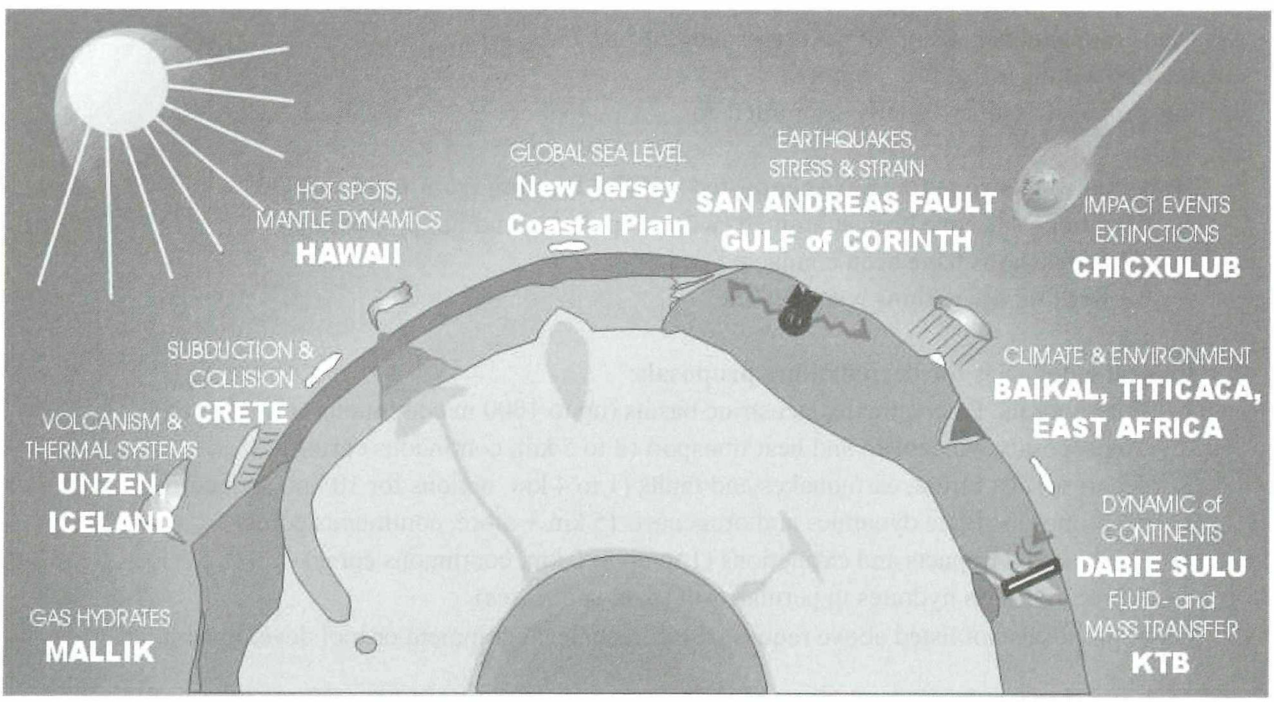
What is ICDP?
The International Continental Scientific Drilling Program is a multinational endeavor to further and fund geosciences in the field of Continental Drilling. Common goals and land-sea projects establish a partnership to ODP.

Why ICDP?
Scientific Drilling is a critical tool in understanding our planet and its structure. It provides direct insight into Earth processes and decisively tests geological models. Results obtained from drilling projects at critical sites can be applied to other areas worldwide. International cooperation in continental scientific drilling is an essential component for a responsible management strategy for the Earth's natural resources and environment.

Which problems are adressed by ICDP?
- The physical and chemical processes responsible for earthquakes and volcanic eruptions
- The manner in which Earth´s climate has changed in the recent past and the reasons for such changes
- The effects of major impacts on climate and mass extinctions
- How sedimentary basins and resources originate and evolve
- How ore deposits are formed in diverse geological settings

What are the objectives?
- to obtain secure funding for an effective planning, implementation and execution of a viable strategic drilling program
- to meet scientific objectives of socio-economic significance
- to identify sites for international cooperation in scientific drilling and thus
- to provide a cost effective means of answering key scientific questions in the ICDP's priority fields
- to ensure that appropriate pre-site surveys are carried out
- to provide a core of technical support for drilling projects
- to facilitate their efficient planning and operation

What are the advantages?
- focusing of scientific effort on drilling sites of global significance (World Geological Sites)
- affordability and cost-effectiveness through sharing
- attraction of high quality researchers to topics of high national and international priority
- intellectual benefits to all participants arising from international cooperation



Themes and projects of the International Continental Scientific Drilling Program

icdp

NEWSLETTER

Volume 5, March 2003

International Continental Scientific Drilling Program

Welcome to Norway and the Czech Republic: ICDP has new member countries.

On behalf of the Executive Committee of ICDP we are pleased to announce that Norway, represented by the Norwegian Geological Survey, and the Czech Republic, represented by the Geophysical Institute of the Academy of Sciences, have joined ICDP.

Ales Spicak (Geophysical Institute, Academy of Sciences of the Czech Republic) and Rolf Emmermann (Chairman Executive Committee, GeoForschungsZentrum Potsdam) signing a Memorandum of Understanding on the Membership of the Czech Republic in ICDP on February 28, 2003 watched by the President of the Academy, Helena Illnerova.

ICDP Members: GERMANY, USA, CHINA, JAPAN, MEXICO, POLAND, CANADA, AUSTRIA, ICELAND, NORWAY, CZECH REPUBLIC, UNESCO, SCHLUMBERGER

Executive Agency: GeoForschungsZentrum Potsdam (GFZ), Germany

Boards: Assembly of Governors (AOG, Chair: Margaret Leinen), Executive Committee (EC, Chair: Rolf Emmermann), Science Advisory Group (SAG, Chair: Mark Zoback)

The ICDP Newsletter is issued once a year and distributed free of charge in digital and printed version

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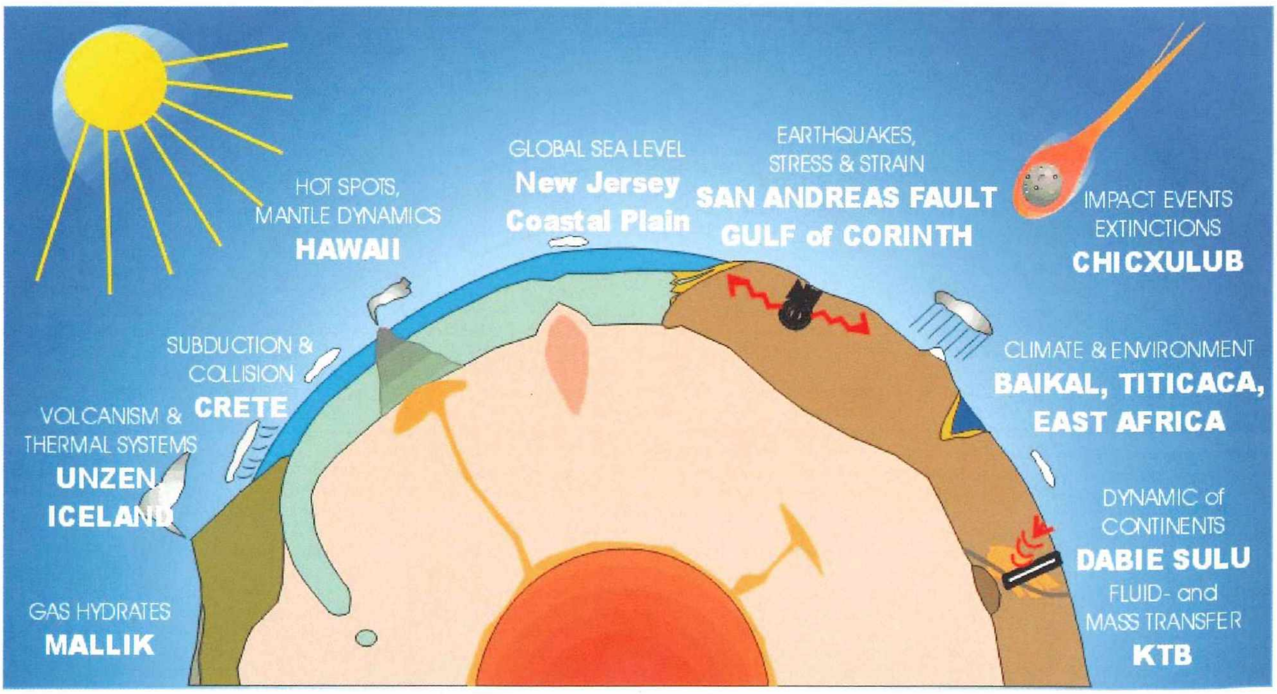

Themes and projects of the International Continental Scientific Drilling Program